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# An analysis of research activity in major UK cancer centres

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ABSTRACT

The organisation of cancer research is critical to its overall creativity and productivity. Cancer centres are a major organisational structure for this research, however, little is known about their effect on research or how national policy-making intersects with this complex policy nexus. This study of the evolution of United Kingdom cancer centres (UKCC), part of a wider European and United States programme, uses a bibliometric analysis of research activity prior to the creation of the NCRI and after its formation (1995–2004/5). In terms of critical research mass UKCC are very heterogeneous with a fourfold difference between the top and bottom quintiles. UK centres published just over one eighth of the total UKCC in 1995 but almost a quarter by 2004. This centrification occurred in the absence of any national strategy. Overall these centres conduct more fundamental (laboratory-based) research than that being conducted in the wider network but this hides major heterogeneity. UKCC collaborate with European investigators in 5–28% of all their outputs and with USA the range is between 6% and 21%. We have also derived new measures of research impact on clinical management and the general public as well as the impact of national policy on research assessment for certain types of cancer research.



## 1. Introduction

The organisation of cancer research into centres is one of the key determinants of progress and future impact on patient outcomes. The shape of the national cancer research base is to a great extent influenced by these centres.[1,2] An objective understanding of how and what research is actually being conducted, rather than *ad hoc* opinions, is essential for both the strategic direction of the centres and national/supra-national planning. Indeed, with the development of cancer centre strategies by national funders as well as the OECI-led European accreditation scheme for such centres, there are pressing needs for high quality strategic intelligence.[3]

Cancer research is one of the most heavily funded and active research areas of science.[4] Its trajectory over the last 50 years has been driven by the biological revolution and in almost every developed country it has been the subject of specific federal mandates. The organisation of this research activity through centres and networks has been vast. However, despite expenditures estimated to be in the hundreds of billions of dollars and vast human capital costs, little empirical work has been conducted to understand the various types and systems of cancer centre organisation and its impact on research. Whilst the United States has the most evolved organisation of cancer centres Europe is rapidly catching up, although with a very different approach. The

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USA cancer centres model has developed through a top-down Pultizer's 'iron triangle' approach whereas Europe with its predominantly social healthcare has seen a more bottom-up trajectory.[5] Across the EU-27, the development of cancer centres and research has been very variable with multiple factors at work. Certain countries such as the United Kingdom have in the last decade rapidly driven cancer research as a major national priority. *De facto* UK cancer centres have been at the forefront of these developments. Indeed the UK in terms of per capita and/or as a percentage of GDP is now the most heavily funded country for cancer research in Europe. The UK thus provides an ideal opportunity using objective well-validated approaches, such as in this case scientometrics,[6] to study research activity within the context of centres and relate this to evidence- based policy-making. The same methodologies that have been used to study the impact of cancer research on public knowledge (media)[7] and clinical practice (through cancer clinical guidelines)[8] can also be used to objectively study the state and evolution of research within major cancer centres. Furthermore, the well-documented socio-cultural and socio-political changes to the UK cancer research community provide a well documented policy context.

In this paper, we seek to understand how cancer research actually maps to major centres and how this relates more broadly to policy-making both within and outside the domain of cancer. Furthermore, we seek to understand whether cancer research is self-organising and whether it is really in need of hierarchial strategies; how centres develop research themes, and whether these are divergent or convergent processes. And lastly what strategies should centres and national/supra-national organisations take to drive creativity in cancer research and innovation in technology. The centres studied are all the top research output locations in the UK (note: many additional centres have high service volumes but very low research activities) and the time period (1995–2004) reflects a balance between activity in the pre-NCRI period (up to 2000/01) and activity in the post NCRI period.

## 2. Methodology

### 2.1. Outputs

Papers were selected from the *Science Citation Index* (SCI), CD-ROM version, for publication years 1995–2004; only articles and reviews were included. Papers were selected on the basis of both the names of the individual researchers associated with each of the research institutions and the name of the institution or its city. Due account was taken of the tendency of some researchers to use more than one set of initials. Some of the address terms were very simple – just the name of the city, sometimes with the requirement for the city to be in England so as to exclude some US and Canadian papers – and some were quite complex in order to distinguish the various London centres. The total tally of papers was 5192 but this included some duplicates where two (or more) centres had collaborated. The total of unique papers was 5048. Of the total tally, 395 papers were reviews (7.6%); this is a similar percentage to that of reviews in cancer papers globally (7.5% in 2004)[9]; Fig. 10).

