TECHNOPOLIS

An Evaluation of the Cambridge-MIT Institute

Prepared for the
Department for Innovation Universities and Skills (DIUS)

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February 2009

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1 Summary

1.1 The report

This report presents findings from an evaluation of the Cambridge-MIT Institute (CMI). The core of the study has been the evaluation of the economic benefits accruing from the *Knowledge Integration in Research (KIR)* theme of the Cambridge-MIT Institute (CMI) programme, one of three broad strands of investment pursued throughout the project. More specifically, the study considered the following:

- Achieved benefits and value for money of the programme
- Contribution of CMI structures to outcomes
- Implementation and achievement of "consideration of use"

While the primary focus was on research collaboration, the evaluation also considered the achievements of the two other principal CMI themes, *Education for Innovation (E4I)* and *Knowledge Dissemination (KD)*.

1.2 The Cambridge-MIT Institute

CMI was an experimental transatlantic programme of collaboration between two of the world's leading research universities, Cambridge University and the Massachusetts Institute of Technology (MIT). It was launched as a virtual institute in 2000, funded by the British government, in recognition of MIT's commitment to share its successful approach to connecting public research with innovation and economic growth.

CMI operated through two primary strands, which were transatlantic research collaborations and educational development, with a smaller communication and dissemination fund to support the sharing of results with the wider UK HE sector and business community.

CMI invested some £65 million in the 6-year period 2000/01 to 2006, through more than 100 research projects and almost 200 education and dissemination initiatives, with the dissemination activities facilitating engagement with scores of universities and several hundred businesses. It touched a wide range of intermediaries, regional economic development agencies and national research and innovation policy makers.

1.3 Achieved benefits

CMI produced a wide range of benefits; from excellent research to educational innovations to changed professional practices within the UK's technology transfer professionals.

On research excellence, the bibliometric analyses show that CMI financed very high quality research, with almost all subject areas outperforming international norms by a factor of two or three, and equivalent research at Cambridge by a factor of two. CMI research outputs overall also registered a greater impact in comparison with the equivalent research fields at MIT, albeit the difference was rather less than for Cambridge.

Furthermore, the analyses suggest that CMI research is likely to have a very significant impact going forward, given its work is already widely cited by other authors, who are themselves publishing in high impact journals. Interest appears to be strongest amongst researchers at the world's leading technological universities, which is further testimony to the quality and relevance of the work supported through CMI.

The bibliometrics do not suggest that the CMI philosophy had compromised research quality at either institution, but rather suggest quite the opposite effect might be realised from this focus on fundamental *applied* research.

CMI financed a large and impressive body of educational development work, which has been of benefit to the two participating universities and students. There have been several exceptional education projects, notably the international exchange programmes and the interdisciplinary MPhils developed in Cambridge. Other education projects have delivered wider benefit, and in particular the entrepreneurship course for undergraduates and the technology transfer training for research commercialisation professionals. Substantial additional potential benefit might accrue in the future through the changed outlook of the several hundreds of students that have participated in the various educational projects.

From a financial perspective, dissemination was by far the smallest budget line within the CMI project. Even though the budget was effectively doubled by the dissemination work embedded within the research and education projects, it seems to have been a minor activity given centrality of dissemination and debate to the CMI objectives lessons learned and communication remit.

The focus on engagement and dissemination developed as the programme moved through its lifecycle and more and more 'content' became available and the many and various CMI-supported networks matured. Interviews and project files suggest a broadening commitment to the importance of second-wave exchange and dissemination, through for example support to student enterprise clubs or the encouragement to researchers and businesses to work together outside CMI on a consultancy basis, to extend and enhance one-another's intrinsic problem-solving capacity.

On capabilities, CMI provided a valuable platform from which the research commercialisation team at Cambridge Enterprise was able to learn from its counterpart at MIT and ultimately improve its capabilities, processes and productivity, which has benefited CMI and Cambridge.

1.4 Economic benefits

CMI produced significant numbers of commercialisation outcomes, with 40 invention disclosures, 20 patents, 11 licence agreements and three university spinoffs, vital statistics that stand comparison with Cambridge University as a whole.

Using time-series data on invention disclosures and patent applications from the Higher Education Business and Community Interaction (HEBCI) survey for all English universities, CMI commercialisation performance exceeds the average performance ratios for the 20 research-intensive universities within the Russell Group and matches the average performance for all universities, on a proportionate basis.

The number of cases of evident economic impact is small in absolute terms, however it is quite impressive in respect to the size of the investment fund. Three of the cases where innovations have been recorded look set to experience commercial success, with two of these UK-based technology businesses showing realistic promise of strong growth in the medium term. This heavily skewed distribution, as regards the benefits to innovation, is very much in line with the literature.

Orthomimetics is perhaps the most obvious candidate poised to enter what is a large and growing global market, and if it succeeds, its growth, whether as an independent company or as part of a merged group, might be dramatic and with ultimate numbers measured in the many tens of millions.

Praxis and one or two of the other non-research projects that look highly likely to yield economic benefits might turn out to have been among the most consequential originators of economic returns.

However even if such an outcome were to come to pass it is unlikely to be revealed without further conscious and quite challenging research and analysis.

In the longer term, the CMI's work with Rolls-Royce through the silent aircraft initiative might very well emerge as a critical point in the evolution of a radical new engine technology that could be at the centre of its business in 10-20 years time. In the nearer term, the CMI work has produced insight and patents that suggest enabling technologies might very well be deployed within 3-5 years on current generations of engine technology, helping to secure future sales and competitiveness.

The extent of the ultimate economic benefits is not predictable and so it is not possible to calculate the programme's return on investment in any exact sense, however a cautious estimate might fall in the necessarily broad range 20-200%. This excludes a view of the economic returns to US-based participants, like Boeing or Dow Pharmaceuticals. Overall, the likely range is at least comparable to the estimates produced for a number of other economic impact assessments carried out in the context of strategic research programmes, from the LINK programme to the UK's civil space programme. In these cases, the estimated return on investment scenarios ranged from about 75-300%.

1.5 CMI structures

CMI principles and structures contributed substantially to the realisation of the social and economic benefits described above, and in particular the ability to support international collaboration projects of real scale and duration where a majority of funding schemes will tend to fund national rather than international work. The international dimension is more typically facilitated through support for international studentships and fellowships, and the natural inclination of researchers to travel widely.[1]

One of the defining features of CMI was its constitution as a single institution that was able to do research and education and innovation and link biology with physics with management research if need be. This absence of boundaries really marked the project out from for example individual research councils or even their inter-disciplinary research centres.

Perhaps most significantly, CMI was a pioneer of a more integrative and multidisciplinary approach to research and innovation, and one can see these principles have become mainstream in the past decade, whether that is at the level of UK government programmes, such as the innovation platforms, or cross-agency collaboration amongst the research councils, facilitated through RCUK.

1.6 The implementation of CMI

CMI was a creditable idea, which sought to learn about and import to the UK the critical aspects of the MIT approach to driving innovation out of research, and with the evident and strongly positive spillover benefits to the Boston and New England economies. The CMI objectives were reasonable too, focused as they were on working with MIT to drive more innovation and commercial value out of a given volume of research and education, while seeking to gain insight as to what were the critical success factors. Setting the project up as a learning experiment, with a commitment to share this insight more generally, is particularly deserving of praise. The budget for the project was respectable too, with a £65 million budget rather than a more typical £6.5 million.

[1] It is a foundation of the academic profession that research excellence demands an international context, with breakthroughs building on the work of predecessors and shaped by debate with one's collaborators and adversaries across the global community. Throughout their career, professional researchers strive to build and renew their social networks in order to both enhance their knowledge and advance their personal interests. In practical terms, the scale and geographical extent of the public-sector research base means that the frontier of knowledge, in almost any field or discipline, will be determined in some degree at least by people and institutions in countries other than one's own.

In operational terms, CMI was initially something of a mixed success. As a wholly new institution with some novel features and a large budget, there was a pretty steep learning curve for all concerned. Interviewees in 2008 still recollect the somewhat disorganised approach of those early years, and several people remarked that the administration had remained a challenge throughout, and that with hindsight there would have been much to be gained in terms of efficiency and orderliness by the appointment of a dedicated Chief Operating Officer.

There must be a question mark too over the very large numbers of projects launched in the early years, and the resulting broadly equal split between research and education development projects. In 2003, a new management team refocused the programme on use-oriented research and the concept of bold, integrated projects. The new leadership launched the Knowledge Integrated Communities, which while not fully implemented across the programme did appear to make a more substantive impact on the commercialisation goals.

The view of operations from the ground is mixed too, with several researchers complimenting CMI for including senior academics within the core administrative team, which they argued had led to more sympathetic and deft handling of project developments. The level of strategic autonomy and researcher-centred quality of the management team clearly marked CMI out as being very different to the majority of research funders.

Other well-liked features were the thematic openness and CMI's flexibility around project size and timing; those that did secure CMI grants believed the bidding process was more straightforward and with better odds than an equivalent research council.

While the CMI-style communications and project monitoring had been a significant additional overhead by comparison with conventional response-mode grants, its modus operandi had made possible real collaboration across disciplines, institutions and countries.

1.7 Implementation of the principle of "consideration of use"

"Consideration of use" was a fundamental principle within the CMI strategy, wherein questions of utility and relevance were expected to guide senior management in making strategic choices about broad research themes as well as guiding individual researchers in the design, execution and dissemination of their research.

In practice, this founding idea was more evident within the constitution of the governing body than it was in strategic or operational terms, echoing the administrative challenges noted previously. CMI's governing body was constituted by policy makers, academics and industrialists with a track record of collaboration and a pre-disposition towards more vocational education and strategic applied research.

In the first several years however, the research programme had a strongly bottom up quality with little in the way of prioritisation of themes or projects based on any sense of relative social or economic worth. From 2003, the new management team did re-commit to this notion, launching the Knowledge Integrated Communities and a series of thematic strategies targeting major social or economic challenges in for example the process of drug discovery or the creation of an aircraft design with noise levels sufficient to permit the further expansion of this mode of transport.

CMI calls and application procedures did less than might have been anticipated to promote consideration of use, and did not develop specific protocols or guidance material to inform prospective participants or support grantholders.

On the positive side, the location of CMI and the composition of its senior management meant that it was most visible to academics within the various applied sciences, a majority of which had long-established links with their respective industrial 'end-users' and as such the default setting for the proposed studies was use-oriented research.

Additionally, the work of the CMI management team and reviewers did provide an important challenge function for projects and was believed to have helped research teams to focus on scientific breakthroughs with the potential for real-world applications. Consideration of use was also inspired through several of the CMI accompanying measures, such as the entrepreneur in residence concept, and the systematic support of the commercialisation offices.

1.8 In conclusion

In conclusion, CMI did achieve its objectives in broad measure. It did deliver a programme of excellent research with good innovation potential; it did deliver some measurable economic impacts; it did deliver a programme of educational innovations, which have led to institutional learning and equipped students, faculty and technology transfer professionals with new knowledge and skills; and it did manage to share at least some of this insight and learning with the wider academic community.

In addition, it has contributed to changed attitudes within the senior management teams at both participating universities, reaffirming the role of interdisciplinary research and the value of international collaboration to even the largest and strongest research universities. CMI's legacy is evident amongst senior academics too, with several having become prominent advocates of this mode of working.

CMI work has contributed to the evolution in policy and practice within the research and innovation community, with new policies and programmes that clearly bear its imprimatur, from the Technology Strategy Board's Innovation Platforms to the European Institute of Innovation and Technology's Knowledge and Innovation Communities.

CMI did less well in its efforts to codify the principles and procedures within which to better manage multilateral cooperation, across disciplines, communities and borders. It also struggled to follow through on its founding commitment to run the programme as an experiment to test the extent to which the CMI 'model' (e.g. use-oriented integrated, interdisciplinary programmes) amounted to a basis for a more productive relationship between public research and innovation.

While the programme has closed and policy makers have already re-used several of CMI's basic principles, there are a small number of potentially worthwhile next steps, including:

- Writing down the lessons learnt about how to work across disciplinary boundaries (the critical success factors) might yet be worthwhile, and in particular a "CMI process manual" might prove to be a very valuable legacy to the newly launched innovation platforms
- Given the effort already devoted to evaluating educational experiences, DIUS (or perhaps ESRC) might reasonably seek to conclude the education for innovation experiment by looking to see just how far the different cohorts of students (and academics) have surpassed their peers' career progression and earnings or have launched successful enterprises

An Evaluation of the Cambridge-MIT Institute

2 Introduction

2.1 The report

This report presents findings from an evaluation and lessons-learned study of the Cambridge-MIT Institute (CMI).

The core of the study has been the evaluation of the economic benefits accruing from the *Knowledge Integration in Research (KIR)* theme of the Cambridge-MIT Institute (CMI) programme, one of three broad strands of investment pursued throughout the project. More specifically, the study has included consideration of the following broad areas:

- Achieved benefits and value for money of the programme
- Contribution of CMI structures to outcomes
- Implementation and achievement of "consideration of use"

While the primary focus of the evaluation was on the outcomes of the Cambridge-MIT research collaborations, the evaluation also considered the achievements of the two other principal CMI themes, *Education for Innovation (E4I)* and *Knowledge Dissemination (KD)*. The evaluation did not dwell on the findings of earlier reviews, although reference has been made to those reports including for example the review published by the National Audit Office (NAO) in 2004.[2]

2.2 The evaluation approach

Exhibit 1 presents an overview of the approach followed, which comprised a mixture of desk research, bibliometric analyses, participant surveys and impact case studies.

Exhibit 1 Overall approach

Work step	Description
Desk research	To compile and analyse the composition of CMI investments and expenditure profiles as well as its recorded invention disclosures, patent and licence data and licence income. The study has also sought to benchmark the commercialisation performance of CMI against that for Cambridge and MIT and for UK research universities more generally, using HEFCE statistics from its annual survey of higher education and business community interaction (HEBCI)
Paper-based review	Desk studies and selected interviews to detail CMI achievements and the contributions of CMI structures to those achievements, for the education and dissemination strands
Bibliometrics	To compile a complete list of publication outputs and to analyse that subset of 300 or so journal articles indexed by the Thomson Web of Science, in order to establish the quality and impact of the CMI-funded outputs in comparison with international norms for the field
Survey of PIs	Semi-structured interviews with the principal investigators of the major research, education and dissemination projects to obtain people's views on the added value of CMI and its unique features, as well as judgements as to the strengths, weaknesses and lessons learned of the CMI model and its implementation
Case studies	Impact case studies of selected research and education projects that are known to have produced substantial social or economic outcomes, and which provided an opportunity to quantify likely commercial outcomes from the programme

[2] NAO Report (HC 362 2003-2004): Cambridge-MIT Institute (Full Report)

2.3 The Cambridge-MIT Institute

The Cambridge-MIT Institute (CMI) has had rather more press than most programmes or projects, and its origins and purpose have been discussed widely in academic and policy circles here in the UK. Notwithstanding this rather public history, it was important to single out the philosophical and architectural qualities of the project that have informed this end-of-life evaluation.

As has been reported widely, the project arose out of a 1998 visit to MIT by the then Chancellor of the Exchequer, which created an ambition to try to recreate MIT's demonstrable and ongoing impact on the Boston and US economies by importing the MIT approach to the UK, wholesale. Negotiations across the following two years resulted in the government taking the decision to launch a UK-financed project that would finance direct collaboration between MIT and just one UK university, Cambridge, through a virtual transatlantic collaboration.

From the standpoint of the UK, the role of CMI was, broadly twofold. Firstly, to enhance national competitiveness by encouraging, through Cambridge-MIT collaboration, the development of new technological ideas in selected areas and their transmission through knowledge exchange and dissemination, to the marketplace. Secondly, and more importantly, to explore the relative effectiveness of a range of novel approaches to the engagement of users in defining research strategies and the subsequent commercialisation of the intellectual property arising from it.

CMI invested some £65 million over the six years, through more than 100 research projects and almost 200 education and dissemination projects, with the dissemination activities facilitating engagement with scores of universities and several hundred businesses. The CMI work touched a wide range of intermediaries, regional economic development agencies and national research and innovation policy makers. It worked through two primary strands, which were transatlantic research collaborations and educational development, with a smaller communication and dissemination fund to support the sharing of results with the wider UK HE sector and business community. CMI projects varied widely in price and scope, ranging from several millions of pounds for integrated transatlantic research projects to a few thousands of pounds for mini-projects in support of broader programmes.

In the first three years, CMI concentrated its investment in four areas: undergraduate education, professional practice education, integrated research, and the National Competitiveness Network for disseminating findings to other universities.

Exhibit 2 presents a final account of CMI investment across the period 2002-2008, using the original structure of four programme areas. In its second phase, under new directors, the CMI project narrowed its focus in both the research and education domains, pursuing a smaller number of larger projects in the former case and placing greater emphasis on the link between education and innovation in the latter case.

Exhibit 2 CMI projects and expenditure, by broad programme area

Area		Project count	Expenditure	Share %	Ave project (£)
Integrated research	RES	108	£33.1M	51%	£306K
Undergraduate education	UE	95	£13.2M	20%	£153K
Professional practice programme	PPP	84	£12.9M	20%	£138K
National competitiveness network	NCN	26	£2.2M	3%	£85K
Management costs	MGMT	7	£3.8M	6%	
Totals		320	£65.2M	100%	

2.4 The structure of the report

Beyond this introduction, the report is organised around the main study questions, and is presented in the following order:

- A review of the scientific and other benefits achieved
- A review of the economic benefits achieved
- A review of the contribution of the CMI model to these achievements
- A review of the implementation of CMI
- A review of the implementation of the ‘consideration of use’ concept
- Appendices presenting (i) the CMI invention disclosures; (ii) the paper-based review of the CMI education for innovation strand and (iii) the impact case studies

In addition, the report is accompanied by a separate annexe presenting a detailed elaboration of the bibliometric analyses of CMI research publications.

3 Review of achieved benefits

3.1 Introduction

The CMI experiment was intended to explore the extent to which it was going to be possible to adopt and adapt the concepts, structures and tools in use in the US, and exemplified at MIT, as a means by which to accelerate and otherwise strengthen the flow of social and economic benefits arising from public investment in higher education and research.

On the research side, the idea of consideration of use was intended to create increased economic value without compromising the autonomy and excellence of the scientific undertaking in question, and as such it was deemed appropriate for the evaluation to look at CMI's scientific achievements. The test here has been to look at research excellence, which was addressed through the bibliometrics analysis of the total recorded CMI publication output.

On the education side, there was a presumption of there being numerous opportunities for cross-fertilisation and learning between the two radically different institutional settings, and that the UK pedagogic system should benefit in some general sense from Cambridge's preceding efforts to observe, acquire and adapt new-to-the-UK educational concepts, tools and content that might provide a positive boost to the relevance of our (technical) education to the demands of an internationally dynamic and innovative market place. The test here has been to weigh the quality and relevance of the pedagogic transfer from the perspective of UK higher education, using a combination of desk research and interviews. Work on this strand of the CMI oeuvre was facilitated greatly by significant numbers of project-level evaluations, which provided a critical and independent edge to the more descriptive materials within the programme archive.

On the dissemination side, there was a presumption that the lessons learned from both the research and education strands should be shared more widely across the UK higher education system. Here the test has been wider take up of the principles of consideration of use on the one hand and education for innovation on the other, which has been addressed by the team using documentary analysis and supplemented by interviews. Work on this strand has had to rely to a greater extent on project descriptions and oral testimony.

3.2 Research excellence

3.2.1 Introduction

The assessment of research excellence was tackled through a bibliometric analysis of a close to complete list of research articles produced by CMI researchers in the period up to the end of 2007 (interviews with researchers made it clear that there are many potentially important papers in train or in plan). The Centre for Science and Technology Studies (CWTS), Leiden University, was subcontracted to carry out the work, and this overview is based on their report, a copy of which is available separately.

The analysis was based on information provided by CMI in February 2008. Based on the information supplied, it is estimated that over 1,000 CMI publications were produced during the period 2002-7. Exhibit 3 provides a breakdown of the types and numbers of publications, and shows that the main types (by volume) were journal articles, conference proceedings and conference papers, together accounting for 81% of the total output. Most, though not all, of this published output derives from the £33 million CMI invested in its 100+ applied research projects.

Exhibit 3 CMI publications, by type of output (n=1051)

Publication type	Number
Journal articles	442
Books (authored)	5
Books (edited)	5
Books (sections)	18
Conference proceedings	94
Conference papers	319
Theses	48
Reports	25
Working papers	95
Totals	**1051**

The bibliometric work involved a quantitative analysis of the citation record of CMI articles published in journals and serials that are indexed in the Web of Science (WoS), the Internet version of the Science Citation Index and associated indices. The bibliometric analysis has worked with around 30% (n= 305) of the total CMI output, which is the proportion included in the citation indices that form the WoS. While this is a minority of all publications it encompasses the majority of journal articles published by CMI-sponsored authors (including normal articles, letters, notes and reviews). Moreover, interviews with researchers suggest that a significant proportion of conference and working papers are precursors to journal articles. The 140 or so CMI articles 'missing' from the bibliometric analyses are those pieces published in journals not indexed by the WoS, or that had been published too recently for a citation record to have been assembled (e.g. those published in 2007).

3.2.2 Main findings arising from bibliometric analysis

Numbers of citations

The 305 CMI articles included in the analysis collectively attracted a total of 2,947 citations over the period 2003-6, an average of 9.66 citations per paper. Of these, 23% were self-citations (i.e. citations by the authors themselves in subsequent papers) and when these are excluded the average number of citations per paper (CPP) is 7.44. Just over a quarter of the papers (26%) were not cited during the reference period.

Comparison of CMI citations with normative reference values

The raw counts of the numbers of citations achieved by CMI, overall and per paper, are only meaningful when they are compared with some kind of normative reference value. For this purpose two reference values were calculated.

1. The first is the average (world-wide) citation rate of the journals in which CMI has published (known as the mean Journal Citation Score, or JCSm). The JCSm is calculated based on the average number of citations achieved by other papers of the same type published in the same years and in the same journals as CMI output, calculated over the same reference period. The mean is a weighted average with the weights determined by the number of papers published by CMI in each journal
2. The second reference value is the mean (world-wide) citation rate for the fields in which CMI has been publishing its papers (known as the mean Field Citation Score, or FCSm). Again, the mean is a weighted average with the weights determined by the total number of papers published by CMI in each field

The calculated JCSm score was 5.10. This means that papers of the same type as CMI outputs published in the same journals and in the same year have attracted an average of 5.10 citations each across the period 2003-6. At 7.44 citations per paper, CMI publications have achieved 46% more citations, so we can conclude that CMI papers have a significantly higher citation rate than average (about one and a half times the average) as measured in these terms.

The calculated FCSm score was 2.81, meaning that papers published in the same fields as CMI output in the same years have attracted an average of 2.81 citations each over the period 2003-6. CMI's CPP score of 7.44 is clearly significantly higher than this reference value, in this case over two and a half times higher. We can therefore conclude that CMI output is attracting citations at around two and half times the rate as other papers published in the same fields.

The findings above reveal another interesting feature of CMI's publication output, which is that CMI papers have been published in journals that attract higher than average numbers of citations, as compared to other journals indexed in the same fields. This is reflected in the fact that the calculated JCSm score (of 5.10 citations per paper) is significantly higher than the calculated FCSm score (of 2.81 citations per paper). In simple terms this means that CMI researchers have published their papers in journals that attract higher than average levels of citation for their respective fields. This can be taken as a proxy indicator for the 'standing' or 'quality' of both the journals and the research being published, since journals attracting higher than average citation counts tend also to be the most widely read and attract the highest numbers of papers submitted for publication. This creates a situation where only the better (high quality / interest) papers are accepted for publication in these 'high impact' journals.

Collaboration
The analysis revealed mixed results in terms of the level of international co-publication, usually taken to be a good indicator of international collaboration and engagement. We know from other bibliometric analyses that around 40% of all UK publications indexed by the Web of Science involve one or more other authors resident in another country. The US dominates the partner countries. The results of this analysis mirror the norm, which was somewhat surprising given CMI was conceived and run as an international project. The analyses found that:

- 43% (n=130) of the papers had an international collaboration element involving researchers from institutions within two or more countries
- Just over a third (n=106) of the indexed publications were written by authors located at a single institution, CU or MIT
- A further 23% involved national-level collaborations and were published by researchers from two or more institutions from the same country (UK or US)

The single-institution publications had a high average impact level (CPP/FCSm of 2.10) but not as high as the collaborative papers (CPP/FCSm of 3.06 for national collaboration and 2.94 for international collaboration), with the gain from international collaboration being less strong here than is the case on average.

Disciplinary profile of CMI publications
Analysis of the CMI publication output by research field is shown in Exhibit 4, along with the impact scores (CPP/FCSm) for each sub-field. Each sub-field counting four or more CMI publications over the reference period is included in the table, and from it one can see that the weight of CMI's publication output is focused on physics, material sciences, engineering and related disciplines, which is what one would expect given the main points of complementary strengths of the collaborating institutions.

Exhibit 4 also reveals that for the vast majority of the sub-fields the citation impact is high, with 21 out of the 24 sub-fields achieving high (CPP/FCSM > 1.2) and in most cases very high (CPP/FCSm >2.0) citation rates in comparison with the field averages. Only in three cases did we find average or low impact scores (Biochemistry and Molecular Biology; Cell biology; Radiology, Nuclear Medicine & Medical Imaging).

The CMI impact ratings (CPP/FCSm) were compared to those obtained for Cambridge University (excluding CMI) within the same fields and across the same reference period. The results revealed that in most sub-fields CMI impact ratings were higher than those achieved by CU, the exceptions being in the biological and medical fields where CMI citation rates were at or below the sub-field averages.

Exhibit 4 CMI publication output and impact by field

Field	Share	CPP/FCSm	Top 10	Impact
Physics, Multidisciplinary	9.5%	3.40	4	High
Physics, Applied	9.0%	2.65	8	High
Physics, Cond Mat	8.1%	3.38	5	High
Optics	7.9%	2.12		High
Physics, At Mo Ch	6.7%	1.66		High
Material Sciences, Multidisciplinary	5.0%	4.20	3	High
Mechanics	3.3%	2.26		High
Multidisciplinary Science	3.0%	2.64	9	High
Polymer Science	3.0%	8.86	1	High
Eng, Elec & Electr	2.9%	2.16		High
Biotech & Appl Mic	2.5%	2.30	10	High
Chem, Multidisciplinary	1.8%	3.24	6	High
Mater Sc, Compos	1.7%	5.59	2	High
Cell Biology	1.7%	0.69		Low
Eng, Biomedical	1.6%	2.18		High
Constr & Buil Tech	1.5%	1.48		High
Mater Sc, Biomat	1.5%	1.61		High
Biochem & Mol Biol	1.5%	1.19		Average
Hematology	1.4%	1.86		High
Chem, Physical	1.4%	3.02	7	High
Genetics & Heredit	1.3%	1.53		High
Energy & Fuels	1.3%	1.42		High
Management	1.3%	2.02		High
Rad, Nucl Med Im	1.3%	0.61		Low
Instrum & instrumentation				

The bibliometrics analyses suggest that CMI has done rather better in its support for the physical sciences than it has in the life sciences and medical research fields. However, oral testimony suggests this might reflect differences in the number and quality of opportunities for collaboration rather than a substantive quality deficit across CMI between these very broad disciplinary groupings. Several interviewees stated that there had been instances where faculty members had not been able to bid into CMI because they were unable to find counterparts across the Atlantic working on complementary issues, and that were available for, or interested in, collaboration.

Comparison of CMI citations with Cambridge University and MIT

Given the strong international standing of both CMI and MIT, one could expect that any collaboration between the two would result in research publications that attract higher than average numbers of citations. Indeed, it would be a surprise if that were not the case. In order to test for this possible intrinsic bias, the CPP and FCSm scores were calculated for Cambridge University (CU) as a whole (excluding CMI output) across the same reference period (2003-6) and compared with the figures achieved for CMI. This was also done for MIT. The resulting aggregate citation ratios are as follows:

- CPP/FCSm for CMI = 2.65
- CPP/FCSm for CU = 1.59
- CPP/FCSm for MIT = 2.43

This means that while CU publications have attracted on average 59% more citations than other papers published within the same fields (confirming the good standing of CU research), CMI publications have attracted 165% more. This demonstrates that CMI's publication output has 'outperformed' the comparable sub-set of CU publications (i.e. analogous publication types and disciplinary mix) over the same period, achieving significantly higher average citation counts.

There was some discussion as to the extent to which leading Cambridge scientists switching from CU to CMI, and crediting the resulting publications to the latter, might explain this performance differential. However, the idea that CMI might have weakened the university's research output for a period, due to the recruitment of key researchers, does not stand up to scrutiny. In practice, CMI had funds enough to support only a small proportion of all CU academics and interviews with those principal investigators that did secure grants from CMI, suggests that a good proportion maintained parallel grants and continued to publish more widely.

A similar comparison of CMI impact with that of MIT (excluding the CMI output) shows that CMI research articles once again registered a greater impact than those of the individual institution, although the difference here was slight. While the CPP/FCSm value of CMI was 2.65, we find for MIT an impact level of 2.43.

A further indicator of CMI's success can be found by identifying the 'top 10% most highly cited papers' within the relevant journals and sub-fields for a given reference year. On average, one should expect that 10% of an institution's or research group's publications would appear in this 'top 10%', and any more than that provides a reasonable indication that their output is 'above average' in terms of visibility and / or impact. An analysis of the occurrence of CMI and CU publications within the 'top 10% most highly cited papers' published in 2003 revealed that CMI papers in that year were four times more likely to be found there, while for CU the figure was 1.75. This means that 17.5% of CU's and 40% of CMI's papers published in 2003 achieved the status of being within the top 10% most highly cited. For MIT, the analysis of its visibility among the top 10% most highly cited publications published in 2003 shows that 26% of MIT papers published in 2003 achieved the status of being within the top 10% most highly cited, which is 2.6 times the level one might expect.

Exhibit 5 compares the research profile of CMI with that of Cambridge University and MIT for that sub-set of all research fields that are significant for CMI (comprising around 80% of all research output). The comparison with Cambridge shows that CMI has a higher impact level in 20 of 25 fields. Cambridge performed better in Cell Biology, Biochemistry & Molecular Biology, Genetics, Energy and Radiology, Nuclear Medicine & Medical Imaging. The comparison with MIT is rather different, with MIT recording higher impact scores in 13 of the 25 fields. In half of the 12 cases where CMI recorded a greater impact, the difference between the two bodies of work was very small. CMI work substantially outperformed the equivalent MIT work in two fields (Polymer science and Materials science). By contrast, MIT work significantly outstripped CMI work in three fields, Cell Biology, Construction and Genetics.

Exhibit 5 Comparison of CMI research output with matched output for Cambridge and for MIT, using average citations per paper at the field level (CPP/FCSm)

	CMI	CU	CMI / CU	MIT	CMI / MIT
Physics, Multidisciplinary	3.4	1.78	1.62	3.94	-0.54
Physics, Applied	2.65	1.81	0.84	1.91	0.74
Physics, Cond Mat	3.38	1.6	1.78	3.31	0.07
Optics	2.12	1.13	0.99	2.05	0.07
Physics, At Mo Ch	1.66	1.43	0.23	1.78	-0.12
Material Sciences, Multidisciplinary	4.2	1.56	2.64	3.41	0.79
Mechanics	2.26	1.64	0.62	2.36	-0.10
Multidisciplinary Science	2.64	1.39	1.25	2.26	0.38
Polymer Science	8.86	1.7	7.16	3.17	5.69
Eng, Elec & Electr	2.16	1.51	0.65	2.54	-0.38
Biotech & Appl Mic	2.3	1.7	0.60	2.73	-0.43
Chem, Multidisciplinary	3.24	1.98	1.26	3.18	0.06
Mater Sc, Compos	5.59	1.71	3.88	1.78	3.81
Cell Biology	0.69	1.6	-0.91	3.05	-2.36
Eng, Biomedical	2.18	1.11	1.07	1.56	0.62
Constr & Buil Tech	1.48	0	1.48	3.77	-2.29
Mater Sc, Biomat	1.61	0.85	0.76	1.8	-0.19
Biochem & Mol Biol	1.19	1.61	-0.42	2.2	-1.01
Hematology	1.86	1.24	0.62	1.7	0.16
Chem, Physical	3.02	1.48	1.54	2.26	0.76
Genetics & Heredit	1.53	1.94	-0.41	4.97	-3.44
Energy & Fuels	1.42	1.74	-0.32	1.86	-0.44
*Management	2.02	1.24	0.78	2.53	-0.51
Rad, Nucl Med Im	0.61	1.01	-0.40	1.58	-0.97
Instrumen & Instrument	3.2	1.18	2.02	3.12	0.08

These comparative analyses suggest that CMI's performance, at least in bibliometric terms, has been strong, outperforming not only worldwide averages, but in very many cases also that of its two host universities, two of the world's leading technology universities. This outturn suggests that CMI managed to generate interest and rivalry amongst academics at the host institutions, with a positive impact on research quality sufficient to set apart CMI articles from other Cambridge and MIT papers published in equivalent fields. The indicated difference in performance is stronger for CMI and Cambridge than it is for CMI and MIT, which no doubt reflects in part MIT's much sharper focus on STEM subjects and Cambridge's broader interest in for example arts and humanities research. However, it might also reflect CMI's preference for research that would involve knowledge transfer from MIT to Cambridge as well as possible differences in the interest generated by CMI calls and the degree to which they provide more or less incentives to faculty to submit the strongest projects.

