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An Ex Ante Evaluation Framework for the Regional Benefits of Publicly Supported R&D Projects

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Abstract
This paper draws on the knowledge-base implicit in ex post evaluations of publicly funded R&D and other related conceptual and empirical studies to suggest a framework for the ex ante evaluation of the regional benefits from R&D projects. The framework developed comprises two main elements: an inventory of the global private and social benefits which might result from any R&D project; and, an assessment of the share of these global benefits which might accrue to a host region, taking into account the characteristics of the R&D project and the region's innovation system.

The inventory of global benefits separately identifies private and social benefits and distinguishes between increments to public and private knowledge stocks, benefits to R&D productivity and benefits from commercialisation. Potential market and 'pure' knowledge spillovers are also considered separately. The paper concludes with the application of the framework to two illustrative case-studies.

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1. Introduction

This paper arose from problems faced by the UK's regional development agencies in assessing *ex ante* the regional benefits of publicly supported R&D. The agencies' policy objective was to address the standard market failure which leads to socially sub-optimal levels of private sector R&D investment (Nelson, 1959; Arrow, 1962; Dasgupta and David, 1994); difficulties arose, however, in justifying public support for R&D within the UK's standard public sector investment appraisal procedures[1]. These typically involve discounted cash flow calculations, raising particular problems when applied to R&D projects due to (a) the difficulty of defining *ex ante* the *range* of benefits which might stem from the project; (b) uncertainty relating to the scale and timing of such benefits, and (c) doubts about the *share* of these benefits which will be appropriated by the host region[2].

Our first attempts to identify any existing approach to ex ante evaluation of R&D centres failed. Despite an extensive literature survey, and consultation with practitioners in the UK, US, Finland and Israel, we failed to identify any existing methodology or approach to measuring *ex ante* the benefits of publicly supported R&D. Instead, in the countries consulted, we found various approaches have been adopted to avoid any necessity to undertake *ex ante* evaluations, at least at the level of the individual project. In Israel until recently, for example, subject to meeting certain eligibility criteria, all R&D projects were assisted at standard grant rates[3]. Similarly, it is not clear how the potential social benefits of R&D are reflected in budget

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[1] For the UK public sector, investment appraisal procedures are defined in the so-called 'Greenbook'. Investment appraisal techniques vary with project size, with full cost-benefit analyses undertaken only for larger projects.

[2] This uncertainty in defining *ex ante* the social returns of publicly supported R&D may itself be a cause of market failure, leading to socially sub-optimal levels of public R&D investment and confounding any attempt to counter private sector under-investment in R&D. This under-investment is likely to be greatest where public spending is rationed and R&D projects are competing with other spending priorities with less uncertain outcomes[2]. This is especially true where 'similar results could probably be obtained by relying solely on technological spillovers. The temptation to free-ride is therefore strong: why invest in R&D when similar outcomes can possibly be obtained by reaping technological spillovers?' (Rodriguez-Pose, 2001, p. 276).

[3] What was less clear, however, is how the difficulties of assessing the benefits of publicly supported R&D *ex ante* were overcome in the setting of Israel's overall R&D support budget (see Trajtenberg, 2000).

allocations for competitive R&D support initiatives, such as the UK's SMART scheme.

While our literature and practitioner surveys identified little by way of *ex ante* evaluation of R&D projects, they did highlight the significant and rapidly growing knowledge-base derived from *ex post* evaluations[4]. This suggested an alternative approach, i.e. to use the accumulated knowledge-base derived from these *ex post* evaluations to develop a framework which could be used to form *ex ante* judgements about the potential benefits of supporting R&D projects in varying geographical, institutional and economic settings. For example, the literature now provides consistent evidence on the tendency for knowledge spillovers, or Marshallian externalities, to be spatially concentrated around knowledge sources (e.g. Jacobs et al., 2002). Anselin et al. (2000), for example, also highlight the spatial concentration of spillovers from R&D, and emphasise the different spillover footprints of university and private sector R&D, and that of different industries. Similarly, Egeln et al. (2002) in their analysis of over 2,000 public-research spin-outs in Germany, report that 66.5 per cent locate within 49km of their incubator institution and Wallsten (2001) points to the strong spatial concentration of award winners within the US Small Business Innovation Research (SBIR) programme. Previous studies have also suggested that the context in which an R&D centre is placed may also be important in determining the extent of any localised spillovers. Lagging regions, in particular, may find it difficult to appropriate spillover benefits due to limited absorption capacity or receptivity (Rodriguez-Pose, 2001). This may reflect specific limitations in the regional innovation system such as a predominance of economic activity in SMEs in old economy sectors, weak inter-firm association (e.g. Cooke and Morgan, 1998), or a weak skill base; or, it may reflect the impact of limitations in the wider national innovation system such as a lack of technology transfer and co-ordination institutions (e.g. Walker, 1993)[5].

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[4] For example, Klette et al. (2000) review five econometric *ex post* evaluations of government R&D subsidies. Georghiou and Roessner (2000) also review a number of *ex post* project and program evaluations using different evaluation methodologies and provide a valuable review of methodological issues. Although as Georghiou and Roessner (2000) comment: 'Evaluation work has probably had less of an impact in the literature than it deserves, in part because much of the detailed work is not easily obtainable. There is a disturbing tendency for evaluation data that could form a valuable reference point for future studies to be lost in the grey literature' (p. 674).

[5] See, for example, Young and Lan (1997) for a discussion of the absorption capacity of Chinese firms from inward investment.

Interest in the spatial distribution of the benefits from public R&D investment is not simply of interest to regional development agencies, however, as promoting technological development has also been seen by national and supra-national organisations (e.g. the EU) as one potential route for counteracting core-periphery disparities. Both the empirical evidence and theoretical models suggest, however, that even if technological spillovers are spatially concentrated it may still be socially sub-optimal to locate R&D activity in lagging regions. Fujita and Thisse (2002), for example, develop a core-periphery model in which the agglomeration effects from concentrating R&D activity in the core, combined with relatively low transportation costs, generate sufficient value added to more than compensate the periphery for the loss of R&D activity (see also Lacroix and Martin, 1988). On the more empirical side, Rodriguez-Pose (2001) examines the EU record of R&D investment in lagging regions, implicitly considering the strategic choice facing supra-national organisations such as the EU of prioritising support for R&D in core or lagging regions. He concludes that the macro evidence to date suggests no clear pattern but argues that 'R&D investment in lagging areas may thus be the only possible solution to prevent the technology and development gap between core and periphery expanding … R&D investment in lagging areas may prove in the long run to be a better and cheaper alternative to social transfers' (p. 293).

In the remainder of the paper we make some tentative steps towards a framework for evaluating *ex ante* the potential benefits of publicly supporting R&D[6]. Our approach has two main elements. First, we focus on the evidence relating to the *range* of potential global benefits of a new R&D facility, drawing on both the 'old economics' literature on the returns to R&D investment and on the 'new economics' literature on organisational capabilities, networks and spatial and industrial clustering (Dasgupta and David, 1994; Georghiou and Roessner, 2000). Second, we focus on the *share* of these global benefits which might accrue to a host region, taking into account issues of appropriation, receptivity and synergies between the knowledge created/assimilated by the R&D project and the region's innovation system. For simplicity, we assume

[6] On approaches to the *ex ante* evaluation of private sector R&D projects see, for example, Hwang and Yu (1998) and Johnson (1995).

zero crowding out and pure additionality both in the traditional sense and in terms of the type of behavioural effects envisaged in Buisseret et al., (1995)[7].

The remainder of the paper is organised as follows. Section 2 examines the total global benefits which might arise from an R&D project, examining separately private and social returns. Section 3 then examines the factors which determine the host region's share of these global benefits focussing on the profile of the R&D centre and the innovation system of the host region. Section 4 focuses on the implementation of the framework developed and describes its application to two illustrative case studies. Section 5 concludes with an overall assessment and some suggestions for future research.

