Annex 4

Evidence on the economic impact or research and development

A great many studies have been performed to assess the economic impact of research and development. The statistical model usually involves the regression of output, or output growth, on a set of explanatory variables which includes the stock of R&D, or expenditure on R&D. The unit of observation varies from the firm to the industry to the national economy. Most studies have been conducted in the USA and Europe, or in the case of cross-country studies across the OECD – countries for which reliable R&D data have been compiled. Some studies examine only the private rate of return on a firm's own R&D expenditures whilst other studies estimate social rates of return which incorporate the benefits that spill over to other firms and industries. Further complications in analysing the literature result from the fact that whilst many studies report rates of return on R&D investment either net of capital depreciation or gross, other studies report the elasticity of output with respect to the stock of R&D capital.[1]

a) Private sector R&D

One of the earliest large-scale econometric studies was conducted by Lichtenberg and Siegel[2]. They studied productivity growth for over two thousand US firms over the period 1972 to 1985, finding that the gross rate of return on company-funded R&D is around 35 percent. They report a high premium on the benefits of research classified as 'basic' rather than 'applied'. Bernstein and Nadiri[3] examined similar data and estimated that whilst private rates of return (net of depreciation) were just over 20 percent, the spillover benefits accruing to firms in other industries exhibited a rate of return varying from zero to over 60 percent.

A study by Griffith, Redding and Van Reenen[4] models the inter-industry and international spillovers amongst 13 industries across 12 OECD countries over 23 years (1970-92). They find that the gross rate of return on own industry R&D is over 40 *percent* (see their Table 2, p.889). This estimate is based on data aggregated at industry level, so it internalises own-country within-industry spillovers. This is a carefully controlled study, taking account of unobserved country and industry specific effects as well as adjustments to the measurement of Total Factor Productivity for problems of measurement with respect to skill levels and hours of work. Their study takes account of most of the problems cited by Atella and Quintieri[5] in relation to microeconomic studies.

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[1] Rates of return (RoR) are related to elasticities (E) by the formula: RoR = E x Output / Stock of Capital.

[2] Lichtenberg, F. R and Siegel, D., *The Impact of R&D Investment on Productivity - New Evidence Using Linked R&D-LRD Data,* Economic Inquiry 29: 203-228 (April 1991)

[3] Bernstein, J. I. and Nadiri, M. I., *Product Demand, Cost of Production, Spillovers, and the Social Rate of Return to R&D*, NBER Working Paper.1991.

[4] Griffith, R. Redding, S. and Van Reenen, J., *Mapping the Two Faces of R&D: Productivity Growth in a Panel of OECD Industries*, Review of Economics and Statistics 8: 883-895. (4 Nov 2004)

[5] Atella, V. and Quintieri, B., *Do R&D Expenditures Really Matter for TFP?* Applied Economics 33: 1385-1389. (11 Sept 2001)

A recent survey by Wieser[6] assesses the international evidence. He reports considerable variation in the estimated social rates of return on R&D, averaging 28 percent but ranging from 7 percent to 69 percent. Taking account of spillover effects, the average social rate of return to R&D is around 90 percent, with spillovers between industries more important than within industries. There are wide variations in rates of return across industries. Significantly, there is no consensus as to which industries yield the highest returns, i.e., there is no evidential basis for 'picking winners' in terms of R&D support. Evidence is found that the contribution of R&D to productivity growth has been declining over time. However, this is likely to be due to the ongoing problem of measuring innovation in ever growing service sectors. It is also found that the differences in returns to R&D across different countries are not large although the USA is an outlier with relatively high returns.

This evidence is backed up in the Australian context by Productivity Commission[7] who report that the marginal rate of return to "R&D elicited through public support" lies between 35 percent and 100 percent.

b) Public sector R&D

Adams[8] investigates the relationship between the rate of productivity growth in 18 US manufacturing industries over the period 1953-83 to the rate of publication of scientific papers across nine scientific fields. Productivity growth is found to depend on the accumulated stock of field-specific scientific research, operating with a twenty-year lag, and on the employment by industry of scientists in the appropriate fields.