### 2.2. Research level

This is a measure of the degree that a research paper (output) is 'basic' or 'clinical'. The research level of a group of biomedical research papers can be measured in two ways: by reference to the journals in which they have been published and by reference to the presence of 'clinical' or 'basic' words in the titles of the individual papers. The allocation of journals to research level was performed on the basis of such words in all the papers that they published that had a biomedical address term. Clinical journals were categorised as RL $j = 1$ and basic research journals as RL $j = 4$, by analogy with the system previously developed by CHI Research Inc.[10] The research level of groups of papers can also be calculated independently of the journals in which they are published. Papers with a clinical word in their title are counted as unity, the ones with a basic word as four, and the ones with both as 2.5. The total is then divided by the number of papers so classified (typically about 70% of the total) to give a value for RL $p$, which is also a number between 1 and 4, usually close to, but not the same as, RL $j$. This is because some institutions and researchers publish either more clinical or more basic papers than the average for the journals that they have chosen.

### 2.3. Potential and actual citation impact

Potential citation impact was defined as the expected number of citations to be received by a paper, on the assumption that it is cited with the average frequency for papers in that journal (and year). A 5-year citation window has been used, i.e. the year of publication and four subsequent years. This time-span is a compromise between the need to allow citations to peak (typically in the second or third year after publication) and the need to have recent data. Each journal has a Potential Citation Impact (PCI) value, based on a file provided originally to The City University by Thomson Scientific. Each paper was characterised by its PCI, with a very few exceptions (papers in new journals for which 5-year citation scores were not available). For each institution and individual researcher, the mean value of PCI was determined. This value can be compared with the mean for the whole set of papers and also with the mean PCI for all cancer research papers from the UK and from the world output. These papers were extracted from the SCI because they were published in cancer journals or had a cancer title word (or both). The ONCOL 'filter' was developed and has a precision (specificity) of 95% and a recall (sensitivity) of 90%.

In order to evaluate the ACI for the papers from UK Clinical Centres and their researchers, it would theoretically be necessary to determine citation scores for the world cancer papers for 1995–2004. Since there are over 200,000 papers in this set, it is not practical with limited resources to count citations to all of them, and we need to take samples. There are two ways in which samples may be taken: purely randomised or structured based on selection of every $n$th paper when they are ordered in some appropriate way, such as descending ACI values. For simplicity, a random sample of 1000 papers from year 1998 were chosen, of which it turned out that there were 82 from the UK and 411 from the USA. These are close to the

numbers that would be expected, based on the respective percentage presences of 8.2% and 39.5% based on integer counts.

### 2.4. *International collaborations*

The last additional task was to measure the amount of international co-authorship for the different UK centres. This is normally measured in terms of integer counts, e.g. if a centre has published 100 papers of which 25 have one or more foreign addresses, then the international collaboration index would be 25%. This is simpler to understand than to determine the fractional count total as a percentage of the integer count total. [A paper with one address from centre A and two from another country, B, would count unity for each on an integer basis, but 0.33 and 0.67 respectively on a fractional count basis.]

## 3. Results

Whilst both UK oncology and biomedical outputs have remained relatively static over the decade of this study, outputs from major UK research active cancer centres have continued to rise similar to those of continental European centres. Their world-share of cancer research outputs has remained steady

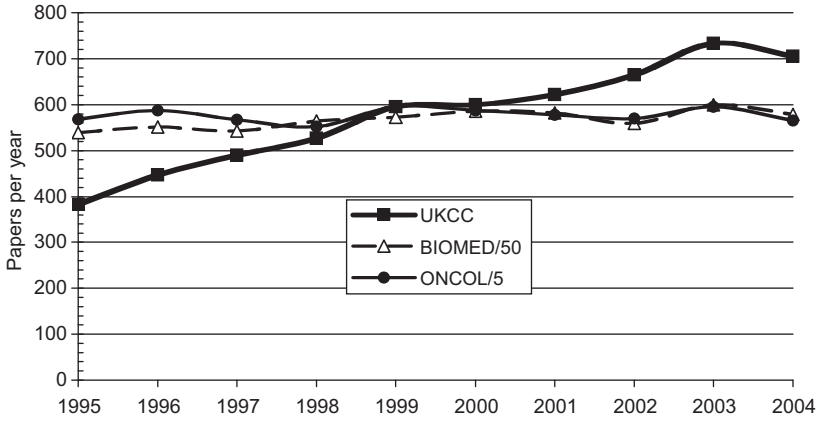


**Fig. 1 – Trends in output from all UK cancer centres (UKCC) (*n* = 20) compared to all oncology output from the UK (ONCOL) and all biomedical output from the UK (BIOMED). *Note:* ONCOL and BIOMED output have been divided by 5 and 50 respectively.**