Country profile of researchers citing CMI publications
The country-profile of the researchers that have cited CMI papers during the reference period was analysed and the ten countries with the highest number of citations to CMI output are shown in Exhibit 6. The profile shows a strong focus on USA publications, with 26% of all citations to CMI outputs coming from researchers based in the US, though China, Great Britain and Germany also figure strongly.

Exhibit 6 also shows the impact scores (CPP/FCSm) for the papers that have cited CMI outputs. The high scores indicate that the papers published elsewhere that refer to CMI work are themselves 'high impact' papers, with citation rates well above the field averages in most cases. This is particularly so for the USA, France and South Korea publications. The high citation rates suggest that leading researchers around the world have recognised CMI outputs and have cited this in their own (high impact) research papers.

Exhibit 6 Country profile of papers citing CMI output

Country	Share of citations	CPP/FCSm	Impact
USA	26%	3.37	High
Peoples Republic of China	11%	1.95	High
Great Britain	9%	2.92	High
Germany	8%	3.07	High
Japan	5%	2.48	High
France	5%	3.65	High
Italy	4%	3.01	High
Canada	3%	1.01	Average
South Korea	3%	4.37	High
Spain	3%	1.91	High

Institutional profile of researchers citing CMI publications

The home institutions of the researchers that have cited CMI output over the reference period were identified and analysed. Exhibit 7 lists the top 10 institutions (based on volume of citations) and also shows the number of citations from those institutes and the average impact scores for the papers that have cited CMI output. The list reveals the importance of citations arising from academics located at leading US and UK institutions, as might have been anticipated, and reflecting established social networks. However, it also reveals a very strong interest in the work of CMI in China, Japan and in several other technology powerhouses in the Far East (i.e. Singapore and South Korea). It also confirms the very high impact scores being realised by the papers that have cited CMI research, particularly those from researchers at MIT, Tsing Hua, Harvard and Seoul National Universities.

It should be noted that the CU and MIT citations are not 'self-citations' as the researchers that produced the CMI papers are excluded from this element of the analysis.

Exhibit 7 Institutional profile of papers citing CMI output

Institution	Number of citations	CPP/FCSm	Impact
Chinese Academy of Sciences	76	2.16	High
University of Cambridge	52	3.15	High
MIT	41	5.51	High
Tsing Hua University	38	5.11	High
Harvard University	37	5.55	High
Imperial College London	32	3.99	High
National University of Singapore	24	2.91	High
University of Oxford	21	2.68	High
University of Tokyo	21	1.28	High
Seoul National University	19	7.10	High

3.2.3 In conclusion

The bibliometrics suggest that CMI financed very high quality research, with almost all areas supported comfortably outperforming international norms by a factor of two or three, and even outperforming equivalent research publications by others at Cambridge.

Furthermore, the analyses suggest that CMI research is likely to have a very significant impact going forward, given its work is already widely cited by other authors, who are themselves publishing in high impact journals.

Interest appears to be strongest amongst researchers at the world's leading technological universities, which is further testimony to the quality and relevance of the work supported through CMI.

In conclusion, the bibliometrics provided no indication that the CMI philosophy had compromised research quality at either institution, but rather suggest quite the opposite effect might be realised from this focus on fundamental *applied* research.

3.3 Review of the education for innovation strand

3.3.1 Introduction

This section of the report presents an overview of a wide-ranging assessment of the education-for-innovation portfolio, with the fuller review presented in the appendices to this report.

3.3.2 The CMI education portfolio

CMI supported around 180 education projects at a cost of around £25 million, with investments made across the spectrum of undergraduate and postgraduate curricula, as well as in support of professional practices in for example the areas of IP management. The projects covered a wide range of types of initiative, a majority of which involved the transfer of educational content from MIT to Cambridge, from the creation of new postgraduate modules to the adaptation of computer-based lab experiments to the introduction of lab-based vacation work experience for undergraduates.

The project evaluation record reveals that a majority of the projects were successful within their own terms, although the project evaluations focused on the student and institutional experiences and did not tackle project outcomes, whether that related to the consequences of upskilling technology transfer officers or inspiring confidence in undergraduates interested in entrepreneurship. Notwithstanding this last remark, the evaluation reports are quite impressive, and the interview programmes made clear that such a thoughtful and reflexive approach to the work made a useful contribution to administrative learning and operational evolution.

Moreover, the individual project reports attest to the depth of commitment of the academics involved in the many and various education projects, on both sides, and interviews with CMI managers point to the critical role played by the scale and discretionary nature of the fund available to work on pedagogic innovations.

3.3.3 Notable achievements

Praxis, the technology transfer training project (see Appendix E.4) is arguably the most impressive of all of the educational projects, when looked at from the perspective of UK higher education in general. This £0.5 million project evaluated, acquired and adapted US-sourced training material for technology transfer professionals (Association of University Technology Managers [AUTM]), which was packaged in two core modules: the 'fundamentals of technology transfer' and 'creating spinouts.' This course material was developed and delivered in conjunction with the universities of Bristol, Manchester and Newcastle. The CMI investment provided the basis for the creation of an independent (not-for-profit) training company, Praxis Courses Limited, which secured a grant from the DTI for £0.35 million to deliver training to technology transfer specialists across the country. The company has prospered, and continues to develop new course modules and is even extending its geographical scope to include parts of continental Europe. In the five years since the project was launched, Praxis has worked with more than 100 universities and trained more than 1200 professionals, with very many repeat clients. As a result, Praxis is widely recognised and – with the support of AURIL and UNICO – can be argued to have helped to create a sense of community amongst UK technology transfer professionals, with all that means for further insight, self-help groups and codification of good practice.

The Enterprisers project (see Appendix E.2) is another notable CMI success. This is another educational programme that has been imported from the US, this time from MIT, and which has been adapted for the UK. In essence, this is a one-week residential course for undergraduates at the end of their second year, which seeks to instil greater understanding and confidence in entrepreneurship through a mixture of lectures, master classes and hands-on projects, much of which involves real entrepreneurs working on a voluntary basis to inject maximum authenticity. The courses were run annually and have involved around 10 UK universities and 800 students (with some 45 new ventures launched by participating students). Several other sponsors, most notably the ESRC, have come forward following the end of CMI support, and it is expected that the course will continue for the foreseeable future. A suggestion was made, based on the insight from successive evaluations, that the week-long residential course could be cut down, and thereby made more relevant and affordable to a larger number of HE institutions and students.

The archiving software, DSpace, is also widely distributed throughout the UK HE sector, and is even now being considered as a potential de facto standard for *all* UK universities' management of publications records for submission to the future Research Excellence Framework. However, CMI contributions here were rather more to do with the support for user groups and associated seminars than they were for the development of the innovation, which tracks back to HP and MIT.

The undergraduate exchange was successful in its own right, with several hundred students and members of faculty having benefited from the experience. Moreover, the exchange programme seeded several other similar initiatives elsewhere in Cambridge and in MIT. There remain substantial costs and compatibility issues, which tend to colour the judgements of senior management as regards the balance of costs and benefits. By contrast, MIT followed up the CMI experience by launching several new international projects with partners in Malaysia, Portugal and Singapore, and its senior staff view this as very much part of a wider trend, the integration and globalisation of universities.

The UROP project was another adoption from MIT, which in this case permitted undergraduates to try their hand at research, working as *paid* research assistants supporting faculty with mini-projects tied to larger grant work, and which comprised a 10-week appointment over their final summer term. The UROP course was run several times at Cambridge, however it has struggled to run post-CMI due to financial constraints. Whether or not it continues to run at Cambridge is perhaps not as important as the fact that the development of the course appears to have helped BBSRC and EPSRC in their decision to launch similar 'taster / recruitment' programmes, and the CMI design is evident in the detailed arrangements of both the research council schemes.

As with most development programmes, the principal beneficiaries in a majority of cases will be CU and MIT although in a small number of cases, wider benefits are anticipated. Aspects of the Education strand have been reviewed and were reported in an eminently readable book edited by Dr David Good (Good et al, 2006), which has enabled CMI to share lessons with other universities and educators.

3.3.4 Economic benefits

Higher education has a fundamental relationship with the wider economy as regards the costs to employers of finding recruits of a suitable quality and outlook, however the benefits unfold over the longer term and success is almost inevitably contingent upon a range of other factors outside the control of the educator. In this case, the classic measurement challenges – timing, attribution of causality – are compounded by the relative smallness of the CMI endeavours, and the constant and parallel educational development work underway at other UK higher education institutions.

Notwithstanding these challenges of measurement and significance, there are several cases where CMI investments appear likely to produce wider economic benefits and where it might be possible, through further study, to say a little more about the nature and extent of those benefits.

The impact of Praxis for example might reveal itself in historical trends in key indicators (e.g. number of IP agreements per head and per £M research income; £M earned income per head arising from those agreements) across UK universities, although one might need to extend the comparison to selected third countries that have strong universities and less active policy measures to promote third stream activities.

No plans exist to gather intelligence on the impact of this kind of educational input to the career choices and entrepreneurial endeavours of our young scientists and engineers. However, the close monitoring of people and experiences arising from successive rounds of enterpriser training, and the elapsed time (first course involving UK undergrads was held in Boston in 2002), might point to a worthwhile follow-up study for DIUS or ESRC.

Similarly, the new MPhils have caught the attention of British employers, where wider adoption might be anticipated, and where further research might be warranted to explore outcomes in business and elsewhere.

3.3.5 CMI structures

The CMI structures reveal themselves across the education portfolio in the sense that a majority of education projects involved one or more of CMI's defining qualities, whether that was the undergraduate exchange programmes, the support for the development / transfer of course content from one partner institution to the other (mostly from the US to the UK) or the development of novel, interdisciplinary higher degrees.

The projects appear to have worked well in terms of managing the very substantial differences in pedagogic styles between the two institutions, while successfully establishing new courses and support methodologies. While the projects were generally transferred successfully, only a minority appear to have endured beyond the life of CMI.

The most successful education projects however, did indeed benefit substantially from the CMI structures and principles, whether that was international mobility, collaborative working or cross-disciplinary working.

3.3.6 Implementation and consideration of use

A majority of the education for innovation (E4I) projects have addressed valuable knowledge exchange opportunities, however they have concerned educational development in some general sense, and have had only an indirect connection to the CMI mission to promote UK innovation and competitiveness. We have no evidence to suggest that any of these projects displaced other proposals that were more closely aligned with the CMI mission, however in researching this strand of activity, the study team came to believe that many of the projects might very well have been supported by the discretionary development funds of one or both universities, outside CMI.

A meaningful minority of projects addressed the CMI education for innovation mission directly. The undergraduate exchange, UROP, the Enterprisers, the new MPhils and interdisciplinary undergraduate modules are the main exceptions, with the latter four going beyond the Education goals to address CMI's competitiveness agenda directly. CMI provided a particular helping hand, because of its cross-institution and transatlantic character and because of its strategic discretion around investing in educational innovations.

3.3.7 In conclusion

Overall, CMI has financed a large and impressive body of educational development work that has more than satisfied the general objectives set for it.

A sharper focus on the education strand's central innovation objectives might have made the portfolio even more appealing, and a stronger commitment to post-project review and UK-wide dialogue and dissemination might have strengthened programme outcomes and value for money.

3.4 Review of CMI 'knowledge dissemination'

3.4.1 Introduction

The CMI strategy on dissemination was bimodal, direct and indirect. The indirect strategy meant that all research and education projects were required to include business, educators and other stakeholders at all stages in the life of a project, from its conception to its exploitation. This embodied dissemination is considered below in the chapter on CMI structures.

In this section, the focus is on direct dissemination. Total CMI investment in knowledge exchange was around £2.2 million across the life of the programme, or around 3% of spend. The great majority was expended on the National Competitiveness Network (NCN), which provided a platform for CMI outputs but also crucially provided a forum for debating the potential for HE to drive competitiveness and feed forward ideas where it was believed CMI had a role to play.

3.4.2 Achievements

While it was a small line in the CMI budget, the knowledge dissemination strand recorded several notable successes and in particular its event programme and its support for a UK-wide network of enterprise educators.

CMI ran a good events programme, which involved many hundreds of organisations in topical debates and discussions. CMI, through the national competitiveness network, delivered some 45 UK-based international events, which encompassed conferences to showcase CMI research and education results, seminars to debate topical issues touched upon by CMI research and education projects and regional events at selected universities, strengthening the links between specific research groups and specific businesses. More generally, the NCN events acted as a forum to discuss issues concerning competitiveness and entrepreneurship as a means by which to identify areas where CMI might contribute.

This 5-year programme of events brought in over 2,000 participants, which involved UK businesses numbering their hundreds, as well as a wide range of other stakeholders, from policy makers to regional chambers of commerce. All events took exit polls, and these evaluative pieces suggest that these occasions were very well regarded by the great majority in terms of both the quality and relevance of the content and the opportunity for networking and relationship building.

The starting point for the NCN was an opportunistic decision to use a corner of the CMI budget to support and extend (at no cost to it) a network of eight universities concerned to develop enterprise education. The network was launched in 1999, with £25 million support from the DTI and the science enterprise challenge. The network helped to articulate research needs and to crystallise support for several of the most successful CMI projects, including Praxis and Enterprisers. This is important and reflects CMI responding to the needs of others. In addition to identifying the need for Praxis and Enterprisers, NCN also identified the need for the Entrepreneurship Development Programme and the need of the (then) newly informed RDAs for a forum to discuss best practice in competitiveness, entrepreneurship and innovation, the latter led to the formation of the Programme on Regional Innovation (PRI).

The network was extended significantly throughout the CMI term, and post CMI the network was re-launched (in 2007) as Enterprise Educators UK, a UK-wide membership organisation offering an impressive array of information and support services to 85 universities and several hundred people involved in the delivery of enterprise education.

There were relatively few one-off communication and dissemination projects, however CMI's support for student entrepreneurship and in particular the Cambridge University Entrepreneurs (CUE) club has arguably gone a long way to helping these student-focused support systems become more generally established across the UK HE sector, as well as to secure policy makers' commitments to such enterprises.

3.4.3 Economic benefits

The dissemination and knowledge exchange work typically involved rather open-ended activities, informing, debating, networking and brokering any of which has the potential to generate insight and change behaviour. The outcomes among the engaged population however are somewhat indeterminate, which makes any notion of measuring the economic impacts really very difficult to conceptualise. Moreover, the evaluation record is comprised largely of narrative accounts of individual projects and descriptive statistics (e.g. counts of events or counts of numbers of delegates).

It seems very likely that at least some of the many hundreds of business people that attended these events would not have gained insights or made new contacts that would subsequently lead to material commercial benefits being realised, however such outcomes are not captured. In light of this fact, the paper-based review can reach only tentative conclusions which is to suggest that measurable economic benefits are very likely to have occurred as a result of the many and various events, and that while there is no way of estimating the value of those resultant benefits, experience of other research and network programmes would suggest they would almost certainly outweigh the £2 million investment.

3.4.4 Contribution of CMI structures

The NCN has accounted for a significant proportion of total CMI support for knowledge exchange, and was launched right at the outset (early 2001) and ran throughout the life of the project.

The National Competitiveness Network (NCN) brought together universities, businesses and government organisations operating through various channels, including the:

- National Competitiveness Conferences, which typically ran two events each year, often showcasing CMI project results on for example interdisciplinary curriculum development or silent aircraft
- The National Competitiveness Forums were run in parallel to the conferences, with one or two taking place each year. The principal difference was in the origins of the keynote talks, which tended to be on very topical issues and were given by people outside the CMI firmament. Topics ranged from the future of regional policy to the importance of manufacturing within the economy
- The National Competitiveness Summit was a larger variant of the Competitiveness Forums, with a single annual event and a UK-wide scope, such as entrepreneurship
- The Competitiveness Workshops were workshops held at institutions around the UK, which brought together academics and industrialists to hear about and debate results from CMI enterprise projects

CMI report that in the five-year period from 2001, the network organised more than 45 events with over 2,000 participants and provided the impetus for Praxis, Enterprisers, the Entrepreneurship Development Programme and PRI. Through these mechanisms, the NCN identified a need for research that could provide evidence for improved policy and practice for advancing knowledge-based growth in urban and regional economies. CMI therefore established the Programme on Regional Innovation, which focused on the creation of new models for developing research and knowledge exchange mechanisms that would improve regional – and thereby national – competitiveness. The NCN also helped to establish better links between university educators and the key UK policy-making institutions in the area of innovation, including DIUS and the UK Regional Development Agencies.

In practical terms, CMI was contracted to support the UK network for enterprise educators, UKSEC, which had been launched previously through the Science Enterprise Challenge in 1999 as a group of eight institutions (£25M DTI grant). The NCN became an integral part of the UKSEC, with CMI providing coordination and planning capacity, substantial content for events and funding for venues, travel costs and sometimes accommodation (e.g. for guest speakers).

Interviews stated that the CMI contribution had been critical to the success of the UKSEC, which had grown and prospered throughout. UKSEC was renamed in 2007 as Enterprise Educators UK, with an impressive array of services supporting over 500 enterprise educators from 85 Higher Education Institutions to develop their practice, network with peers, and collaborate in enterprise and entrepreneurship teaching and research across all curriculum areas.

While much of the attention of the NCN was on coordination of SEC events and the dissemination of content to other universities, there was an extensive outreach programme and the CMI records show that over 1000 companies have participated in CMI-related activities, be it through direct involvement in a CMI project or by taking part in one of CMI's many events, conferences and workshops. Several of these organisations are large multinationals, such as BP, Pfizer and Rolls-Royce. The majority, however, are small and medium enterprises (SMEs).

3.4.5 Conclusions

From a financial perspective, dissemination was by far the smallest budget line within the CMI project. Even though the budget was effectively doubled by the dissemination work embedded within the research and education projects, it seems to be a minor activity given centrality of dissemination and debate to the CMI objectives. With hindsight, there ought to have been a much sharper focus on communication and dissemination.

Pleasingly, the focus on engagement and dissemination developed as the programme moved through its lifecycle and more and more 'content' became available and the many and various CMI-supported networks matured. Interviews and project files suggest a broadening commitment to the importance of additional exchange and dissemination building on the work carried out by CMI. For example support to student enterprise clubs or the encouragement to researchers and businesses to work together outside CMI on a consultancy basis, to extend and enhance one-another's intrinsic problem-solving capacity.[3]

Notwithstanding dissemination this strand can point to several notable successes, and in particular cite its influence on the decision to launch key education projects, notably Praxis, and its ability to connect business into the science and engineering agenda.

CMI has managed to engage large numbers of HE institutions and stakeholders in debating the role of HE in competitiveness as well as showcasing much of CMI's research output to significant numbers of businesses, public administrators and others.

Several of the stand-alone dissemination projects appear rather weakly connected to the programme logic, and one might argue that the funds should have been invested in more appropriate vehicles.

[3] This broadening of thinking echoed the earlier work of Martin and Salter, and was further endorsed by a follow-on research paper that underlined the importance of open and informal social interaction on the one hand and problem solving consultancy on the other. See, 'The benefits from publicly funded research, SPRU Electronic Working Paper number 161, Ben R. Martin & Puay Tang (SPRU) 2007.

There does not appear to be a strong rationale for inclusion of the D-Space project and the Programme on Regional Innovation appear in particular to be rather wide of the CMI objectives, with in the case of the latter numerous other sources of funding available for such development work, at the regional, national and European levels and through research councils and client commissions.

3.5 Research commercialisation capabilities

One of the ambitions for CMI and CU was to learn from MIT's long-standing and successful experience of research commercialisation and IP management. The CU head of central research services took a close interest in the collaboration from the outset, with a view to improving the consistency and productivity of Cambridge's technology transfer operations. Technology transfer started in Cambridge in the 1970s, with the Wolfson Centres and laid some of the foundations for what was to become Cambridge Enterprise.

An early review of approaches and arrangements revealed several important differences in approach and operations between the two universities, which provided vital orientation for both parties as they sought to work together. It also provided what might have been termed an agenda for development of the research commercialisation services within CU.

1. US university interest in technology transfer has arisen to a very large extent through market forces, with federal government being appreciative of this economic function but largely taking a hands off approach to its encouragement. By contrast the UK government has taken a much more proactive position in its encouragement of research commercialisation, with numerous national schemes having been launched to change values, build capability and subsidise technology transfer activities
2. US universities separate research and education activities from commercialisation at an early stage, with quite stringent rules closely observed on conflicts of interest, open publication and commercial interests. In the UK, the segregation occurs at a later stage. There is reportedly far more incubation of spinouts for example, use of research students on company development work and pipelining of new university technology to those spinouts. In contrast, US universities seek venture capital at a very early stage and adopt a more formal relationship to spinouts as licensor, although there is substantial mentorship and brokering of introductions to financiers and other businesses
3. US universities insist on retaining ownership of patents arising from sponsored research, usually granting the sponsor a license to use the invention. Where that is an exclusive licence, royalties would typically be payable to the inventing researchers. Where sponsors are content to accept a non-exclusive licence agreement, there would typically be lower or no royalties payable. In the UK, it is more common for universities to allow the business partner to take the title to any patents that arise from sponsored research
4. MIT commercialisation people were on average far more experienced than their counterparts at CU, and in many cases had wide-ranging experience of venturing, management of IP, direct management of technology startups and research commercialisation work more generally. Many are alumni that have had successful business careers and want to give something back by providing a guiding hand and mentorship to the many young entrepreneurs at MIT. By contrast the CU team was typically far younger, and with rather less well developed expertise in the field. They were rather less well paid too
5. MIT is a private foundation and has a strong focus on all things commercial, so for example MIT staff are required by their employment contracts to work with industry one day a week

In addition to the initial exploratory work and interaction at the most senior levels, CMI devised and launched several initiatives to facilitate cross-institutional learning and the transfer of tools and lessons designed to expand the capacity and infrastructure available through Cambridge Enterprise. These included:

- A programme of staff exchanges, running across several years and moving in both directions
- An entrepreneur in residence, a novel post that was intended to give CMI researchers ready access to a professional with a strong track record in high technology startups in a position to give immediate advice on anything from business planning to public offerings as well as brokering introductions to venture capitalists
- Access of researchers to student teams at either university, which conducted commercialisation reviews for CMI projects as part of their course work, swapping their time for practical experience and demanding clients (the researchers)
- The technology lifecycle seminars where senior figures from leading IP-based businesses have lead interactive seminars based on their commercial experiences, targeted at researchers and TT professionals
- A commercialisation committee of CMI representatives, TTO staff, venture specialists and eminent business people to meet monthly to review disclosures, proposed licences and to hear about progress with specific commercialisation projects

The staff exchanges produced 15 one-month visits and a great deal of insight and learning on both sides. Altogether, some 10 Cambridge staff visited MIT, each one of which went with a specific brief to study and learn from one or other aspect of the partner's approach to technology transfer, which ranged from studying MIT procedures for processing new cases to the benchmarking of licensing terms for specific classes of technology to studying how MIT marketed its inventions.

The entrepreneur-in-residence and student teams were fascinating experiments that proved not to be quite as effective as had been hoped, for reasons to do with the diversity of the CMI research portfolio on the one hand, and, on the other, the difficulty of packaging commercialisation work into suitable and timely projects with the appropriate educational content and values. On a positive note, feedback from individual researchers would seem to suggest that the independence of the entrepreneur from the university hierarchy was welcomed, arguably because the advice came without expectations and because it was bespoke rather than more 'corporate.' The entrepreneur-in-residence invested the bulk of their time in communication with researchers, and diversity of the portfolio meant that this communication was conducted on a case-by-case basis for relevant projects, with researchers being introduced directly to relevant potential investors. The entrepreneur-in-residence role has not been retained post CMI, and presently such interaction is carried out by CE staff directly on an ad hoc basis, or with the support of their extended network of angels and business contacts.

The CMI records show that the lifecycle seminars managed to attract high profile speakers and generated good attendance levels, although this appears to have worked rather better for students than for faculty. The number of seminars reduced over time and has not been continued in any formal sense beyond CMI, however Cambridge's relationships with the various business people has endured and we understand that Cambridge, its researchers and CE continue to make use of this social network from time to time. The commercialisation committee provided an important forum that was able to both provide rounded advice to individual technology transfer officers and researchers as well as providing an opportunity to discuss commercialisation issues at a programme level, which helped to drive further institutional efforts to develop commercialisation capacity.

The impact on Cambridge Enterprise was substantial, and it reported that it had learnt several important lessons from its involvement with CMI, which included:

- A stronger focus on technology transfer transactions has helped Cambridge Enterprise improve its reputation with its CU customers and its connections to the business community
- A recognition of the efficiency gains and increased effective capacity that comes from greater codification of processes, with simplification of those processes too as a way to reduce the incidence of bespoke negotiations and agreements
- Benchmarking of licence terms has refined protocols and increased confidence and negotiating abilities of Cambridge Enterprise staff

- The added value of a staff with much higher levels of commercialisation experience

Cambridge Enterprise reports that its processes and performance have continued to improve in the four years since the staff exchange programme came to an end, as the organisation has been able to be more reflexive within its own walls and has upskilled and upgraded the people at its disposal. More weight is given to due diligence work and for example carefully investigating contracts, patents and other legal agreements to establish the extent to which the inventor and seller is able to grant rights to the full commercial exploitation of the invention. Similarly, CE requires researchers to develop credible business plans for the technology in question before signing any legal agreements. It has also learnt to seek more specific terms in licence agreements, for example, as regards the anticipated timing and likely volume of sales of licensed products as well as more stringent reimbursement of such things as patent costs.

CU has adopted and modified some of the collaboration principles at work in MIT, and this is enshrined in both working principles and model agreements. The CMI senior management stated that work done at CU as a result of CMI had helped to persuade Richard Lambert to recommend the UK government implement such a model agreement as a framework for all university-industry research collaboration and that the CMI / CU protocol had also been used as the basis for the collaboration agreements at the EPSRC and the Technology Strategy Board.

The interest in university spinouts has softened in light of discussions with MIT and gathering experience within Cambridge Enterprise. Other modes of industry engagement and research commercialisation have come to be seen as rather more important, and in particular business purchases of university know how through consultancy contracts. Traditionally, academic consulting was seen to provide a poor route for commercialisation of research, being a distraction at best. CU takes a rather more pragmatic view these days, seeing consultancy as a fact of life on the one hand and an opportunity to energise and focus research on the other, as well as being a means by which to apply senior researchers' know how to important real-world problems.

According to CE, the MIT technology transfer team had gained insight on several fronts too, and in particular:

- The value of a more standardised and back-loaded valuation strategy, wherein the 'purchase' price of any IP is pitched at a lower level, broadly in line with the costs of running the commercialisation office, with tighter licence agreements designed to produce future income streams from the *success* of the businesses supported
- The value of a more routine commercialisation process, and its consistent implementation, to an ability to secure invention disclosures and commercial agreements (and the productivity of the commercialisation staff)
- The approach to and value in coaching academics with little or no business experience
- The value of the provision of a central service to academics wishing to undertake consultancy work through the university, ranging from support in negotiations to advice on pricing and comment on terms and conditions
- The value in more active management of marketing and communications, with active management and collateral material for the press, investigators and business

3.5.1 Conclusions

CMI made a substantial positive contribution to the research commercialisation capabilities of Cambridge University. Cambridge Enterprise used the CMI technology transfer infrastructure grant to improve its technology transfer support to CU in general, which it achieved through improving its collective command of how technology products are developed and sold and through a sharper focus on consistently applied and simpler commercialisation processes.

Cambridge Enterprise's codification and transfer of good practice from MIT has also contributed to wider improvements in research commercialisation in the UK, through the wider debate and sharing of these principles with influential reviews of university-industry interaction and even the content of standard collaboration agreements at national funding bodies.

Additionally, CMI has made a positive contribution, albeit indirectly, to the wider capacities of the UK technology transfer community through its support for the codification of professional practice and its indirect support for the training of more than 1200 technology transfer officers across the country, which one would expect might seed improvements in commercialisation practice and outcomes across the community.

4 Economic benefits

4.1 Introduction

CMI set out to create a research portfolio to underpin technological advances with the potential to have a direct impact on the UK and world economies over the 20 years following the launch of the programme.

This is arguably a rather ambitious objective for a £30 million, five-year programme of investment in applied research, however in practical terms it was understood to mean that CMI should be chasing a small number of bold investments; big ideas, with the potential to radically alter a research agenda in a given field (globally) and deliver two or three obvious commercial success stories.

The evaluation has therefore sought to arrive at an overview of the nature and extent of CMI-supported economic achievements through:

- Consideration of the 'outcome' statistics captured by the CMI commercialisation 'agent,' Cambridge Enterprise, the research commercialisation arm of Cambridge University
- Exploration and detailing of the economic impacts of CMI's most successful commercial work to date, through a series of impact case studies

4.2 Research commercialisation outcomes

4.2.1 CMI statistics

While the first benefit arising from the collaboration might have been an improvement in the general capacity and standing of CU's research commercialisation team and support infrastructure, the CMI project was also committed to make an impact on research commercialisation *outcomes*, from the numbers of invention disclosures to the amount of licence income accruing to its investment portfolio.

CMI aimed to make use of all opportunities for commercialisation to maximise the likelihood of successful outcomes through the determined and professional pursuit of commercial opportunities. It also meant CMI kept track of the commercial outcomes from its investments. The commercialisation work was carried out by the technology transfer offices in MIT and CU, and not by CMI.

The CMI focus on user-oriented research was followed through in a procedural sense with research projects being chosen and framed in light of potential application and with ongoing monitoring being concerned to support progress and user engagement. As research projects progressed, those promising specific breakthroughs were encouraged to disclose those 'inventions' to Cambridge Enterprise with a view to working with principal investigators to develop and implement commercialisation activities.

Cambridge Enterprise's commercialisation work for CMI has been wide ranging, from due diligence work, patent applications and announcement of the invention to potential licensors, to marketing more generally, to negotiations of licences to the pursuit of seed funds to advice on seed funding and startup management teams. In addition to the front-of-house work, CE has also worked with MIT to develop and codify new procedures, guides and contracts.

CMI management and records suggest that Cambridge Enterprise has provided the project with a good technology transfer service that has helped researchers in focusing their research objectives as well as clarifying and making explicit potential commercialisation paths.

Exhibit 8 Invention disclosures and other commercialisation outcomes of CMI research, June 2002 to June 2008

	Total	CU	MIT	CU / MIT
Disclosures	40	14	22	4
Patents	20	9	8	3
Licences	11	6	3	2
New companies	3	3	0	0
Licence income	£20K	£20K	0	0
Equity income	0	0	0	0

Exhibit 8 presents the counts of invention disclosures from the CMI project, as recorded by Cambridge Enterprise in the period up to June 2008.[4] A list of these disclosures is appended to this report.

There have been 40 CMI disclosures in total, associated with the 100 or so projects of the £33M integrated research strand. To help readers understand where benefits might accrue from this intellectual capital, the 40 disclosures have been placed in three categories according to the ownership of the IP: MIT only, CU only, MIT/CU joint.

Of the 40 inventions disclosed in total:

- 14 were received at CE (35%)
- 22 were received at MIT (55%)
- 4 were received jointly at MIT and CE (10%)

20 of the 40 invention disclosures (50%) had resulted in patents (initially in US or UK or both). No further patent applications were outstanding:

- 9 of the disclosures notified to CE have resulted in patents (22.5%)
- 8 of the disclosures notified to MIT have resulted in patents (20%)
- 3 of the disclosures jointly notified to MIT and CE have resulted in patents (7.5%)

11 of the 40 invention disclosures (27.5%) had some kind of licensing or commercial activity associated with them at the time of writing:

- 6 on the CE list (15%
- 3 on the MIT list (7.5%)
- 2 on the joint MIT/CE list (5%)

Of the above 11 inventions, 3 companies have been set up in the UK to exploit those inventions (developed within the context of the CMI programme):

- OrthoMimetics Ltd (4 inventions), and a Cambridge spin-out
- e-stack Ltd (1 invention), and a Cambridge spin-out
- Fibrecore Developments Ltd (1 invention), a subsidiary of Fibre Technology Ltd

In the case of OrthoMimetics and e-Stack, members of the CMI-funded research teams have joined the companies on a full-time basis, and other members of the research teams remain involved as scientific advisors. Two pre-existing spinouts also existed, which were Vivamer Limited and

4 Cambridge Enterprise prepared an overview of the accumulation of invention disclosures, patents and licences associated with CMI projects, with the figures amounting to a total to date for CMI through to the end of June 2008.