2. Assessing the Global Benefits of R&D Projects

R&D activity generates distinct ‘private’ and ‘social’ returns each of which may occur through a number of different mechanisms (Cohen and Levin, 1989; Griliches, 1979, 1991; Nadiri, 1980, 1993). Private returns accrue to the organisation conducting the R&D (i.e. the company or university), with the most obvious ‘private’ return being the addition to organisations' stock of knowledge capital. This may then lead to commercial applications or the sale of licenses to other technology users. The social benefits derived from R&D depend on additions to the science base and infratechnology and the extent of (positive) Marshallian externalities, ‘spillovers’, or economies of localisation[8]. Two main types of externality or spillover are commonly identified: *rent (or pecuniary*) externalities which are the result of market transactions; and *pure knowledge spillovers* which are independent of any market mechanism (Griliches, 1979, 1992). Beugelsdijck and Cornet, (2001, p. 3) summarise the distinction as follows:

> *‘Rent spillovers arise when quality improvements by a supplier are not fully translated into higher prices for the buyer(s). Productivity gains are then recorded in a different firm or industry than the one that generated the*

[7] In practical terms, of course, these issues may be of substantial importance in any specific investment. In the evaluations of UK and EU R&D programmes considered by Buisseret et al. (1995), for example, full additionality occurred in 17-51 per cent of supported projects. On crowding out, see the discussion in David and Hall (2000), pp.1167-1168.

[8] The potential empirical importance of spillovers etc. is suggested by Mansfield et al. (1977), for example, who find a median social rate of return of 56 per cent more than twice the comparable median rate of return (see also additional references in Klette et al., 2000). More recently, Mohnen (1996) considered more than 50 studies and concludes that 'spillovers exist and have to be taken into account when evaluating the returns to government-financed R&D'.

productivity gains in the first place. Rent spillovers occur in input-output relations. Pure knowledge spillovers refer to the impact of the discovered ideas or compounds on the productivity of the research endeavours of others. Pure knowledge spillovers are benefits of innovative activities of one firm that accrue to another without following market transactions'. (Beugelsdijck and Cornet, 2001, p. 3).

Pure knowledge spillovers do not require this type of 'market' interaction but depend instead on the free flow of knowledge from the R&D centre, and its absorption and adoption by other organisations. For example:

> *'Positive externalities of scientific discoveries on the productivity of firms which neither made the discovery themselves nor licensed its use from the holder of intellectual property rights' (Zucker et al., 1998a, p. 65).*
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> *'A prototypical externality, by which one or a few agents investing in research or technology development will end up facilitating other agents' innovation efforts (either unintentionally, as it happens when inventions are imitated, or intentionally, as it may happen when scientists divulge the results of their research)'. (Breschi and Lissoni, 2001, 975).*

Our assessment of the *range* of potential global benefits which may result from R&D projects is based around an inventory suggested by *ex post* evaluations and related empirical and conceptual studies. This approach was suggested by the inventory-based approach to identifying the benefits which might stem from a publicly supported health R&D centre developed by the health economics research group (HERG) at Brunel University (e.g. Buxton and Hanney, 1994, 1996, 1997; Hanney et al., 2000) We generalise the HERG typology in two main areas: we distinguish between private and social benefits; and, we allow for the distinction between rent based and pure knowledge spillovers.

In terms of private benefits, we distinguish: first, increments to the firm's stock of knowledge capital resulting from the R&D project; second, developments in the firm's organisational or managerial capabilities which might influence subsequent R&D productivity; and third, benefits the firm derives from commercial application of R&D results (Table 1)[9]. In terms of social benefits, we follow a similar approach distinguishing between: benefits to the public science or knowledge base; benefits to

[9] The distinction between the organisational benefits of undertaking R&D and the effects on business performance reflects the distinction made by Georghiou (1994) between behavioural and output additionality.

R&D productivity in other organisations; rent or pecuniary spillovers mediated through market transactions; and, pure knowledge spillovers (Table 1).

2.1 Private Benefits

It is clear that one of the main benefits of undertaking R&D to an organisation is the increment to the private knowledge base (Table 1, Items 1.1-1.3). In the case of private sector organisations this may provide the basis for creating or sustaining competitive advantage; while for public sector organisations or universities this may lead to spin-out businesses or revenue streams based on licensed technologies. Empirical measurement of firms' knowledge capital in its infancy, however, although Klette and Johansen (1998) do demonstrate a positive link between knowledge (R&D) capital stocks and business performance and, in the context of multi-national enterprises, Dunning comments that 'possession and control of technological capacity is indeed one of the main [organisation]-specific advantages of enterprises' (p. 289). Trajtenberg (2000) offers more direct evidence on the links between public R&D support and firms' proprietary knowledge base. In his examination of government support for commercial R&D in Israel operated by the Office of the Chief Scientist (OCS), he concludes: 'It is clear then that industrial R&D expenditures are closely linked (with a reasonable lag) to patents, and so are R&D grants awarded by the OCS' (p.20).

More evidence exists on the organisational advantages which firms' may derive from undertaking R&D, benefiting R&D capability and productivity (Table 1, item 2.1-2.5). One element of this is the potential for one R&D project to lead on to further projects with commercial potential (Table 1, item 2.1). Mansfield and Switzer (1984), for example, suggest that around a third of the publicly-funded R&D projects undertaken by their sample of US firms from the chemicals, petroleum, electrical equipment and primary metals sectors led on to further R&D projects which the company funded from their own resources[10]. Luukkonen (2000) also indicates that participation in the collaborative EU Framework programmes by Finnish firms laid

[10] Mansfield and Switzer (1984) also note, however, that the probability of such spin-off projects was higher, however, where: the company was very strongly involved in the formulation and design of the R&D project and the R&D project was undertaken alongside the firm's company-funded R&D projects rather than in a separate location

the basis for future R&D by contributing to firms' involvement and influence in standards negotiations, viz. participation 'provided background information for standardisation negotiations … [and] … facilitated their contacts, since the experts of the companies could get better acquainted with each other, which again helped their interactions. It was a question of an intangible impact' (p. 716)[11].

Research activity may also lead to developments in firm's human resources and the managerial capacity of an R&D centre and therefore to more positive outcomes in future research projects (Table 1, item 2.2)[12]. Sakakibara (1997) p. 462, for example, indicates that the managers of publicly supported collaborative R&D projects in Japan rated researcher training as the most important benefit which their companies derived from their project[13]. The critical role of human resources to R&D success is also suggested by the positive results reported by Meyer-Krahmer et al. (1983) in their evaluation of the German Programme of Grants Towards the Costs of R&D Personnel. This measure replaced traditional investment assistance with a subsidy for R&D personnel in order to strengthen the innovative capability of smaller firms. In Meyer-Krahmer et al.'s evaluation, sixty grant recipients were interviewed of which: 10 per cent indicated that the grants had had a 'climatic effect' bolstering the prestige, internal status or appreciation of R&D; 75 per cent of grant recipients indicated that grant had 'budget' relevance, i.e. had been additional in terms of expanding or accelerating firms' R&D programmes. In only 15 per cent of cases do Meyer-Krahmer et al. (1983) indicate that this human resource support had no real impact on firms' R&D activities.

Other reputational and 'halo' effects may also stem from having an R&D facility, or having a reputation as an R&D active or innovative business (Table 1, item 2.3). For example, the brand images of 3M and HP are largely based on their capability as

[11] Leyden and Link (1992) interpret this type of benefit from R&D as a contribution to infratechnology having both private and social benefits.

[12] Relatively few empirical studies have until recently included variables explicitly reflecting the skill composition of firms' workforces as a determinant of innovation. See, for example, the material reviewed in Cohen (1995) and the papers included in Kleinknecht (1996). More recent studies based on firm-level surveys have addressed the question, e. g. Shefer and Frenkel (1998), Love and Roper (2000).

[13] Somewhat surprisingly, this 'intangible' benefit from collaborative R&D was seen as more important than 'increase in the awareness of R&D in general', 'breakthrough in a critical technology', and 'accelerated development of the technology'.

innovative firms, while Powell (1998) points out, in the context of R&D collaboration in technology intensive industries, that 'a firm's portfolio of collaborations is both a resource and a signal to markets, as well as to other potential partners, of the quality of the firm's activities and product'. (p.231). Potential employees may also find R&D active employers more appealing, and economic development agencies may feel more comfortable if otherwise mobile manufacturing operation have a (relatively immobile) R&D facility attached (Kearns and Ruane, 2001).