In a subsequent paper, Adams[9] examines the relationship between the volume of R&D activity and the scientific base for a panel of fourteen R&D-performing industries in the USA over the period 1961-86. He seeks to explain R&D activity as a function of the lagged stocks of scientific research in particular fields (proxied by the number of papers published worldwide) interacted with the proportion of employed scientists specialised in the field. He reports that the size of the scientific base does have a significant positive impact on the level of R&D activity. The implication is that basic scientific research provides fertile ground for applied commercial development.

This conclusion is supported by Mansfield[10], who analyses surveys of US businesses. Firms reported an average lag of seven years between the publication of academic research on which they have relied and the timing of their subsequent commercial innovation. Using estimates of the commercial value of the recorded innovations,

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[6] Wieser, R., *Research and development productivity and spillovers: empirical evidence at the firm level*, Journal of Economic Surveys, 19:587-621. 2005.
[7] Productivity Commission Research Report, *Public Support for Science and Innovation*, p. 628. March 2007.
[8] Adams, J. D., *Fundamental Stocks of Knowledge and Productivity Growth*, Journal of Political Economy 9(4): 673-703. 1990.
[9] Adams, J. D., *Science, R&D, and Invention Potential Recharge: U.S. Evidence*, American Economic Review, American Economic Association, 83(2): 458-62. May 1993.
[10] Mansfield, E., *Academic Research and Industrial Innovation*, Research Policy 20: 1-12. (1 Feb 1991)

Mansfield calculated the average rate of return on academic research to be of the order of magnitude of 28 percent.

Some studies of the productivity effects of public R&D have suggested that returns were lower than those estimated on business R&D - for instance Lichtenberg and Siegel[11], Nadiri[12] and OECD[13]. Subsequent research suggests that the results of these studies may be misleading for two sets of reasons. First, they failed to distinguish between different types of publicly funded research. Second, they failed to account for the time delay between productivity outcomes and the performance of public R&D, which tends to be focused more on the research than on the development side. Studies which incorporate lagged effects and distinguish types of public R&D do, in fact, find significant positive productivity effects. For example, Mamuneas and Nadiri[14] distinguish publicly funded R&D in the USA according to whether it is carried out in the business sector or in the public sector. Examining the cost-reducing benefits of R&D stocks in fifteen industries over the period 1956-1988, they find that both forms of public financed R&D generate statistically significant benefits, albeit with the stronger reduction in marginal costs coming from R&D performed within the business sector.

Guellec, and van Pottelsberghe de la Potterie[15] directly address the economy-wide returns to public R&D in their cross-country study and estimate that the long-run elasticity of productivity with respect to public R&D capital averages 0.17 over their sample of sixteen OECD countries. Furthermore, the elasticity is higher for countries with a relatively large share of university-performed research compared to government lab research and in countries where the business R&D intensity is relatively high, indicating that the spillover benefits of public research are complementary with corporate research activities.

It is possible that public sector research crowds out private sector research. A survey by David, Hall and Toole[16] found that studies conducted at firm level were more likely to report net substitution or crowding-out than were studies carried out at a higher level of aggregation. Moreover, crowding out was a common finding in US studies whereas a large majority of studies conducted in other countries found complementarity between public and private R&D. Guellec and van Pottelsberghe de la Potterie[17]examine the effect of government funding on business R&D across 17 OECD countries from 1981-96. They report that government funding stimulates business R&D expenditure (BERD) if the government research is contracted to the

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[11] Lichtenberg, F. R and Siegel, D., *The Impact of R&D Investment on Productivity - New Evidence Using Linked R&D-LRD Data*, Economic Inquiry 29: 203-228 (April 1991)
[12] Nadiri, M. I., *Innovations and Technological Spillovers*, NBER Working Paper No. 4423. 1993.
[13] OECD, *The Sources of Economic Growth in OECD Countries*, Paris: OECD Publication Services. 2001.
[14] Mamuneas, T. P. and Nadiri M I., *Public R&D Policies and Cost Behavior of the Us Manufacturing Industries*, Journal of Public Economics 63: 57-81. (1 Dec. 1996)
[15] Guellec, D. and van Pottelsberghe de la Potterie, B., *R&D and Productivity Growth: Panel Data Analysis of 16 OECD Countries*, OECD Economic Studies 33: 103-126. 2001.
[16] David, P. A., Hall, B. H. and Toole, A. A., *Is Public R&D a Complement or Substitute for Private R&D? A Review of the Econometric Evidence*, Research Policy 29: 497-529. (4-5 April 2000).
[17] Guellec, D. and van Pottelsberghe de la Potterie, B., *R&D and Productivity Growth: Panel Data Analysis of 16 OECD Countries*, OECD Economic Studies 33: 103-126. 2001.

business sector, but tends to partially crowd out BERD when performed in government laboratories. BERD is not affected by university research. They also find that tax incentives are effective in stimulating BERD, whilst recognising that some of this effect may work through an increase in R&D costs.