Cambridge Biotransforms Limited, both of which had previous IP licenses through Cambridge Enterprise. Vivamer has benefited directly from the results of the CMI-funded research, although no new patent resulted from that work.

Three inventions with licensing activity on the CE list are joint inventions with a Japanese manufacturer of precision measurement equipment (Samco), 2 of which might have commercial potential although the third is not expected to lead to a commercial outcome.

Work on the CMI portfolio by the technology transfer officers at Cambridge Enterprise is largely complete, and CE has just three open projects where it is continuing to promote and monitor progress.

Other businesses have been launched indirectly as a result of the work of CMI, for example by students responding to the business plan competitions run by Cambridge University Entrepreneurs, which benefited from CMI support with PR and networking issues, which allowed it to grow and attract more funding.

The CMI project was instrumental in the formation of Praxis, which was founded in 2004 by the two CU and MIT directors of commercialisation who had orchestrated the packaging of MIT know-how and practices in course material delivered through a CMI project to technology transfer officers across the UK. The company has secured commissions from a range of other quarters, including most significantly a contract from the former DTI to provide training to technology transfer professionals across the UK. Since CMI funding came to an end, the company has extended its product range and continues to provide training to technology transfer officers in higher education, and commercialisation professionals elsewhere. While the company is a small professional services business in its own right, its key economic contribution has been the up-skilling and professionalisation of UK university technology transfer officers across the country.

4.2.2 Comparative analyses

There is no obvious available analogue with which to compare the performance of CMI with respect to its commercialisation of research, as the standard metrics are often not collected by other agencies such as the Technology Strategy Board or the RDAs or the devolved administrations.

HEBCI data provide a reference point for CU and CMI, however these data are for all UK universities and for all facets of research, from the arts to the physical sciences, from fundamental research to more applied work.

Exhibit 9 shows indicators of research and commercialisation activities, overall for higher education institutions (for 2006-07) and specifically in relation to the CMI (covering the total period of activity). The former include the ‘Russell Group’ of 20 research-intensive universities.

Exhibit 9 Universities and CMI – Some input and output data

	Institution Totals – 2006-07				CMI Data 2000-2007	
	1	2	3	4	5	6
	All UK universities (incomes in £m)	**Russell Group of universities (incomes in £m)**	**Cambridge (incomes in £m)**	**MIT**	**CMI total**	**o/w Cambridge (incomes in £m)**
Total Research Funding			394	$1212m	£33m	16.5
Total Research Grants and Contract Funding	3377	2026	211		£33m	16.5
Income from Collaborative Research	670	299	49			
Invention Disclosures	3,746	2014	118	523	40	18
New patent applications filed	1,913	1114	112		20	12
Licenses granted	3,286	1276	35		11	8
Income from licensing	40	21	3.5		£20th	n/a
Number of spinouts	1,796	255	3		3	n/a
Spinouts excluding staff and graduate start-ups	226	71	2		3	

The following definitional issues should be noted:

- ‘Total Research Funding’ for Cambridge includes research grants, contract funding and the HEFCE block grant for research. Figures supplied by Cambridge Enterprise, who also supplied all figures in columns 5 and 6
- ‘Total Research Grants and Contract Funding’ for all UK universities is supplied by HESA. Figures for individual institutions are not readily available; the Russell Group figure is estimated at 60% of the total, based on their estimate of their proportion of public- and privately-funded university R&D. Cambridge figure supplied by Cambridge Enterprise
- ‘Income from collaborative research’ for UK Universities, the Russell Group and Cambridge is taken from the annual HEFCE ‘Higher Education – Business and Community Interaction Survey’ (HE-BCI). It covers research involving a third partner from business or the community together with the public funder engaged with the HEI
- Figures in columns 1-3 for each of the five research output/commercialisation indicators are derived from the 2006-07 HE-BCI Survey, columns 2 and 3 from the institutional-level data in HE-BCI Annex H

None of the data provide exact comparators for outputs of the CMI. In particular:

- ‘Total Research Funding’ includes funding unrelated to S&T work
- ‘Total Research Grants and Contract Funding’ also contain a (smaller) element of this, and also exclude funding from the HEFCE block grant dedicated to scientific research
- ‘Income from Collaborative Research’ only covers work involving a business or community partner

In view of these issues, and pragmatic questions of data availability, ‘Total Research Grants and Contract Funding’ – despite its shortcomings – seems to provide the best basis for comparison with CMI activity. Another important issue is that annualised data for CMI were not immediately available, and that the figures presented are unlikely to be final, as some knowledge-transfer activity arising from CMI work is still ongoing. However, significant increases seem unlikely to occur, and the problem of the incompatibility of the time periods covered by the CMI and other data is minimised by consideration of ratios of outputs to inputs.

Consequently, in Exhibit 10, we present a series of commercialisation indicators adjusted for the size of the undertaking through the conversion to ratios of commercialisation outcomes to research grant and contract funding. The health warnings highlighted above should be borne in mind.

Exhibit 10 Indicators as ratios of research grant and contract funding

	Institution Totals – 2006-07				**CMI Data 2000-2007**	
	1	2	3	4	5	6
	All UK universities	**Russell Group of universities**	**Cambridge**	**MIT**	**CMI - Cambridge and MIT**	**o/w Cambridge**
All figures show quantities per £100m of research grant and contract funding						
Invention Disclosures (no.)	111	99	56	86	121	109
New patent applications filed (no.)	57	55	53	n/a	61	73
Licenses granted (no.)	97	63	17	n/a	33	48
Income from licensing (£th)	1194	1053	1641	n/a	61	n/a
Spinouts (no.)	53	13	1	n/a	9	n/a
Spinouts excluding staff and graduate start-ups (no.)	7	4	1	n/a	9	n/a

The table suggests the following:

- The Russell Group shows outputs per unit of income of the same order as those of all UK universities on most indicators. The Group comes out significantly lower on licences granted and spinouts, and Cambridge is significantly worse than the average for the Russell Group
- Invention disclosures and new patent applications filed, per unit of funding, are slightly higher for CMI than for other groups
- Licences granted is lower than the ratios for all UK universities and the Russell subgroup
- Figures for 'Cambridge CMI' outputs per unit of funding, where available, are significantly higher than 'total Cambridge' figures

These figures probably understate the performance of CMI, in that the data for its outputs represent a 'lower bound' given ongoing activity, while the volume of research activity, the denominator, by other groups is probably underestimated (owing to non-inclusion of their HEFCE block-grant research funding, partly offset by inclusion of some non-S&T Research Council sponsorship).

4.3 CMI case studies

4.3.1 Research impacts and case studies

It is widely understood that the economic impacts of strategic applied research tend to unfold in a somewhat diffuse and unpredictable fashion over many years. Moreover, the majority of research 'projects' tends to be confirmatory, or incremental, with respect to intellectual progress [5] and only a minority produces insight or artefacts sufficient to pursue specific innovation opportunities and potentially secure directly measurable economic gains.[6]

Tracing even this minority of directly observable outcomes presents its own measurement challenges and is perhaps best done through the use of qualitative research methods that are better able to cope with open systems, multiple actors, points of uncertainty and contention and of course timelines measured in years rather than days or weeks.

Impact case studies can work well in this context, permitting one to develop a systemic picture of inputs and outputs through an iterative process of interviewing key actors, cross-checking oral accounts with documentary evidence and gradually building up a rounded account of both the players and the results. In other programme evaluations, this case-study methodology has been used successfully to capture and quantify the commercial costs and benefits associated with a particular government investment and associated innovation. These case studies have also permitted the evaluators to explore other issues of interest to budget holders, including the important questions of project 'additionality' or 'displacement.' Where the number of cases was large enough, the resultant data have been used to estimate return on investment scenarios (max, min, most likely) for the programme in question. Here, unfortunately, the number of candidate cases proved to be small, reflecting the size of the CMI research programme rather than its fecundity, and the majority of those cases, upon closer inspection, appear unlikely to yield significant commercial benefits. Moreover the three that do show promise remain some years away from being in a position to fully explain the nature and extent of the commercial outcomes anticipated.

4.3.2 CMI impact case studies

The Cambridge Enterprise statistics provide a reasonably comprehensive list of CMI research projects where there had been an invention disclosure, along with a brief account of CE assistance and the various commercialisation outcomes.

This data set provided a list of seven projects, or clusters of projects, where commercialisation outputs had been recorded (invention disclosures, patents and licences, licence income, university spinoffs), and where it was hoped to obtain a more up-to-date view of developments and ideally some degree of quantification of anticipated future benefits.

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[5] This is a phrase that has come into regular use in innovation policy circles and is used in a positive sense to convey the notion that most, if not all, intellectual progress uses the understanding gained by major thinkers who have gone before, whether as building block or opposition. Its origins are often cited as being a jibe set out in a letter from Sir Isaac Newton to his rival Robert Hooke, in 1676: "What Descartes did was a good step. You have added much several ways, and especially in taking the colours of thin plates into philosophical consideration. If I have seen a little further it is by standing on the shoulders of Giants."

[6] You can find a reference to the issue of skewed distributions in DTI economics paper no 7, which cites 'Scherer, FM and D Harhoff, Technology Policy for a World of Skew-distributed Outcomes, Research Policy 29, 559-566 (2000)'. Using data on innovations and inventions the authors show that 10% of innovations account for between 48-93% of the total sample returns.

For each of the cases, interviews were conducted with the PIs on both sides of the Atlantic and with the industrial partners wherever possible. Working with the project files, the interviews sought to compile an overview of each project around a series of standard headings:

- Project description and CMI support
- Nature of the collaboration
- The CMI added value
- Project outputs in terms of technology or know how produced
- Project outcomes and future direction of development
- Summary of costs and benefits, where these are known

Exhibit 11 lists the six CMI inventions that have been case studied, with a brief overview of each project and its commercial outcomes. The full case studies are presented in Appendix D. It is notable that the most 'successful' projects tended to be the larger programmes of work involving substantial collaboration between CU and MIT, often with substantial financial and in-kind support from industrial partners.

Exhibit 11 CMI inventions commercialised through licence agreements and new companies

E-Stack	The 'e-stacks' project brought together a team of scientists and engineers from Cambridge, MIT and BP to devise designs for 'green' buildings based on solar energy and natural ventilation techniques. It was a £2.5 million project run over a period of 5 years, with financial and in-kind support from BP, one of CMI's principal industrial partners. As a result, a design was developed and tested for a proprietary low-energy mixing ventilation system for existing buildings and for new-builds. The system offers significant savings on capital and recurrent costs, as compared with existing technologies, as well as providing measurable improvements in the internal environment. The system was patented as the 'E-Stack', and a spinout company was set up to exploit the invention commercially. The company, called E-Stack Limited, employed 4 people as at the end of July 2008, when e-stack® systems were operating in eight UK schools, and the company has a substantial current and forward order book. Turnover was not disclosed. As a spinout from the BP institute at Cambridge, E-Stack was well placed to secure early stage investment from BP's Alternative Energy Venturing business in return for an equity stake in the company. This financing has been used to continue the development of the technology, and the e-stack concept has also been implemented in spaces larger than classrooms. For example, a series of mixing stacks has been designed and installed into the roof of the new 250-seat hall at the Unity College secondary school in Northampton.
Fibretech	This 3-year £0.5 million project developed an ultra-lightweight composite structure intended to deliver improved functional performance across a range of industrial applications. The resulting composite is based on a pair of thin stainless steel face-plates separated by an 'intelligent' core of cast stainless steel fibres, which can be engineered to give different performance profiles to suit a given application. Two patents were filed by Cambridge Enterprise, one for the composite itself, the other for a novel method for surface treating or coating fibres. The composite technology was licensed to Fibretech, subsequently, in return for small equity stake in a newly created subsidiary of Fibretech, and agreed royalties. The details are commercial in confidence. The project led to the launch in 2006 of a commercial product, Fibrecore™ which was followed by a related product, Fibresheet™, following further product development by Fibretech, based in Nottingham, UK. The product has already met with some commercial success, and Fibretech is continuing to research new markets and further develop the project. The company projects an annual turnover of £10 million from Fibrecore by 2010, substantially increasing its overall turnover and profitability. It is also projecting additional employment, nearly doubling its current strength of 13. In addition to a new product line and expanded business, the CMI project has strengthened Fibretech's links with the HE sector in the UK and US, although it interacts mainly with materials scientists in Cambridge, and has used these relationships to boost its sales of technology consultancy and test work.

Ferro-electric nanotubes	This £0.9 million project involving collaboration between CU, MIT and a Japanese equipment manufacturer developed an ultra-small (nano scale) photonics device with several performance advantages over competing technologies, based on a novel fabrication process that permits a level of control over the deposition and porosity of constituent materials not previously possible. Two UK patents have been filed for the technology in the fields of electronics and microfluidics. These patents are jointly owned with Samco as a result of their contribution to the research. Samco retain exclusive rights for the Japanese market, and also rights in the electronics field, as part of their support for the original research. Further commercialisation efforts resulted in a company being spun off with the help of a £80,000 grant from Cambridge Enterprise. The company, Cambridge Nanoelectronics, will be incorporated in late 2008. The company is seeking to raise £1,500,000 from venture capitalists to fund the development of products in three application areas: inkjet printers, drug delivery systems and usage in memory devices. It is seeking to develop generic components that in principle should be available to all major manufacturers, so that the company does not have to compete directly with these major producers. The business plan does not include target numbers, however each of the markets being addressed are global and growing and measured in hundreds of millions of dollars (e.g. even 5% of market in US for drug delivery application is around 100 million dollars).
OrthoMimetics	This 4-year £2 million project focused on the development of biological scaffolds that could provide support for tissue regeneration in the areas of orthopaedics and regenerative medicine. The project resulted in the development of a novel medical device that is expected to have a higher success rate and greater durability than existing technology, thereby helping to reduce the need for major joint replacement surgery. The newly developed technologies address a worldwide market estimated at $1 billion a year. The Cambridge-side post-doc from the project, Dr. Andrew Lynn decided to set up a spin-out company, launched in 2005, called OrthoMimetics, to exploit the four patents that had resulted from this research. The company successfully completed a Series A funding round of £5 million in December 2006. In addition to the CMI grant and Series A funding, the company secured an additional £2.1 million in development grants from UK government agencies. These include a £817,000 grant from the Technology Programme of the former Department of Trade and Industry, to conduct preclinical trials and a pilot clinical trial to further test ChondroMimetic and obtain permission for it to be sold in the EU. The company also received grants amounting to around £1.4 million from the UK Technology Strategy Board (TSB) for the commercial development of LigaMimetic, the second product based on the company's technology platform. No company employment or financial data were disclosed.
Rhodococcus	This 5-year £3 million CMI project involved CU and MIT researchers working in collaboration with several biopharma companies and sought to determine the potential for using a strain of Rhodococcus bacteria to improve both the process and pharmacological efficacy of novel drugs made through biological synthesis, for the treatment of infectious diseases such as AIDS and TB. In addition, the CMI funding was used in part to pursue a piece of experimental work that led to the team at MIT producing a new type of antibiotic. No patents were applied for based on work funded through this project, although three patents were granted to members of the research teams for earlier, related work, however these were applied for in the period before the launch of CMI. The Cambridge PI is the chief executive of Cambridge Biotransforms, a CU spinout company (CU is a shareholder) that is involved with the commercialisation of his research group's work at CU, including the insights and breakthroughs arising from this CMI project. None of the partners has yet to commercialise the specific breakthroughs from this project.

Silent aircraft initiative	The 3-year £4 million CMI Silent Aircraft Initiative (SAI) was a large multidisciplinary project which produced a novel and creditable next generation but one (N2) aircraft concept design. It involved 30+ faculty and research students from CU and MIT, as well as close collaboration with Boeing and Rolls-Royce as well as other interested parties (e.g. airport operators, regulators and public interest groups). The most obvious project output was the achievement of a credible conceptual design that met its objectives with respect to noise (and fuel efficiency). For the concept aircraft, 'community' noise levels are estimated not to exceed 63 dBA, which is comparable with noise levels found in urban daytime environments. Fuel burn is estimated to improve by 23% (passenger miles per gallon), as compared with the Boeing 777 reference figure. The project did not set out to develop methodologies, tools or technologies that would be likely to be commercialised directly, at least not in the years immediately following the end of the project. However, several of the enabling technologies do appear to have caught the interest of manufacturers, and in particular the trailing edge brushes, the faired undercarriage and the variable area exhaust nozzle. The project developed a novel descent approach, which is being trialled at Nottingham airport along with airlines like easyJet and Lufthansa cargo and looks set to result in fuel savings in addition to noise reduction.

CMI supported a wide range of projects, not all of them research projects, and several of these initiatives have been revealed as being potentially important sources of (indirect) economic benefit. Exhibit 12 lists the four other CMI investments that have been case studied, with a brief overview of each project and its likely social and economic outcomes. The full case studies are presented in Appendix E.

Exhibit 12 Other case studies of potential economic impact

EHGI	The CMI Education for High Growth Innovation (EHGI) project was a £40K education project that ran for two years between January 2004 and February 2006, and which set out to study the influence of university education on the motivation and capability of undergraduates to engage in entrepreneurial behaviour, both in the narrow sense of starting new enterprises, and in the broader sense of leading innovation in existing companies. The EHGI project has led to a number of wider achievements and a useful legacy in the shape of robust evaluation methodology and a growing body of educational evaluations using that methodology • The dissemination of a robust educational evaluation methodology, which has been adopted by a range of UK educationalists and evaluators, and has since been demonstrated in evaluations of other educational courses and courses in other countries • The creation of a development group, the EHGI group, which has continued to function through to 2008, and which has expanded its membership to entrepreneurship educationalists and evaluators at MIT and four other UK universities • The securing of a range of research grants and evaluation commissions, which have further demonstrated the robustness of the methodology and extended the data set for comparative analysis (of operational effectiveness of entrepreneurship courses)

Enterprisers	The CMI Enterprisers project (first called Connections) was an education for innovation project launched in 2002 and supported through a £70K CMI grant. The project evaluated the relevance and transferability (to the UK) of the MIT LeaderShape programme, which has run each year at MIT since 1995 and has trained hundreds of undergraduate students. This novel idea of entrepreneurial teaching contributed to the development of enterprise education across the UK. From the outset, the Enterprisers team managed to engage other universities in the UK, which was the key motive in spreading the idea of the more entrepreneurial focused teaching throughout the UK. While the project received only a small fraction of CMI funding, it is one of the few education projects, which became self-sustaining as the project team was successful in attracting a broad range of sponsors when the CMI funding ended. That was the time when the Connections name disappeared and the more expressive 'Enterprisers' came into force. The main funding organisations include regional development agencies and research councils (the ESRC has been the key sponsor of the course since 2006), in addition to financial support provided by private companies. The content of the programme has been modified in line with the different sponsor's requirements. For example, in 2008, due mainly to the ESRC sponsorship, Enterprisers is focusing on PhD students with a social science background. The facilitators on each course include social scientists in addition to 20-25 entrepreneurs. The fourth course run under support from the ESRC will be held in January 2009. Since the launch of the programme, more than 800 students have participated in the courses with contributions from 150 different facilitators. Altogether, around 45 new entrepreneurial ventures have been launched by participating students since the start of the programme.
EPRG	The electricity policy research group (EPRG) was launched at Cambridge University in part as a result of the 3-year £0.75 million electricity project, which permitted Cambridge economists to launch a series of events, exchanges and mini-projects in conjunction with the MIT Centre for Environmental and Policy Research. Success in this project helped the CU and MIT team to secure a second CMI grant (£0.15 million) to formalise and extend an international network of energy policy experts, the energy policy forum. The EPRG has grown significantly, secured further research funding, established an industrial research club and a series of important consulting relationships all in part as a result of the international comparative analyses it conducted with the financial assistance of CMI.
Praxis	The Praxis Technology Transfer Training Programme began as a 1-year, £0.5 million CMI education for innovation project to acquire (from AUTM in the US), adapt and implement two linked courses designed for TT practitioners. In 2003, Praxis won a 12-month £0.35M DTI contract to deliver TT training to all UK HEIs, working in partnership with the Universities Companies Association (UNICO) and the Association of University Research & Industry Links (AURIL). The DTI contract required the Praxis-led partnership to expand its training delivery capacity, and provided the partners working capital to set up a dedicated office and staff. The contract provided the team with the momentum to continue to market its services and deliver training courses in the 12 to 18 months after CMI funding came to an end. The experience and success of the DTI contract encouraged the team to consider forming a new company that would be dedicated to professional training in the IP and knowledge transfer space. Praxis Courses Limited was established in 2004, becoming the first spinout company of CMI. Since the establishment of Praxis as an independent company, more than 1200 people from 100 universities have participated in its courses. Praxis has earned a good reputation in the field of technology transfer training and was mentioned, for example, in the Sainsbury Review of Science and Innovation. Furthermore, one of the most important benefits of the training courses is the contribution they have made to community building amongst technology transfer staff across the UK. With the establishment of Praxis as an independent company, the team was able to take advantage of an invitation from the Association of European Science and Technology Transfer Professionals (ASTP). In each of the four years since it was set up in 2004, Praxis has delivered one course a year outside the UK, in collaboration with the ASTP. Such has been the success of the courses that, from 2008, Praxis and ASTP plan to organise two non-UK courses each year. Recent courses have been delivered in Austria, Ireland and Denmark and the organisers are considering expanding their activities further afield.

4.4 Conclusions

CMI has produced significant numbers of commercialisation outcomes, in terms of invention disclosures and patents, which easily stand comparison with equivalent results for Cambridge University as a whole.

HEBCI data show an improving trend in terms of technology transfer outputs and productivity across the UK in the period since 2001, and this is echoed in the main innovation statistics for CU. Unfortunately, we cannot determine the causes of these trends within the confines of this present evaluation, and one can see important counterfactuals, which suggest that the CMI impact is likely to have been small. Statistics from AUTM and elsewhere in Europe, for example, show strong year on year growth in commercialisation staff, invention disclosures, patent applications and licences, although the productivity metrics show rather less growth.

Analysis of wider university performance on key commercialisation indicators suggests that CMI is matching the average for all universities on invention disclosures and patent applications, and exceeds the performance of the 20 research-intensive universities within the Russell Group. Current data suggest it is performing less well on spinouts, and, understandably, given the time lags involved, its licence income is a fraction of that achieved on average.

The number of cases of evident economic impact is small in absolute terms, however it is quite impressive in respect to the size of the investment fund. Three of the cases where innovations have been recorded look set to experience commercial success, with two of these UK-based technology businesses showing realistic promise of strong growth in the medium term. This heavily skewed distribution, as regards the benefits to innovation, is very much in line with the literature.

Orthomimetics' is perhaps the most obvious candidate poised to enter what is a large and growing global market, and if it succeeds, its growth, whether as an independent company or as part of a merged group, might be dramatic and with ultimate numbers measured in the many tens of millions.

Praxis and one or two of the other non-research projects that look highly likely to yield economic benefits might turn out to have been among the most consequential originators of economic returns. However even if such an outcome were to come to pass it is unlikely to be revealed without further conscious and quite challenging research and analysis.

In the longer term, the CMI work done with Rolls-Royce through the Silent Aircraft Initiative might very well emerge as a critical point in the evolution of a radical new engine technology that might be at the centre of its business in 10-20 years time. In the nearer term, the CMI work has produced insight and patents that suggest enabling technologies might very well be deployed within 3-5 years on current generations of engine technology, helping to secure future sales and competitiveness.

If one must add it all up now, in 2008, then the immediate market value impacts are few in number and small in extent and are unlikely to amount to a total attributable figure of more than £1 million. The real economic impact can be expected to arise, similarly to that of the UK research base as a whole, from the changes in economic exploitation opportunities – the technology and knowledge frontier – that CMI's very high quality research has materially advanced.

However, if DIUS were to look again in perhaps three years' time, it is likely that the impact will be more significant with the most successful 'CMI' innovations established in their respective market places and producing annual sales in the tens of millions of pounds and annual licence income in the tens of thousands of pounds. This suggests a return on investment that might fall in the range 20-200%, a result that is at least comparable to a number of other economic impact assessments carried out in the context of strategic research programmes, from the LINK programme to the UK's civil space programme. In these cases, the return on investment scenarios ranged from about 75-300%.

5 Contribution of CMI structures to achievements

5.1 Introduction

The CMI model has a number of novel features when compared with other large-scale research and innovation projects, from its central involvement of 'users' in its governing bodies to its coordination through a virtual, transatlantic institute and its delivery through extensive thematic networks or communities. The success of these novel structures and arrangements is of policy interest to DIUS and others.

The work has focused on documentary analysis, interviews with the CMI management team and interviews with project leaders, which together have provided a qualitative insight as regards the contribution of the CMI model and the significance of its different elements.

5.2 CMI governance

CMI was overseen by a Board of Directors, which is responsible for approving the programme of work. The Board comprised a chairman, two executive directors and four non-executive directors, together with observers from UK Government. Cambridge and MIT had equal representation among the executive and non-executive directors. The two executive directors also sat on an advisory board, which is composed mainly of industrialists, with additional representation from charities and government. Lastly, a four-person audit committee, which includes the directors of finance of Cambridge University and MIT, oversees expenditures and financial monitoring systems.

The construction and membership of the Board of Directors reflects wider views on good practice in governance, and fits well with the Guidance on Codes of Practice for Board Members of Public Bodies (Cabinet Office, October 2004).

Interviews and Board minutes suggest the Board functioned well, provided an equitable platform for all stakeholders and helped to keep CMI moving forward. In particular, the Board provided a vital, steady hand in the early days when the project had to contend with a good deal of bad press and resentment from the wider UK HE community.

The Board arguably did less well at ensuring CMI was sharply focused on its core objectives of piloting novel structures to strengthen research commercialisation, with its annual reports presenting a somewhat operational account rather than any kind of strategic assessment of direction, learning and progress. However momentum and motivation are arguably just as critical to a productive organisation and its overall achievements, and the eminent individuals on the board appear to have provided CMI with just such a force and reputation.

Even while the NAO and others might have been critical of administrative arrangements in the early years, project-level evaluation worked well at the outset and went far beyond the kind of inquiries, reflection and debate one might see in equivalent collaborative research projects, whether financed by the EPSRC or the European Commission or the Technology Strategy Board. However aggregation and reporting of lessons learned to the Board appears to have been less good. Indeed, commitment to evaluation fell off in time, presumably because of the scale of effort involved in such an undertaking reinforced by the limited use of project-level insight beyond the immediate senior management team. In this context, it was arguably difficult for the Board to comment in a meaningful way on how to progress the experiment.

5.3 A dedicated institute

CMI was established as a budget holding organisation setting its own strategies and evolving priorities and implementation arrangements in line with practical experience. Interviews with members of the senior management team underlined the importance of this configuration as compared with a more conventional approach. It meant that CMI was able to implement procedures that were more strongly focused on use than might be the case in research councils, and in particular it came to operate with much closer monitoring of project progress and much greater support for and encouragement of commercialisation. Crucially, it also meant CMI was able to respond flexibly and promptly to developments in projects, where more bureaucratic systems might have stalled and compromised research progress.

PIs reported that this funding regime was particularly attractive, that projects could be more ambitious in scope and that the CMI monitoring system's focus on research progress and the added value of collaboration was much more constructive, if more challenging and uncomfortable, than the more traditional focus on detailed accounts of the appropriateness and location of project expenditure. Quarterly meetings with CMI directors and annual joint progress meetings, often through videoconferences, amounted to a much more formal and intensive review procedure than anything one might experience with a research council grant.

The creation of a large, branded institution also gave greater authority to the project in negotiations with the two host universities, and, according to the various principal investigators interviewed, meant that CMI was a more visible and attractive funding vehicle.

The desk research exploring the education and dissemination strands suggests that the creation of a dedicated organisation helped to build visibility and brand value within the two host universities, and within the UK higher education sector more generally.

On the downside, the novelty and scale of the newly created institution did bring early teething problems as priorities and procedures took time to be defined and perhaps even longer to settle and be made fully transparent. On the question of time, several PIs remarked that the creation and cessation of the project within a 6-year period was arguably too short. "The time constant for successful structures in academia is quite long, and micro-structures like CMI might even be counter productive where they do not have sufficient space, perhaps 10-15 years, to conclude their work."

The choice of a separate organisation rather than a more traditional programme was reported to have created some delays and frictions with respect to several established functions within the universities, such as the management of intellectual property by central research services at CU where CMI was adamant, arguably rightly, that it wanted to develop its own approach and style, and yet struggled to mobilise the management resource sufficient to make good use of existing operational expertise in CU and MIT.[7]

5.4 A transatlantic collaboration

The transatlantic link was a defining feature of the CMI project and one that the PIs in particular signalled as being novel and hugely value adding over alternative funding streams.

While bibliometric data suggest the US is the UK's most frequent research partner,[8] the opportunities for carrying out real projects together are rather scarce. Most researchers argue that while the UK's

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7 This is detailed in the National Audit Office (NAO) review published in 2004, HC 362 2003-2004: Cambridge-MIT Institute (full report)

8 There is a strong structural quality to this 'popularity,' with the statistics reflecting the size of the US research base at least as much as its absolute excellence. Indeed, the US is the dominant overseas partner for all G8 countries and many others besides: 30% of all of the UK's internationally co-authored papers

mainstream research programmes will fund international cooperation in principle, this is difficult in practice and a high-risk strategy few follow. In turn, UK international programmes tend to finance mobility rather than research proper and are more likely to award a £20K grant than a £200K grant. The EU RTD Framework Programme provides funds to support joint research with teams working across borders, however its geographical focus is intra-Europe although FP7 has seen an increased emphasis on collaboration with third countries. The situation has changed somewhat since the inception of CMI with the further extension of the science bridges programme, of which CMI became part, however the balance of opinion remains one of scarcity of funds. On the US side, several major federal research programmes within the NIH and NSF are open to overseas teams, however the prospects for success have proved to be rather poor (this is a particular focus for the newly opened office of the RCUK in Washington).

Within this context, CMI was seen by many as a largely unique opportunity to secure grants running into the millions of pounds with collaborations with established world-class researchers at MIT.

5.5 Integrated research communities

One other feature of CMI was its commitment to create integrated research communities, comprising multiple projects and brigading the complementary research expertise of CU and MIT, sometimes drawing on new disciplines and working within the context of technology roadmaps and strategies that had been defined in conjunction with lead users.

While this was a novel construction, it was not entirely unique. The DTI Faraday Partnerships had something of the same quality here in the UK, while the various competence centre programmes in continental Europe (from Austria to Germany to Sweden) and technology institutes (e.g. Denmark's GTS programme and the Netherlands Top Technological Institutes). However, it is arguable that CMI was very much in the van of a new way of thinking, and one can see variants of the integrated research model emerging throughout the period. The EU Technology Platforms and Integrated Projects are notable recent examples, albeit these are an order of magnitude bigger than anything CMI has done.

The idea continues to take hold in the UK too. The technology Strategy Board's Innovation Platforms and Knowledge Transfer Networks set much store by the marshalling of the manifold interests at work within the many, and often weakly connected, stakeholder groups. These schemes all see new communities as being the precursor necessary to create commitment to a singular agenda in new and emerging fields and the prospects of progress and breakthroughs. Roadmapping is one of the key outputs of such coordination and agenda setting, and the CMI integrated research projects have been particularly active in this regard.

5.6 Conclusions

CMI principles and structures contributed uniquely to the realisation of the social and economic benefits described in the previous chapters, and in particular its ability to support international collaboration projects of real scale and duration where a majority of funding schemes will tend to fund national rather than international work. The international dimension is more typically facilitated through support for international studentships and fellowships, and the natural inclination of researchers to travel widely.[9]

(equal to 40% of all UK journal output indexed by Thomson ISI) included a US-resident author, while the figure for second-placed Germany was 15% (Evidence Limited, 2007).

9 It is a foundation of the academic profession that research excellence demands an international context, with breakthroughs building on the work of predecessors and shaped by debate with one's collaborators and adversaries across the global community. Throughout their career, professional researchers strive to build and renew their social networks in order to both enhance their knowledge and advance their personal interests. In practical terms, the scale and geographical extent of the public-sector research base

The bibliometric analyses tend to confirm this view of research excellence and impact arising from the collaboration and parallel work of researchers at the two universities, with typical impact gains for CMI work, and internationally co-authored work in particular, of two or three times as compared with the average for a given field.

One of the defining features of CMI was its constitution as a single institution that was able to do research and education and innovation and link biology with physics with management research if need be, and this absence of boundaries really marked the project out from for example individual research councils or even their inter-disciplinary research centres, hence the choice of the title for the CMI final report, Accelerating Innovation by Crossing Boundaries.

Perhaps most significantly, CMI was a pioneer of a more integrative and multidisciplinary approach to innovation, and one can see these principles have become mainstream in the past decade, whether that is at the level of UK government policy and programmes, such as the innovation platforms, or the cross-agency collaboration amongst the research councils, and facilitated through RCUK.