Undertaking R&D may also improve firms' ability to absorb R&D results or knowledge from elsewhere and manage collaborative R&D projects with other organisations (Table 1, item 2.4). For example, Veugelers and Cassiman (1999) in their analysis of Belgian data suggest that firms undertaking in-house R&D benefited more from external information sources than companies which had no in-house R&D activity. Cassiman and Veugelers (2002) also emphasise the complementarity between internal and external R&D activity, and demonstrate that firms engaging in both activities introduce more innovative products than firms engaged in either external or internal R&D alone. One possible explanation is that undertaking internal R&D increases firms' ability to take advantage of external knowledge sources. Love and Roper (2001), however, suggest an alternative explanation, finding that UK and German firms were obtaining economies of scope in the management of outsourced R&D. In other words, management competencies developed in outsourcing in one element of the product development process were being used to take advantage of the potential benefits of outsourcing in other activities (Table 1, item 2.5). More specific evidence of the complementarity of publicly supported R&D and firms' other internally-funded R&D activity comes from Ballesteros and Rico (2001). They conduct an econometric analysis of the Spanish 'Concerted Projects' support scheme and demonstrate that Spanish firms which were more R&D intensive were also more likely to make use of government funding for collaborative university-business R&D projects.

Public funding of R&D may also create the potential for R&D cost savings through collaborative R&D and the sharing of research results (Table 1, Item 2.5). One well documented example is the Sematech collaborative R&D facility, set up by the US semiconductor industry in 1987 with financial support and staff secondments (assignees) from member companies and substantial financial support from government[14]. Irwin and Klenow (1996) use a simple econometric model to compare the R&D intensity of Sematech member and non-member companies, and conclude that participation in the Sematech collaboration reduced members' R&D spending by 9 per cent. The suggestion being that participation in this publicly supported collaboration, enabled firms to acquire knowledge more cheaply by sharing the results of joint R&D. Importantly, Irwin and Klenow (1996) note that this reduction in R&D costs is also reflected in positive effects on company profitability although their statistical evidence on this point is less robust.

The weakness of Irwin and Klenow's results linking publicly supported R&D and business performance reflects a wider 'gap' in the literature with relatively few studies considering the link between the sources of funding for R&D and business performance. Moreover, at national and sectoral level evidence of the positive relationship between publicly financed R&D and economic performance inevitably reflects both the private benefits of undertaking R&D and related spillover effects. For example, Mamuneas and Nadiri (1996) consider the impact of publicly funded R&D investments on the cost structure of a group of US manufacturing sectors (Table 1, Item 3.1). Reflecting both private benefits and potential intra-sectoral spillovers, Mamuneas and Nadiri find that publicly funded R&D has a strong association with reduced costs across a range of sectors, although the extent of the effect varies between sectors. In addition, Mamuneas and Nadiri (1996) are also able to identify some inter-sectoral spillovers from publicly funded R&D although these tend to be weak relative to the 'own industry' effect[15].

Some more specific evidence is available, however. For example, Bessant and Rush (1993) present two case-studies of public support measures in the UK and Germany designed to encourage the adoption of advanced manufacturing techniques (AMTs)[16].

[14] Sematech's members are required to contribute 1 per cent of semi-conductor revenue to the project with a minimum contribution of $1m and a maximum of $15m. Around half of the 400 staff at the Sematech facility are seconded from member companies (Irwin and Klenow, 1996).

[15] Interestingly, Mamuneas and Nadiri (1996) also highlight some aspects of the relationship between publicly financed R&D and company financed R&D finding a substitute relationship in low technology industries and a weak substitute relationship in high-tech sectors. Thus there is evidence of some crowding-out, particularly in the low-tech sectors.

[16] The UK Flexible Manufacturing Systems Scheme and the German Project Fertigungstechnik (Project for Manufacturing Technology).

The UK scheme ran from 1982-86 and provided assistance for firms with the introduction of CAD/CAM, robotics, automated testing and opto-electronics. The German scheme, with broadly similar objectives, began in 1984 with a particular focus on supporting AMT adoption among SMEs although 'indirect' funding was also provided with the intention of stimulating the supply and availability of AMTs in Germany. In each case, Bessant and Rush (1993) emphasise the positive outcomes of the initiatives in terms of increased AMT adoption *and* the derived business benefits. Specifically, AMT adoption allowed the firms to diversity their product offerings creating opportunities to enter new markets and increase, or at least defend, market share (Table 1, item 3.2). In addition, the introduction of AMTs had organisational advantages, inducing a more systematic approach to production management, with benefits in terms of product quality and internal communication. More generally, it is clear from Mamuneas and Nadiri (1996) and the other evidence reviewed by Griliches (1995) that public support increases individual firms' investment in R&D[17], and this can be linked to other elements of business performance (Table 1, items 3.3-3.5)[18].

2.2 Social Benefits

The social benefits of publicly funded R&D can be split into four main categories. First, there will be potential increments to the public science base through published papers, patents or knowledge codified in new products or equipment (Table 1, items 4.1-4.3). In this sense little has changed since the House of Lords Committee on Science and Technology published in 1986-87 commented that: 'basic research, as a quest for understanding the natural world, is an essential part of cultural development, and every civilised country should accept some commitment to its furtherance. Research, as carried out in the universities, is an important factor in maintaining the standards of teaching and the production of skilled manpower. The knowledge obtained by basic research provides a source for industrial development and the exploitation of new products and processes for solving industrial problems' (HOL Report, cited by Smith, 1989, p. 102).

[17] Although, as in the case of the Sematech project, government support for collaborative projects and R&D sharing can clearly reduce overall R&D investment.

[18] Increased R&D spending to increased levels of innovative activity (e.g. Love and Roper, 2001), higher business profitability (e.g. Geroski et al., 1993), faster productivity growth (e.g. Crepon et al, 1998; Lööf and Heshmati, 2000, 2001), higher export propensity (e.g. Roper and Love, 2002).

Other social benefits of publicly funded R&D relate to its impact on R&D productivity. Leyden and Link (1992), for example, stress the potentially positive benefits which may result from R&D investments in 'infratechnology' which they define as: 'technologies that facilitate R&D production … including evaluated scientific data …; measurement and test methods used in research , production control and acceptance testing for market transactions; and various technical procedures such as those used in the calibration of equipment'. Some such R&D investments may be by public laboratories and would include investment in standards development such as the National Institute of Standards and Technology's investments to implement standards for optical fibres and electro-migration characterisation (Leyden and Link, 1992, pp. 83-126). Leyden and Link (1992) also report evidence from a 1991 postal survey of 62 Federal laboratories of whom 47 per cent said they were engaged in infratechnology research which accounted for 37.6 per cent of their total budget.

Investments in infratechnology, with potential social benefits, are not, however, limited to public laboratories. Among a sample of 126 US manufacturing companies in 1991, Leyden and Link (1992) report that 45.2 per cent were engaged in infratechnology investment, accounting for 16 per cent of their R&D budget. Much of this infrastructure investment was capital spending intended to support the firms' R&D activities through the purchase of equipment for measurement testing, process control, data formatting/translating etc[19]. Another more recent example of infratechnology investment is the participation of Finnish telecomms companies in European Framework programmes as part of development of standards which could provide a platform for future product development and sales (Luukkonen, 2000, p. 716-717).

The third type of social benefits from publicly funded R&D are rent or pecuniary spillovers. Rent spillovers occur where an R&D centre or project generates either a local supply or demand in which either cost reductions or quality improvements are not fully reflected in price changes. This type of effect may be mediated through the supply-chain, with positive effects on an R&D centre's suppliers and customers

[19] See also Link and Tassey (1993).

(Table 1, items 6.1 and 6.2), or factor-markets with positive effects on other local organisations with similar factor demands (Table 1, item 6.3).

Other forms of rent spillovers may depend on the movement of research-trained staff who act as localised carriers of knowledge (Table 1, item 6.3). Where individuals are patent-holding scientists or engineers, or have the skills and know-how to engage in technological advance, such local moves may generate localised knowledge spillovers. Some studies of this process have been conducted but these have tended to examine in detail a particular industrial sector, often located in a single geographical area. For example, Zucker et al. (1998a, b) examined the role of 'star' scientists in the development of the biotechnology industry in California. Using a version of the 'knowledge production function' approach, Zucker et al. (1998a) consider how the innovation output (defined as products in development) of 78 biotechnology firms was affected by the number of relevant articles authored by identified star researchers within the firms' geographical region. The result is positive and significant. While this might at first sight appear to support the (pure) localised knowledge spillover concept, Zucker *et al* go much further, and trace whether each star was directly in collaboration with a given firm at the time of each article's publication. When they separate out those stars which did and did not have direct links with enterprises, only the former were found to have a positive effect on new products in development. The publications of local stars with no company contacts had no effect on innovation. They conclude that the positive impact of research universities on nearby firms is not the result of localised knowledge spillovers, but arises mainly from identifiable market exchanges between individual university star scientists and the firms. These scientists act as conduits between universities and the companies with whom they are affiliated, but not to all companies. Thus to the extent that knowledge 'spills over' it happens as a result of clear market mechanisms and only to those firms that pay for the expertise; this is quite different from the informal, face-to-face knowledge exchanges assumed by much of the literature on pure knowledge spillovers[20].