Of course, publicly funded R&D may result in benefits that are not captured in productivity measures. Salter and Martin[18] cite a number of surveys of firms which suggest that the private sector gains substantially from publicly funded research in a variety of ways:

1. Increasing the stock of useful knowledge;
2. Training skilled graduates;
3. Creating new scientific instrumentation and methodologies;
4. Forming networks and stimulating social interaction;
5. Increasing the capacity for scientific and technological problem-solving; and
6. Creating new firms.

c) The geographical location of research

There is a body of work investigating the links between scientific research, sometimes defined as university-based research, and measures of innovation. Some of these studies investigate the extent to which the benefits of research are concentrated within the geographic region where the research is carried out.

For example, Acs, Audretsch and Feldman[19], following Jaffe[20], analyse survey data on the rate at which firms register both patents and significant product innovations across US states and fields of technology in 1982. The authors conclude that own R&D activity is particularly important for large firms, which have sufficient scale to run their own labs, whilst smaller firms tend to benefit from the knowledge created in publicly funded research. The effectiveness of public research is enhanced by geographical proximity to private sector research labs. Similar results are found by Audretsch and Vivarelli[21] in their study of the determinants of annual regional patenting activity across fifteen regions of Italy over the period 1978-86. These studies deal with the contemporaneous relationship between innovation, private sector R&D activity and publicly funded research. As such, it is not clear that the strong correlations that have been identified are necessarily evidence of causation. It is plausible to suppose, for instance, that universities might respond to patterns of industrial activity and innovation by concentrating their research activities in those areas where the private sector is locally active.

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[18] Salter, A. J. and Martin, B. R., *The Economic Benefits of Publicly Funded Basic Research: A Critical Review*, Research Policy 30: 509-532. (3 March 2001)
[19] Acs, Z. J. Audretsch, D. B. and Feldman, M. P., *R&D Spillovers and Innovative Activity*, Managerial and Decision Economics 15: 131-138. (2 March (1994)
[20] Jaffe, A. B., *Real Effects of Academic Research*, American Economic Review 79: 957-970. (5 Dec. 1989)
[21] Audretsch, D. B. and Vivarelli, M., *Firms Size and R&D Spillovers: Evidence from Italy*, Small Business Economics 8: 249-258. (3 June 1996)

d) International technology spillovers

There is widespread evidence that the rate of technology transfer between countries depends on the policies and activities of the recipient country. Coe and Helpman[22] inspired a series of studies which report evidence that international technology spillovers amongst OECD countries are enhanced by trading with high R&D-intensive countries.

A second school of thought on international technology transfer is based on the models of Nelson and Phelps[23] and Abramovitz[24]. There are two forces in operation. The size of the technology gap relative to the world frontier represents the scale of opportunity to acquire productivity-enhancing technology. The opportunity to acquire foreign productivity is not sufficient, however, to generate rapid economic growth. A country must also possess the capacity to identify, capture, implement and adapt the technology. This ‘absorptive capacity’ is often modelled as a function of the level of human capital of the technology-acquiring country. Without a highly skilled scientific workforce to identify the appropriate technologies, or without a technologically capable management and production workforce, a country will be unable to make use of the foreign technologies.

A series of studies confirms that domestic investment in education enhances absorptive capacity.[25]

Further evidence on the determinants of absorptive capacity comes from a study of industry-level productivity growth covering 12 industries in 13 OECD countries since 1970[26]. It found that the role of trade is relatively weak whilst investment in both R&D and education increase the capacity of industries to absorb technology from the overseas leaders. The dual role of domestic R&D in promoting not only domestic innovation but also technology transfer from overseas is particularly interesting. The importance of own R&D for the acquisition and implementation of foreign technology is confirmed by the macroeconomic study of Guellec and van Pottelsberghe de la Potterie[27]. They suggest that the most important criterion for effective absorption of particular technologies is active domestic research in the cognate field.