CMI senior managers and researchers alike point to important intellectual and practical benefits of this integrative and multidisciplinary approach, which produced a legacy in the shape of a continuing commitment to such collaborative working, whether international or not as well as a host of operational lessons with respect to the successful conduct of such research. It has secured converts to systematic dialogue with stakeholders and the value of wider networking both to academics ability to focus on more fecund research questions while ensuring more active engagement by business and other stakeholders in the work of universities.

While CMI performed strongly in terms of invention disclosures, comfortably outperforming Cambridge and the other members of the Russell Group of universities, there remains some uncertainty as to the extent to which it has managed to demonstrate an unequivocally better research commercialisation model.

The work on invention disclosures, patents and licences reveals no strong pattern, with success seemingly just as likely to emerge from single projects as from the integrated programmes. The impact case studies by contrast do suggest that the larger, inter-disciplinary collaborations are more likely to be more successful in producing IP that has a real chance of being commercialised whether through spinout companies or through application by established businesses. Equally, the oral testimony from a small proportion of PIs does lend support to the CMI hypothesis that large-scale, use-oriented research comprising integrated, inter-disciplinary teams will dramatically outperform more narrowly focused and self-oriented work.

While the evidence on its relative performance might not be absolute, it seems incontestable that CMI and its Knowledge Integrated Communities were an important conceptual development, which has resonated with academic leaders and policy makers in the US and the UK. The KIC concept, while not fully implemented throughout CMI, has been adopted in a number of important new measures in the UK and further afield, most notably in the UK government's newly created Innovation Platforms, which focus on major societal challenges and bring together government and other stakeholders to work with industry and academia on the definition of priorities and programmes of work. The public ambition is to use these integrative devices to produce a step change in the rates of innovation and the delivery of social and economic solutions. There are clear echoes also in the recently launched European Institute of Innovation and Technology (EIT), which is a cross-border virtual research university with a governance structure similar to CMI and will operate through core instruments called Knowledge and Innovation Communities.

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means that the frontier of knowledge, in almost any field or discipline, will be determined in some degree at least by people and institutions in countries other than one's own.

6 Review of CMI implementation

6.1 The origins of CMI

The origins and history of the Cambridge-MIT Institute have provided an important backdrop to the evaluation, and in particular an understanding of its goals and construction, although the study has concerned itself primarily with detailing CMI's achievements and exploring the extent to which the CMI approach holds out lessons for future UK research policy. The present evaluation did not dwell on the findings and recommendations of earlier financial and operational reviews, although reference has been made to such.

The idea for a UK/MIT initiative dates from 1998, following a visit by the then Chancellor, Gordon Brown, to MIT. Adoption in the UK of practices and associated skills available in MIT, reflecting its highly entrepreneurial culture, were seen as likely to address some perceived deficiencies in the UK innovation system, such as a lack of management skills in academic institutions, and weak industry-university links.

Initially, two options were considered. The first was for the establishment of a satellite MIT campus in the UK, undertaking teaching and research. The second was for a joint venture between MIT and an existing UK university, sited some distance away from the UK institution to provide a stronger identity, and perhaps also eventually becoming wholly independent. In 1999, the idea of satellite campuses was rejected on the grounds that the quality of research and of students was likely to be compromised. Cambridge was nominated as the UK partner, apparently a key condition insisted upon by MIT due to its internationally regarded strength in education.

It was decided that activities would comprise staff and student exchanges, joint research and curriculum development, executive education and industrial collaboration. The British Government indicated a willingness to commit £68m[10] to the Institute, over five years. Creation of the Institute was subsequently publicly announced in November 1999, and it was formally launched in July 2000.

As with any major new venture, there were problems during the early stages. As early as May 2001, Patricia Hewitt, Minister of State for Trade and Industry, commissioned an independent review of the CMI from Arthur Anderson, following Departmental concern that spending in the first year had been substantially below profile, and about the effectiveness of systems for project selection and financial management. Among other things, the review recommended that operational milestones should be set for individual programmes and projects, that procedures for approving project funding and controlling expenditure should be tightened, and that a finance officer should be appointed at board level. The Select Committee on Science and Technology was informed in 2004 by Mrs Hewitt that the CMI board had accepted and acted upon all the recommendations, and that a further independent audit (February 2003) found CMI's internal systems and controls and corporate governance practices to be satisfactory. That audit made no recommendations for further action.

There was also press criticism in the early years, alleging discontent amongst other universities that the venture had not been put out to competitive tender, and more challenging to the pilot venture, that its results were disappointing, and that the initiative had been oversold.[11]

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[10] Eventually £65.1m was allocated to CMI

[11] From *The Guardian,* April 22 2003: 'What CMI has actually come up with is good solid stuff…but none of it is exactly earth-shattering or guaranteed to revolutionise the competitiveness of UK plc.
There is a general feeling in the academic world that if CMI hasn't exactly stalled, it has become becalmed and lacking in direction – a feeling enhanced late last year [i.e. in 2002] when the two directors, MIT's John Van der Sande and Cambridge's Alan Windle, unexpectedly resigned'

In 2004 the NAO reported on the Institute, concluding that the two-stage initiation process (involving first the Treasury setting broad parameters, including overall funding, and then the DTI to negotiate detailed arrangements) was appropriate. However, setting up the CMI had been a 'much bigger task than anticipated' and initial expectations had been 'very ambitious'. It also noted that key outcomes from the Institute were difficult to measure and would take a long time to be realised.

In early 2003, CMI had revised and tightened its procedures for project appraisal and monitoring. According to the NAO review (2004):

> *The process is largely based on the process used by research councils to decide funding for academic research projects, which focuses on the research achievements of the project leader, the quality and scope of the proposed research, and its fit with the research council's objectives.*

The NAO (2004) found that, in contrast to pre-2003 appraisals, bids received in response to a call for proposals in April 2003 were assessed against pre-defined criteria, and subject to internal and independent external reviews to test their quality, relevance to the programme and commercial significance. Monitoring procedures had been strengthened – in the fourth-year operating plan, quarterly milestones specifying objectives for all funded projects were introduced, and progress reports were to include details of activities, spend against forecast, and explanations of variances.

While the origins of the CMI project were clearly out of step with convention as regards the design and implementation of major public-sector research programmes, the political decision to seek to secure a transfer of MIT know how and procedures to the UK left administrators with little room for manoeuvre. To the distant observer, the UK was essentially agreeing to buy aspects of MIT's intellectual property and gaining access to CU's educational expertise was very much part of a package of inducements as the budget alone was not sufficient. MIT commentators have stated that there would have been a more natural fit between it and Imperial College, however MIT is reported to have made its participation in the CMI project contingent upon CU being its partner precisely because of the pedagogic differences between these two world-leading institutions, and two-way learning opportunities.

As an aside, MIT senior managers stated that one of the lessons learned by MIT was recognition that a research university can achieve and sustain world-class performance through an approach that is radically different to the 'MIT way,' culturally and procedurally; there is not only one way to excellence. This was reported as having been something of a surprise, and one that has contributed to a slightly different outlook with subsequent international strategic partnerships, and which is expected to pay dividends in the longer term.

6.2 CMI rationale and objectives

6.2.1 The need for action

The CMI rationale is a familiar one, wherein national policy makers wish to derive greater social and economic value from their significant investment in public sector research and believe that the connections between that research community and national businesses are less extensive and less well developed than is ideal. Innovation and economic growth should follow from improved engagement between research and business.

It is increasingly recognised that scientific research is more likely to deliver economic benefits where the requirements of users, channels for easy exchange of information and knowledge transfer, are important components of the process of defining, conducting and using research. The research base frequently does not recognise the most appropriate direction and focus for their activities to realise commercial objectives, even where such objectives form important targets for their work. These imperfect information flows and information asymmetries comprise an important form of market failure which, given the other interests of academia and the financial and other pressures on business, are not readily overcome.

The great majority of commentators believe it is entirely appropriate for governments to intervene to correct such market failures, and in particular where they are at work on a broader front to tackle other impediments from flexible labour markets to efficient fiscal regimes.

The innovation paradox has been commented on almost continuously over the past 25 years, and the UK government has mounted various assaults on this particular market failure, with some success if the innovation statistics are to be believed, with increasing numbers of collaborations and collaborators. Other indicators seem somewhat stuck, whether that is rates of change in industrial productivity or the efficiency with which business is able to access and translate research into product. Almost every OECD member is of a broadly similar opinion, which is to say that important progress has been made however there remains much more to be done.

What more should be done is a question that brings much debate, however it seems entirely appropriate that the UK government should be exploring its options and launching novel, experimental programmes such as CMI so as to produce both strategic and operational insight.

6.2.2 The wider policy context

The central tenet of the CMI project was not particularly novel in its concept, for either the UK or Cambridge. Indeed various interviewees, at management and project level, were adamant that CU had been working closely with industry over many decades as a means by which to shape their research and increase its relevance and take up.

In one sense, CMI might be regarded as one initiative in a long line of experiments into ways of shortening and strengthening the links between public research and industry in order to accelerate innovation and economic growth in geographically concentrated spaces (fiscal territories). The LINK scheme, launched in the mid-1980s, was an early government response to what is often referred to as the 'innovation paradox.' The national Technology Programme was launched in 2003/4, as a replacement for LINK, 'owned' by what was called the Technology Strategy Board, a high-level advisory group (to DTI) comprising industrialists predominantly tasked with the formulation of a series of national priorities for technologies and emerging economic sectors.

The UK's 10-year Science and Innovation Framework (2004) devotes many paragraphs and specific measures to the notion of research as a vehicle for social and economic gain, and has put the incentives in place to deliver this. Research exploitation has been made one of the core missions of the research councils, and while this might still be argued to be an 'end of pipeline' activity, with the most obvious effort being given over to knowledge transfer schemes, this is not the whole story. Consideration of use is now evident in calls for proposals, appraisal criteria and the constitution of programme boards. Moreover, every research council is embarked upon a programme of impact assessment, albeit predominantly through the preparation and publication of small numbers of case studies. DIUS annual monitoring reports are trying to push beyond the more traditional science and technology indicators, with a focus on counting inputs (people, money) and outputs (bibliometrics), albeit the issue of utility is generally being tackled through qualitative measures and small n case studies.

In 2007, the Technology Strategy Board and the Technology Programme were made independent, and given agency status and co-located with the headquarters of most of the Research Councils. The Technology Strategy Board will only support development projects and knowledge transfer networks that have consideration of use at heart. The EU RTD Framework Programme deploys a similar rhetoric, and maintains a sharp focus on socio-economic achievements at both the appraisal and evaluation stages in the project life cycle.

The other important development within the CMI period was the devolution and delegation of responsibility for a great deal of business support, from the DTI to the devolved administrations and the regional economic development agencies (RDAs). The latter were launched with a tasking framework that had a specific output related to university-business interaction, which all nine English RDAs count and report as part of the funding process.

In budgetary terms, the Technology Strategy Board invests around £200 million a year in demand side initiatives and the nine RDAs collectively invest another £350 million annually on research and innovation. The EU RTD Framework Programme (FP7 presently) also provides a broadly equivalent annual income, on the order of £300 million a year for user-oriented research and development. All three invest a substantial proportion of their total investment with public sector institutions, in essence to provide universities with the incentive and wherewithal to collaborate with business.

It is not clear that the CMI approach offers much in the way of big new ideas for other UK research funders and research performers, which is not to say that 'consideration of use' should not be a core principle for a significant proportion of the UK's science budget.

CMI's support for use-inspired basic research is arguably an embodiment of the more interactive view of science and technology found increasingly in policy documents and the research policy literature, and which creates at a new relationship between (public) science and government (the taxpayer), which will create more recognition, both within the research community and in society of the importance of "Applied Science". Equally, use inspired research should catalyse an expansion of private investment rather than its substitution, as very significant market failures still remain.

6.2.3 CMI objectives

From the standpoint of the UK, the role of the CMI was, broadly twofold:

- To enhance national competitiveness by encouraging, through Cambridge-MIT collaboration, the development of new technological ideas in selected areas and their transmission through knowledge exchange and dissemination, to the marketplace
- To explore the relative effectiveness of a range of novel approaches to the engagement of users in defining research strategies and the subsequent commercialisation of the intellectual property arising from it

The focus of these dual objectives is comparable, in that they address implicitly at least the ambition of finding a way round the 'innovation paradox,' referred to repeatedly by successive policy documents, by implementing an anglicised version of the 'MIT approach,' and all that has delivered in terms of economic dynamism to Boston and the regional economy of New England.

The scale of the CMI investment, and its constitution as a pilot to explore the possibility of acquiring new techniques and content from a leading global practitioner, was also reasonable. While the budget ought to have been sufficient to develop and test a variant of the MIT approach, the implied commitment to secure an improvement in the competitiveness of the UK economy was always going to be beyond a £65 million programme. In practice, successive directors have simply embraced the idea that the project should deliver meaningful economic benefits in the UK.

The objectives might better have been cast as hypotheses, with specific and measurable outcomes, wherein CMI would have committed to implement its unique approach on the assumption that such a strategy would deliver more directly observable economic benefit, for a given spend, than might be expected from a more conventional research council programme.

One other rider is perhaps worth mentioning and that relates to the extent to which the CMI strategy was ever going to be generalisable to universities and locations throughout the UK. Assuming there is such a thing as an MIT approach, was CMI likely to be able to capture and distil its essence, and could such an approach ever prosper without the massive infrastructure and innovation ecosystem that has grown up around MIT and Harvard and Boston over many decades? The MIT approach hasn't taken hold in Illinois or Miami or Pennsylvania, and one might conjecture that it will struggle to take hold in Bournemouth or Lancaster or Teesside (a challenge awaiting the recently launched European Technology Institute).[12] Whether coincidentally or by design, Cambridge, along with London and Oxford, is one of the very few locations in the UK where that kind of innovation ecosystem was to be found.

6.3 CMI operations

Programme documents, minutes and interviews reveal an impressive mobilisation of senior figures and institutional resources in a relatively short space of time, and this early momentum was carried forward across the life of the project, albeit with one or two blips. The early evaluations noted a number of administrative shortcomings in the early years, and CMI principals and senior researchers still remember the somewhat disorganised quality of those early years, and the challenge of starting an institution from scratch. People remember the project as going through a major transformation in its focus and orderliness when Professors Michael Kelly (CU) and Ed Crawley (MIT) took over as directors. One interviewee described it as having been 'a game of two halves,' using this sporting metaphor to convey the idea that CMI had a rather different character post 2003.

In several other cases, respondents suggested that were they to do this all again, and with the benefit of hindsight, they would recommend the appointment of a Chief Operating Officer, located at the operational HQ. This was partly a reflection of the specialist skills needed to look after the day-to-day business of any large (international) business, and partly a recognition that the senior academics that tried to fulfil this role continued to have academic interests and ongoing pressures from their host institutions. Notwithstanding these mildly negative comments about the efficiency and orderliness of CMI operations, especially in the early years, and suggestions that future similar institutions should have an academic lead and an operational lead, the commitment and dedication of successive directors is noteworthy, both from the standpoint of their management of an unusual and rather demanding institutional configuration and from the perspective of their being charged with the responsibility for transforming research and innovation performance across the UK HE sector!

During the first two or three years, CMI appears to have struggled with the expectation of the UK government (and other stakeholders) to get on and in response to this external pressure launched a very large number of projects, a good proportion of which appear to be of questionable relevance to the overall objectives. The scale of the ambition might very well have detracted from the need to deliver on the experiment too, wherein the budget was invested in a large number of quite heterogeneous projects, almost 300 in total, with financing ranging from a few thousands of pounds (and a duration of a few months) to more than two million. The second-period saw the senior management team attempting to focus the CMI research strand on a smaller number of so-called bold initiatives and grand challenges (10 big ideas), a change in strategy which has great outward appeal but which the project files and output statistics suggest might have been begun too late.

Our current survey of principal investigators confirms this evolutionary perspective and suggests that on balance CMI procedures were reasonably well regarded by the majority of researchers. Indeed, in most cases a majority would point to a characteristic as being positive, while a minority saw the same

[12] One contributor suggested that the success of the cross-border, virtual-institute as embodied in CMI, had been an important inspiration and reference point to EU policy makers when debating the organisational model for the European Institute of Technology, which will be a closer match to CMI than to MIT.

quality as a negative. In addition to the availability of funds to do work with leading academics in another country, positive operational points included the fact that CMI was:

- Supportive of the need to help researchers meet international counterparts, to explore areas of complementary interests
- Open in terms of themes and disciplines
- Open to big projects or programmes, as well as small (post 2003)
- Flexible as regards the bidding rules, with, in one reported case, a half-page proposal being the starting point for what amounted to a negotiated procedure, and in other instances projects were occasionally commissioned
- Administered in part by senior academics with the competence and management authority to respond quickly and deftly to changing circumstances
- Frequent and demanding communication and review procedures, which facilitated collaboration and helped teams to make good choices at key decision points within projects

Negative operational points included:

- Somewhat opaque appraisal and selection procedures
- Frequent and burdensome monitoring procedures, which went far beyond the demands of most other funders
- Too many dissemination and networking events, which add little value to what are established relationships in the main and cost the researchers (and therefore the programme) a great deal of time

The appraisal and selection procedure was said to have been somewhat opaque throughout, however this might simply reflect the difference in perspectives between an individual proposer and a budget holder rendering decisions on tens of competing projects. That said, feedback was thought to be less well developed as compared with the UK grant-awarding research councils, for example. There was a minority view that schools and faculties were able to wield influence behind the scenes, shaping decisions on broad swathes of investments. Our wider research revealed no evident negative impact that might be associated with potentially poor investment choices, through for example anomalous results in the bibliometrics or shadows across the commercialisation results.

6.4 Monitoring and evaluation

Project-level monitoring was a particular feature of the CMI approach, and was reported to be much more frequent and intensive than the more conventional approach followed by the light touch research councils (and CMI achieved this with a management cost that matches the Councils). The aggregation and reporting of outputs was less good, however the raw data was being collected and the CMI office was able to furnish the evaluation team with a complete list of related publications.

The two paper-based reviews have had to make full use of CMI evaluation material, and the overall impression is that CMI devoted more attention and more intelligence to evaluation than would have been typical at that time, even for such flagship projects. The methodological care and thought that went into most of the end-of-year, project-level evaluations stands out, as does the independence and authority of the external people contracted to carry out these formative reviews.

The evaluation record is much stronger in the education area than it is in the research or dissemination strands, which reflects the more experimental approach adopted with respect to the education endeavour as compared with the more operational focus of the research and dissemination strands. Unfortunately, the excellent evaluation work of the early years tended to fall off, and very few projects or strands of work were subject to further independent reviews.

6.5 Conclusions

Overall, CMI must be regarded as a creditable project, which sought to learn about and import to the UK the critical aspects of the MIT approach to driving innovation out of research, and with the evident and strongly positive spillover benefits to the Boston and New England economies.

The UK government's decision to launch CMI as a bilateral international project exclusively financed by the British taxpayer, was a necessary response to MIT's not unreasonable ambitions, given that CMI objectives amount to an agreement to acquire the MIT approach such that we might apply it here in the UK, to the benefit of British universities and businesses. The CMI objectives were reasonable too, focused as they were on working with MIT to drive innovation and commercial value out of a research and education programme, while seeking to gain insight as to what were the critical success factors. Setting the project up as a learning experiment, with a commitment to share this insight more generally, is particularly deserving of praise. The budget for the project was respectable too, with a £65 million budget rather than a more typical £6.5 million.

We have some small doubt as to the extent of the transferability of the model to UK HE in general, where the majority of institutions do not enjoy the critical mass, support infrastructure and innovation ecosystem available to researchers and business people in Cambridge UK and Cambridge Massachusetts. The importance of place and agglomeration to innovation has become more evident in the intervening period since CMI was created.

In operational terms, CMI was something of a mixed success with various minor administrative shortcomings in evidence, particularly in the first couple of years. The early evaluations suggest that there was a pretty steep learning curve as regards the development of robust, codified and transparent procedures, which the NAO review of 2004 suggests the development and maturing of administrative procedures was largely complete by 2003. Interviewees in 2008 still recollect the somewhat inconsistent approach of those early years, and a number of people remarked that it ought to be a requirement in the future for any similarly large and novel projects to at least consider the possibility of appointing a Chief Operating Officer.

As evaluators, we might be expected to say that CMI should have done better with regard to its programme-level monitoring and evaluation. Moreover, having begun impressively, particularly in the education strand, M&E work fell off noticeably in the later years. However, professional interests aside, this tapering off of evaluative work has reduced the value to the UK of the CMI experiment, with the more synthetic self-assessments produced by CMI, and indeed this evaluation, struggling to match the insight and penetration of an academically stringent, longitudinal evaluation deploying appropriate controls.

The view from the ground is mixed too, with several researchers complimenting CMI for including senior academics within the core administrative team, which they argued had led to more sympathetic and deft handling of project developments. The level of strategic autonomy and researcher-centred quality of the management team clearly marks CMI out as being very different to the majority of research funders.

Other well-liked features were the thematic openness of the project, and CMI's flexibility around project size and timing; those that did secure CMI grants believed the bidding process was more straightforward and with better odds than an equivalent research council.

On the down side, researchers were less comfortable with what they described as somewhat changeable and uncertain bidding arrangements and most important, what a majority saw as being an additional overhead of CMI (for monitoring, reporting, disseminating) as compared with a council grant. A minority noted that while the CMI-style communications and project monitoring had been a significant additional overhead, it had made possible real collaboration across disciplines, institutions and countries.

7 Consideration of use

7.1 Use-oriented research

The CMI experiment might be characterised as an experiment in exploring ways to improve the *chances* of success and the economic yield derived from the large and growing spread of public investment in research, without corrupting its wider social benefit and long-run contributions.

The project sought to do this not by 'picking winners,' but rather by attending to certain framework conditions and principles, and in particular the idea of 'consideration of use,' which was expected to be a pre-requisite for securing funds.

While consideration of use is hardly a novel idea, there remains a question as regards the extent to which CMI managed to implement this principle more fully in practice than do its analogues inside the Technology Strategy Board or the grant awarding research councils.

From an institutional standpoint, CMI tended to involve academic leaders from departments and faculties in the applied sciences and in that regard it was most visible and most actively marketed to researchers in these industrially-engaged groups.

From a procedural standpoint, the CMI arrangements appear to be every bit as concerned to encourage a user orientation as do the more applied and industrial research programmes here in the UK and elsewhere in Europe. So, for example, user orientation is evident at various points within the CMI administrative system:

- Industrial membership of the CMI governing body
- Industrial engagement in various roadmapping exercises that helped to identify research challenges and shape individual proposals
- An expectation that research proposals should address the question of use and commercialisation explicitly
- An expectation that research partnerships should include industry in some capacity, whether as research partners or sponsors observing and reflecting on developments
- The inclusion of questions regarding technology application, industry engagement and commercialisation within the monitoring procedure
- Industrial membership of the CMI commercialisation committee

CMI project records make clear that user orientation was not exclusively about links with high-technology manufacturers, and there was clearly an openness to the idea that lead users and diffusers might be found in any area of economic activity, from banks to utilities to public administrations nationally and regionally (e.g. RDAs).

The bibliometrics and commercialisation statistics would tend to support the contention that CMI did indeed address user issues, however the extent to which this is more or less well developed than other programmes is less clear.

Our analysis of the HEBCI data does suggest that CMI has a stronger commercial focus than does CU, or indeed the Russell Group of 20 research-intensive universities. However, perhaps unsurprisingly, CMI does not outperform the average for all UK HEIs on a proportionate basis on several key indicators for example invention disclosures, patents granted or licences signed. These aggregate figures are driven by the much stronger performance of the former polytechnics and colleges of art, and the much weaker performance of the world class research institutions in Cambridge, Oxford and London.

On the downside, a minority of PIs report that their research was rather fundamental and had been a continuation of past interests with little or no contact with business and other users. For these few individuals, the attraction of CMI was reported to have been its more flexible approach to research funding rather than its intended sharp focus on use. Moreover, a majority of PIs suggested that the calls for proposals, such as they were, and application process did not give any particular weight to consideration of use, nor was it obvious that credit was given to those projects that had secured direct industrial interest and co-financing.

The Board's annual reports tended to be concerned more with activity than with outcomes, and as such these accounts tend to deal with user orientation indirectly, through showcasing notable research projects and their industrial partners or through an overview of activity within the industry outreach aspects of the project.

7.2 Conclusion

CMI governance and leadership was dominated by academics and industrialists with a track record of collaboration and a pre-disposition towards more vocational education and strategic applied research.

CMI calls and application procedures however look to have done less than might have been anticipated to promote consideration of use, and for example to choose use-oriented research over curiosity driven research. CMI did not develop specific protocols or guidance material to inform prospective participants or support grantholders.

The work of the CMI management team and reviewers did provide an important challenge function for projects and was believed to have helped research teams to focus on scientific breakthroughs with the potential for real-world applications. Consideration of use was also inspired through several of the CMI accompanying measures, such as the entrepreneur in residence concept, and the systematic support of the commercialisation offices.

Appendix A Invention disclosures from CMI projects

A.1 MIT disclosures

CE Case No	MIT Case No.	Title	PIs	Description	Owned	TLO	Patents Filed	Licenses	Comments
Ros-1331-05	10147	Magnetic Memory Elements Using 360 Degree Walls	Fernando J. Castano and Caroline A. Ross	Magnetic memory that incorporates ring-shaped memory elements.	MIT	BP	US- 6906369 UK-pending 0516821.6	None	Dropped from CM Innovations license negotiations Grant: 061/P-IR MAGNETOELECTRO
	10184	Polaritonics Related Research	Keith A. Nelson		MIT	AG	None	None	Case Closed
Tur-1332-05	10334	Device for the Measurement of the Work of Adhesion of Solid Surfaces	Simon Mark. Spearing and Kevin T. Turner	Design for a device that measures the work of adhesion between two materials.	MIT	CB	None	None	Case Closed Grant: 059/P-IR(FT) MEMS
	10338	Biologically Active Scaffolds with Spatially Uniform Activity	Lorna J. Gibson, Brendan A. Harley, Fergal J. O'brien and Ioannis V. Yannas	A biological active scaffold allowing for uniform biological activity.	MIT	SV	None	None	Grant: 054/P-IR (FT) INTERDISCI
Yan-1904-07	10339	Gradient Scaffolds, or Scaffolds with Spatially Distributed Biological Activity	Ricardo R. Brau, Lorna J. Gibson, Brendan A. Harley, Fergal J. O'brien, Stephen V. Samouhos, Myron Spector and Ioannis V. Yannas	A biological active scaffold allowing for a gradient of biological activity.	MIT	SV	US pub application 11/230918 PCT pending US05/33873	Licensed to Orthomimetics	Grant: 054/P-IR (FT) INTERDISCI Licence being novated to CE Equity in name of CMI Ltd to be gift-aided
Hat-1281-04	10369	Responsive Compositions for Active Encapsulation	Lev E. Bromberg, Seyda Bucak, T. Alan Hatton and C. Ted. Lee	A formulation for the encapsulation of PAP in novel polymeric vesicles, thereby segregating the bleaching agent from the enzymes that are located in the external phase.	MIT	ARS	None	None	Case Closed 089/P-P&G (CO-FORMULATIN
Sin-1280-04	10683	pB264, a Small, Mobilizable, Temperature Sensitive Plasmid from Rhodococcus	Philip Lessard and Anthony J. Sinskey	A plasmid, called pB264, that can be used to manipulate bacteria from the genus Rhodococcus. Gram-positive bacteria from this genus have shown an extraordinary capacity for metabolizing recalcitrant organic compounds	MIT	ARS	US application - abandoned	3 active MTA licenses	Grant: 016/P-IR (RHODOCOCCUS) MIT to manage the MTA licences
	10684	Consensus Annotation by Phylogeny Anchored Sequence Alignment	Jefferson A. Parker	Bioinformatics software for genetic research	MIT	DD	None	None	Request to open source granted Grant: 016/P-IR (RHODOCOCCUS)

CE Case No	MIT Case No.	Title	PIs	Description	Owned	TLO	Patents Filed	Licenses	Comments
Lod-1279-04	MIT 11357W	Hematopoietic Stem Cells	Lodish, Harvey	Method for expansion and analysis of cultured hematopoietic stem cells					Closed
Dub-1282-04	11485	Dielectric Elastomer Actuator,	Steven Dubowsky, Sauro Liberatore and Jean-Sebastien Plante		MIT	CB	None	None	Case closed. Grant: 049/P-IRFT (DIGITAL MEC
Lod-1323-05	11513W	Angiopoietin-Like Proteins Stimulate Expansion of Hematopoietic Stem Cells	Harvey F. Lodish and Chengcheng Zhang	Angiopoietin-like proteins stimulate ex vivo expansion of hematopoietic stem cells.	WHEAD	SV	US Serial No. 60/753212, Filed 12/22/05 US Serial No. 60/795548, Filed 4/27/06 US Serial No. Filed 5/23/06 PCT Serial No. US06/	None	Grant: 075/P-IR FT(MICROFABRICA
	11539	EEstimator, A Quality Control Method for BLAST Homology Searches	Jefferson A. Parker	Bioinformatics software for genetic research	MIT	RPP	None	None	Request to open source granted Grant: 016/P-IR (RHODOCOCCUS)
Kis-1460-05	11602	Lentiviral Anti-Repressing Elements,	Stephan Kissler and Patrick Stern	Two DNA elements significantly improve the utility of lentivirus reagents by preventing random, and often significant, silencing of the integrated virus in cells. These elements insure higher expression of transgenic gene products in a greater number of cells.	MIT	LF	US Serial No. 60/783449	None	Provisional filed 3/17/06 & converted to PCT designating all states including the US Grant: SYSTEMS BIOLOGY KIC (MIT)
	11630	COGsensus, Software Tool for Automated Annotation of COG Function	Jefferson A. Parker	Bioinformatics software for genetic research	MIT	RPP	None	None	Request to open source granted Grant: 016/P-IR (RHODOCOCCUS)
	11632	Bio-JParker-Shared.pm, Bio-JParker_BlastPack.pm	Jefferson A. Parker	Bioinformatics software for genetic research	MIT	RPP	None	None	Request to open source granted Grant: 016/P-IR (RHODOCOCCUS)
Ros-1452-05	11770	Magnetic Logic Device	Fernando J. Castano, Deborah Morecroft and Caroline A. Ross	Magnetic logic devices are nano-structures (magnetoresistive thin films) whose output (resistance) is dependent upon its two inputs (two assignable magnetic fields) and therefore can act as a logic gate or switch	MIT	YK	None	None	Grant: 061/P-IR (MAGNETOELECTRO

CE Case No	MIT Case No.	Title	PIs	Description	Owned	TLO	Patents Filed	Licenses	Comments
	11797	Power Harvesting System for In-Pipe Wireless Sensor Networks	Alexander M. Gorlov, Eduardo A. Kausel, George Kokossalakis and Andrew J. Whittle	The power harvesting system of the acoustic in-pipe wireless sensor network communication system, disclosed in M.I.T. Case 11798. A specially designed helical turbine will extract energy from the flow of the moving water, converting it to electrical energy.	MIT	DD	US Serial No. 60/752322, Filed 12/20/05	None	Converted provisional to full US patent application – combined into one utility application for Case 11789 NEastern's Gorlov design probably not rising to level of jointly owned Grant: 080/P-IRFT (AGING INFRAS
Kau-1454-05	11798	Acoustic Data Communication for In-Pipe Wireless Sensor Networks	Eduardo A. Kausel, George Kokossalakis and Andrew J. Whittle	Proposed system is a wireless acoustic data communication network capable of operating within pressurized water transmission lines.	MIT	DD	US Serial No. 60/752324, Filed 12/20/05 US Serial No. 11/643750, Filed 12/20/ 06 PCT Serial No. US06/049087, Filed 12/20/06	None	Converted provisional to full US patent application Grant: 080/P-IRFT (AGING INFRAS
Sin-1459-05	11817	Conversion of Oils, Lipids and Fatty Acids to PHA including Medium Chain and Long Chain PHA using Rhodococcus as the Production Organism	Philip Lessard, Chokyun Rha and Anthony J. Sinskey	This invention utilizes the potential of Rhodococcus to be a versatile and valuable industrial strain for producing PHA using fatty acids or lipids as medium.	MIT	SV	None	None	Grant: 016/P-IR (RHODOCOCCUS)
	12216	Eliciting Production of Bioactive Molecules via Co-Cultivation of Microbes	Kazuhiko Kurosawa, Philip Lessard and Anthony J. Sinskey	Disclosure describes the use of heterologous microorganisms to produce bioactive molecules.	MIT	SV	None	None	Grant: 016/P-IR (RHODOCOCCUS)
	12287	Developing and Managing a Successful Technology and Product Strategy: Designing a Distance Offering Project	Rebecca M. Henderson	Copyrighted educational materials – DVD or CDROM	MIT	RPP	None	Copyright License to Sloan School	Grant: 098/P-PP (DESIGNING A DI
	12545	CoolVent	Leon R. Glicksman and Jinchao Yuan	CoolVent is a software model that incorporates transient airflow, temperature, and thermal mass solutions, especially for natural ventilation systems.	MIT	DD	US Serial No. 60/897753, Filed 1/26/07	None	CMI-BP Project OSP 6892280 Filed provisionally to protect BP's international rights due to late notification of public disclosure. BP has informed CMI, MIT and CU that they do not want to go forward with a patent filing