[20] The knowledge flows identified by Zucker et al. are therefore designed to exclude some firms, and cannot be regarded as a non-excludable quasi-public good benefiting all firms in a given area, in the sense of the 'pure' knowledge spillover. This may indeed have a localised effect, but only because the stars prefer to have company links or engage in start-ups within commuting distance of the universities in which they retain their affiliation. Zucker et al. therefore conclude that previous research on localised knowledge spillovers may have resulted from a serious specification error, in failing to control for the contractual relations of individual scientists with local firms.

The final group of social benefits from publicly funded R&D are pure knowledge spillovers, although the very nature of such spillovers makes them particularly difficult to observe (Table 1, item 7.1). Audretsch (1998), for example, notes the strong statistical relationship between R&D inputs and innovation outputs at the level of countries and industrial sectors, but the less robust relationship at the level of the individual firm, especially when small firms are included in the analysis. This suggests that small firms, in particular, may derive their knowledge inputs not from their own R&D but from knowledge spillovers from other firms and from universities within the country or industrial sector (Table 1, item 7.1).

Other empirical evidence on 'pure' knowledge spill-overs comes from a number of studies which have attempted to link levels of innovative activity in a region to indicators of academic research output or inputs. The pioneering work in this area is Jaffe (1989) on the 'real effect' of academic research. Working at the level of US states, Jaffe found that the number of patents registered in any state for a given sector was a positive function not only of industrial R&D expenditure in the state but also of the amount of research expenditure by universities in the state (after allowing for differences in the absolute size of states). This is interpreted as indicating that knowledge generated at universities spills over into the industrial sector, leading to higher innovative output than would otherwise be the case. Very similar results for the French administrative regions are found by Piergiovanni and Santarelli (2001).

Using the same methodology, Acs *et al.* (1992; 1994) perform similar studies but using a broader measure of innovation, i.e. the number of innovations registered with the US Small Business Administration. Like Jaffe (1989), they find that both corporate and university research expenditure has a positive effect on innovation levels.

Breschi and Lissoni (2001), however, criticise the work of Jaffe (1989) and Acs *et al* for operating at very aggregated levels of both space and technology. For example, it seems unlikely that US states are the appropriate area within which academics, inventors and entrepreneurs will have frequent face-to-face contact. In addition, Jaffe used very broad industry sectors (such as 'electronics, optics and nuclear technology'), which Breschi and Lissoni argue are too wide to presume a match between, say, corporate R&D objectives and university expertise which could give rise to meaningful spillovers. Audretsch and Feldman (1996) attempted to deal with the second of these issues by employing more narrowly defined industrial sectors (4-digit SIC level), but again operating at the level of the US state. Their paper examines the extent to which there is geographical clustering of innovative activity, even after allowing for the general spatial concentration of production. They find a systematic tendency for innovations to cluster, and that this can be explained by three factors: the extent of industry R&D expenditure; the extent of skilled labour; and the pool of the science base as measured by university research expenditure. Audretsch and Feldman interpret this as supportive of a flow of tacit knowledge being transmitted through face-to-face contact. However, it should be noted that at least one of their explanatory variables (extent of skilled labour) is more appropriately considered as a Marshallian rent (or pecuniary) spillover, available to all firms within a given spatial/technological area through the workings of the market, rather than as a 'pure' knowledge spillover.

The clearest attempt to look for knowledge spillovers at a more local scale is made by Anselin et al. (2000). This study focuses on the Metropolitan Statistical Area (MSA) level, a level of spatial scale based around cities, and much smaller than the state level. Their results indicate that spillovers from university research do indeed have a positive impact on the levels of innovation within MSAs, and that this effect can extend beyond the boundary of the MSA up to 75 miles from the central city. Crucially, however, they find that this effect varies substantially across (2-digit) industrial sectors; for example, they find no spillover effect in chemicals and pharmaceuticals, but very strong and significant spillover effects in electronics and scientific instruments. (Jaffe, 1989, also finds that spillover effects vary significantly by industry sector).

Almost all the analysis reviewed above is US based, and all, to a greater or lesser extent, finds evidence of knowledge spillovers. There is, however, a series of research from the Netherlands which consistently fails to find similar effects. For example, Beugelsdijck and Cornet (2001) apply the knowledge production function concept to an analysis of Dutch manufacturing firms, relating the innovative output (i.e. share of new products as a proportion of turnover) of each firm to its own innovation expenditure, the innovation expenditure of firms within 1, 2, and 3-digit postcode of the firm, and the location within a 2-digit postcode of a technical university. They find no evidence that innovation expenditures by nearby firms have a greater effect on a firm's innovative performance than expenditure by firms located further away. They do, however, find some evidence of positive spillovers from local technological universities. The difference between this result and the American studies may in part be due to differences in variable definitions, but the authors suggest it is more likely to be due to differences in scale: they point out that many of the US studies reviewed above regard proximity in terms of a two-hour train trip, which in the Netherlands will imply a journey into Belgium or Germany. "This study thus suggests that the Netherlands is too small a country to have proximity play the leading role in facilitating knowledge spillovers. This conclusion might a fortiori hold for other regions of similar size." (Beugelsdijck and Cornet, 2001, p. 17).

Spin-outs also represent one of major routes through which publicly supported R&D activity - particularly that undertaken by universities - is commercialised (Table 1, item 7.2). Roberts (1991), for example, documents a number of high-tech spin-outs from MIT (although, see also Bania et al., 1993). Egeln et al. (2002) identify a number of reasons why spin-off from universities or public research laboratories might be expected to cluster around their incubator's location and therefore benefit the host region. First, co-location may reduce the costs or accelerate the transfer or sharing of tacit knowledge or information. Second, it may allow spin-out entrepreneurs to maintain contact to the incubator organisation for either research or teaching collaboration. Third, proximity to the incubator organisation may allow the company to use the facilities of the incubator organisation (see also Roberts, 1991). Fourthly, co-location may reflect the preferences of the entrepreneur to stay in the region with which they are familiar. Countering these largely factor related inertial forces are the potential need to be close to key customers, particularly where spin-outs are involved in the supply of innovative products or services. As Egeln et al. (2002) point out these are unlikely to be co-located with the incubating organisation.

Egeln et al. (2002) consider the locational choices of a large sample of over 2,200 spin-outs from universities and public research organisations in Germany over the 1996 to 2000 period. In general terms, business start-ups in Germany are found to reflect the regional distribution of population and demand, although spin-outs from universities and public research organisations are more strongly concentrated in urban agglomerations, reflecting a balance between the spatial distribution of demand and the predominantly urban location of spin-outs. Egeln et al (2002) conclude that 'Spin-offs tend to move away from their incubator's region if urbanisation economies are less pronounced. … Incubators located in smaller and peripheral regions thus have a lower probability that firms spinning out of their institutions will stay nearby, i.e. spin-offs tend to transfer knowledge outside the region'. (p. 7). This tendency is particularly strong where local demand for the products or services of the spin-out is weak, again a factor which may characterise may smaller peripheral regions.

Finally, it has been suggested that publicly funded R&D might contribute to the development of agglomeration and clustering advantages (Table 1, Item 7.3). Malecki (1981), for example, provides an early review of the evidence on the tendency for the clustering of R&D activity commenting: 'Even as agglomeration has become less important for manufacturing activities, and as the latter have become increasingly footloose, agglomeration seems to be of continuing or even growing importance to R&D (p. 74).

3. Assessing Host Region's Share

In this section we consider the factors which determine the share of the global benefits of any specific R&D project which can be captured or appropriated by a host region. We consider two main factors[21]. First, we consider the *profile* of the R&D facility itself such as industrial sector, size, ownership etc. For example, recent evidence from Guellec and van Pottelsberghe de la Potterie (2001), who analysed R&D and productivity growth in 16 OECD countries, suggests that a 1 per cent increase in business R&D generates a smaller (0.13 per cent) productivity increase than either a similar increase in foreign R&D (0.44 per cent) or public R&D (0.17 per cent). The technological character of the R&D being conducted may also have an impact on the benefits which might be expected, with a range of studies suggesting that globally, at

[21] One suggestion which was made to us was that these factors essentially act as 'filters' successively reducing the range of potential benefits which accrue to the host economy. The physical analogy with a white light source and overlapping coloured filters is easily imagined.

least, the social returns from basic R&D are likely to be higher than those from more strategic or applied research activity (e.g. Jaffe et al., 1993).