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[22] Coe, D. T. and Helpman, E., *International R&D Spillovers*, European Economic Review 39(5): 859-887. 1995.

[23] Nelson, R. R. and Phelps, E. S., *Investment in Humans, Technological Diffusion, and Economic Growth*, American Economic Review 56: 69-75 (1-2 March 1966)

[24] Abramovitz, M., *Catching up, Forging Ahead, and Falling Behind*, Journal of Economic History 46: 385-406. 1986.

[25] Benhabib, J. and Spiegel, M., *The Role of Human Capital in Economic Development: Evidence from Aggregate Cross-Country Data*, Journal of Monetary Economics 34(2):143-173. 1994.; Frantzen, D., *R&D, Human Capital and International Technology Spillovers: A Cross-Country Analysis*, Scandinavian Journal of Economics 102(1):57-75. 2000.; Dowrick, S. and Rogers, M., *Classical and Technological Convergence: Beyond the Solow-Swan Growth Model*, Oxford Economic Papers 54: 369-385. 2002.

[26] See Griffith, R. Redding, S. and Van Reenen, J., *Mapping the Two Faces of R&D: Productivity Growth in a Panel of OECD Industries*, Review of Economics and Statistics 8: 883-895. (4 Nov. 2004)

[27] Guellec, D. and van Pottelsberghe de la Potterie, B., *R&D and Productivity Growth: Panel Data Analysis of 16 OECD Countries*, OECD Economic Studies 33: 103-126. 2001.

2. Design Principles and Criteria[1]

It is useful to consider and apply certain basic policy and program design principles, applying some of the lessons of the experience in Australia and other countries. Adherence to clear design principles is the best way to avoid flawed programs and unintended consequences. Good policy design should reduce inefficiencies in the innovation system and the extent of 'innovation regulatory red tape' around support programs. Approaches to design will frequently be influenced by the political mindset as to whether public innovation outlays represent 'expenditure' and costs to the community, or 'investments' for future benefit. Too often the former prevails over the latter.

Designing good policy essentially revolves around identifying the best solution to a problem. Gary Banks, the Chairman of the Productivity Commission, recently provided a succinct overview of the key steps in good policy development[2].

Key steps in best practice policy development

Developing the best policy approach to a particular social, environmental or economic issue requires systematic processes to ensure that the ultimate decision is as well informed as possible and therefore unlikely to have adverse or unintended consequences. The key steps are:

- *Understand the nature of the problem or issue and its causes.*
- *Determine why some form of policy intervention is called for and thus specify the policy objective.*
- *Outline the range of possible policy options (including non-regulatory approaches).*
- *Assess their relative efficacy in addressing the problem, and their impacts (costs and benefits) across different parts of the economy and sections of the community.*
- *Choose the option that maximises net social benefits, taking all impacts into account.*
- *Develop an effective implementation strategy to avoid undue transitional costs, and monitor the outcome.*

In 1998 Australia's Productivity Commission undertook a comprehensive survey of design principles for business programs[3], the so-called Lattimore review. This provides an excellent reference point and resource, and continues to be a reference model in Productivity Commission reviews. The following checklist is adapted from this framework, and its further elaboration in the recent Commission report on public support for science and innovation

[1] Cutler, T. *Alliances for innovation and economic development: the Australian experience* A study prepared for the United Nations Economic Commission for Latin America and the Caribbean (ECLAC). 2008.
[2] Gary Banks, Public inquiries in policy formulation: Australia's Productivity Commission, Address at China-Australia Governance Program, Beijing, 3 September 2007.
[3] Lattimore R, Martin, B. Madge, A. and Mills, J., *Design Principles for Small Business Programs and Regulations*, Productivity Commission Staff Research Paper, Canberra, August 1998.

support for science and innovation[4].

Policy Design Criteria

Clarity about the problem to be solved.

Is there a clear and unambiguous statement of objectives and rationale? Does the policy or program target the problem effectively?

Inducement effect (additionality or behavioural change)

Is it clear how policy or program incentives will affect behaviour? Will it induce new or different activity? Is it likely to have acceptable take-up? Is the scale of the program consistent with the desired outcomes?