A.2 Cambridge Enterprise disclosures

CE Case No	MIT Case No.	Title	Lead Inventor	Department	Description	Owned	Case Mgr	Patent Number	RG number	Licenses	Comments
Aga-1099-04		Sound Propagation Through Potential Flows	Agarwal, Anurag	Engineering	Ttransformation of coordinates is used to solve this problem		MWS		38329	Closed	
Arc-1237-04		Anti-tubercular drugs & NCE	Archer, John	Genetics	In vivo assays for efficacy and potency of antitubercular drugs and NCE		MWS		33469	Closed	
Arc-1589-06		CMI tuberculosis treatment	Archer, John	Genetics			MWS			Closed	
Bon-767-03		Collagen/Glycosaminoglycan/ Calcium phosphate Biocomposite for Tissue Engineering	Bonfield, William	Materials Science		CE	MLW	GB0325161.8			See Lyn-1203-03
Cly-150-01		Development of an ultralight stainless steel sheet material	Clyne, T William	Materials Science	Steel sandwich - two metal plates are separated by and brazed to a fibrous core	CE	JMG	US 10/000117	33224	Licence to Fibretech royalty + equity originally to go to CMI	Licence being novated to CE Equity for CMI to go direct to MIT and CE
Cly-438-03		Treating short magnetic fibres	Clyne, T William	Materials Science	A continuous process for uniformly treating the surfaces of short magnetic fibres by exposure to a fluid		JMG	GB0303339.6	34733	Closed	
Hol-820-03		Amination Reaction	Holmes, Andrew	Chemistry	A method for preparing arylamines by palladium coupling of N-trimethylsilyl amines with functionalised aromatic compounds.		MWS	GB0406125.5	34261	Closed	
Luo-897-03		Planar microspring electo-thermal actuator	Luo, Ji Kui	Engineering	New type of planar microspring thermal actuator.		MLW		33623	Closed	
OiD-1061-03		Electric field measurement device	Oi, Daniel	Applied Maths & Theoretical Physics	A small, solid state device sensitive to electric potential differences. (200mK)	CE Fujitsu	MLW	GB0418332.3	33199	Joint patent with Fujitsu – JIA letter signed	No likelihood of revenue from Fujitsu
San-1753-06		Multistable plate structure for flexible screens	Santer, M	Engineering		[CE]	MLW	GB716585.5	RG33477		
Sco-303-02		Voltage-tunable photonic device and method for producing same.	Scott, James	Earth Sciences	Voltage-tunable photonic switch for switching optical laser beams. For telecoms and fibre optics.	CE Samco	MWS	GB0302655.6/ GB0516172.4	31980	Joint patents with Samco, JIA in place	No likelihood of revenue from Samco

CE Case No	MIT Case No.	Title	Lead Inventor	Department	Description	Owned	Case Mgr	Patent Number	RG number	Licenses	Comments
Sco-458-02		Ferroelectric nanotubes	Scott, James	Earth Sciences	Relates to methods for the production of arrays of tubes and rods with voltage-dependent index of refraction, for photonic devices.	CE Samco	MWS	GB0708513.7 GB0708524.4	35581	Joint patents with Samco, JIA in place.	No likelihood of revenue from Samco
Smi-1470-05		Targeted AAVS1 Locus in Human ES Cells	Smith, Joseph	Pathology			MWS		RG34878 [CMI 075/P-IR]	Closed	
Woo-1324-05		E-stack	Woods, Andrew	BP Institute	Low energy heating stack that pre-heats air in displacement mode natural ventilation.	CE	MLW	GB 0510007.8		Licence to e-stack Equity only (no royalty).	Licence being novated to CE. Equity in name of CMI Ltd to be gift-aided

A.3 Joint CU – MIT disclosures

CE Case No	MIT Case No.	Title	PIs	Description	Owned	TLO	Patents Filed	Licenses	Comments
Lyn-1203-03	11374	Porous, Layered Scaffolds of Collagen, Glycosaminoglycan and Calcium Phosphate	William Bonfield, Lorna J. Gibson, Brendan A. Harley, Andrew K. Lynn and Ioannis V. Yannas	Porous, layered scaffolds of collagen, glycosaminoglycan, and Calcium Phosphate	Joint	SV	United Kingdom Serial No. 0504673.5	OrthoMimetics, Ltd.	Grant: 054/P-IR (FT) INTERDISCI Licence being novated to CE Equity in name of CMI to be gift-aided
Dan-1432-05	11548	Sustainable Chemical Processes in Environmentally-Friendly Media. Synthesis of Complex Organic Compounds in Carbon Dioxide and Carbon Dioxide-Water Mixtures	Rocco P. Ciccolini, Rick L. Danheiser, Joshua Dunetz, Andrew B. Holmes, Catherine Smith, Jefferson W. Tester and Melanie W. Tsang	Sustainable Chemical Processes in Environmentally-Friendly Media. Synthesis of Complex Organic Compunds in Carbon Dioxide and Carbon Dioxide-Water Mixtures	Joint	CB	None	None	Grant: 071/P-IR/FT (SUSTAINABLE)
Lyn-1385-04	11730	Methods for the Production of Porous Scaffolds Comprising Multiple Layers with Distinct Characteristics	William Bonfield, Lorna J. Gibson, Brendan A. Harley, Andrew K. Lynn, Zachary D. Wissner-Gross and Ioannis V. Yannas	Methods for the production of porous scaffolds comprising multiple layers with distinct characteristics	Joint	SV	GB 0616026.1	Licensed to Orthomimetics	Related to Ortho deal Lyn-1203-03 054/P-IR (FT) INTERDISCI Licence being novated to CE Equity in name of CMI to be gift-aided
Lod-1461-05	11758W	In Vitro Erythroid Micronucleus Assay for Genotoxicity	Linda G. Griffith, Harvey F. Lodish, Leona D. Samson, Dharini Shah, Joseph F. Shuga and Jing Zhang	Eliciting production of bioactive molecules via co-cultivation of microbes	Joint	SV	US – pending PCT - pending	None	Grant: 075/P-IR FT(MICROFABRICA

Appendix B Paper-based review of CMI Education for Innovation

B.1 Introduction

This section explores the rationale and objectives for the education for innovation strand before moving on to explore the achievements of a selection of high-profile themes and projects, which were highlighted by the CMI management team as being particularly noteworthy.

B.2 Rationale and objectives

The CMI rationale

The CMI rationale is expounded in the original proposal and CMI Final Report, both of which talk about the need to enhance higher education in order to ensure that science and engineering students are better equipped / motivated to work between industry and the research base on the one hand and, on the other, to be committed innovators and even entrepreneurs in their own right.

While neither the CMI proposal nor the CMI final report include evidence to explain the nature and extent of the stated problem, nor indeed the scale of the improvements sought, the project rationale sits comfortably alongside many contemporary analyses, including:

- In 1997, the Dearing report emphasised the need for enhancements in the quality and consistency of higher education
- In 2002, Professor Sir Gareth Roberts (SET for Success) produced a long list of recommendations for government action to tackle weaknesses in the supply of STEM skills, which was believed to be compromising UK business competitiveness
- In 2003, the Lambert Review suggested that Universities become more engaged with employers in order to address a perceived mismatch between the needs of industry and the provision offered by HEIs. Subsequently, the Foster Review of Further Education in England (November 2005) focused heavily on meeting the needs of employers
- In 2007, the final report of Lord Leitch, concluded there was a clear need to raise employees' awareness and aspirations as regards the value of skills, he also emphasised the need to increase employer investment in Level 3 and Level 4 qualifications in the workplace
- In 2007, the CIHE report on 'workforce development and employer engagement' underlined employers' critical focus on the skills and knowledge that are of high quality and high relevance

Six years after the Roberts Review (2002) the supply of graduates and postgraduates with STEM skills has increased markedly, no doubt helped by various new government measures (e.g. golden hellos for STEM-trained teachers, bigger stipends and increasing R&D budgets), with STEM graduates increasing at almost double the rate for all graduates. The Institute of Physics' analysis of first-destination statistics published by the Higher Education Statistics Agency also reveals some important trends from the past decade (1995/6 – 2005/6), which is growing demand for STEM disciplines amongst employers in general and employment in the expanding public sector in particular.[13]

[13] For undergraduates, the employment / further education split has been inverted across the period, moving from 40:60 in favour of further education in the mid-1990s to 40:60 in favour of employment in the mid-2000s. The relationship for post-graduates was unchanged. Looking at employment specifically, the data show expanding demand from the public sector, which accounted for around 20% of undergraduates in the mid-1990s, rising to around 30% in the mid-2000s. For post-graduates, the public sector has increased its share of recruitment (by public administrations, education and health care) from around 50% in the mid-1990s to around 67% in the mid-2000s.

CMI did not set itself the ambition of changing the supply of graduates to industry in the UK, but rather focused on the argument that a competitive UK business community needed graduates with somewhat different and more relevant skills and aspirations, as compared with the typical qualities that most UK graduates emerged with.

The CMI proposal and reports do not explain why a collaboration between CU and MIT might be well placed to provide a solution to this perceived under-performance in higher education in the UK. Given both institutions desire to strengthen the relevance of CU or MIT graduates to prospective employers, it seems reasonable that they would want to work together to increase the skills base of their students.

<u>*Objectives*</u>
CMI's overarching educational goals are shown below, and make clear the focus on broadening student experiences and the preparation of new course material:

- *Bring about cultural change through student and faculty exchanges between Cambridge and MIT in areas of mutual interest*
- *Adapt to the UK environment Professional Practice Programmes developed at MIT in such areas as the management of technology, manufacturing, logistics, entrepreneurship and new product development*

The objectives were not over arching, with any specific targets or timetable for the achievement of these improvements, and nor did they make an explicit connection between CMI and UK higher education more generally.

Moreover, the logic behind the choice of the education objectives is not explained in any of the CMI documents, however interviews with the CMI management team suggest that there was always a strong connection in people's minds between the project and UK HE more generally:

- The focus on culture change related to a general perception that UK courses provide graduates with fewer business skills – from business acumen, to team working, to communication to analysis – than do their US counterparts, and these 'soft skills' are important to employability and competitiveness
- The focus on the adoption and adaptation of new courses was driven by a perception that Cambridge and a majority of other UK universities had an insufficient portfolio of courses and modules of direct relevance to the future employees and leaders of high-technology, high-growth businesses

<u>*CMI programme arrangements*</u>
Leading academics within CU and MIT took the lead in defining the objectives and the project's implementation strategy.

The implementation strategy revolved around faculty coming forward with proposals for projects, and did not include any significant top-down targeting of issues. Projects were not required to engage with external stakeholders, whether that be employers, other educationalists or accrediting bodies, and nor were the projects expected to prepare for wider dissemination throughout UK HE or the subsequent evolution and refinement of any educational innovation, with a view to ensuring its sustainability.

This is not to suggest that CMI did not engage with employers or other educationalists, but rather that this was not a formal requirement at the project level. Clearly it has done so at numerous levels and at numerous points in time, CMI did attract sponsorship and joint funding by various private sector interests, and the CMI board included several eminent industrialists associated with major technology companies (e.g. Ford, Rolls-Royce) and scientific entrepreneurship. The CMI Board did not include members from other leading UK or US universities, nor any UK representative bodies (quality assurance agency for higher education, CIHE).

Education projects were launched as pilots with good project-level review procedures and controls. It is not clear that work was selected on the grounds that it was thought to be of particular importance to the improvement of UK higher education more generally.

The portfolio of projects

The CMI project database shows that 124 education projects were launched, with a combined expenditure of around £15 million between 2001 and 2006, or 23% of the total CMI spend. These figures are judgements based on the allocation of projects to the education strand, an exercise that is open to debate as a significant minority of projects have a range of objectives and could be assigned to any one of two or even three of the main investment strands.

Exhibit 13 maps the E4I portfolio onto its two overarching goals, in terms of the distribution of project numbers and the distribution of project expenditure. The third row includes the number of projects that we were not able to reconcile with either of the education objectives, along with their monetary value.

Exhibit 13 Count of CMI projects by education objective and expenditure, 2001-2006

CMI education objective	Number	Expenditure	Share of spend
Cultural change through exchanges	1	£2M	13%
Adoption and adaptation of MIT course modules	29	£10M	67%
Non-aligned	94	£3M	20%
Total	124	£15M	

This simple analysis shows that the majority of expenditure was directed to the transfer of insight and techniques in use in MIT, from MIT to Cambridge. This flow of content from MIT to Cambridge appears to be somewhat at odds with the MIT motivation for getting involved with the CMI project, however it seems clear that MIT had a large number of course modules and tools that were missing from the CU repertoire.

The analysis also shows that the great majority of projects, in numerical rather than monetary terms, did not align with either of the two primary CMI objectives. When looked at a little more closely, most of these non-aligned projects are the kinds of opportunity-led development projects most universities will engage in from time to time, using their own resources. The difference here is the scale of the endeavour, with tens of projects underway at any point in time throughout the life of CMI. The projects fall into one of four broad groups of educational development work:

- New curriculum development techniques
- New degrees and courses
- New teaching methods and tools
- New placements / work experiences

B.3 Cambridge MIT undergraduate student exchange

Documents included within the review

CMI commissioned a solid evaluation of the first year of the exchange programme (2001/02), which was carried out by a US-UK team in 2002. The study design was a single snapshot rather than pre-test and post-test and the study team only managed to get a comparison group of students from MIT.

The 2002 review stated that there were good early signs that the exchange project would be able to achieve several of its principal objectives, as regards developing core skills, broadening cultural awareness and helping people to better grasp the career opportunities offered by science and engineering. This interim review was intended to provide CMI with advice on how to develop the exchange, and it flagged a series of operational issues, which the CU response (March 2003) states were dealt with directly.

The 2002 review includes 100+ pages of good source material on experiences and anticipated benefits, from that first year. However, we have no evaluation on file for any subsequent years, and do not know whether further reviews were carried out. The exchange project was also touched on in two chapters of a recently published book, which reflected on the intellectual and personal experiences of the participating undergraduates in that first year.[14]

This means the 2008 evaluation has had to rely on the CMI Final Report and selected interviews to obtain a view on the project overall and its outcomes, which included ambitions such as improving students' abilities to thrive in diverse cultural workplaces and to better manage their own careers.

Description of the theme or project

CMI set up the Cambridge-MIT Exchange (CME) as its first major education project, and the 2002 evaluation states that this international undergraduate exchange programme was the first of its kind for both universities. In essence, CME enabled students at Cambridge and MIT – reading the same subjects and at the same stage in their degree courses – to swap places for one year.

According to the CMI Final Report, more than 450 undergraduate students participated in the CME between 2001/02 and 2005/06, with students recruited from seven science and technology departments at both MIT and Cambridge, around 50 students a year from each university, at a cost of around £4,000 for each student.

Academics from both universities agreed which courses the students should take, so that students received full academic credit for work done in the year away and the exchange did not delay their educational progress.

Project objectives

The interim evaluation describes the project objectives of the Cambridge-MIT Exchange (CME) at some length, which were to:

- Broaden experience for students and faculty through exposure to different cultures, learning environments and pedagogical styles
- Transfer knowledge and skills between institutions

For MIT students, the exchange was expected to enable students to experience Europe and a different pedagogical style. For Cambridge students, a year at MIT was expected to expose them to the highly entrepreneurial culture to be found on the MIT campus. More specifically, the principal outcomes were expected to be:

[14] University Collaboration for Innovation: Lessons from the Cambridge-MIT Institute (2007), Edited by David Good and Suzanne Greenwald (CMI), Roy Cox, Institute of Education and Megan Goldman, Department of Social and Political Science, University of Cambridge, Sense Publishers, Rotterdam.

- More commercial awareness amongst students
- Enhanced core skills, from team work to communication to organisation
- Specific skills in technical and managerial areas
- Improved sensitivity to differences in the diversity of cultures in the workplace
- Better able to manage their own careers

Lessons learned

The interim evaluation points to a long-list of procedural lessons arising from interviews with students and faculty on both sides, which we understand were implemented by coordinators in the subsequent year.

The recent book chapter (Good et al, 2007) on intellectual development provides further support for the positive experiences of the majority during this first year, with most reporting noticeable differences in approach and pedagogical style across the two institutions, which the authors see as meaningful.[15]

The CMI final report does not point to any particular lessons learned, however it states that the exchange programme has become part of the standard provision / offer to students at both universities, and has encouraged Cambridge to launch other similar programmes, which is testament to its educational value.

Conclusion

CME was well aligned with the educational goals of CMI, and in particular the requirement to broaden the experiences of the participating students. It was also run at a reasonable scale, providing an opportunity for 40-50 undergraduates at each institution each year, which is around 15% of the year group in the engineering department in CU.[16]

The interim evaluation, CMI Final Report and 2008 interviews with CMI make clear that it was a major undertaking to create a successful exchange programme between two very different educational systems. In that sense, all parties are to be congratulated on having made it work.

We are told that the scheme has encouraged the creation of other similar exchange programmes at Cambridge and MIT, however we have no further information on those new schemes and no information on wider take up in UK HE system.

There were some concerns raised in interview about the longer-term sustainability of the exchange scheme, which continues to be quite time consuming to maintain and compatibility issues across the institutions remain a concern for some faculty members.

We understand no data have been gathered on the impact of the exchange project on participants' subsequent career choices, experiences or innovativeness. With six cohorts (years) and approaching 450 graduates to its credit, it might be worthwhile revisiting the scheme in an attempt to establish just how the exchange has benefited people in their working lives.

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[15] Chapter 3 of University Collaboration for Innovation, 'Learning through a student exchange programme: domains of intellectual development' Roy Cox, Institute of Education, University of London

[16] The Department of Engineering is the largest department in the University and the largest integrated engineering department in the UK with 132 faculty, 195 contract research staff and research fellows, nearly 600 research students, and over 1000 undergraduates (annual intake of 300+). Growth throughout its history has been consistently strong. For instance, between 2000 and 2007, research expenditure doubled, the number of contract research staff nearly doubled, and the number of research students increased by over 40%. Rapid growth has been coupled with greater integration through the development of cross-linking themes and stronger connections with other disciplines, as demonstrated by a six-fold rise in the Department's share of expenditure on grants jointly held with other departments.

B.4 Education for entrepreneurship

Documents included within the review

The study team were provided with a range of documents, a book chapter, a presentation and a series of academic papers. The latter presented and developed an argument about a performance measurement methodology for higher education courses, in this case a one-week entrepreneurship residential course for under-graduates, which was developed at MIT originally and was subsequently refined and evolved by the CMI team.

The CMI team designed in the review methodology from the outset, and the resulting papers, refereed articles for the most part, offer an excellent assessment of the learning experience and make good comparisons with this module and several others in order to arrive at pretty robust conclusions about students' gains in knowledge and self-confidence, an approach that has been evolved through successive courses and has been diffused to other educational institutions delivering entrepreneurship training.

The assessments presented in the papers cover the educational and attitudinal gain, and do not deal with outcomes and the achievement of CMI objectives. They do not describe the connections with the CMI research strand, or indeed the Cambridge or MIT research portfolios more generally, and nor do the papers describe or analyse the experiences of students in the workplace several years down the line.

Description

CMI implemented several projects designed to increase the confidence of students to pursue innovation or entrepreneurship in their subsequent careers. The centrepiece has been the development and evolution of the 'Enterprisers' module, a week-long series of residential workshops for undergraduates involving a range of different entrepreneurial inputs, from lectures / seminars on startups, to presentations by entrepreneurs to debates about technology developments. Enterprisers was modelled on an MIT initiative called LeaderShape, and was first run in the UK at the university of Durham. Since its adoption by CMI in 2003, Enterprisers has been run nine times with over 550 participants from over 40 UK universities.

Social science research points to the need to convey not only knowledge about enterprise, but also to employ teaching and learning approaches that build self-confidence in the ability to become an entrepreneur. It is generally understood that without this self-confidence, individuals are less likely to start companies, and less likely to be successful once the business activity has started.

The programme also provided the CMI team with an opportunity to study the pedagogy of entrepreneurship education and for the development of measures of educational gains.

The CMI team devised a three-step review procedure (pre-test, post-event test and six month follow-up survey), which helped to separate short-term transitory change from more enduring effects attributable to the course.

This internal review work has begun an expanding programme of study across the UK, which allows the comparative study of different approaches to entrepreneurship education using the same metrics.

Rationale and objectives

In the last decade, the UK government has been pressing schools and universities to do more to develop an entrepreneurial outlook amongst young people, which is expected to result in higher birth rates of innovative businesses and aims to boost productivity and competitiveness. CMI entrepreneurial projects sit squarely within this more general push to develop enterprise education.

CMI was invited to explore what it might achieve with this enterprise agenda and the encouragement of entrepreneurs ready to commercialise developments at the frontiers of research.

Lessons learned
The Enterprisers course set out to strengthen the likelihood that its participants would pursue entrepreneurship, and from one perspective it was successful. The confidence that the participants had the knowledge and capability to start a company soared as a direct result of the programme. The follow-up survey was six months or more later, and the levels of self-confidence generated by Enterprisers still persisted although the programme did not do much to change the active intention of the participants to start a company. However, it seems that Enterprisers increased the desire in certain people to become an entrepreneur, an aspiration that one might imagine can be more readily triggered by need or opportunity in the future.

In research and education, to claim that any particular intervention *caused* a specific and desired effect is often open to challenge, for a variety of measurement issues, however, here there is clear evidence of a positive effect on student confidence. Unfortunately, at this time, CMI has no systematic information about the impact of these summer residentials on students' subsequent entrepreneurial behaviour or career decisions.

The CMI Final Report does note that several Enterprisers students have launched their own companies, where possibly this might not have happened without the support and encouragement of CMI.

In addition to progressing the state of the art in educational evaluation, the Enterprisers course has lead to the creation of two student entrepreneurship societies, which have grown rapidly to the point that the CMI management team believe the Cambridge societies are as big and dynamic as any in the country.

Conclusions
The Education for High Growth Innovation (EHGI) work is in direct fulfilment of the CMI objective of identifying effective educational practice and the design of new model programmes to test approaches to strengthening entrepreneurship in Britain.

The papers on file make clear that the Enterprisers courses have been run many times for hundreds of students and that a great majority of those students gained in terms of both entrepreneurial skills and aspiration.

Equally important, the creation of a rigorous assessment methodology has been widely adopted by other enterprise educators and one might expect this gathering body of empirical data and reflection to facilitate the speedier evolution in our understanding as regards educating and equipping young people to become successful entrepreneurs in the future.

B.5 Undergraduate research opportunity programme

Documents on file
The study team was provided with copies of a series of papers presenting the results from surveys and interviews with 44 students (26 Cambridge, 18 MIT) and six faculty (all Cambridge) carried out by the CMI education team in 2002. This interim evaluation considered the experiences of the first year and found that the great majority of students and faculty at both institutions were very satisfied and were happy to recommend UROP to friends (faculty and students) and would consider supporting another UROP project in future (Cambridge faculty). The interim evaluation also revealed some minor concerns around information and preparation ahead of starting the research project, the short time in which to conduct their research, the limited interaction with the project supervisor and other members of the research team and the arrangements for accommodation. These operational niggles were reportedly designed out where possible in subsequent iterations of the scheme.

There is no subsequent evaluation on file, although the scheme has been running continuously in the intervening period, and so there is no review of the impact of the scheme on student choices as regards post-graduate study and careers.

Description
According to the CMI Final Report, more than 80 per cent of undergraduates at MIT spend time in faculty research laboratories working as research assistants on real-world academic studies and reporting to faculty research teams, paid for by the institute's Undergraduate Research Opportunity Program (UROP). While some students do this work for course credit or as volunteers, over 70 per cent do so as paid employment, either alongside their academic work or during vacations.[17]

In the light of MIT's positive experiences with this form of work experience, CMI decided to establish a UROP at Cambridge. Initially on the basis of summer exchanges in 2001 and 2002, UROP saw Cambridge students going to MIT, and vice-versa, to work in research groups as paid assistants. A local version followed, with Cambridge students working through the summer with research groups in a number of departments at Cambridge.

In this model, second-year students from any Cambridge department are provided with the opportunity to work full time on real research projects in one of several Cambridge departments for 10 weeks across the summer break. Students are paid a £2,000 fee (£200 per week for a 37.5 hour week). There were around 10 UROP projects supported in 2007, and the scheme is being run in 2008, although there are concerns over its funding from 2009 as the majority have had to be supported through funds other than mainstream research grants or industrial contracts.

Rationale and objectives
Undergraduates in Cambridge have traditionally done research only as part of a final year project, and their contact with faculty researchers and business research projects has been rather limited.

Getting involved in business research is believed to be a useful form of work experience, which is a source of empowerment and motivation in its own right, and good for academic achievement, but can also increase the numbers of under-graduates electing to do post-graduate studies and possibly choosing research careers. It was hoped that such experiences would also provide students with a strong sense of where and how to access / use leading edge research, which they might exploit when they take up professional posts in industry or wherever, thereby increasing the numbers of people acting as knowledge exchange agents between science and industry.

Several UK universities and research centres operate small schemes or provide informal support to permit undergraduate students to gain first-hand experience of research, as a possible taster and recruitment opportunity for post-graduate study, perhaps most notably the UROP scheme at Imperial College which has been running for many years.

During the lifetime of CMI, the value of this kind of work experience has been recognised nationally, as witnessed by, for example, funding from the BBSRC and the EPSRC for trial programmes.

The EPSRC Vacation Bursary Programme was launched in 2006, modelled loosely on the UROP schemes at Cambridge and Imperial (and at the National Science Foundation). In 2007, the EPSRC provided £20K to 15 leading research universities (£300K in total) to support up to 10 undergraduates working as research assistants for 10 weeks.

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[17] UROP has been running at MIT for over 30 years, and many people see the programme as one of the university's most successful educational innovations, the value of which is reflected in the funding that MIT receives, alongside standard research grants, to support UROP.

Lessons learned
There is no information on file to help one to understand how the CMI scheme has evolved in light of experience, nor indeed what impact UROP might have had on undergraduate research in the UK more generally. However, one might imagine that it works in much the same way as other undergraduate research schemes, providing an appetiser to curious students, encouraging some and dissuading others. The impact of such tasters on post-graduate applications and completion rates might be expected to be positive, however there is no data on this aspect.

The 2006 EPSRC pilot was evaluated in 2007 and the survey found that the majority of students and supervisors had had a positive experience and would be happy to recommend the scheme to others or to use the scheme again in subsequent years. The evaluation did not look at outcomes, however it did reveal that while almost 9 in 10 people were considering a research degree / career pre-vacation job, that statistic had fallen to around 6 in 10 people post work-experience, arguably showing that the work experience was discouraging rather than encouraging people to apply for research degrees.

The EPSRC evaluation also noted that the stipend was far too small to compete against other summer vacation opportunities, a view which almost certainly holds for the CMI project and its use of the minimum wage as the basis for its weekly payment.

Conclusions
Undergraduate research is a well-established arrangement in the US, but less so in the UK although there are various exceptions, and the CMI scheme appears to have been well regarded by its users. It is similar in format to the schemes in operation across the US and in other UK universities, most notably at Imperial College.

The CMI scheme might have contributed to the positive mood regarding undergraduate research, which seems to be an area of growing interest, with both EPSRC and BBSRC running pilot schemes, targeting strategic disciplines and struggling fields. However the CMI initiative seems to be rather small to be of any wider significance to national educational or career choices.

B.6 Student engagement in learning

Documents included within the review
We have several project reports, a 10-page book chapter, an evaluation of the MIT iCampus initiative and the CMI Final Report. The majority of this material is somewhat descriptive and does not tackle the question of outcomes for CMI, Cambridge or the UK. The evaluation of the MIT iCampus initiative is an exception, however this piece of work is concerned firstly with developments within MIT and the US and only touches briefly on the contributions, experiences and results within CU.

Description
There have been two main projects within this CMI work to develop novel learning materials and tools, involving (i) the sharing and adaptation of courses with promising, innovative modes of delivery between the two institutions (CATAM, C++) and (ii) the adoption by Cambridge of a particular MIT-developed web-based teaching aid, iLabs, which had been developed over the previous five years with the assistance of the MIT-Microsoft iCampus educational project. Within this activity, CMI designed experimental courses that explored the teaching systems of the two universities. These experiments went alongside the development of web-based platforms to share teaching resources and analyse their effectiveness.

CATAM and Math Lab
An MIT professor took advantage of the existence of CMI to secure a grant to review and subsequently adopt and adapt the established Cambridge CATAM course module, which was launched as Math Lab in MIT, and is seen as being a very useful and worthwhile addition to the MIT curriculum. A reverse process began when CMI brought an MIT (online) computing course to

Cambridge, and adapted it to teach the programming language C++. The revised course has been returned to MIT.

iLabs

CMI also supported the development and transfer of the MIT iLabs project, when a Cambridge chemical engineering undergraduate on his MIT exchange suggested that Cambridge might be interested in the facility. The MIT and Cambridge professors submitted a joint proposal to CMI, and the resulting grants funded several years of use of the MIT equipment by students at Cambridge, and its further refinement. This equipment continues to be in use as at 2008, however there are concerns over its medium term viability in the absence of substantial additional funds to keep the software / architecture up to date.

An iLab is a piece of laboratory equipment that can be controlled over the Web. Students need not be in the same room with the equipment in order to design the experiment, gather or analyse the data. In a traditional science or engineering laboratory course, all the students usually come to the same room for a scheduled period where they find a large number of identical laboratory setups: one for each student or each small group of students and the experiments must be completed in that single period. The equipment then is idle. In contrast, with experiments that can be configured as iLabs, students can design and carry out experiments at any time, and from any place. One piece of equipment can be used by each member of the class, one after another. Where iLabs are feasible (and especially when they can run 24 hours a day, 7 days a week), they have several advantages over more conventional experiments:

- Students have more opportunities to do a series of experiments in order to carry out an unfolding inquiry, using the results of each experiment to design the next trial
- One piece of equipment can serve a much larger number of students
- Undergraduates can be assigned experiments requiring equipment that would have been out of the price range of labs that had to buy 20 of each piece of equipment in order to incorporate an experiment
- Institutions can share laboratory equipment, so that each faculty member could have access to a diverse set of laboratory opportunities

DSpace

CMI also provided project funding to help to progress development of an open source software package for the creation and management of digital archives of scholarly materials that are open to any and all registered users through the Internet. DSpace was developed originally in 2002 by MIT Libraries, with support from HP.

CMI became involved from around 2004 and hosted the 2005 user group conference, and has been an active promoter in the period since. Successive versions of DSpace (v1.5 in 2008) have produced steady but impressive growth in its installed base, with more than 320 establishments in 50 plus countries around the world having registered to use the software, including more than 10 UK university libraries from Brunel to Wolverhampton, with the software essentially becoming a standard.

Rationale and objectives

Cambridge and MIT devote substantial energy and funds to experiments in education and the early experience with the Cambridge-MIT Exchange programme gave both parties insight into some of the novel educational practices at partner institutions. The students' experiences and their feedback prompted several initiatives in Student Engagement in Learning.

Lessons learned
Chapter 7 of University Collaboration for Innovation (Good et al 2007) presents a fascinating historical account of the evolution in the use of computers within the context of mathematics teaching in Cambridge, from the 1960s. The chapter makes clear how computer-based project work facilitates a more open-ended approach to mathematics education, which the hard working and talented maths students at both institutions reportedly find very rewarding and satisfying in comparison with the more directed problem sets they are more familiar with.

The connection of the Math Lab course to the UK's innovation agenda and the wider CMI educational objectives is not immediately clear, however it is hardly the only project against which one might level that challenge. More significantly, it is one of the few instances where CMI course material has moved from CU to MIT. Most undergraduate course material has moved in the opposite direction, perhaps reflecting the rather more structured strategies in use in MIT. It is important to any equitable partnership that insight and advice should move in both directions, from time to time at least.

The Teaching Learning and Technology group (MIT) evaluation of the MIT iCampus project, and the CMI iLabs project within this, is rather challenging, in that it notes the significant potential learning advantages for students associated with faculty-developed, content-specific software, but goes on to say that the general diffusion of such tools is difficult, even unlikely given the myriad of opportunities and threats confronted by faculties around the world, and that few such projects survive more than one or two years beyond the ending of their project-specific development funding. It states that even though it is close to eight years old, the iLabs initiative continues to look somewhat fragile and that its most promising opportunities might ultimately be in the mass education systems growing up in China and India.