Secondly, we focus on the character of the innovation system in which the R&D project is located. Rodriguez-Pose (2001), for example, highlights the particular difficulties of less favoured regions (LFRs) in appropriating spillovers from locally conducted R&D due to their limited absorptive capacity. Other recent studies such as that by Fernandez et al. (1996) on government supported R&D in Spain, have suggested that for less developed regions, or those with an intermediate technological and industrial base, the locally captured social returns might be greater from strategic or applied rather than basic research. Reflecting the general comments of Rodriguez-Pose (2001), Fernandez et al. (1996) also argue that the dominance of the Spanish economy by small and medium-sized firms, limits its capacity to appropriate locally the full benefits of publicly supported basic research activity.

3.1 Profile of the R&D Project

Perhaps the most important characteristic of an R&D project in terms of determining the share of the benefits which will accrue to the host region is the type of R&D being undertaken. For basic research, for example, where the knowledge generated is not specifically linked to any immediate market need, global spillovers are generally thought to be greatest. Here, social benefits arise from the production of skilled manpower and the 'public good' nature of the research outputs, i.e. the results of pre-competitive research can be shared by a group of companies without reducing the incentives to develop products or processes. There may also be strategic benefits from conducting basic research. Smith (1989), for example, argues that public support for basic research is important if the fundamental science base of the country is to be sustained. Investments in basic research may also act as an attraction for both academic staff and high quality students to move to and remain within a region. Nonetheless, the links between basic research and economic development - particularly at a regional level - remain ill-defined and unpredictable. Hence, Smith (1989) argues that investment in this type of activity may be difficult to justify in the context of a slowly growing LFR facing tight budgetary constraints. As indicated earlier Fernandez et al. (1996) argues that for LFRs, at least, the returns may be greater from applied or near-market R&D activity.

Applied R&D is directed at specific problems or possibilities but is not aimed at achieving direct practical application. From a public perspective this type of research generates knowledge and internal capability which keeps firms, industry, and the public sector at the forefront of technological developments. The knowledge generated by applied research activity is likely to be more 'specific', however, than that generated by basic research. This may limit the extent of any knowledge spillovers, which may be further eroded depending on the IPR regime adopted by the researching organisations. Experimental development activity is aimed at addressing specific market opportunities or the development of specific new products or processes. This type of research may generate strong private returns and rent spillovers but is less likely to lead to very significant pure knowledge spillovers. The weakness of pure knowledge spillovers stems from (a) the extent to which experimental development leads to proprietary knowledge, and (b) the specificity of the research undertaken to the firm's own product range.

The regional share of benefits arising from an R&D centre will depend, not only on the type of R&D being conducted, however, but also on the institutional and organisational setting of the R&D project. For example, Blind and Grupp (1999) draw a distinction between those organisations focussing on the generation of private and public knowledge: *'Private knowledge comes primarily from the enterprises themselves, but also from associations of enterprises and scientific and professional organisations. Public knowledge is drawn from institutions which conduct scientific and technical R&D. In this category are mainly universities but also other public and semi-public research institutions and transfer bureaux' (Blind and Grupp, 1999, p.452).*

Research centres outside universities, for example, may be more flexible than those in a university setting due to the lack of normal academic restrictions (e.g. teaching, academic promotion criteria, contractual restrictions etc.). Blind and Grupp (1999) suggest that this type of restriction may shape the orientation of university-based research centres making it more difficult for them to respond to the specific needs of their local region. Instead, Blind and Grupp argue that university-based centres are likely to have a more general (i.e. national or international) orientation towards the needs of a specific sector or industry. Larger research organisations may also find it difficult to relate effectively to local small businesses, while smaller units may be more flexible and able to adopt a more specific focus. This is the implication drawn from their German study by Blind and Grupp (1999) who comment that 'polytechnics tend to support small companies in their region, while universities and research labs transfer knowledge more effectively to larger companies with no regional priority' (Blind and Grupp, 1999, 452).

Similar issues arise in terms of publicly funded R&D conducted by business. Locally-owned, single-plant companies will per force exploit locally-conducted R&D locally. For larger, particularly multi-national firms, however, the increasing internationalisation of economic activity and the increasing globalisation of R&D activity may mean that the spatial distribution of the commercial benefits of R&D activity may be very different to that of the R&D activity itself. Reddy (1997, p.1821-22) summarises the situation as follows:

> *'Today, new needs or trends can arise in any advanced market and the latest technologies may be located in another. TNCs attempt to gain a competitive advantage by sensing needs in one country, responding with capabilities located in a second, and diffusing the resulting innovation in markets world-wide'.*

Miotti et al. (2001), for example, note that among Korean multinationals FDI to the US has been partly motivated by technology sourcing in high-tech sectors whereas their investments in Europe are more concentrated on the development of manufacturing facilities for consumer electronics.

Perhaps the other key aspect of the profile of an R&D centre is its industrial focus. Some sectors may provide advances in 'general purpose technologies' which may be more useful in producing generalised productivity advances across a range of sectors than R&D conducted in other more specific technological areas (Bresnahan and Trajtenberg, 1995). Ten Raa and Wolff (2000), for example, in their study of US TFP growth examine both within-sector and between-sector sources of productivity growth. They identify 10 sectors or 'engines of growth' which made the largest contributions to TFP growth over the 1958-97 period. All of these sectors are in manufacturing with the largest sectoral TFP contributions coming from computer and office equipment and electronic components[22]. These sectors also had the strongest spill-over effects of any manufacturing sector although spillovers from some non-manufacturing sectors (trade, restaurants and transportation) were also important due to strong rent spillovers[23].

3.2 Innovation System of the Host Region

In addition to the characteristics of the R&D centre itself, the extent of any localised benefits will also depend crucially on the innovation system of the host region. The industrial composition and absorptive capability of local firms, the strength of local knowledge dissemination networks and the integration of public and private knowledge mediating institutions will all be important as will the extent of synergies between the research focus of the R&D centre and the needs of the regional economy.

One framework within which the situation of a host region might be considered is that of the regional innovation system or RIS (Braczyk et al., 1998; EU, 1998; Nasierowski and Arcelus, 1999)[24]. This perspective recognises both the complexity of the innovation process, its dependence on organisational capabilities, 'untraded interdependencies' (Dosi, 1988), knowledge 'spillovers' (Audretsch & Feldman, 1996), knowledge integration through 'open systems architecture' (Best, 2000), and the potentially important influence of regional innovation policy (EU, 1998, p. 3-6). In this framework, the absorptive capacity of the RIS will depend first, on the capabilities of firms and other organisations within the RIS and secondly the degree of 'association' between the various elements of the RIS, (e.g. the extent of any links between firms and universities etc.).

In terms of the absorptive capacity of firms, Young and Lan (1997) make an important distinction between the technical capability of firms and their willingness to

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[22] See also Mamuneas (1999) on the economy wide productivity benefits of government support for R&D in high-tech sectors.

[23] Both effects reflect the strong forward linkages of these sectors, i.e. productivity gains or cost reductions in either sector have significant knock-on effects throughout the economy.

24 To quote Metcalfe, (1997, pp. 461-462) a national or regional system of innovation is 'that set of distinct institutions which jointly and individually contribute to the development and diffusion of new technologies and which provides the framework within which governments form and implement policies to influence the innovation process. As such it is a system of interconnected institutions to create, store and transfer the knowledge, skills and artefacts which define new technology. The element of nationality follows not only from the domain of technology policy but from elements of shared

take on board new knowledge or technology. Both aspects of firms' capabilities may be less well developed among smaller firms, which are generally less advanced in terms of use of new technologies and have lower levels of innovative capability (e.g. Roper and Anderson, 2000). In terms of technology intermediaries, Heidenreich and Krauss (1999), for example, document the positive role of 'intermediate' institutions in the Baden-Württemberg RIS, while Walker (1993) notes the weakness of such institutions in the UK. Intermediate institutions may be particularly important in linking small firms with the knowledge-generating organisations given the observed difficulties of small firm-university or small firm-research centre linkages observed by Blind and Grupp (1999), for example.