Contestability and transparency

Should there be contestable funding arrangements? Deliberate choices should be involved in deciding between contestable or noncontestable arrangements. The Productivity Commission notes[5] that such choices should be informed by:

- *the ability to define appropriate objectives in terms of community benefits;*
- *the ability to evaluate the merits of competing proposals against those objectives;*
- *the administrative and compliance costs involved in the application and evaluation of funding proposals; and*
- *the potential for strategic behaviour by stakeholders to obtain preferential treatment.*

A different insight might come from the tests for ‘policy market’ contestability. Are there low entry and exit barriers? This directs our attention to the appropriateness of any hurdles to accessing a program, or to potential problems with ‘lock-in’, both for participants or programme providers.

In the case of non-contested funding arrangements (as in block funding or bi-lateral arrangements) how might monopsony market pricing disciplines be applied to public policy?

Consistency

What are the possible interactions with other policies? Where does this policy fit within the overall policy portfolio?

Duration

How long would the programme need to be in place to produce the desired outcomes, or to produce sustainable results? This also draws attention to the desirability of aligning carefully the cycles for funding, milestones, and evaluation. It is also worth considering whether there is scope or benefit in program ‘tranches’, as in a venture

[4] Productivity Commission, *Public Support for Science and Innovation, Research Report*, Canberra, March 2007, See Chapter 10.1
[5] Ibid., p. 374.

capital model of migration through a development cycle. Finally, there is the question of planned program exits, discussed further below.

In addition to program duration, there is an ancillary question about the presumed lifecycles for participation by individual entities (this refers to expected or desired churn or turnover in participation).

Calculated risk

Lattimore et al tend to express risk criteria in terms of 'the avoidance of risk' and this can lead to a policy or industry culture of risk aversion. The more basic aspect to risk criteria is *the understanding of the nature of risk*. Research and entrepreneurship entail risk by definition. In science, for example, progress is made by the fallibility of the current state of knowledge, with as much learning arising from null hypotheses as from proofs. There is inevitably waste within a robust innovation system, but the key issue is how to capture the lessons from apparent failure. Most things involve risk. The appropriate test revolves around assumptions about the profile of risk and the potential return. 'Is this worth the risk?' Good public policy formulation will explore the appetite for risk and proceed on the basis of 'calculated' risk. Some assessments of high risk and high return might, for example, lead to policy models built around experimentation, or pilots. These are standard processes in leading edge industrial innovation, which often proceeds through a cycle from proof of concept (does it work in test conditions?) to pilot plants (can this be scaled to industrial strength?). Public policy discussions sometimes conflate these notions of experimentation and piloting, to the detriment of appropriate outcomes. Nonetheless, there are special categories of risk which are usefully addressed by design principles.

Risk management: (i) Adverse interactions with other programmes

This calls for attention to the possibility of conflicting signals arising from different programs or policies. Pertinent examples might include:

- conflict between objectives about research excellence and productivity (i.e., output by quality versus volume, as in the value of patents versus the number); or
- the conflict in building knowledge capability between knowledge diffusion and commercialisation (or public knowledge *versus* privatised knowledge).

A different kind of negative interaction might involve the scope for 'double dipping' and 'programme shopping'.

The flipside is to look for ways in which different programmes might be rendered more complementary and mutually reinforcing. This is particularly important where programme interventions occur at specific points in a value chain (such as R&D incentives). Both the potential positive and negative impacts on upstream or downstream activity or behaviours needs to examined. The risk of isolated interventions at a single point of the innovation system is that outcomes may become stranded or 'orphaned', with no path to impact.

Risk management: (ii) Unforeseen liabilities for government and 'moral hazard'.

The most basic example here is excessive risk to government revenue from uncapped or open-ended incentive programmes, especially those delivered through the tax system. The Australian experience has shown that the impact of variations to the R&D Tax Concession has proved notoriously difficult to predict.

The biggest pitfalls arise from inadequate attention to possible ‘contingent liabilities’ for government, or the ‘moral hazard’ of policies which might leave government captive to the claims of sectional interests. Moral hazard often surfaces when the termination of a programme is contemplated. This frequently results in inefficient or sub-optimal programmes being continued because the expenditure of political capital in closing them down is just too high[6]. As with venture capital, there is merit in building ‘exit’ options into programme design. A very useful mechanism is to have explicit sunset terms, linked to an appropriate funding cycle, and explicit, *ex ante* criteria for the renewal of a programme.