Conclusions
The engagement in learning projects appear to have been pretty successful within their own terms of reference, with good satisfaction levels registered amongst students, faculty and partners on both the CATAM and iLabs projects. There is no data on the outcomes arising from these novel course delivery mechanisms, which is almost certain to reduce their wider appeal.

DSpace is continuing to be developed, and is diffusing widely around the globe. While this began as an MIT project and has progressed through the manifold inputs from other developers and users, within the open source user group, we note the early support and contributions of the CMI project to the software development and its wider promotion.

There is no strong link between these two projects and CMI Objectives, with little or no direct connection to the objective of improving education for innovation or the programme objectives of strengthened UK innovation and competitiveness.

B.7 Graduate education

Documents included within the review
CMI commissioned a comprehensive set of evaluation activities of the MPhil programmes. The study team was provided with a large number of documents prepared by the evaluator, which includes the reports of annual student surveys plus a range of discussion documents and reports on the alumni survey. The set does not seem to be complete and many documents are not in their final version, however they do provide plenty of useful information.

Each cohort of MPhil students was surveyed at the start and end of their MPhil course and many were also interviewed. A number of participant observation activities were conducted.

The surveys focused on the students' experiences of the MPhil programmes, their content, learning methods, and delivery, and on their individual educational gains. In the early years, the surveys provided CMI with important feedback on course design and enabled improvements to be made. The surveys also sought to assess changes in the students' professional confidence using a methodology used elsewhere in CMI activities (the Lucas and Cooper measure). This aimed to provide some measure of programme outcomes.

A further survey carried, out in late 2005, and directed to a large proportion of the MPhil alumni, also added to the information on impact by identifying where, and in what roles, the alumni were employed. However the extent to which the MPhil programmes contributed to the wider CMI objectives is not directly addressed, although the evaluator did approach the issue in a number of discussion and summary papers.

Description of theme / project

CMI wished to develop 'premium' taught MPhil programmes in professional practice that combined technology with business and policy subjects. The courses were to be aimed at students with backgrounds in science and engineering who would undertake advanced studies in new interdisciplinary fields, while developing their business skills and attitudes to enterprise. The MPhils were to be designed jointly with MIT staff to harness the latter's experience in delivering such interdisciplinary programmes.

During the period from September 2002 to August 2006, CU staff, with help from faculty and staff at MIT in Cambridge MA, developed and ran six MPhil programmes. CMI provided funding to support the development of the programmes across faculties and departments and to support the development of a common platform and taught modules in business processes and skills that would be used by all MPhil programmes. It hoped to create a 'family' of MPhil programmes in professional practice with a sense of cohesion and commonality amongst them. CMI also supported the promotion of the programmes to potential students and provided the funds required to secure MIT staff input to course design and delivery.

The programmes were selected based on: technology areas that MIT had successfully implanted into the new economy sectors around Massachusetts such as biotechnology, nanotechnology, advanced chemical engineering and genomic informatics; technology areas which were expected to play a major role in the future 'new economy' (such as information and communication technologies); and the emerging biotechnology and nanotechnology sectors where CU research had already begun to play a major economic role. There was also significant interest at both MIT and CU for a programme in engineering for sustainable development.

An initial three MPhil programmes were subsidised by CMI for the three years from 2002 to 2005 with further support provided in 2005-06: Bioscience Enterprise; Engineering for Sustainable Development; and Technology Policy. These were followed by three later MPhil programmes, supported by CMI during 2004 to 2006: Advanced Chemical Engineering; Computational Biology; and Micro- and Nanotechnology Enterprise.

The initial three programmes worked closely with MIT to develop the programmes although each had slightly different solutions for levels of MIT involvement in the delivery of the final programme. All made use of MIT teaching expertise brought to the UK and some also arranged for students to take courses and/or visit MIT. Two of the later MPhil programmes (Computational Biology and Micro- and Nanotechnology Enterprise) had no involvement from MIT in either the development or delivery phase.

All programmes included a mandatory double-module on the Management of Technology and Innovation. This aimed to provide an introduction to basic business-process analysis and skills. It was developed and delivered by staff at the Judge Business School, supported with CMI funds, based on elements of Judge's MBA and MPhil programmes, but with a distinct technology focus. It included both traditional lecture-based activities plus a team consultancy project for business clients.

By the end of the 2004-05 academic year 242 students had taken the MPhils with 239 graduating (no later figures are available in the documentation) and the final report records 63 companies and public sector bodies being involved in hosting CMI students.

Project rationale and objectives

Innovation requires business skills and an entrepreneurial attitude as well as technological knowledge. The MPhil programmes in professional practice aimed to produce a new generation of high-tech entrepreneurs and innovators who would contribute to UK productivity and competitiveness by imparting new skills and the spirit of enterprise. The MPhil students were to become the innovators and technology entrepreneurs of the future.

Part of the thinking behind the new MPhil courses was that MIT experts could help CU academics to produce new business leaders and innovators in the 'new economy' sectors of the UK by showing them how postgraduate training in advanced technology could be combined with the right kind of enterprise-boosting business education.

The project also enabled CU to experiment with interdisciplinary programmes that bridged faculty and departmental boundaries and made use of different teaching and learning methods. In utilising a more modular delivery format, CU could also experiment with creating a family of courses that shared a common platform and sense of purpose. This might lead to longer-term changes in graduate education that could be shared across CU and with other HEIs.

Lessons learned

The evaluation points to a long list of lessons learned which it suggests could and should be shared within CU and more widely. The lessons learned include issues related to teaching methods for interdisciplinary courses (e.g. mixed methods and progressive coursework) and student needs (e.g. vocational programmes must provide strong career support), but also more general leadership and cultural issues; innovative master's programmes need committed support in terms of sponsors and hosts and a common programme platform must win hearts and minds. It was suggested that, while the links to MIT enriched the programmes in terms of relationships with individual MIT staff, support for a ten-year run of the programmes would have enabled the development of a deeper relationship and a more secure partnership.

The evaluation documents report that (based on the alumni survey) while only about a third of MPhil students were from the UK, around 10% of the non-UK students immigrated into the UK to take a job with a UK-based employer or to pursue a PhD or other postgraduate studies, thereby increasing the numbers of potential innovators/entrepreneurs in the UK at least for the time being. Early career destinations of the students showed that the largest group were employed by large corporations, this was followed by small firms, the public/voluntary sector, and self-employment, which is a stronger showing for the private sector than would be the case for overall postgraduate employment.

Despite the number in large corporations, respondents, particularly from the Bioscience Enterprise and Micro- and Nanotechnology Enterprise MPhils reported that starting up and developing a new enterprise was the most sought-after longer-term goal. Other alumni were described by the evaluation as 'already entering roles that were providing leadership or support to important R&D activities promising industrial innovations in the next decade or so'. The evaluation reports evidence of seven graduates (5 from the MPhil in Bioscience Enterprise and 2 from the MPhil in Computational Biology) with intentions to set up businesses after graduating. 15% of the students had gone on to further postgraduate study and, despite the business focus of the courses, academics still appeared to view the student intake as fertile ground for recruiting PhD students. The evaluation also reported gains to the measure for students' self-confidence ('self-efficacy') though it varied among the programmes taken. However the evaluation does not make comparisons between the findings above with other master's level programmes at CU or elsewhere.

As the evaluation notes, the full impact of the MPhil graduates on UK productivity and competitiveness will not be apparent for some time (a report to the House of Commons Public Accounts Committee in 2004 suggested in three years' time i.e. in 2006-07) and even then, the issue of attribution to the CMI MPhil programmes as opposed to other activities will inevitably arise. The evaluation reported that CMI was committed to a further review of MPhil courses during 2006-07 but we have no evidence of it.

The evaluation found that the initial three MPhil programmes benefited from significant involvement with MIT staff in course design and delivery. Two of the later three programmes had no input from MIT and it is suggested that this was due to lower levels of CMI support. However although all six MPhil programmes are still offered by CU, the MIT contributions are either non-existent or have significantly decreased, and where they exist their future is in considerable doubt. This is predominantly due to the cessation of CMI funding but other factors have also contributed, such as incompatibilities between CU and MIT in admissions processes and standards and in teaching/ learning methods. The evaluation has suggested that MIT as an institution gained little from the MPhil activity and that the MIT contribution was, in the end, viewed by MIT as a service-provision exercise, which is unlikely to continue when funding is no longer available. It is reported that the view from MIT senior staff is pessimistic and that collaboration cannot be continued without CMI or replacement funding.

The evaluation found that the MPhil programmes would not have been developed without CMI support. It provided a nurturing environment and enabled CU to innovate in course design and delivery in a relatively short timescale.

The evaluation found mixed feelings amongst both staff and students towards a key aspect of the family of MPhil programmes (the mandatory module in Management of Technology and Innovation) with its value contested by some and viewed more positively by others.

The evaluation reports that the relationships built during the development of the MPhil programmes were instrumental in successful proposals for Knowledge Integration Centres, of which two were successful.[18]

Conclusions

Adapting the MIT Professional Practice Programmes to the UK environment was a specific objective of the CMI educational strand. New master's level programmes were developed that encompassed both interdisciplinary technologies and business skills, though only four of the six programmes benefited from MIT input.

The nature of the programmes, blending technology with business, was a learning process for CU in terms of inter-faculty/department administration as well as teaching/learning methods and student support.

The evaluation concluded that the programmes had had a positive impact on student ambitions with regard to employment and entrepreneurship, and also recorded a strong flow of graduates to leading corporations and high-tech businesses with a clear focus on technology-enabled business development and growth. It is too soon to tell if the programmes will have an impact on wider CMI objectives on improving UK productivity and competitiveness.

The six MPhil programmes are still offered, and one might expect a continuing gain to the UK as a result of the numbers of postgraduates with these inter-disciplinary skills of especial relevance to the new economy. Sustainability is a concern. MIT appears unlikely to continue its involvement post

[18] Centre for Competitiveness and Innovation, Communications KIC.

CMI. It remains to be seen if the six programmes remain connected to each other as a 'family' of programmes and how much they retain their interdisciplinary nature as they lose the CMI oversight and return to the 'ownership' within an academic department.

B.8 Interdisciplinary curriculum development for undergraduates

Documents included within the review

The study team were provided with a final report on each of the two areas of undergraduate curriculum development, bioengineering and MEMS[19], written by members of the curriculum development teams. The courses underwent academic/teaching evaluation but there was no independent evaluation of their impact with respect to CMI objectives. For bioengineering two interim progress reports and accompanying slide presentations were also provided. The CU web pages for Engineering for Life Sciences (within the CU Engineering web pages) were also highlighted as a source of information. The final project reports provide details of the modules created, the departments involved and the interaction with MIT. For MEMS, the numbers of students taking the courses was also given.

Description of theme / project

CMI wished to develop new undergraduate specialist modules in interdisciplinary technologies. Bioengineering and MEMS were selected; no evidence is provided as to why these two areas in particular were selected, but they were both areas where MIT had already developed and or was delivering modules for undergraduates.

Both areas required collaboration across a number of academic areas. In bioengineering input was required from teaching staff within engineering, genetics, computer science, applied mathematics and biotechnology. In MEMS, input was required from departments covering applied mathematics, theoretical physics, engineering and materials science.

Prior to the CMI funding, CU was offering a single course in MEMS and MIT was offering a minor in Biological Engineering. CMI funding supported the development of two new bioengineering lecture-based modules plus a laboratory course and three new MEMS modules. CMI supported staff time (in MEMS, two new academic staff were appointed) and the purchase of laboratory equipment. Course modules were developed, piloted, evaluated and revised in collaboration with MIT.

The bioengineering modules are now fully absorbed into the course provision of the CU Engineering Department (under its Engineering for the Life Sciences initiative), which offers the modules to engineering students in their fourth year. The end-of-project report notes that the modules may also be offered under the Biological and Biomedical Sciences and Plant Sciences specialisms of the Natural Science Tripos, although they do not appear to be available at the present time (based on the CU undergraduate website). MIT is now able to offer a major in Biological Engineering.

The MEMS modules have been delivered to students at both MIT and CU and are now routinely taken by engineering students at CU in their third and fourth years. The courses are also offered to first year graduate students and to students on the (CMI supported) MPhil in Micro- and Nanotechnology Enterprise.

Project rationale and objectives

The technology underpinning innovation is often interdisciplinary in nature, bringing together aspects of different academic disciplines. However, and quite naturally given the time it takes for curricula to be developed and stabilised, most university teaching, particularly at undergraduate level, is centred around traditional disciplines and established fields. Against this background of very gradual and incremental evolution of curricula, it is likely that students will not be exposed in any meaningful

[19] Micro Electro-Mechanical Systems

sense to areas of emerging technologies and are therefore less likely to acquire mastery of the knowledge and skills that underpin them.

CMI supported the development of new interdisciplinary modules for undergraduates in bioengineering and MEMS. In bioengineering the aim was to develop new curricula for delivery at both CU and MIT, whereas in the MEMS areas the focus was on adapting current MIT graduate courses and developing new courses for delivery with the Engineering Department at CU.

Lessons learned
The interdisciplinary undergraduate modules and their curricula appear to have been successfully developed and are available to students.

Details of specific lessons learned are not provided, however the experience of cross-departmental and cross-institutional working was said to have been of value to CU and that it had helped to encourage and inform others wishing to develop similar interdisciplinary teaching modules.

Conclusions
Strongly aligned with the education for innovation goals. Developing interdisciplinary curricula that cover important emerging areas of technology is likely to become increasingly important to any university seeking to better anticipate and respond to evolving business demands.

In both the case of bioengineering and MEMS the curricula development was closely aligned to existing or developing interdisciplinary research areas at CU, so the teaching modules will enable students to be exposed to recent research developments which might encourage a greater proportion to take up careers in business or applied research in these technological areas, and so contribute to the CMI objectives, but there is as yet no evidence to support this.

The experience gained through these CMI-funded activities has been valuable to the participating students and universities. CU appears to have secured a methodological legacy too, however the benefits to employers and their new recruits, in terms of career opportunities and rates of advance, is unknown. Were these outcomes to have been researched, one might imagine that the course-development methodology and even the individual modules, might have been be disseminated more widely within CU and the UK university community, to ensure that the learning is not lost and to encourage other departments to consider interdisciplinary curriculum development.

Appendix C Paper-based review of CMI support for knowledge dissemination

C.1 Introduction

CMI had not carried out any formal self-assessment of its knowledge exchange activities, which has meant that this aspect of the paper-based review has had to draw on an extensive but rather diffuse and partial record comprising project abstracts, OPAS papers and CMI board reports. As noted at several points elsewhere in this report there was substantially less evaluative material related to the knowledge exchange work of CMI, as compared with the education strand.

C.2 The knowledge exchange rationale

The CMI rationale is expounded in the original proposal and CMI Final Report, both of which talk about the pressing need for UK stakeholders to develop a better understanding of how universities and enterprises interact, and to devise new ways to enhance knowledge exchange between the two parties and the social and economic benefits that are realised as a result.

Overall, the CMI rationale was based on a robust and well-theorised view of the spectrum of roles that universities can play in the innovation process in general and knowledge exchange in particular, for example as producers of new knowledge (increasing the stock of useful knowledge) on the one hand and suppliers of trained specialists on the other.

The Science Policy Research Unit at the University Sussex has been studying the links between research and innovation for more than 40 years, and its researchers have published numerous papers on the economic benefits of research down the years. However, the 2001 report entitled The Economic Benefits of Publicly Funded Basic Research: A Critical Review (Ammon Salter and Ben Martin for the Office of Science and Technology) was contemporaneous with CMI and neatly confirms the range of innovation channels addressed by CMI, both formal (e.g. new instruments) and informal (social interaction).

The CMI rationale is notable in elaborating a need for action on a broader front than was typical at the time through the work of the research councils and the office of science and technology, where the principal instruments were collaborative R&D and industry-oriented higher education, and where those knowledge transfer measures accounted for a small fraction of the total UK science budget.

Total direct CMI investment in knowledge exchange was around £2.2 million across the life of the programme, or around 3% of spend. This appears rather low given the CMI rationale and objectives although we have no ready reference with which to compare this level of expenditure. Moreover, industry engagement and knowledge exchange activities have formed an important element of most projects in the research and education strands and as such one might imagine total spend on knowledge exchange rising to a more creditable 10-15% of total activity.

Pleasingly, the focus on engagement and dissemination developed as the programme moved through its lifecycle and more and more ‘content’ became available and the many and various CMI-supported networks matured.

Interviews and project files suggest a broadening commitment to the importance of second-wave exchange and dissemination, through for example support to student enterprise clubs or the encouragement to researchers and businesses to work together outside CMI on a consultancy basis, to extend and enhance one-another's intrinsic problem-solving capacity.[20]

In practice, the CMI activities have been closer to the norm than might have been expected from these original proposal and supporting documents, with a preponderance of research projects, with their necessarily limited partnerships and external networks, and educational development projects leading to new course materials and courses with a strengthened enterprise / entrepreneurial content, but only occasional direct industrial engagement.

As we have seen elsewhere, there was a noticeable fall-off in activity and commitment from 2006 onwards. Several knowledge exchange projects have endured however, and there is arguably a stronger and more extensive legacy here, in proportionate terms at least, than there is in either the research or education strands.

CMI has made impressive connections between its research, education and dissemination activity.

C.3 The CMI objectives

The basic objective for the CMI knowledge exchange and dissemination work was to bring the benefits of the CMI project to a wider community of universities and businesses. In its founding documents, CMI made a commitment to deliver workshops and other special events and to create material / content which could be used elsewhere in Britain.

Latterly, the CMI knowledge exchange objectives were extended beyond this idea of business engagement in research and education to include:

- Proactively engage business around research and educational programmes that address their needs
- Develop and enable agents of innovation and knowledge exchange, including students, faculty, managers and technology transfer professionals
- Develop structures and incentives that encourage interactions between universities and industry

The 'knowledge exchange' implementation strategy has followed this triptych of related ambitions, wherein CMI:

- Research projects were to be anchored in transatlantic networks of academics and business people
- Education projects were expected to have a strong industrial / employer input and logic, and where possible to produce graduates with the confidence, skills and ambitions to become more enterprising
- Exchange projects were expected to create the opportunities within which less formal, goal-oriented interaction might occur

The knowledge exchange strand was dominated by the National Competitiveness Network, which was complemented by a series of other CMI programmes and projects, and most notably:

- Student entrepreneurship networks
- Professional Education Activities

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[20] This broadening of thinking echoed the earlier work of Martin and Salter, and was further endorsed by a follow-on research paper that underlined the importance of open and informal social interaction on the one hand and problem solving consultancy on the other. See, 'The benefits from publicly funded research, SPRU Electronic Working Paper number 161, Ben R. Martin & Puay Tang (SPRU) 2007.

- Digital Spaces for Knowledge Exchange
- The Programme on Regional Innovation

The following paragraphs visit each of these three strands in turn, paying especial attention to the knowledge exchange strand proper.

C.4 User engagement in research

KICs and research agendas

An important aspect of CMI's work was in its dialogue with industry when setting the agendas for new research activities. Here the goal was to understand what research was important for businesses and what would engage their interest. The starting point for this process was to work with enterprises to develop a regional or national agenda that addressed key issues – such as healthcare, energy security, transport and so on – or strategies to exploit emergent technologies or new business processes, or to fulfil educational needs. Having established the agenda, the next stage brought academics into the process, to collaborate with stakeholders to identify the roles that university-based research and education can play, and to develop and implement a programme to realise the stakeholders' vision.

The CMI Communications Research Network is a case in point, a 'Knowledge Integration Communities' (KIC) wherein CMI in conjunction with BT developed and launched a wide-ranging programme of activities with the intention of stimulating innovation within the UK communications, an industry confronted by rapid convergence of computing and communications technologies, major new markets and intense competition.

By reaching across technology, business, architecture, regulatory dynamics and economics, the CRN brought together a cross-section of important individuals to essentially re-conceptualise the industry, develop strategic roadmaps and demonstrate disruptive technologies. The two principal objectives were to:

- Establish a better understanding of the communications industry value chain, resulting in roadmaps to possible futures. This research was to inform investment decisions by large-scale operating companies as well as to reveal opportunities for SMEs and entrepreneurial newcomers. The activity was to span communications providers, suppliers, manufacturers, content developers and consumers and was done with an international suite of participants who represent the interests and concerns of industry and economic segments
- Demonstrate new technologies that have the potential to overcome architecture bottlenecks and thereby encourage innovation. This segment was to examine the core technologies of tomorrow's communications infrastructure – wireless, fibre and digital signal processing – and the business and regulation issues associated with their implementation. This will provide commercial opportunities for industry as well as lessons for communications policy-makers

The CRN worked in conjunction with its MIT analogue, the Communications Futures Programme (CFP), which seeded the idea of an industry club in this field as well as providing a trigger and input for several of the CRN working groups on for example viral networking, broadband access and security.

The CRN worked through a combination of events, working groups and small research projects, and for example included Working Groups covering Innovation in Telecommunications, Spectrum Policy, Interconnection, Critical Infrastructure Protection, Telecoms for Transport, and Photonics. In its first two years, the CMI files state that the network had attracted over 800 delegates to a series of 8 high-profile events. In 2006, its early success (wide-ranging activity and scale of industrial engagement) led to the CRN being established as an independent, not-for-profit company limited by guarantee, with BT and Fujitsu as its first two founder members.

The CRN roadmaps and industry-engagement model led to a decision by the Technology Strategy Board in 2007 to launch a new national 'knowledge transfer network' in the area of digital communications. This new, UK-wide network of networks has established good links with the Cambridge-based CRN and is making significant use of the CRN brand, events and networks and as such one can say that the imprimatur of CMI has reached through the UK's national knowledge transfer scheme.

Interviews and case material suggest the commitment to industry engagement and wider dissemination was part of the core principles at work in projects across the CMI research portfolio. This appears to have held across fields too, whether that is earth sciences, computer science or social science. CMI used this approach in, for example, the formation of projects such as the Electricity Policy Research Group and the Energy Security Initiative, which aimed to address the UK's need to increase security and reduce the country's exposure to the uncertainties of the international fuel supply chain.

The boxed section presents a case example of the Electricity Policy Research Group (EPRG), a research centre based at Cambridge University, which grew out of previous research work, including the Cambridge-MIT Institute *Electricity Project*. The CMI project built up a network of associate researchers throughout the UK, Europe, the USA and Japan and also established links with major industrial groups, regulators and policy makers. The EPRG has built on this groundwork, and is both conducting policy-relevant research and providing research and analytical support for a key UK industrial segment.

Sharing CMI research with the electricity industry

Economists at Cambridge, with MIT's Center for Energy and Environmental Policy Research, secured a CMI grant to conduct comparative analyses of international experiences with market liberalisation and the associated policy responses. The ultimate objective was to facilitate innovation in electricity supply and as such the research had a strong industry and policy input from the outset.

The success of the CMI electricity project, which began with two faculty members and a research assistant, provided the platform for the creation of the Electricity Policy Research Group (EPRG), a small but high-profile research centre with around 20 researchers and support staff at Cambridge University. EPRG senior researchers have secured almost £5M in major grants from the UK research councils, principally the EPSRC and ESRC, to extend their CMI-supported research, encompassing issues that affect electricity markets internationally, from regulation to pricing to security of supply to emissions trading.

The EPRG, with CMI support, established the Electricity Policy Forum (EPF) as a membership body to engage in and influence the policy debate; improve understanding of the drivers for change; and leverage publicly funded research. The EPF membership is comprised of major UK-based utilities in the main (BP, British Energy, BG Group, E.ON UK, Lehman Brothers, Ofgem, National Grid) and functions as something close to a research club, defining research agendas and sharing EPRG research findings. The EPF also provides members with preferential access to the EPRG research team, and supports individual organisations in their strategic decision-making.

The EPRG also continues to host an annual international conference on energy policy research in collaboration with the MIT Center for Energy and Environmental Policy Research. The September 2007 event was held in London over two days and was entitled 'policies for a sustainable and secure electricity market.'

Digital Spaces for Knowledge Exchange
Industry has not been the only user community to have been targeted by CMI, and the DSpace project is arguably a good example of an opportunistic investment that might very well generate substantial benefit for the world's librarians, and the CMI contribution has been very much about strengthening user engagement in the development of successive versions of the software and its wider promotion to other users around the world.

DSpace is a digital archive that has come into widespread use by university and other libraries around the world, and one might imagine that it will come to be seen as a valuable and secure means by which to store / archive scholarly data and material. Interviewees suggested that DSpace meant that Britain's research libraries had been able to jump a generation of software. Moreover, the demand for such a facility is growing year by year, as a growing number of research subjects – from bioinformatics to oceanography – are producing many terabytes of data.

DSpace is now firmly embedded at the University of Cambridge and at MIT, has been adopted by hundreds of other institutions in over 40 countries. CMI has sponsored the development of the DSpace Federation to coordinate the planning, research, development and distribution of DSpace as an open source digital repository system.

The CMI contribution to the development of the technology was limited, however its support for various user groups and development fora has been important.

Notwithstanding the potential importance of this CMI project for scholarly work, its relevance to the innovation agenda appears rather weak and few if any businesses have adopted DSpace, which compares poorly with the several hundred public institutions around the globe that have adopted the software / standards associated with the service.

Regional Innovation Programme
The CMI regional innovation programme is another example of CMI working closely with user communities other than business, in this case the regional development agencies. However unlike the DSpace project, this engagement work had a strong focus on UK innovation albeit at a regional level and from a theoretical perspective. That said, the various studies conducted within this programme of research were designed to provide regional innovation people with both insight about the phenomenon and practical tools and analyses that their own economists and statisticians might rerun on an ongoing basis.

CMI's Programme on Regional Innovation (PRI) was a hybrid of research and dissemination and supports this activity by undertaking novel and detailed theoretical and empirical research into how regional and urban economies compete in the global marketplace, and how they contribute to national economic performance. The programme also involves:

- Developing a programme on the economic and social dimensions of urban and regional competitiveness
- Educating students and practitioners in techniques for understanding and influencing local and regional systems of innovation
- Informing evidence-based regional policy development and providing cross-disciplinary forums to share best practice and the latest research findings

The regional innovation programme has published several well-cited papers on for example the influence of absorptive capacity on regional innovation and the extent to which geography and agglomeration (clusters) are more or less meaningful for different economic sectors. The research built successfully on the interdisciplinary research programme of the Centre for Business Research, supported by the ESRC, and the centre's established business survey and its commercial work for DIUS on the Community Innovation Survey.

The research trajectory was confirmed by the 2002 NCN conference on regional policy, where the Regional Development Agencies (RDAs) in England and their counterparts in Scotland, Wales and Northern Ireland, confirmed their ambition to play an increasing role in promoting knowledge-based growth in urban and regional economies.

The team at the Centre for Business Research within the Judge Institute have deployed this expertise to wider benefit also, securing a series of consultancy contracts to conduct mapping studies and to help RDAs to address strategic issues. A recent study into the economic potential of the greater South East was conducted with the London Development Agency, the East of England Development Agency and the South East England Development Agency. In this way, the programme has collaborated with the RDAs to provide research support and to work with stakeholders in the development of a science and innovation strategy for the South East.

C.5 Innovation carriers

Enterprise education and dissemination

The Education and High Growth Innovation (EHGI) project, which studies the influence of university education on the motivation and capability of undergraduates to engage in entrepreneurial behaviour, is a particular success, with its steering group having been widely influenced by its findings, and the course(s) it has studied having come into much more general usage.

EHGI builds on the CMI 'Enterprisers' course, which was an adaptation of the MIT LeaderShape course, which CMI purchased under licence and modified. This is discussed from an educational perspective in the education review. Here we have focused on the wider dissemination of course content and related evaluation techniques.

The principal achievement here had been (i) the delivery of the Enterprisers course at a large number of UK universities and (ii) revealing to the 80 or so members of the UK-wide network of Science Enterprise Centres (SECs) as to what aspects of an entrepreneurship course bear most heavily on its effectiveness. Contributors report that 3.5% of all HE students were being put through the EGHI course, and that 50-60 UK HEIs have been involved with EGHI at some point in time.

Professional education activities

CMI established forums, networks and professional educational programmes to share the results of its work in engaging with industry and to bring others into the debate as to what constitutes effective practice in knowledge exchange.

CMI also played a pivotal role in establishing Praxis, a national training programme for technology transfer professionals. Praxis has provided training to over 1200 individuals. It is primarily aimed at staff from technology transfer or contracts offices in academic institutions, public sector research establishments and the National Health Service.

Facilitating the Transition from Research to Business in the UK

From its work on the National Competitiveness Council, CMI identified a need for training among technology transfer professionals in the UK. Support for this view came in a report from the Bank of England which found that, while there were over 1200 technology transfer professionals in the UK, there was a shortage of training for them.

An exchange of licensing professionals between MIT and Cambridge led to the idea of developing a training programme suited to UK needs. Supported by CMI, volunteer teachers delivered four highly successful courses in 2002-03.

In April 2004, this effort gave rise to CMI's first spin-out company, **Praxis Courses Ltd.** Courses range from the fundamentals of technology transfer and research contracts to advanced licensing, developing intellectual property, and setting up spinout companies. Praxis is now the UK's leading national training programme aimed at technology transfer professionals. The courses are overseen by a programme committee that carefully reviews feedback from each course, creating a "market-led" syllabus. Praxis tailors its training for staff from technology transfer or contracts offices in academic institutions, public sector research establishments and the National Health Service. Nearly 1200 individuals from more than 100 organisations in the UK have now taken part in more than 4000 training days.

Professional Education activities also included the UK Entrepreneurship Development Programme (UK-EDP), the Women in Technology Conference (2005, jointly with Cambridgeshire County Council) and Mid-Career Enterprise Education for Technology and Science (MEETS), a two-weekend short course at CU targeting mid-career women as a means by which to equip and encourage more women to consider creating their own businesses.

Student Entrepreneurship Networks

CMI sponsored several student entrepreneurship projects with the aim of increasing the number of graduates that go on to develop new business ventures and otherwise commercialise their research. These projects also set out to boost students' confidence and to help them make the most of the skills and knowledge they acquired while at university. They are:

1 Cambridge University Entrepreneurs (CUE), which operates through a combination of information, training and networking events and all of this is given a particular boost through its annual business planning competition
2 Cambridge University Technology & Enterprise Club, which organises an annual venture capital roadshow at CU and a twice-yearly series of talks by entrepreneurs and VCs
3 i-Teams, which was a short educational programme on entrepreneurship targeted at post-graduates inspired by a similar activity at MIT. Working in teams of five, students have six weeks to investigate 'go-to-market' strategies for real research projects
4 The Annual Gala Networking Reception & Dinner
5 The 50K Business Plan Competition
6 Acumen-UK, a source of common resources (network) for four UK HEIs with active student enterprise societies. This notion of cross-institutional support and learning is part of the remit of the national council for graduate entrepreneurship

Cambridge University Entrepreneurs (CUE) is the largest of these projects. It was launched in 1999 and CMI support has helped both to raise its profile and to develop various resources. CUE continues to operate post CMI and is sponsored by high profile organisations, including 3i and ARM. The added value of the CMI support is unclear, however CUE titles itself the most successful *student-run* business competition in the world and states that CUE has contributed to the formation of more than 40 companies, where the surviving members of this cohort had an estimated balance sheet value of more than £40 million in 2007.

One of those new ventures included the 2003-04 winner of the £50K Business Plan Competition, Light Blue Optics, which recently secured $26 million VC investment to underwrite the cost of the development of its miniature laser projectors.

For CMI overall, as opposed to any one project with total investment running into a few hundreds of thousands of pounds, it seems likely that the student entrepreneurship work has given something of a higher profile to business and enterprise throughout the university.

The Higher Education-Business Community Interaction (HEBCI) survey does show long-run growth in the numbers of new graduate businesses being registered annually for Cambridge, which is reassuring.[21] This trend also holds for the top 20 institutions (graduate startups), which suggests there are other factors at play here and not just the creation of CMI. On the subject of the HEBCI top 20, the other notable feature of these statistics is the dominance of the former polytechnics and art schools in the top 10 and top 20 institutions, whether that is on numbers of businesses still active after three years, estimated employment or estimated current turnover of those businesses. CU is ranked 17th on new graduate businesses in 2005/06 and 30th on the cumulative total of active businesses, and these rankings would worsen were the figures adjusted to reflect the differing sizes of the reporting institutions.

On balance it would seem that the support to student enterprise clubs was well regarded and that CMI has made a positive contribution to changing attitudes and confidence within the university, albeit within the context of several other UK-wide initiatives to promote enterprise and innovation, from Dearing to HEIF.

C.6 Structures to promote university industry interaction

National Competitiveness Network

The National Competitiveness Network (NCN) was the original and primary CMI dissemination vehicle, wherein the founding documents required CMI to establish this national network by building upon the pre-existing, UK-wide network of Science Enterprise Centres (UKSEC).

In autumn 2000, senior CMI figures and UKSEC representatives concluded that the leading areas of common interest were university policy on intellectual property and a very general interest in entrepreneurship education, an exchange that produced a very particular cast to the subsequent work of the NCN.