The absorptive capacity of any RIS will also depend, however, on the systemic capability for knowledge diffusion between local firms and other organisations, in other words it will depend on the extent of local inter-organisational linkages and knowledge transfers. For example, the extent of any rent-based spillovers will depend on whether the R&D performing organisation is embedded within the local economy, i.e. is sourcing locally and selling services and products to other local organisations. Relatively little is known about the embeddedness (or otherwise) of R&D centres in different regional settings, however, useful parallels can be drawn with the much better understood situation of high-tech, multi-national inward investment projects. Here, particularly within LFRs, the evidence suggests that projects are often only weakly embedded in their host region, with local purchasing limited by the availability of the type of complex products and services demanded by high-tech firms (e.g. Turok, 1993; Crone and Roper, 1999). Local demand for the type of products or services offered by an R&D performing organisation is also more likely to be weaker within an LFR than within a host region with, say, a greater concentration of high-tech industry again reducing the potential for localised spillovers through forward linkages[25].

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language and culture which bind the system together, and from the national focus of other policies laws and regulations which condition the innovative environment'.

[25] The strength of local linkages and levels of knowledge transfer may also depend on the size of region with lower linkages in smaller regions (Hewitt-Dundas et al., 2002). Numerous studies have also suggested that small firms are less likely to have external links than larger businesses, and may therefore find it more difficult to benefit from the presence of a local R&D centre (e.g. Love and Roper, 2001).

The geographical distribution of industry within a host region may also be an important factor in determining the potential benefits which the region can capture due to spatial economies of clustering and agglomeration (e.g. Dobkins, 1996). How significant such agglomeration effects are likely to be, however, remains uncertain. Evidence from the US (e.g. Audretsch and Feldman, 1996) identifies a positive relation between R&D spillovers and the extent of agglomeration while the European evidence is more mixed[26].

Finally, the regional share of the benefits of an R&D centre will also depend on the synergy between the research focus of the R&D centre and the host region. At one extreme here is the literature on inward investment by multi-nationals into developing countries, where the technical weakness of indigenous firms, and a lack of synergy between the activities of local and incoming firms essentially curtails any local spillovers. At the other end of the scale are situations where international R&D investment in a specific sector is attracted to a region to take advantage of existing clustering or agglomeration advantages (e.g. Saxenian (1996) on Silicon Valley or Crone (2002) on Dublin) and by doing so further extends the localisation economies.

4. Implementation

In this section we describe a simple implementation of the framework described earlier as a narrative template. In this implementation the inventory of global benefits developed in Section 2 is used a as checklist of potential benefits; the profile of the R&D centre and the characteristics of the RIS are then used as 'filters' to define the final set of benefits which might accrue to the host region as outlined in Section 3. To illustrate the use of the framework we consider two case-studies of publicly funded R&D: an R&D project conducted jointly by a textile company and university and a university-only research centre.

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[26] Shefer And Frenkel (1998) in their recent work on Northern Israel, for example, distinguish between the ‘metropolitan’ area of Haifa, ‘intermediate’ (i.e. suburban areas), and peripheral (i.e. rural) locations. Their results suggest – that for high-tech businesses at least – a metropolitan or urban location does have substantial advantages for product innovation. Brouwer and Kleinknecht (1996) using Dutch data also identified positive urban effects on some aspects on firms’ innovative activity, while Harris and Trainor (1995) found that firms in urban locations in Northern Ireland were more likely to introduce new products than those elsewhere. While these studies provide a clear indication of the potential Contrary evidence suggesting the weakness of any urban or metropolitan effects is presented by Develaar and Nijkamp (1989, 1992) and Kleinknecht and Poot (1992) for the Netherlands, Koschatzky et al., (1998) for Germany, Roper (2001) for Ireland.

Case Study 1: Collaborative Textiles R&D Project

Figure 1 applies the framework developed to a collaborative, applied R&D project proposed for support by a locally-owned textiles business in collaboration with its local university. The aim of the project was to develop an innovative type of effluent control system for the textile firm's dyehouse, drawing on basic research previously undertaken in the university. The initial aim was to develop a product which could be used by the textiles business and subsequently exploited through a new joint venture partnership between the company and university.

Looking first at the impact of the project profile on the potential 'global' benefits. This project involved primarily applied research. Gains to the private knowledge base of the company and university were therefore primarily applied with some 'experimental development' gains (Figure 1, items 1.2 and 1.3). Private R&D productivity benefits were also possible due to the collaborative nature of the project and the fact that this was the firm's first collaborative R&D venture (Figure 1, items 2.2-2.5). Benefits from commercial application were also possible but were limited by the nature of the application to (a) cost reduction for the participating firm (Figure 1, item 3.1) and (b) the potential introduction of new or improved products (Figure 1, item 3.2). Gains to the public knowledge base were also limited to applied and developmental research results by the applied nature of the project (Figure 1, items 4.2 and 4.3). Public R&D productivity gains were unlikely due to the lack of any infratechnology investments in the project (e.g. standards development etc.). Rent spillovers were more possible due to potential cost reductions in the output of the participating firm (Figure 1, item 6.1). Pure knowledge spillovers were also possible (Figure 1, items 7.1-7.4) but were perhaps limited by the specificity of the technology being developed.

The share of the social benefits of this R&D project appropriated by the region will also depend on the nature of the RIS. As the university partner was local, public knowledge base effects were possible, although again the value of these was perhaps limited by the specificity of the technology being developed (Figure 1, Items 4.2 and 4.3). Public R&D productivity benefits were also possible with the development of research skills in both the university and company partners, although the extent of these benefits would depend on staff remaining within the host region (Figure 1, item

5.3). Rent spillovers were limited because the firm had few local customers and pure knowledge spillovers were limited both because the firm was in an isolated geographical location and was in a sector in which spin-outs were uncommon. Pure knowledge spillover effects on productivity etc were also limited due to the lack of other similar firms locally.

The profile and RIS filters suggest that this project was likely to have larger private than social benefits and that some of the major social benefits (e.g. rent based spillovers) were likely to fall outside the region. In fact, the products developed were technically successful but commercially unviable. This limited the downstream advantages but the project did leave a legacy of trained staff in both the company and university. Subsequently the university staff left the area, but staff within the company did use the knowledge gained in the project as the basis for future R&D.

Case Study 2: University-Based Plastics Research Centre

Figure 2 applies the framework to the case of a basic research centre established within a university. This initiative built on two earlier research centres operated by the university, both of which had built up extensive local relationships to firms within a cluster of plastics businesses. The aim of the project was develop a centre of excellence which could conduct leading-edge research and rapidly disseminate research findings into local firms. The research centre would also act as a resource for local firms with product or process difficulties.

In terms of global benefits, the project had potential private gains in terms of both basic and applied research (Figure 2, items 1.1 and 1.2). Research capability within the university would also be strengthened with a range of potential advantages (Figure 2, items 2.1-2.5). Private benefits from commercial application are probably fewer due to the university base of the project, but there may be gains in terms of profitability if licensing arrangement for IP or joint ventures developed from the research centre (Figure 2, item 3.5). In terms of the public knowledge base gains, considerable benefits might be anticipated through publication of research results, patent registrations etc (Figure 2, items 4.1 and 4.2). In addition, there may be gains to public R&D productivity due to some spending on infratechnology (testing equipment, systems) (Figure 2, item 5.1). Rent spillovers mediated through the supply-chain will not occur due to the university-based nature of the project, but there may be gains from an increase in the availability of research trained staff (Figure 2, item 6.3). Knowledge spillovers may also be significant as may spin-outs and clustering advantages (Figure 2, Items 7.1, 7.2 and 7.3).

In terms of the RIS effects, it is notable that the research centre being supported here has established links to a cluster of local firms. These links are likely to have little effect on the region's share of any public knowledge base effects, with firms from all over the world able to access codified knowledge in the form of patents or published papers. Local gains here are therefore likely to be positive but relatively modest (Figure 2, items 4.1, 4.2). In terms of public R&D productivity, infrastructure investments by the research centre are likely to improve local R&D productivity allowing testing to be done locally rather than at a distant national centre (Figure 2, item 5.1). Similarly, the local availability of research trained staff may also help generate market based spillovers of benefit to local firms (Figure 2, item 6.3). Pure knowledge spillovers are likely to be more strongly localised due to the local clustering of firms, which may also reinforce agglomeration or clustering advantages. Spin-outs are uncertain but possible given the sectoral focus of the technology (Figure 2, item 7.3).

The localised (social) benefits of this project were strengthened by the relevance of the technology being developed to a cluster of local firms, and established university-industry linkages. In actuality the project proved highly successful producing both high quality research output and making a substantial contribution to the development of a group of related firms. Some staff moves from the university to the related companies were evident and the centre has produced some nascent spin-outs.