Risk management: (iii) Strategic behaviour by firms

This is code language for the risk that firms and beneficiaries may be able to ‘game’ the system. Poor programme design may leave the way open for unexpected behaviours, some of which might undermine the integrity of a policy. A good example of this in Australia was the financial engineering around R&D Tax Concession Syndication. Another example is the way the new ventures backed by private equity might use the R&D grant schemes to leverage the value of their equity stake and to free up working capital for other purposes. No judgement is being made here as to whether or not this is inimical to the public interest. The real risk in public private interfaces around programmes arises from the often mutual incomprehension of the operating context and culture of the other. Where one party sees an opportunity to take advantage of ‘blind spots’ on the part the other, the risk is that this undermines the intended alignment of interests in certain outcomes. It can also breed suspicion and lack of trust.

The test in policy design is to keep asking how a self-interested, commercially savvy party would seek to optimise the private benefit from a public programme. There are several ways in which this can be done. The first design strategy is the ‘hacker challenge’ in computer software, where developers co-opt hackers to fireproof a system design. Where the stakes are high, this strategy can be used in public programme design. Retain the smartest commercial operators to tell you all the ways they could find to ‘rort the system’. More generally, one of the sources of value from private sector participation in public sector governance or evaluation processes is the ability for these participants to provide a critique of how programmes might operate in the ‘real world’. For example, anyone with a business background would quickly provide feedback that a small incremental tax benefit with high compliance costs is likely to have little industry impact. Another example is in the area of making judgements about the points at which ‘additionality’ might kick in as the threshold below which a firm or entity would be likely to undertake an activity anyway.

Administrative and compliance efficiency

While this is an obvious design principle, it is frequently ignored in practice. Problems arise when there is a mismatch between the inventive instrument or funding mechanism and the administrative framework. An example would be where a small grant programme involves complex application and assessment procedures. A

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[6] This approach is exemplified in the EFIC case study.

proportionality principle should apply. Another source of inefficiency is where compliance regimes require special-purpose reporting which is different from related reports a firm may be required to produce for normal business compliance[7]. This practice commonly creates significant additional overhead costs for an entity. Compliance and evaluation can be over-engineered. Often very simple mechanisms can substitute for massive red tape.

Accountability and transparency

The strongest mechanism to promote accountability and transparency is the timely and open reporting of activity. The default position should be full public disclosure unless there are sound reasons for the introduction of limitations (such as the privacy implications of fully disaggregated data). Where commercial sensitivities limit disclosure there should be robust independent audit processes to provide assurance about the integrity of programmes.

Cost effectiveness

The cost effectiveness of programmes is best secured by establishing a business case model as part of the design process. This has the benefit of:

- enabling a proposal to be evaluated against alternative programme solutions for a given objective; and
- articulating the *ex ante* assumptions for review in evaluation processes.

Thinking about costs should not preclude attention to non-price factors and externalities. Externalities include examining whether an initiative might impose some significant costs on a particular group. Positive externalities should not be ignored.

Compliance with international obligations

There has been increased focus on compliance with international treaty obligations in policy design. Unfortunately, there is often little expert knowledge brought to bear on such compliance, leading to unnecessarily barren policy frameworks. On occasion international trade rules will be used an alibi for inaction.

As with all compliance regimes, there is often a great difference between the actual ‘black letter’ obligations and the purported intent or ‘spirit’ of an undertaking. It is arguable, for example, that obsessive concern with keeping to an expansive interpretation of an undertaking will penalise a country relative to others that operate on the basis of minimum compliance. Germany and Japan are good examples of the latter in the area of the application of WIPO rules to patent law.

Evaluation, monitoring and reporting.

The key principles here are:

- the development of the evaluation criteria and reporting requirements *ex ante*;
- a requirement for *ex ante* and *ex post* performance data;
- the independence of the review function as an ‘audit’ process; and
- proportionality.

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[7] The CRC programme, for example, requires detailed financial reports as a different chart of accounts to those which a CRC needs to prepare as its statutory corporate returns.

Annex 4

In monitoring frameworks, there is scope for greater attention to be given to ‘lead’ as well as ‘lag’ indicators. The distinction between group or portfolio evaluation versus individual programme evaluation should be considered carefully.