Without decrying the importance of such issues to UK competitiveness, the common ground between SEC and CMI was unduly narrow and, with the benefit of hindsight, such a contractual obligation appears unnecessarily risky. It is to CMI's credit that it managed to satisfy the ambitions of the UKSEC network and also, over time, build a growing programme of conferences and events that more fully captured the spectrum of its research and education activities and competitiveness ambitions.

The NCN has accounted for a significant proportion of total CMI support for knowledge exchange, and was launched right at the outset (early 2001) and ran throughout the life of the project.

The National Competitiveness Network (NCN) brought together universities, businesses and government organisations operating through various channels, including the:

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21 Given the nature of the phenomenon under review there is quite a lot of year-on-year movement in the statistics, up and down. For example, the 2005/06 return (HEBCI 2007) shows that CU reported 19 new graduate businesses, while it had recorded 29 in the previous year.

- National Competitiveness Conferences, which typically ran two events each year, often showcasing CMI project results on for example interdisciplinary curriculum development or silent aircraft
- The National Competitiveness Forums were run in parallel to the conferences, with one or two taking place each year. The principal difference was in the origins of the keynote talks, which tended to be on very topical issues and were given by people outside the CMI firmament. Topics ranged from the future of regional policy to the importance of manufacturing within the economy
- National Competitiveness Summit was a larger variant of the Competitiveness Forums, with a single annual event and a UK-wide scope, such as entrepreneurship
- The Competitiveness Workshops were workshops held at institutions around the UK, which brought together academics and industrialists to hear about and debate results from CMI enterprise projects

CMI report that in the five-year period from 2001, the network organised more than 45 events with over 2,000 participants and provided the impetus for Praxis, Enterprisers and the Entrepreneurship Development Programme. Through these mechanisms, the NCN identified a need for research that could provide evidence for improved policy and practice for advancing knowledge-based growth in urban and regional economies. CMI therefore established the Programme on Regional Innovation, which focused on the creation of new models for developing research and knowledge exchange mechanisms that would improve regional – and thereby national – competitiveness. The NCN also helped to establish better links between university educators and the key UK policy-making institutions in the area of innovation, including DIUS and the UK Regional Development Agencies.

In practical terms, CMI was contracted to support the UK network for enterprise educators, UKSEC, which had been launched previously through the Science Enterprise Challenge in 1999 as a group of eight institutions (£25M DTI grant). The NCN became an integral part of the UKSEC, with CMI providing coordination and planning capacity, substantial content for events and funding for venues, travel costs and sometimes accommodation (e.g. for guest speakers).

Interviews stated that the CMI contribution had been critical to the success of the UKSEC, which had grown and prospered throughout. UKSEC was renamed in 2007 as Enterprise Educators UK, with an impressive array of services supporting over 500 enterprise educators from 85 Higher Education Institutions to develop their practice, network with peers, and collaborate in enterprise and entrepreneurship teaching and research across all curriculum areas.

While much of the attention of the NCN was on coordination of SEC events and the dissemination of content to other universities, there was an extensive outreach programme and the CMI records show that over 1000 companies have participated in CMI-related activities, be it through direct involvement in a CMI project or by taking part in one of CMI's many events, conferences and workshops. Several of these organisations are large multinationals, such as BP, Pfizer and Rolls-Royce. The majority, however, are small and medium enterprises (SMEs).

In Education for Innovation for instance, the Management of Technology and Innovation (MOTI) module, which was common to all six CMI MPhils at the University of Cambridge, involved working with over 100 companies, including a good number of SME placements, at businesses such as Alphamerix, BlueGnome and Plastic Logic. Research-based projects, such as New Ultra-Light Metallic Sheet Material, forged a relationship with Volvo, but also with the smaller Fibretech. Together they have produced and successfully commercialised an outcome of their collaboration: Fibrecore™.

Appendix D Compendium of CMI case studies (research)

D.1 A low energy mixing ventilation system (e-stacks) for existing buildings

The CMI project
The 'e-stacks' project brought together a team of scientists and engineers from Cambridge, MIT and BP to devise designs for 'green' buildings based on solar energy and natural ventilation techniques. CMI provided £2.5 million to the project over a period of 5 years, with additional financial and in-kind support from BP, one of the CMI's principal industrial partners.

The CMI added value
The added value of the CMI award was largely a matter of funding, with the CMI programme being openly receptive to the proposed collaboration between fluid dynamicists, architects, engineers and energy specialists, in pursuit of improved modelling techniques and more energy efficient ventilation systems.

The CMI collaboration
The work was led by Professor Andrew Woods, at the BP Institute in Cambridge, and Professor Leon Glicksman, Professor of Building Technology and Mechanical Engineering at MIT. The work was conducted in collaboration with several other senior faculty members on both sides of the Atlantic, including Professor Les Norford at the Department of Architecture in MIT and Dr Koen Steemers at the Martin Centre for Architectural and Urban Studies, Cambridge University.

In Cambridge, the research was carried out at the BP Institute, which was set up in 1999 with an endowment from BP to research some of the fundamental scientific challenges that the oil industry might encounter. In the CMI project, the researchers used their expertise in fluid mechanics by using the flow of water to simulate the flow of air. In the laboratory, small-scale model buildings were immersed in a water bath and currents of dye-coloured hot and cold water were pumped through them at different speeds to simulate the flow of hot and cold air through a building. The researchers then used their findings to develop models and control strategies for natural ventilation flows. The researchers studied a hybrid scheme, which combined both natural ventilation methods and air conditioning. At MIT, the research team (consisting of architectural and engineering faculty members and students) worked on accurate computer techniques to predict natural ventilation flow in buildings.

The Cambridge team focused on developing generic products for improving the energy efficiency of naturally ventilated buildings, which could be retrofitted to existing buildings, while the MIT team looked at ways to enhance the design of new buildings to improve their energy efficiency through the use of natural ventilation.

The project outputs
The project led to new understanding of natural ventilation flows in buildings; with a range of papers published by Professor Woods and his colleague Dr Shaun Fitzgerald exploring the non-linear dynamics of natural and forced ventilation and convection flows. The study was used to show how the combination of laboratory modelling and simplified mathematical modelling enables one to rapidly identify the various flow regimes which can occur, to quantify the resultant flows and mean temperatures and to thereby develop appropriate ventilation strategies for the different external conditions which occur through the year.

In addition to improving modelling techniques, and understanding of ventilation flows, a novel design was developed and tested a proprietary, low energy mixing ventilation system for existing buildings and for new-builds. The system is called 'e-stack'.

A UK patent for the e-stack was filed by Cambridge University in mid-2005. At that time the primary Cambridge-based researchers, Professor Andrew Woods, and Dr Shaun Fitzgerald, expressed interest in creating a spinout company to commercially exploit their invention. Due to the involvement of BP as a project financier, and the desire of E-Stack to have *exclusive* exploitation rights, the IP licensing negotiations were quite complex. The license was signed in May 2006. E-Stack Limited was founded shortly after, with financial support from both Cambridge and BP.

As a spinout from the BP institute, E-stack was well placed to secure early stage investment from BP's Alternative Energy Venturing business in return for an equity stake in the company (BP's corporate venturing is expected to make sound financial returns and help to build strategic business options in emerging markets and exploiting novel technologies).

The project outcomes

E-Stack Limited launched its proprietary system in 2008, and its team of half a dozen people have been successful in selling systems to several schools and retail outlets as well as continuing to develop new variants and prototypes of the technology. The technology is reported to cost less to purchase and install than the equivalent mechanical ventilation systems, and costs substantially less to operate and maintain.

As at July 2008, e-stack systems were operating in eight UK schools, and the company has a substantial current and forward order book where it is actively engaged in supplying e-stack® systems.

In schools, the e-stack installation has been designed to recycle the heat generated within the classroom in the winter. This is achieved by mixing the incoming and outgoing air streams at the top of the space, so that the incoming air is pre-heated. In parallel to this thermal control of the inflowing air, the overall flow rate is controlled dynamically using CO2 sensors in the occupied zone. This ensures that, in winter, the interior air quality always remains fresh without using energy unnecessarily. To judge the potential benefits of the system, e-stack was compared with a system whereby the air is pre-heated using a radiator or heating battery on entering the space. The two were tested experimentally in a controlled laboratory setting. The difference between the two systems in terms of energy consumption was significant. Combining the hourly weather data over a year in Cambridge, for example, with the energy use in a classroom, the Building Services Journal estimated that the expected savings could be as much as 80 kWh/m^2 a year, which with electricity prices at around 10 pence for a kilowatt hour, could amount to tens of thousands of pounds saved each year. The other benefit of the e-stack system is that in summer, upflow displacement ventilation can be used by coupling the outflow stack to the inflow through the perimeter openings. This enables effective ventilation of the hot air from the space, thereby reducing the cooling requirement in warm conditions.

A number of new schools have adopted the new strategy for their ventilation and one, Harston and Newton community primary school in Cambridgeshire, had e-stack installed in an existing classroom as a prototype to collect data on performance. Similar positive results have been found with a system installed at Queen Alexandra College, Birmingham, which has been running for 18 months.

The company's development work is focusing on the deployment of multiple e-stacks within larger spaces, where the current product is optimised around the use of single stacks to ventilate individual rooms or small spaces. A substantial part of the commercial building stock comprises large interior spaces, such as open-plan offices or auditoria, which require substantial and well-distributed ventilation.

More recently, the e-stack concept has also been implemented in spaces larger than classrooms. For example, a series of mixing stacks has been designed and installed into the roof of the new 250-seat hall at the Unity College secondary school in Northampton. This installation was developed by carrying out detailed water bath modelling to explore how a system of stacks interacts. As a result, the Unity system has the facility to operate in mixing mode in the winter while providing ample displacement ventilation in the summer. The system is now being developed to allow for mixing ventilation in larger buildings, in which a group of classrooms may draw air from an atrium. Initial laboratory model results are encouraging, and the first system is being installed in Port Regis School, Dorset.

The value and potential of the innovation at E-stack has been recognised by two awards for innovation at the 2008 annual energy innovation awards organised by the East of England Energy Group (EEEGR). The potential for e-stack® to make a very significant impact on the renewable energy market is recognised by the company having won 'Most Enterprising New Market Entrant of the Year,' at the 2008 Euromoney and Ernst & Young Global Renewable Energy Awards.

D.2 Development of an ultra-light stainless steel composite sheet

The CMI project
This CMI project relates to the development of an ultra-lightweight composite structure intended to deliver improved functional performance across a range of industrial applications. The resulting composite is based on a pair of thin stainless steel face-plates separated by an 'intelligent' core of cast stainless steel fibres, which can be engineered to give different performance profiles to suit a given application.

The key research objectives were to characterise the performance of various design configurations of a pre-existing stainless steel composite, developed by Volvo Technology, in order to advance understanding of and control over key design parameters, for example stiffness, formability, weldability and energy absorption.

The auto industry was the primary target application field, and the project had the overarching ambition of enabling car-makers to design lighter, more fuel-efficient vehicles, without compromising safety. The concept was an affordable, engineered material that would challenge or substitute for conventional sheet metal as the material of choice for a variety of key components from structural elements to metalwork integral to a vehicle's passive safety performance (from bonnets to bumpers).

The project was conducted in two phases: Phase I was a 1-year preparatory study carried out in 2001, followed by the Phase II project, which ran for 3 years from 2002 to 2005.

The collaboration
The CMI programme provided researchers within the impact and crashworthiness laboratory at MIT with a good opportunity to take forward a proposal from Volvo Technology Development Corporation to help the Swedish team research its prototype stainless steel fibre composite. The ambition was to execute a programme of applied research to characterise and model the performance envelope for this type of composite, encompassing all of the performance dimensions that go towards making a given material or structure of interest to a vehicle manufacturer: structural, durability, consistency, manufacturability, economy, and so on. The range of parameters to be brought under control made the work a little too complex for Volvo to want to pursue the development work in isolation, and as such the Swedish team was delighted to have an opportunity to offset the risks / costs through CMI and the resultant access it gained to the spectrum of structural and metallurgical competencies and facilities at MIT and Cambridge.

Professor Bill Clyne led the team at Cambridge, drawn from the university's Materials Science and Metallurgy and Engineering departments, which focused on experiments with different core components and arrangements of fibres, as well as examination of the structure, durability and weldability of the material. In parallel, Professor Tom Wierzbicki of the Mechanical Engineering department at MIT, focused on researching and modelling the energy absorption, crashworthiness, impact and fatigue characteristics of the different variants. Both the academic groups then contributed towards developing constitutive modelling of the composite.

The partnership went beyond the academics and Volvo Technology and included representatives from each of the key points in the supply chain, including the Swedish multinational stainless-steel producer, AvestaPolarit, with operations in the UK and the US and a mixture of vehicle manufacturers from the car, truck and aircraft sectors, including Airbus UK, car makers BMW and Saab and Volvo Truck. Last but not least, the partnership included a team of metallurgists from a UK-based SME with an established reputation as a developer and manufacturer of novel, direct-cast metal fibre products, Fibre Technology Limited. While the manufacturers were expected to advise on performance benchmarks (from stiffness to price) for different components / applications, Fibretech was contracted to undertake the controlled manufacture of batches of prototype variants, sufficient to meet the requirements of the universities' research and (destructive) testing.

The global partnership was unlikely to have found alternative funding from national bodies in the US, Sweden or the UK and as such CMI was perhaps uniquely placed to facilitate the development and commercialisation of a new product, which promises short term and long term economic gains and possibly an environmental boost too.

Project outputs

The CMI project produced advances in understanding amongst the researchers and technologists inside the consortium, as well as adding to (published) scientific knowledge about the performance of partiuclar classes of metallic composites incorporating metallic fibres. In addition, all parties reported extensive knowledge exchange, including between academia and industry, providing a platform for the potential future development of other, broadly related technologies and products. Indeed, Fibretech has developed and launched another two new metal fibre products, which have drawn in part on the insight and learning gained through the CMI experience.

The collaboration was also successful in producing a novel composite with known / replicable properties, which can be engineered and manufactured to suit different performance specifications. The product offers several advantages over available technologies, which include its high stiffness to weight ratio and energy absorption properties. It is also environmentally friendly, being fully recyclable at the end of its life cycle (it can be made from scrap too) and is corrosion resistant to ensure long-term durability. Perhaps most significant, the composite is described as being 'intelligent', as it is possible to tailor its properties to suit the specific application by changing the materials on the one hand and, critically, the specification of the manufactured sheet-fibre combination on the other (e.g. sheet thickness, fibre aspect ratio and core density). The product utilises spun fibres manufactured by a low-cost, rapid solidification process as the core of the structure.

Its low cost, light weight, high structural efficiency and good energy absorption characteristics make it attractive for a range of other commercial structural applications including filtration, heat exchange, structural cladding, containers, aircraft fuselage, crumple zones, fire protection and impact protection. The project partners believe the wide-ranging potential applications for this type of metal composite could mean annual global sales of more than £1 billion within 5-10 years.

Two patents were filed by Cambridge Enterprise, one for the composite itself, the other for a novel method for surface treating or coating fibres. The composite technology was licensed to Fibretech, subsequently, in return for small equity stake in a newly created subsidiary of Fibretech, and agreed royalties. The details are commercial in confidence.

Project outcomes

The project led to the launch in 2006 of a commercial product, Fibrecore™ which was followed by a related product, Fibresheet™, following further product development by Fibretech, based in Nottingham, UK.

The product has already met with some commercial success, and Fibretech is continuing to research new markets and further develop the project. In 2008, the company was planning to begin to offer larger sheets, approaching 1 metre by 5 metres. The company projects an annual turnover of £10 million from Fibrecore by 2010, substantially increasing turnover and profitability. It is also projecting additional employment, nearly doubling its current strength of 13. In addition to a new product line and expanded business, the CMI project has strengthened Fibretech's links with the HE sector in the UK and US, although it interacts mainly with materials scientists in Cambridge, and has used these relationships to boost its sales of technology consultancy and test work.

Volvo Technology has continued to carry out development work in the filed, but only indirectly through a spin-off company Lamare, in Sweden, which is working on a range of products and processes involving hybrid stainless steel assembly (HSSA) using nickel stainless steel. Volvo was also very appreciative of the role of the CMI project because of which they could evaluate the performance and develop new constitutive models of the new material developed.

None of the manufacturers chose to implement the technology immediately following the project, however all continue to maintain an interest in the product and are monitoring its further development. BMW is a case in point, with its representatives having tracked the development of the new composite material and ultimately electing not to proceed due to a combination of financial, manufacturing and technological uncertainties. On the last point, the company was not persuaded fully that technology was ready to be deployed in high-quality, volume production in part because of the lack of production experience and in part also because of a question mark over the exact reproducibility of the material's properties.

The technology does look set to find wider application, with technology assessment proejcts in hand in both the civil aircraft and defence industries. For example, Defence Science & Technology Laboratory (DSTL) has set up a project on the use of sandwich sheets in personal ballistic protection systems.

The project also had some worthwhile impacts on the future direction of the resaerch team. Dr Athina Markaki, a post-doctoral research associate in the Department of Materials Science and Metallurgy was awarded the 2004 De Montfort Medal. Chosen from several hundred entries from young researchers in the UK, Dr Markaki received the prize for her work within the CMI project on the mechanics of ultralight stainless steel composites and their application to improving bone prostheses.[22] She was subsequently awarded an EPSRC Advanced Fellowship and continues to pursue biomedical applications of variants of the CMI-developed composite.

[22] Mechanics of thin ultra-light stainless steel sandwich sheet material Part II: resistance to delamination. Acta Materialia, Volume 51, Issue 5, Page 1351, A. Markaki,

D.3 Ferroelectric nanotubes

The CMI project

Nanotubes of conducting materials such as carbon have received considerable attention. Microtubes of non-conducting materials like SiC have also been reported in the literature. However, ferroelectric nanotubes made of oxide *insulators* were first developed during this CMI project. These nanotubes have a variety of applications in pyroelectric detectors, piezoelectric ink-jet printers, and memory capacitors that cannot be filled by other nanotubes. The project received funding of £900,000 from CMI.

The collaboration

The team at Cambridge University, lead by Professor J F Scott, dealt specifically with the fabrication of the nano-structures, whilst their counterparts at MIT, lead by Professor K A Nelson, focused on the measurements involved. The partnership with MIT was less significant for this case study than others, and the interaction was concentrated in the first two years of the 5-year project.

The academic partnership was closely supported – and co-financed – by a Japanese company, Samco, a process equipment company that develops and manufactures a wide variety of deposition, etching, and surface treatment systems for a worldwide network of major industrial customers and academic facilities. The ferroelectric nanotube manufacturing technology is based on Samco's "misted deposition" technique, which enables simultaneous fabrication on large numbers of micro-devices, a significant breakthrough in this vital process.

The CMI added value

The CMI added value was its ability to fund types of research that other research funders, public and private, were less likely to consider, which is scientifically challenging, user-oriented research that requires the interaction and integration of several disciplines. According to the principal investigator, the project would not have been possible without funding from CMI. EPSRC does not typically fund work of this nature, given it sought to develop and manufacture a novel photonic device for immediate industrial and medical application, and which involved some rather challenging inter-disciplinary research, drawing on physics, materials science and engineering. The challenging science and ultra competitive market place meant that it was unlikely industry would have fully funded the development work, and the EU RTD Framework Programme has tended towards supporting very much larger, pan EU projects.

Project outputs

The project developed an ultra-small (nano scale) photonics device with several performance advantages over competing technologies, based on a novel fabrication process that permits a level of control over the deposition and porosity of constituent materials not previously possible and as such benefiting the performance of the resultant microelectronic devices.

The team concentrated on a technique in which ferroelectric crystals, in liquid form, were used to fill pores in a substrate of silicon or alumina and then heated to crystallise into nanotubes. The nanotubes were fabricated with a diameter of 800 nm, a thickness of less than 100 nm, and a length of 80µm. The nanotubes were formed in an array across the silicon wafer with a gap of approximately 1.5µm between adjacent tubes. The dimensions and distance between the nanotubes can be adjusted at will. Afterwards, electrodes were added top and bottom so that the nanotube properties can be tuned by applying an electric field. The process is bismuth-based, as opposed to the more common lead-based ferroelectrics. This has an environmental advantage in that bismuth oxide is non-toxic. In fact, as the primary ingredient in "Pepto-Bismol" medicine, it is edible.

It is possible that either individual high aspect ratio nanotubes developed during the project, or an entire array of nanotubes, could be used to fabricate functional devices. More specifically, there exists the potential for utilization in fields such as photonics devices, MEMS devices (microelectromechanical systems), and data storage devices. For example, it might be possible to create a voltage variable photonic crystal device by adding upper and lower electrodes to an array of SBT nanotubes. In addition, there are other potential applications, such as use in inkjet printer heads, micro pump implants for drug delivery, creation of new compound materials, and the development of 3D-FRAM and trenches for next-generation DRAM memory devices. The drug delivery systems include aerosol insulin delivery for diabetes sufferers and using the nanotubes to deliver drugs precisely where the body needs them.

As a result of this work, five patents were filed and granted in the UK. Cambridge and Samco own the IP jointly in two cases and by Cambridge for others.

Project outcomes
The project has helped to consolidate the PI's international reputation within the field, with current research focused on experimental studies involving fabrication of nano-devices and characterisation of their electrical properties for high-dielectric crystals and ferroelectrics. Both theoretical modelling and data analysis are emphasised. Recent research highlights include the fabrication of ferroelectric thin films only 77nm thick with bulk-like properties, the clarification of the conduction mechanism in commercial ferroelectric memories from Samsung and the discovery of a metal-insulator transition in the room-temperature multiferroic $BiFeO3$.

Cambridge Enterprise has pursued technology commercialisation through two channels, through its licensing agreement with Samco on the one hand and through its support for the startup ambitions of the Cambridge professor on the other. In September 2005, a licensing agreement was signed between Nano Electronics Limited (a subsidiary of Advance Nanotech), Samco Inc. and the University of Cambridge for exploitation of the ferroelectric nanotube manufacturing technology. As at 2008, Samco was not using the technology and has no immediate plans to do so.

Further commercialisation efforts have resulted in a company being spun off with the help of a £80,000 grant from Cambridge Enterprise. The company, Cambridge Nanoelectronics, will be formed soon. Chris Poulter, who has been associated with 11 successful startups, will be the CEO of this company. Professor Scott will be the chief scientist and the team plan to recruit three more engineers in the immediate future. The company is seeking to raise £1,500,000 from venture capitalists to fund the development of three products. For each of the applications they need around £500,000 to develop the prototypes and take them to the market. The fledgling company has also entered into a licensing agreement with the Max Planck Institute for the use of three of their patented, complementary technologies. The company intends to develop prototypes for application specific devices. They are targeting three application areas: inkjet printer, drug delivery systems and usage in memory devices. For example, in the inkjet printer it is expected that this technology will provide better control of the ink jet permitting higher resolution and better printing in grey scales. In drug delivery it is expected that liquid medicine will be squirted in accurate amounts using these devices. The drug delivery applications include nebuliser-like devices for example for delivering insulin.

Cambridge Nanoelectronics is seeking to develop generic components that in principle should be available to all major manufacturers, so that the company does not have to compete directly with these major producers. The business plan does not include target numbers, however each of the markets being addressed are global and growing and measured in hundreds of millions of dollars (e.g. even 5% of the market in the US for drug delivery application is around 100 million dollars). The big companies like Epson or Tsar (for printers) and Omron or Pfizer (for drug delivery) are being targeted as customers and not competitors to this enterprise.

The IP is jointly owned by Cambridge and Samco in two cases and by Cambridge for others. The company will licence these from CU and then further give these to its clients at a licence fee. The negotiations on licence fees with CU have not been carried out so far.

D.4 Biomaterial and Tissue Engineering

The CMI project
The 4-year, £2 million CMI project on Biomaterial and Tissue Engineering was established to develop novel implant materials and tissue scaffolds with enhanced lifetimes or effectiveness in medical applications. The project resulted in the development of a novel medical device that is expected to have a higher success rate and greater durability than existing technology, thereby helping to reduce the need for major joint replacement surgery and repeat surgery.[23] More than 2 million joint replacements are performed each year worldwide, at an estimated combined cost of $30 billion.

The CMI added value
The CMI added value was the willingness of the project to fund large research projects of an inter-disciplinary nature with academic teams located in two countries; the majority of national research funders will only very rarely support the costs of non-national research partners. While the senior researchers had established relationships, the opportunities for joint projects were scarce.

The CMI project provided the academic team, and UK plc, to build on the existing strength of MIT in this area: an analogous scaffold for regeneration of skin in burn patients, developed by Professor Ioannis Yannas.

The collaboration
The project was one of several projects supported by CMI through its interdisciplinary research cluster on orthopaedic biomaterials and tissue engineering. The joint Cambridge-MIT academic team of eleven men and five women encompassed a range of disciplines from Materials Science, Physics and Engineering to Medicine. At MIT, it involved pioneers in the fields of tissue engineering, and artificial skin, and is led by Professor Gibson. At Cambridge, the project was led by Professor William Bonfield, Professor of Medical Materials at the University of Cambridge, alongside a team of international experts in bone replacement and biomaterial innovation. The ultimate goal was to engineer materials that would enable the body to regenerate damaged or diseased tissue, such as cartilage in arthritis patients or bone in patients with osteoporosis.

At both MIT and Cambridge, co-investigators maintained direct contact with orthopaedic research groups at teaching hospitals: part of the Cambridge team were clinicians and international experts in orthopaedics and bone research at Addenbrooke's hospital, Cambridge.

The project outputs
The collaborative project developed a novel technology that encourages the swift regeneration of natural tissue. By guiding and supporting the body's natural repair mechanisms, the multi-layered, sponge-like technology encourages cartilage, ligaments or tendons to regenerate concurrently with the bone that anchors them in place. By helping surgeons treat damage to cartilage, ligaments and tendons when it first occurs, the technology allows patients to either postpone joint replacement surgery until their first implant can last the rest of their lives or avoid it altogether.

The new technology is easily sculpted by surgeons to arrive at the right shape and size of 'scaffold,' and can then be inserted simply into an area of cartilage, ligament or tendon damage, bonding to the site without screws, sutures or glue. The sponge-like devices then wick up blood and other cell-containing fluids, using their zonal structure and composition to encourage the swift regeneration of natural tissue, which is both healthier and more durable than might be the case otherwise.

[23] The average joint replacement begins to fail after 15 years. Additional surgery can then be performed once or perhaps twice, offering 5 to 10 years of pain-free life. After this period, however, further surgery is usually impracticable, and the patient must live with persistent pain and reduced mobility.

The project outcomes
The Cambridge-side post-doc from the project, Dr Andrew Lynn decided to set up a spin-out company, launched in 2005, called OrthoMimetics (www.orthomimetics.com), to exploit the patents that had resulted from this research.

The Cambridge PI, Professor Bill Bonfield, took up a position as a member of the company's medical advisory board role. In addition to Dr Lynn and Professor Bonfield, OrthoMimetics' founders also include: Dr Brendan Harley, from the Children's Hospital in Boston and the University of Illinois; regenerative-medicine pioneer Professor Ioannis Yannas of MIT; and materials scientist Professor Lorna Gibson at MIT. The OrthoMimetics founder group also benefited from inputs from world-renowned surgeons, scientists and engineers at the medical schools and universities of Cambridge, Harvard and Kyoto. The company continues to place great importance on engaging eminent scientists and surgeons to advise on its strategy and product development.

OM's flagship product, ChondroMimetic, is an off-the-shelf medical-device product that works to improve the efficacy of existing first-line surgical procedures that recruit marrow-derived stem cells to the site of articular-cartilage injury. OrthoMimetics has completed two preclinical trials of ChondroMimetic, the results from which were published in peer-reviewed journals in 2007. A second product (LigaMimetic), addressing the market for donor-site repair during anterior cruciate ligament (ACL) reconstruction, will follow ChondroMimetic closely in OrthoMimetics' development pipeline.

After the £2 million CMI grant, the company has secured an additional £2.1 million in development grants from UK government agencies. These included a £817,000 grant from the Technology Programme of the former Department of Trade and Industry, to conduct preclinical trials and a pilot clinical trial to further test ChondroMimetic and obtain permission for it to be sold in the EU. The company also received a grant of £747,000 from the UK Technology Strategy Board (TSB) for the commercial development of LigaMimetic, the second product based on the company's technology platform. LigaMimetic is a porous restorable tissue-regeneration scaffold that uniquely mimics the composition and structure of ligaments and their bony insertions. It will initially be used for enhancing existing surgical techniques for anterior cruciate ligament (ACL) reconstruction, a procedure performed worldwide an estimated 500,000 times each year.

ChondroMimetic, the Company's flagship product for cartilage repair, and LigaMimetic, OM's pipeline product for ligament repair, address a combined global market in excess of $1bn per annum.

The company successfully completed a Series A funding round of £5 million in December 2006. This financing round, which was managed by Eden Financial and supported by a syndicate of institutional investors including Schroders Investment Management Limited, Oxford Capital Partners and Sloane Robinson Private Equity (SRPE) and Eden Financial private investors. Dr Martin Hall, Senior Healthcare Analyst at Eden, joined the OrthoMimetics Board representing the investor consortium. This funding will enable OrthoMimetics to advance the first two products derived from its orthobiologics scaffold platform towards market approval.

In contrast to drugs, hormones and other pharmaceutical products, OM's medical-device technology offers what the company believes is an effective, low-risk treatment option that is capable of rapid progression through the regulatory process. Following completion of this investment round, Dr Martin Hall and Ms Heidi Hsueh, Managing Partner of SRPE, will join Dr Andrew Lynn (CEO), Dr Bill Mason (Chairman), Mr Max Dyer Bartlett (Chief Financial Officer) and Professor William Bonfield CBE FREng FRS (Non-Executive Director) on the Board.

Initially four patents were filed under CMI. These were on bio materials and gradient scaffolding and methods of producing the same. The company entered into an exclusive licencing agreement with CMI for the use of these patents. Since the inception of the company, Orthomimetcs has filed four more patents (implant delivery devices, Cell-Seeded In Vitro Tissue Scaffolds, Resiliently Deformable Composite Biomaterial and Hydraulic Implant Delivery Method).

OrthoMimetics has signed product-distribution agreements with three distributors and expects the first product to begin shipping by the end of 2009.

The CEO of the company Dr Andrew Lynn stated that this advanced stage of technology development in the spin-off company was possible only because of the initial CMI grant, which helped them to develop this new technology. Cambridge Enterprise helped them set up the company, which employed 11 people as at the end of August 2008. The assistance they received from the technology transfer office at MIT was very good. However, the negotiation on the licensing agreement with CMI was a difficult and protracted process, due to widely differing opinions between the parties as to what were appropriate terms for an exclusive licence.

D.5 Rhodococcus as Biological Catalysts for Chiral Synthesis and Novel Pharmaceuticals

The CMI project

The Rhodococcus project is an example of a research project where CMI funding presented a unique opportunity to researchers on both sides of the Atlantic to take advantage of the complementarities in their pre-existing studies. CMI made possible an otherwise difficult to imagine collaboration, which from the outset held out real promise of breakthroughs with potentially significant, real-world applications in the pharmaceutical and other industrial contexts, and which secured substantial funds from CMI and the private sector.

For some years, strains of the Rhodococcus bacterium have been used at industrial scale to synthesise valuable compounds of consistent quality from higher-volume, lower-cost stock, including the contraceptive pill. With this pre-existing success in mind, the opportunity to sequence the Rhodococcus fascians genome promised to reveal new opportunities to employ this particular strain of the bacterium in the manufacture of lower-cost or more efficacious industrial or pharmaceutical compounds.

The project sought to determine the potential for using Rhodococcus to improve both the process and pharmacological efficacy of novel drugs made through biological synthesis, for the treatment of infectious diseases such as AIDS and TB.

The project ran for five years between 2001 and 2006, and involved a £1.1 million grant from CMI and an additional £2 million from partner pharmaceutical and biotechnology companies.

The collaboration

The CMI grant funded linked studies and researcher exchanges in the biology departments of Cambridge and MIT, permitting the teams to exploit a real research synergy between Cambridge and MIT, where the CU team had done the preliminary work on the biology of Rhodococcus, and at MIT, Professor Sinskey's group had studied the genetics and chemistry of the 'building block' metabolism.

Professor Archer had been a post-doc with Professor Sinskey in the 1980s, and the two had remained in contact throughout much of the intervening period, following one another’s work on Rhodococcus, amongst other things. The CMI project made available the funds that would permit a research ‘project’ involving intensive research at both institutions, where other funding sources in the UK or the US would have been much less likely to have approved funds for an international collaboration of this nature.

While this was one of the larger CMI projects, its objectives, structure and programme of work pre-dated the KIC concept. Its collaboration style might better be described as cross-fertilisation between parallel programmes rather than a single partnership with an integrated programme of work. It did catalyse faculty and student exchanges however, and much was learned by both groups about long-range collaborative working across sub-fields.