5. Conclusions

Our basic argument here is that the knowledge-base derived from *ex post* evaluations of publicly supported R&D projects, and related conceptual and empirical studies, now provide sufficient evidence to enable *ex ante* judgements to be made about the likely regional benefits of publicly supported R&D projects. We develop a framework for *ex ante* evaluation based around an inventory of potential global benefits (i.e. Table 1), and an assessment of the factors which determine the share of these global benefits which will accrue to the host region. Two case studies illustrate the application of the evaluation framework.

The inventory of potential benefits we use in the evaluation framework is an extension of that developed by the HERG research group at Brunel university (e.g. Hanney et al., 2000). This is extended to reflect the results of ex post evaluations of publicly funded R&D and makes a clear distinction between private and public benefits and between rent and pure knowledge spillovers. The results of ex post evaluations are also used to identify the factors which will determine host regions' share of the potential benefits of R&D. In particular, we argue this will depend on the nature of the R&D project itself and the innovation system of the host region. For example, the extent of any 'rent' spillovers from an R&D project to other local firms, in terms of cost savings or quality improvements in their inputs, will depend on the strength of the downstream linkages between the firm conducting the R&D and other local companies. Similarly, the extent of any 'pure' knowledge spillovers from an R&D project will depend on the type of R&D being conducted, the extent of any synergy with other production activities being undertaken in the host region and the absorptive capacity of the region's innovation system. One implication is that for LFRs in particular it may be difficult to appropriate many of the potential spillover benefits (both rent and pure) from local R&D activity. Localised spillovers from basic research and applied research, in particular, may be difficult for such regions to capture locally, especially where the R&D being conducted is of limited relevance to local firms. Experimental development activity may have stronger direct benefits for LFRs but even here R&D within multi-national groups may lead to the main production benefits being enjoyed elsewhere. Labour market spin-offs - as envisaged by Griliches (1995) may be more strongly localised and of more importance to LFRs. although evidence on the scale of any such impacts remains elusive[27]. This is not of course to say that supporting R&D is necessarily a bad public investment in LFRs. Regional attractiveness may be enhanced by the presence of R&D facilities, and these

[27] This is not of course to say that supporting R&D is necessarily a bad public investment in LFRs. Regional attractiveness may be enhanced by the presence of R&D facilities, and these may contribute to cluster and industrial development. Moreover, the presence of R&D facilities within inward investment plants has been shown by Kearns and Ruane (2001) to enhance plant longevity. What is necessary, however, is a realisation of the potential weakness of both rent and knowledge based spillovers from R&D in LFRs and a structured approach to the *ex ante* evaluation of public R&D investments.

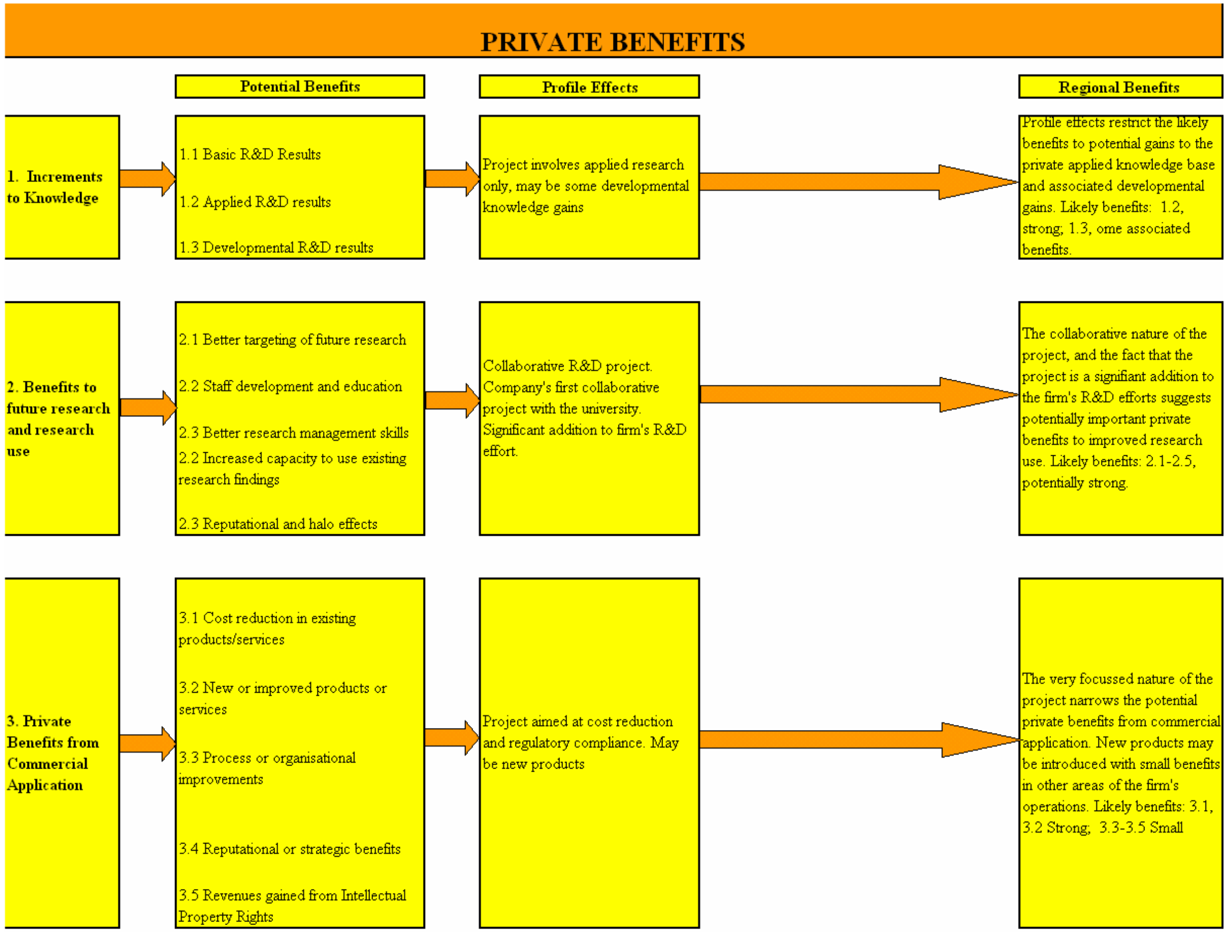
may contribute to cluster and industrial development. Moreover, the presence of R&D facilities within inward investment plants has been shown by Kearns and Ruane (2001) to enhance plant longevity. What is necessary, however, is a realisation of the potential weakness of both rent and knowledge based spillovers from publicly funded R&D in LFRs and a structured approach to the *ex ante* evaluation of public R&D investments.

More generally, the evaluation framework developed here remains experimental having been applied to only a relatively small number of individual projects in a single host region. Useful future developments might be to examine a wider range of project types using the framework, and to consider the potential impact of different regional innovation systems on the regional benefits of specific types of R&D project.

Table 1: Inventory of Private and Social Benefits from R&D Activity

A Private Benefits	B. Wider Social and Public Benefits
1. Private Knowledge Base	**4. Public Knowledge Base Effects**
1.1 Basic R&D Results	4.1 Basic Research Results
1.2 Applied R&D results	4.2 Applied Research Results
1.3 Developmental R&D results	4.3 Developmental R&D results
2. Private R&D Productivity	**5. Public R&D Productivity**
2.1 Better targeting of future research	5.1 Infratechnology improvements
2.2 Staff and research management development	5.2 Better targeting of future research, public
2.3 Reputational and halo effects	5.3 Development of research skills, personnel and overall research capacity
2.4 Increased capacity to use existing research findings	
2.5 Sharing research results	**6. Rent Spillovers**
	6.1 Cost advantages to customers
3. Benefits from Commercial Application	6.1 Scale advantages to suppliers
3.1 Cost reduction in existing products/ services	6.3 Availability of research trained staff
3.2 New or improved products or services	
3.3 Productivity gains	**7. Pure Knowledge Spillovers**
3.4 Growth gains	7.1 Knowledge spillovers on productivity, growth etc.
3.5 Profitability gains	7.2 Spin-outs etc
	7.3 Agglomeration or clustering advantages
	7.4 Reputational, image or demonstration effects