Project outputs

The scale and synergy of the collaboration produced a deal of creative science, with four invention disclosures and a number of articles in high-impact journals. There is an expectation that the project, even though it came to an end in 2006, produced insight and data sufficient for several further articles, when the CU team has time to write these.

From the perspective of non-academic users, the collaboration successfully streamlined the time-consuming step of manipulating and expressing recombinant synthetic pathways for several pharmaceuticals, using Rhodococcus to introduce a major reduction in the number of steps in the process by which those compounds are produced.

This advance is expected to aid the inexpensive development of more effective and potent variants of existing therapeutic molecules and or new chemical entities for anti-cancer drugs, anti-fungal, insecticides and antibiotics.

Following on from the insights gained from the sequencing of the genome, and in addition to the new synthetic pathway, the project led to an unplanned breakthrough by the MIT team, which demonstrated that it is possible to cause Rhodococcus to produce a new type of powerful antibiotic.

The CMI funding was used in part to pursue a piece of experimental work that led to the team at MIT producing a new type of antibiotic. By studying the genome sequencing of the bacterium, the researchers noticed that, although Rhodococcus does not normally produce antibiotics, it does have several of the required genes. The team therefore suspected that the Rhodococcus might produce antibiotics under certain circumstances. Following several failed attempts at stressing the Rhodococcus, the MIT team decided to expose it to another bacterium known to produce antibiotics (Streptomyces) to determine how Rhodococcus would react to this threat. The Streptomyces produced their antibiotic as expected, and the provoked Rhodococcus responded by doing the same, and the antibiotic produced eliminated the Streptomyces. The researchers isolated the new antibiotic, dubbed 'rhodostreptomycin', and discovered that it could be used to kill several other bacteria including those responsible for stomach ulcers. The work is reported in the February 2008 issue of the Journal of the American Chemical Society.[24]

No patents were applied for based on work funded through this project, although three patents were granted to members of the research teams for earlier, related work, however these were applied for in the period before the launch of CMI.

Professor Archer is the chief executive of Cambridge Biotransforms, a CU spinout company (CU is a shareholder) that is involved with the commercialisation of his research group's work at CU, which included results from the CMI project.

Project outcomes

The CMI project involved collaboration with several biotechnology companies, Biotica and Chirotech, as well as Dow Pharma and others with an interest in the process industries such as the Malaysian Palm Oil Board. Each has gleaned new insight about the potential to use Rhodococcus as an industrial agent, whether that is in respect to the synthetic biology involved in the production of novel drugs or the intermediate industrial process of helping to convert major waste streams into useful and possibly commercially valuable industrial by-products.

Beyond the new knowledge produced, the CMI project is reported to have led to a change in the outlook of the team of biologists at MIT, in terms of their willingness to share data and hypotheses with collaborators from other institutions and disciplines, with a recognition that a more open approach can facilitate advances in understanding that a more conventional and rivalrous approach might impede. This recognition has been translated into the development and implementation of a new collaborative working platform, to manage knowledge and information exchange amongst multiple research groups in different locations around the globe, working on joint and linked projects. This new web-based, knowledge management tool is based in a model of translational research, which the MIT team expect to evolve over time.

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[24] Rhodostreptomycins, Antibiotics Biosynthesized Following Horizontal Gene Transfer from Streptomyces padanus to Rhodococcus fascians, Kazuhiko Kurosawa, Ion Ghiviriga, T. G. Sambandan, Philip A. Lessard, Joanna E. Barbara, ChoKyun Rha, and Anthony J. Sinskey. Journal of the American Chemical Society, 130 (4), 1126 -1127, 2008.

D.6 The silent aircraft initiative

The CMI project

The CMI Silent Aircraft Initiative (SAI) was a large multidisciplinary project working on the next generation but one (N2) aircraft design. It ran for three years, from November 2003 to October 2006, with total funding of around £4 million, around half of which came from CMI while the balance was derived from cash and in-kind contributions from industry partners. The CMI share was £2.3 million.

Aircraft noise pollution is becoming an increasingly important constraint on the growth in aviation, and the CMI Silent Aircraft Initiative (SAI) aimed to research ways to reduce aircraft noise to the point where it would be imperceptible to the public outside the airport perimeter. The aim was to help to identify a concept design and associated technologies that might produce a step change in noise, in recognition of the fact that improvements by way of incremental innovation had plateaued.

The expectation was that even a partial solution would ultimately benefit the global aerospace industry as well as travellers and communities situated close to airports. The technological innovations were expected to be of more immediate commercial interest, in particular to UK aircraft engine and component manufacturers.

The project began with a 'clean sheet of paper' with the goal of creating a viable conceptual aircraft (mid-range, passenger) with *noise as the primary design variable*, although there were certain other key parameters too, such as fuel efficiency, to avoid the possibility that one problem might be simply swapped for another. The project worked toward this goal by researching airframe configurations and techniques for controlling airflow, drag and descent. In addition, design specifications emphasised low fuel consumption.

Professor Ann Dowling led the Cambridge researchers, while Professor Ed Greitzer was the PI on the MIT side.

The CMI added value

The added value of CMI was twofold. The first benefit was money, and specifically the ambition to fund 'grand challenges' involving virtual research teams working across the Atlantic. CMI provided a rare opportunity for the two universities to collaborate on a major joint project, where otherwise interaction was more sporadic and interpersonal (there was a pre-existing relationship between the two PIs, where Professor Dowling for example had previously been a visiting professor at MIT).

Secondly, the CMI modus operandi meant there was a presumption that the research would be carried out by a multi-disciplinary, transatlantic *team* working on a programme that had been defined in part by a wider community of stakeholders. This requirement meant the project was strongly goal-oriented and adopted a systems approach where otherwise the collaboration might have been rather less well integrated with individual researchers pursuing their own interests with a single component or discipline focus. It was the system focus rather than consideration of use, which marked the project out as being rather special. This kind of user-oriented research is widely evident at MIT, but was rather patchier at Cambridge, although the aerospace department was very much in the van of this kind of applied research.

The CMI collaboration

The collaboration brought together UK and US academics and research students in a team of 30+ people with complementary expertise in every aspect of aircraft development, from aerofoil design to aircraft control to economics to noise propagation modelling to vectored thrust. The project had strong support from two leading aerospace companies, Boeing Phantom Works (long-range projects) and Rolls-Royce, and worked with other stakeholders too, including regulators, airline and airport operators and even public pressure groups.

The list of partners is very impressive, originating from all parts of the civil aerospace and aviation industry, including: British Airways, BAA, Boeing, the Civil Aviation Authority, Cranfield University, DHL, EasyJet, Eurocontrol, HACAN Clearskies, Lochard, London Luton Airport, Lufthansa Cargo, Marshall of Cambridge Aerospace, National Air Traffic Services, Nottingham East Midlands Airport, the Royal Aeronautical Society, Rolls-Royce and Brüel & Kjær.

By embracing this wide community of interests, the SAI sought to produce a concept design optimised around a very different set of parameters to the industry norm (social, operations, manufacturing, etc.), which was both more complete and more radical than alternative N2 concepts being pursued by other leading research groups and even by the long-range research groups within partner companies.

The trust engendered between the academics and industrialists is reflected in the latters willingness to provide the team with access to design codes. For example, the team was able to make use of Rolls-Royce design codes in modelling fundamental redesigns of the elements of the engine that contribute most to noise. Similarly, Boeing allowed MIT to use its advanced design optimisation software to consider aerodynamic, structural, stability, control, and mission performance factors. Noise prediction models were added to this, as was on-demand advice and consultancy support from senior engineers at Boeing and Rolls. In addition to accessing industry codes and simulation tools, the close interaction with the two leading industry partners meant the team had unparalleled access to some of the world's very best engineers and design knowledge acquired over many decades.

The big manufactuers were not the only active contributors. London Luton Airport has made a long-term commitment to the initiative, and an Airport team led by Airfield Environment Manager Neil Thompson assisted the CMI team in a variety of practical ways, allowing data acquistion vital for the development of the next generations of low noise emission passenger aircraft.

The collaborative model has echoes in the Integrated Product Development Teams in use across the aerospace industry, and in many other sectors too, and essentially sought to promulgate this kind of team based, integrative, multi-disciplinary approach within a research environment. The experience underlined the need for a pretty fundamental overhaul of established research norms, and in particular the development and implementation of certain new values, new coordination structures, new procedures, new tools, etc.

The collaboration demanded high leves of interaction. Frequent telephone and email exchanges were anchored by weekly video conferences and at several stages during the course of the project key decisions were dealt with through ad hoc task forces, which involved week-long team sessions involving people from all relevant discisplines on both sides in the deliberation of major questions such as "should the engines be podded or embedded," where the former offered greater intrinsic fuel efficiency while the latter offered much improved noise performance. The constant movement of personnel, with medium term exchanges, proved vital to working relationships and team development, while helping to dispel the 'them and us' perspectives common to other joint projects.

The SAI is widely regarded to have been the most successful of the KICs in terms of its embracing of the ideas of collaboration and integration and the subsequent wider use of these lessons regarding large-scale, multilateral collaborative working.

The project outputs

The most obvious project output was the achievement of an independently verified, credible conceptual design that met its objectives with respect to noise (and fuel efficiency). For the concept aircraft, 'community' noise levels are estimated not to exceed 63 dBA, which is comparable with noise levels found in urban daytime environments. Fuel burn is estimated to improve by 23% (passenger miles per gallon), as compared with the Boeing 777 reference figure.

The project has progressed the understanding of the fundamentals of noise reduction and defined development trajectories for a long list of enabling technologies, from airframe centrebody design to faired undercarriage to variable exhaust nozzles (on ultra-high bypass ratio engines).

An enhanced form of Continuous Descent Approaches was designed too, thereby significantly reducing the noise generated by aircraft.

Based on the work in the project, one patent has been filed in the UK, by Rolls-Royce plc. The patent entitled aircraft propulsion arrangement, where the exhaust nozzle is designed to have a variable area to facilitate optimal performance at take-off, cruise and landing. The exhaust area can be greatly increased on approach thereby permitting lower fan speed and lower exhaust velocity which reduces rearward fan noise and airframe drag.

The project outcomes

The project sought to develop a radical design concept and as such did not set out to develop methodologies, tools or technologies that would be likely to be picked up and commercialised directly, at least not in the years immediately following the end of the project. However, several of the enabling technologies do appear to have caught the interest of manufacturers, and in particular the trailing edge brushes, the faired undercarriage and the variable area exhaust nozzle.

The continuous descent approach is being used by airlines like Easyjet and Lufthansa cargo and is resulting in fuel savings in addition to noise reduction, and this is also being trialled at Nottingham airport.

The research groups have also benefited. The Cambridge team has continued its work on noise through two EPSRC-funded projects. The first with £180,000 funding, led to the development of computationally efficient calculations of the noise made by helicopter blades moving at high subsonic speeds. It involved developing innovative but simple computer-based models that can provide a better understanding of how noise is produced during flight. The second project, with £171,000 funding, aimed to develop a prediction capability for jet noise which can be used, for instance, to assess how incorporating serrations or other modifications into jet engines can reduce jet noise at take-off. Achieving this will involve developing a computer model capable of predicting jet noise, improving understanding of noise source mechanisms, and identifying potential ways of modifying these mechanisms.

Additionally, Cambridge has secured a £300,000 grant from EPSRC on a fan system for a boundary layer ingesting engine and has an MIT collaboration included. Rolls-Royce is also involved in a project on fan distortion interaction and has funded a PhD student for the same.

Aspects of SAI continue in the Aviation Integrated Modelling project ('Highly modular systems model for integrated assessment of aircraft emissions', EPSRC EP/D060001/1 funding £763,405) where the Technology Module has built on understanding from Silent Aircraft Initiative and SAX-40 is being considered as a possible future technology option for fleet characteristics into the future.

The Energy Efficient Cities project, lead by Professor Dowling has £2,862,119 of EPSRC funding. This project aims to address energy demand reduction in the urban environment, by integrating design and the development of novel technologies for energy efficient cities, with links to economic, policy and regulatory considerations. A feature of the project and a statement in the proposal was Professor Dowling's previous experience of managing the Silent Aircraft Initiative. The SAI process is equally appropriate in this initiative, including a structure of regular meetings to link the specialised areas (transport, buildings and de-centralised power generation) into an integrated energy efficient city.

There has also been further work through several of the Cambridge masters programmes, including ‘the Green Aircraft project (a final year MEng group project and one self-funded PhD student), two Silent Aircraft Masters Projects and four MEng projects around the theme of silent aircraft technology and future propulsion.

The MIT team has deepened its commitment to this integrated model and has launched a series of new projects in the two years following the end of the CMI project. These new projects encapsulate the core values of the SAI project; the grand challenge (very big projects), the system perspective and the commitment to open collaborative working across disciplines and functional specialisms. For example, in 2008, MIT secured a major concept design project for an N+3 subsonic transport aircraft for the NASA Fundamental Aeronautics Program, which involved Boeing, Pratt and Whitney and several other US aerospace businesses. The credibility, experiences and achievements of the SAI project are reported to have been critical to MIT’s success in winning the contract against strong opposition.

Other MIT work includes a project to develop a methodology for inlet distortion noise and multiple-pure tone noise in highly integrated propulsion systems. The work is funded by NASA Langley Research Center, with a $0.5M 3-year award.

Lastly, the SAI has left both groups with a lasting positive impression of the benefits of interdisciplinary collaboration, and in particular:

- An appreciation of cross-disciplinary challenges, including a willingness by experts in a given field to address the intellectual, technical and organisational issues inherent in research that spans several disciplines outside that field
- A willingness to accept and even embrace the potential value of ideas and questions posed by people located outside one’s particular research group or field of study
- A realisation that while successful collaboration demand substantial effort and additional cost, there can be major scientific and commercial benefits that far outweigh the cost of this ‘overhead’

Appendix E Compendium of CMI case studies (non-research)

E.1 The Education for High Growth Innovation (EHGI) project

The CMI project
The CMI Education for High Growth Innovation (EHGI) project was a £40K education project that ran for two years between January 2004 and February 2006, and which set out to study the influence of university education on the motivation and capability of undergraduates to engage in entrepreneurial behaviour, both in the narrow sense of starting new enterprises, and in the broader sense of leading innovation in existing companies:

- Use a novel education evaluation methodology to evaluate distinct entrepreneur courses as a means by which to refine the methodology and condense critical success factors for entrepreneurial education in general
- Feedback strengths and weaknesses to the convenors of the evaluated courses
- Disseminate the methodology and insights amongst UK HE institutions

The EHGI project team established the EHGI Group, which was intended to be an open group of researchers with an interest in entrepreneurship education that would exist beyond the life of the CMI project, to both pursue the continued use and refinement of the evaluation methodology and the wider promotion of both the tool and the pedagogic insight deriving from its use.

The CMI added value
The project involved the acquisition and adaptation of an MIT evaluation methodology, which comprised a novel data collection strategy with a pre and post design and a third review point some 6 months after a course had been run. The evaluation also deployed some novel concepts around motivation, intent, skills and self-confidence, which has confirmed the importance of designing courses to increase students' 'self-efficacy.'

The partnership
The EHGI project involved researchers from MIT and Strathclyde, as did the EHGI group at the outset.

The project results
Within the life of the project, the evaluation methodology was applied to the CMI Enterprisers course and Scottish Enterprise's EDGE course:

- Insight about critical success factors with respect to entrepreneurship education, and most significant the demonstration of the importance of developing self-confidence (de-mystifying entrepreneurship) and high-quality authentic learning experiences through interaction with real entrepreneurs and business people
- Views on strengths and weaknesses of each of the evaluated courses, which were fed back to the course convenors
- The EHGI project evaluations were used as the basis for preparing a series of conference papers and various refereed journal articles
- The EHGI project team also showcased the methodology to other UK universities through a special meeting of UKSEC where educationalists from some 12 UK universities were introduced to and trained in its use

The CMI project outcomes
The EHGI project has led to a number of wider achievements and a useful legacy in the shape of robust evaluation methodology and a growing body of educational evaluations using that methodology:

- The dissemination of a robust educational evaluation methodology, which has been adopted by a range of UK educationalists and evaluators, and has since been demonstrated in evaluations of other educational courses and courses in other countries
- The creation of a development group, the EHGI group, which has continued to function through to 2008, and which has expanded its membership to entrepreneurship educationalists and evaluators at MIT and four other UK universities
- The securing of a range of research grants and evaluation commissions, which have further demonstrated the robustness of the methodology and extended the data set for comparative analysis (of operational effectiveness of entrepreneurship courses)

E.2 Enterprisers

The CMI project

The CMI Enterprisers project (first called Connections) was an education for innovation project launched in 2002 and supported through a £70K CMI grant. The project evaluated the relevance and transferability (to the UK) of the MIT LeaderShape programme, which has run each year at MIT since 1995 and has trained hundreds of undergraduate students. The programme was based on the recognition that there was a gap in the US educational system in the field of entrepreneurial skills teaching. It was developed in order to address this need and enables undergraduate students to improve their entrepreneurial skills.

The CMI added value

In the UK there were no specialised programmes in the field of entrepreneurial training in higher education at that time. The Lambert review[25] had noted the importance of equipping future students with the outlook and skills to pursue creativity and innovation. CMI purchased the rights of the LeaderShape programme, adapted the methodology and launched the new joint programme.

The collaboration

The Enterprisers courses are 4.5 days residential courses for undergraduates with the aim of developing the students' entrepreneurial skills through experimental learning - "Learning by doing". The central factor is the engagement of two or three lead facilitators, from different participating universities and businesses, who spend the whole week with the students in addition to the lecturers. Since the early days of Connections, Shai Vyakarnam from the University of Cambridge and Neal Hartman from MIT have been two of the lead facilitators and have been passionate about the programme and its success. In 2003 Andrew Mitchell joined the team as the programme manager until 2006.

After the launch of the project, the first pilot course was held in Boston in 2002. The course involved students from both MIT and the University of Cambridge in order to build an international environment, with the intention of creating a more effective learning process through the differing cultural approaches to problem solving. Based on the success of the initial course, it was decided to continue with a series of courses across the UK.

The experiences of the Boston course and feedback received led to the redesign and modification of the course in order to provide a better fit to the needs of UK students. The new curriculum kept the elements, which seemed to be appropriate and effective while placing more emphasis on the entrepreneurship aspect and involving more students from various UK universities with different disciplinary backgrounds. After the initial course in the US, an additional four more courses were run using CMI funding (until it reached its original end point, in 2005), involving students and facilitators from five different universities in the UK.

Project outputs

The week-long courses provide learning opportunities for undergraduate students with the help of two lead facilitators and lecturers. All of the facilitators are volunteers without any financial reward. The course has also benefited from the contribution of facilitators from the entrepreneurial sector, mainly from SMEs. The commitment and effort given by the participating facilitators creates a key strength of the course but at the same time can be the main problem in as much as the facilitators have to be enthusiastic and talented in order to motivate and inspire the students and it can be difficult to find volunteers who are able and willing to take on this role.

[25] Lambert Review of Business-University Collaboration, December 2003

The course is a vehicle for entrepreneurial skills development, with the goal being that the students leave the course motivated and inspired. The course curriculum is concentrated around the following modules:

- Self management - how to find and assess personal values, including issues around how to value yourself and learning about cultural differences
- Team building – the values of networking and working in a team
- Identifying your idea – the importance of identifying needs and learning about creativity when developing a new idea

The structure and content of the course has been developed and modified through feedback and in relation to the changing requirements of the project sponsors. This has resulted in a continuous improvement in the programme quality. Throughout the changes, the focus of the course remains the same: to unleash the creativity of the students and endow them with entrepreneurial spirit. The courses are designed to provide the participating students with the opportunity to:

- To learn about entrepreneurship in the broadest sense
- To become inspired, to engage in more entrepreneurial behaviour
- To develop successful entrepreneurial attitudes and skills

During the course the students create a close community through networking which they are encouraged to build and use. The factors that make the programme successful include:

- The enthusiasm of the contributors, which creates a special atmosphere throughout the course
- The dedicated people who devote their time and energy to the programme
- The new method used, which applies the "Learning by doing" method instead of the regular way of training, for example listening to presentations

The course is designed to focus on long-term impacts, on the contribution of a cultural change through pushing the current generation towards a more entrepreneurial approach. There has been an assessment of the programme by another CMI funded project, the Education for High Growth Innovation Group (EHGI Group), however the assessment was focused on the programme's effects on the individuals rather than the programme itself.

Project outcomes

This novel idea of entrepreneurial teaching contributed to the development of enterprise education across the UK. From the outset, the Enterprisers team managed to engage other universities in the UK, which was the key motive in spreading the idea of the more entrepreneurial focused teaching throughout the UK. The developed course materials (as a product) were available for CMI to share with other universities as appropriate.

While the project received only a small fraction of CMI funding, it is one of the few education projects, which became self-sustaining as the project team was successful in attracting a broad range of sponsors when the CMI funding ended. That was the time when the Connections name disappeared and the more expressive 'Enterprisers' came into force.

The main funding organisations include regional development agencies and research councils (the ESRC has been the key sponsor of the course since 2006), in addition to financial support provided by private companies. The content of the programme has been modified in line with the different sponsor's requirements. For example, in 2008, due mainly to the ESRC sponsorship, Enterprisers is focusing on PhD students with a social science background. The facilitators on each course include predominantly social scientists in addition to 20-25 entrepreneurs. The fourth course run under support from the ESRC will be held in January 2009.

Since the launch of the programme, more than 800 students have participated in the courses with contributions from 150 different facilitators. Altogether, there are around 45 new entrepreneurial ventures launched by participating students since the start of the programme.

The benefits of the course are twofold:

- Entrepreneurial skill development: participating students go through a journey, which helps them to improve their entrepreneurial skills
- Community building aspect: the participants belong to the community they built during the course. The networking enhances the opportunities of the students on the one hand to be employed, to sell themselves or their idea, while on the other hand it is a good opportunity for the facilitators and the entrepreneurs to find their future employees
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The course provides such motivation and inspiration that some of the participating students express their intention to become a facilitator in the next course.

There are other courses throughout the UK that offer entrepreneurial learning opportunities similar to the Enterprisers course, with some even using its methodology. These courses include among others; the CMI funded MEETS programme which focuses on the entrepreneurial education of mid-career women; the EDGE programme launched by Scottish Enterprise which provides an eight-week entrepreneurial learning process for under graduate students including a six week placement at a company, or the Intraprisers launched by the University of Cambridge which adopted the idea of the Enterprisers course however with the training taking place within a multinational company.

E.3 Electricity Policy Research Group

The CMI project

The £0.75 million Electricity Policy project was funded by CMI and ran for three years in the period between 2002 and 2005. The project was intended to facilitate interaction and knowledge exchange between the researchers at the MIT Center for Environmental and Energy Policy Research (CEEPR) and the University of Cambridge in the field of energy policy research.

The CMI added value

CEEPR has been carrying out research in the field of energy economics since the mid 1970s, successfully maintaining close links to decision makers in both government and industry. The CMI grant was seen as an opportunity for Cambridge to learn from and possibly even adopt the US model, and ultimately to explore and make plans for a new Electricity Policy Research Group at Cambridge.

The collaboration

The CMI grant allowed the two centres to form an international research group, which was coordinated through joint meetings every six-months and led to a number of joint research projects, researcher exchanges and joint presentations at international conferences.

The project outputs

The applied researcher exchanges maximised the effectiveness of the joint research, which included researcher and teacher exchanges for whole semesters in addition to short-term exchanges including PhD thesis committee exchange and participation in each other's workshops, seminars or jointly held workshops. An institution-building partnership from the Cambridge side, including the adaptation of new methodologies, enhanced relationships and industrial contact exchange in addition to the access to new partners in the field of electricity supply regulation.

During the 3-year project, an international network of leading US, UK, Japanese and European academics was built up. The international network successfully consolidated and augmented knowledge in the field of electricity market regulation and liberalisation covering a broad range of issues such as security of supply, competition and emission trading or pricing behaviour. The CMI-funded group encouraged the active participation of industry, regulators and policy makers to share the research results with them already at early stages, to be able to fit and refine the direction of the research according to user's perspective and interest. The organised research seminars, conferences and workshops provided the key fora for these activities. Through their activities they managed to establish excellent relationships with European regulators and policy makers. The project resulted in a published working paper series, publications in distinct issues, mostly focused on regulatory research in the field of electricity policy and gas markets and a broad range of dissemination activities such as presentations in national and international conferences. The project was beneficial for all of the participants either in the UK or in the US. It intensified the research partnership through the time spent together and the work carried out in collaboration. The Cambridge partners participated in two workshops organised by MIT each year and vice versa. The Group members presented jointly the research results of the collaborative work at distinct international fora.

Following the three years funding period by CMI, Electricity Policy Forum (EPF) arose from the Electricity Project. The Forum was established to further develop the adopted CEEPR model, with the engagement of industrial partners in the activities of the research group. The model has been already introduced in the US and has obtained industrial sponsors for energy policy research activities.

Project outcomes

The Electricity Policy Research Group (EPRG) as it is now known is a newly formed research centre, based at the University of Cambridge. The Research Group grew out of previous research work, the

CMI Electricity Project and the international expert network that the CMI project helped to create (with an additional £0.15 million investment). Launched in 2005, the aim of EPRG was to coordinate the network of research expertise together with its membership division, the Electricity Policy Forum.

Due to the achievements and improvements resulting from the CMI funded projects, new government research funding became available for the Electricity Policy Research Group. Research grants include an ESRC grant from 2005 with £2.1 million over five years, from the joint Research Councils' initiative, 'Towards a Sustainable Energy Economy which represents the core research activity of the Group at present, in addition to other smaller national grants. Furthermore through the established network, the Group members jointly participate in research projects funded by the European Framework Programmes. Since its establishment, the Group has been growing continuously. Currently it comprises of more than 20 researchers and PhD students at the University of Cambridge in addition to international associate researchers for example from the UK, Germany, the US, France, Spain or Belgium. As such, EPRG represents a focal point for applied interdisciplinary research in the field of the electricity policy research.

E.4 Praxis technology transfer training

The CMI project
The Praxis Technology Transfer Training Programme began as a CMI education for innovation project, and secured around £0.5 million to develop and implement two linked courses designed for TT practitioners.

The project arose from a gap in the market identified by CMI, prompted by the expressed opinions of several influential commentators and other interested parties. The Ninth Report on Finance for Small Firms, published by the Bank of England in 2002, suggested university 'technology transfer offices lack[ed] the necessary experience and expertise and that there need[ed] to be an increase in resources available to these offices.' This sentiment was echoed by members of the National Competitiveness Network and by staff involved in exchanges between the MIT and University of Cambridge Technology Transfer Offices.

The CMI added value
CMI wished to finance the development of a training programme to address the training gap and its initial concept was to fund established professional associations from the UK to develop and deliver a specialised training course. UNICO and AURIL were both active in the field, however organisational rivalries got in the way, so CMI decided to commission MIT's Technology Licensing Office and the Research Service Division of the University of Cambridge to develop a new training programme for UK university technology transfer personnel. A proposal to launch the Praxis training programme was put forward by Lita Nelsen at MIT and David Secher at the University of Cambridge (Director of Research Services at the time). Lita Nelsen has long experience in the field of technology transfer; as well being Director of the Technology Licensing Office at MIT she is a former president of the Association of University Technology Managers (AUTM) in the USA.

The new training programme was to be based on the technology transfer courses run by AUTM in the USA, however instead of simply franchising the US model the co-founders developed new training material tailored to UK needs.

The CMI partnership
With financial support from CMI and the participation of volunteer lecturers, the Praxis training programme was launched in 2002 offering a range of courses specially developed for UK university technology transfer personnel.

The courses covered all aspects of university technology transfer activities. The curriculum contained not only intellectual property protection issues but also negotiation techniques for licence deals, topics on effective management of the university-industry relationships plus lectures on the role of the university technology transfer personnel in the commercialisation process and the role of venture capital.

The curriculum was adapted and developed by a volunteer committee made up of experts from universities, industry and government. Two key courses were developed: The Fundamentals of Technology Transfer and Creating Spin-outs.

The project outputs
Initially Praxis ran at least four courses each year, which took place at venues throughout the UK. The training courses helped to equip tens of university technology transfer personnel with the necessary skills to be able to support the process of translating the results of university research into products and services in an efficient and effective way.

The main features of the Praxis courses were (and still are):

- The informal style of presentation
- The active participation and interaction between the participants
- The mixture of seminar-style talks and smaller group activities, with feedback sessions

The content of the courses was improved course by course as the Praxis team incorporated the feedback from participants. This process of learning and evolution has been crucial to ensuring the courses continued to meet the changing needs of the market addressed. In addition to delivering the training courses, Praxis intends to develop best practice guidelines for technology transfer activities in the UK, based on the experience gained.

The project outcome
It was a requirement of CMI from the outset, as well the intention of the co-founders, that Praxis should become self-sustainable, beyond the CMI funding period.

In 2003, Praxis won a 12-month £0.35M DTI contract to deliver TT training to all UK HEIs, working in partnership with the Universities Companies Association (UNICO) and the Association of University Research & Industry Links (AURIL). The DTI contract required the Praxis-led partnership to expand its training delivery capacity, and provided the partners working capital to set up a dedicated office and staff. The contract provided the team with the momentum to continue to market its services and deliver training courses in the 18 months after CMI funding came to an end.

The experience and success of the DTI contract encouraged the team to consider forming a new company that would be dedicated to professional training in the IP and knowledge transfer space. Praxis Courses Limited was established in 2004, becoming the first spin-out company of CMI.

The collaboration with UNICO provided the basis for a longer-term strategic relationship, and in 2005 Praxis and UNICO entered into a formal alliance, which aimed to improve the quality of their services by sharing the administrative burden of organising conferences and training courses.

Praxis operates as a not-for-profit company and offers its training courses on a commercial basis. It has been successful in drawing in further sponsorship from a number of sources, including the English Regional Development Agencies, which have enabled it to enhance its scope of activities and to provide its services across large parts of the UK.

Further sponsorship has come from: the London Development Agency's Opportunities Fund; the Mercia Institute of Enterprise at the University of Warwick; One North East; Scottish Enterprise; Advantage West Midlands; BTG; Wales Spinout Programme; Invest Northern Ireland; Enterprise Ireland and HEFCE.

In addition to offering its established courses (The Fundamentals of Technology Transfer and Creating Spin-outs), Praxis has added several new courses to its portfolio, covering new topics in some cases and more advanced material in others, including: Advanced Licensing Skills; Market-based Strategy for Technology Transfer; Advanced Patents and Business Development. Key success factors included:

- A clear and strong market demand and the accurate identification of the target market i.e. university technology transfer personnel
- Early engagement of other universities across the UK. The first three courses were held in Bristol, Manchester and Newcastle with the intention of demonstrating that this was a training programme available throughout the UK and not a training course exclusively for the University of Cambridge
- The involvement of very-experienced TT professionals as volunteer trainers who were keen to share their knowledge with younger technology transfer personnel

- Post CMI, UNICO administrative support enabled Praxis to reduce costs and offer their courses at lower prices without sacrificing quality. Lower fees have meant larger numbers of technology transfer staff are attending courses

Since the establishment of Praxis as an independent company, more than 1,200 people from 100 universities have participated in its courses.

Praxis has earned a good reputation in the field of technology transfer training and was mentioned, for example, in the Sainsbury Review of Science and Innovation[26]. Furthermore, one of the most important benefits of the training courses is the contribution they have made to community building amongst technology transfer staff across the UK.

The development of social capital has occurred in two ways:

- Through delegates participating in courses. They not only gain new knowledge and skills, but also develop new relationships with their peers with whom they can keep in touch and share their experiences and discuss problems informally on an ad hoc basis. Lita Nelson has suggested that her links with the women directors of the TT offices at Harvard and Stanford have been maintained over many years, and that these exchanges have been hugely valuable to them individually and severally, and have prompted numerous instances where new principles or policies have been codified, which has come to benefit the entire community of technology transfer professionals in the US (and further afield)
- Through the pool of volunteer experienced teachers and programme planners. Although they receive no financial reward, Praxis has consciously sought to create a sense of belonging through regular social events and more general communication. In this way, the staff, volunteers and delegates have become part of a Praxis community

From the early stages of the project, Praxis received many requests to run their courses overseas. However the CMI and DTI grants required the delivery team to concentrate on the UK. With the establishment of Praxis as an independent company, the team was able to take advantage of an invitation from the Association of European Science and Technology Transfer Professionals (ASTP). In each of the four years since it was set up in 2004, Praxis has delivered one course a year outside the UK, in collaboration with the ASTP. Such has been the success of the courses that, from 2008, Praxis and ASTP plan to organise two non-UK courses each year. Courses have been delivered in Austria, Ireland and Denmark and the organisers are considering expanding their activities further afield.

[26] The Race to the Top, A Review of Government's Science and Innovation Policies, Lord Sainsbury of Turville, October 2007, Page 152.

First published May 2009
Department for Innovation, Universities and Skills www.dius.gov.uk
URN 221-09-HE-ON