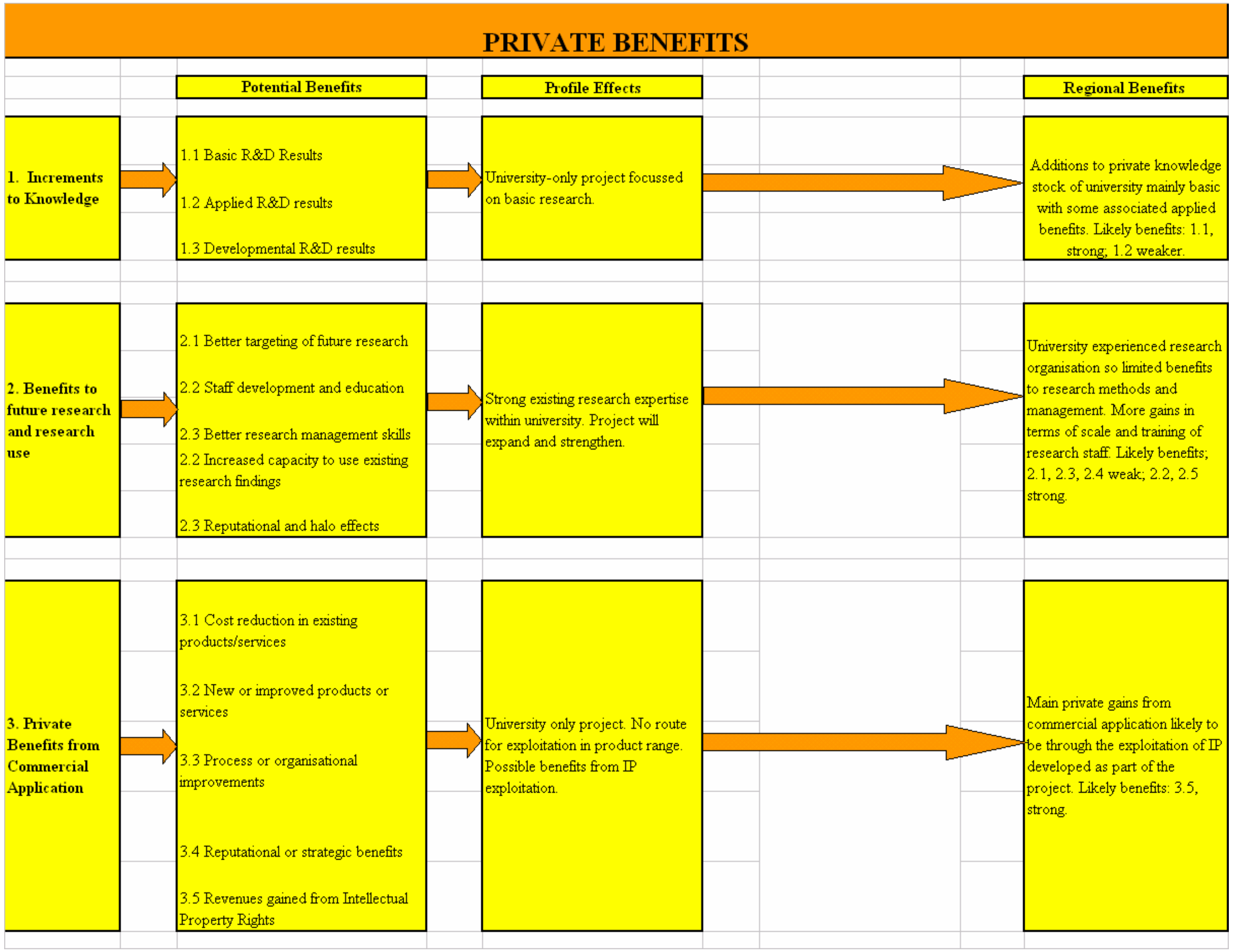
Figure 1: Collaborative Business-University Textiles R&D Project



SOCIAL BENEFITS

	Potential Benefits	Profile Effects	Innovation System Effects	Regional Benefits
4. Increments to Knowledge	4.1 Basic Research Results 4.2 Applied Research Results 4.3 Developmental R&D results	Collaborative, applied project with university.	RIS has relatively weak internal linkages (particularly university-company links) so may reduce potential benefits from this source. University part of bio-technology cluster.	Public knowledge base gains from company likely to be weak as weak local links and very specific technology. University may be more important in terms of papers, patents and application of knowledge within cluster. Mainly 4.2.
5. Benefits to future research and research use:	5.1 Better targeting of future research, public 5.2 Development of research skills, personnel and overall research capacity 5.3 Research clustering or agglomeration benefits	Applied project. No public infra-technology effects. Possible personnel effects	University is part of naescent bio-technology cluster.	Through cluster may may be able to utilise skills developed locally and possibly find applications for knowledge developed. Likely benefits: 5.2, Weak; 5.3, possible.
6. Wider Social or Public Benefits – Market Transactions (Rent spillovers)	6.1 Benefits of cost reductions in other organisations 6.2 Benefits of new improved products or services to other organisations 6.3 Availability of pool of trained staff etc. 6.4 Partnership or network gains	Potential cost savings to customers and trained research staff	Firm is relatively isolated within the RIS with few local customers for potential products from the research project. The firm also has relatively few local customers who might benefit from cost reductions in its existing product range. University part of bio-technology cluster which may magnify labour market benefits.	Lack of local customers reduce potential local impact of cost savings. Clustering may mean local labour effects are more possible. Likely benefits: 6.1, weak; 6.3, weak.
7. Wider Social or Public Benefits - (Pure) Knowledge Spillovers	7.1 Intentional knowledge spillovers 7.2 Unintentional knowledge spillovers 7.3 Spin-outs etc 7.4 Reputational, demonstration, image or halo effects 7.5 Agglomeration or informational advantages	Applied project, but very specific technologies	Plant is geographically isolated with no local small-business incubator or tradition of spin-outs. University is part of bio-technology cluster.	Specificity of technology and isolated nature of plant make business-to-business spillovers unlikely and spinouts. University spillovers more possible. Likely benefits: 7.1, 7.2 limited; 7.3, 7.4 weak.

Figure 2: Case Study 2: University Based Plastics R&D Centre



SOCIAL BENEFITS

	Potential Benefits	Profile Effects	Innovation System Effects	Regional Benefits
4. Increments to Knowledge	4.1 Basic Research Results 4.2 Applied Research Results 4.3 Developmental R&D results	University only project focussed on basic research which may be expected to lead to patents, publications etc. Centre had well developed links to local firms	Cluster of local businesses with established links to the university.	Gains to public knowledge base through publication of research results and patents. Knowledge may be applied to cluster rapidly. Likely benefits: 4.1, strong; 4.2 medium to strong.
5. Benefits to future research and research use:	5.1 Better targeting of future research, public 5.2 Development of research skills, personnel and overall research capacity 5.3 Research clustering or agglomeration benefits	Project involves some investment in infratechnology (standards). Development of research staff in university may also create resource which can be used positively by companies.	Clustering of firms around university and involvement may spread research gains and facilitate research clustering	Developments in the university and strength of links to companies in cluster may facilitiate public research gains. Gains likely to be limited to cluster, however. Likely benefits: 5.1-5.3 strong but limited to cluster.
6. Wider Social or Public Benefits – Market Transactions (Rent spillovers)	6.1 Benefits of cost reductions in other organisations 6.2 Benefits of new improved products or services to other organisations 6.3 Availability of pool of trained staff etc. 6.4 Partnership or network gains	Research project may lead to new knowledge and staff expertise which can be used by local companies. No products as such as university-only project but services may be offered to local companies which may reduce their costs	Clustering again important. Likely to be main customers of research centre. Cluster also creates potential demand for trained staff from university. May identify opportunities for partnership or network gains.	Potential benefits in terms of trained labour and improved/cheaper services may extend to cluster companies. Partnership or network gains are also possible. Likely benefits: 6.1-6.4, potentially strong
7. Wider Social or Public Benefits - (Pure) Knowledge Spillovers	7.1 Intentional knowledge spillovers 7.2 Unintentional knowledge spillovers 7.3 Spin-outs etc 7.4 Reputational, demonstration, image or halo effects 7.5 Agglomeration or informational advantages	Basic research project with possibilities of spillovers and spinouts. University systems in place to encourage spinouts.	Clustering may encourage agglomeration advantages and facilitate spillovers. Spinouts may be discourged by small scale of local market.	Clustering may contribute to spillovers and spinouts which are facilitated by the generic nature of the research being conducted. Spinouts may be forced to locate outside the region if local demand is insufficient. Likely benefits: 7.1 to 7.5, potentially strong

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