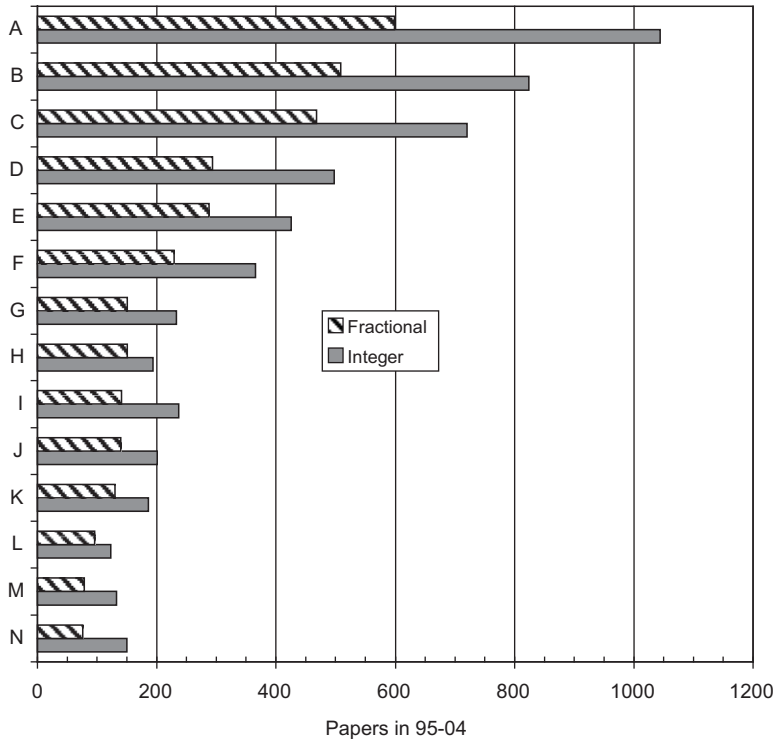


**Fig. 2 – Total cancer specific outputs of top 14 UK cancer centres (anonymised) shown as integer and fraction counts terms between 1995–2004.**

and/or declined, depending on the Member State, as a result, mostly of the competition from emerging cancer research nations in East Asia. Overall our data have shown that the 'centralisation' [what does this mean?] of cancer research is an organisational trend that has been going on for at least 12 years and has progressed independently of any 'top-down' strategic direction. UK CCC output was about a quarter of the UK total in 2004, whereas it was barely one eighth in 1995, see Fig. 1.

There is a big range in the absolute research output of centres, whether on an integer or fractional count basis. Thus there is an eight-to-one ratio between the largest and the 14th largest centres in Fig. 2. Interestingly, the correlation with designated 'academic' principal investigators and/or research income in many centres is low suggesting the input–output model is too simplistic to describe or frame such concepts of what a 'critical mass' of research really is. We have found that a major index that is needed is patient recruitment into cancer research projects (here it is essential to weigh this properly against type of research project). However, the comparable data are very hard to obtain and many centres do not report like-for-like activities. Furthermore, trial recruitment beyond first-in-man is an emergent property of networks rather than centres.

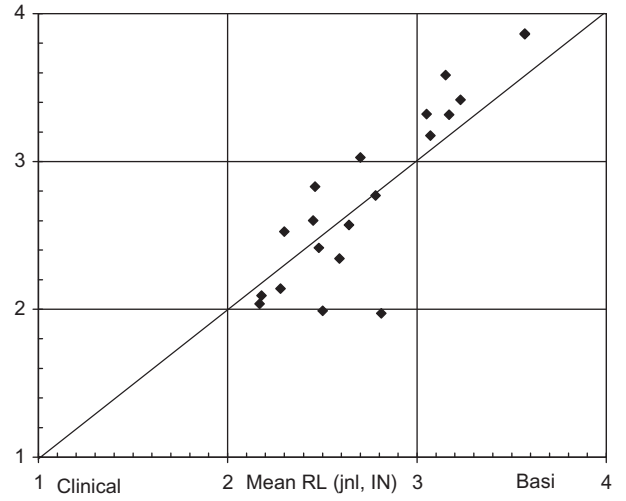


**Fig. 3 – The Research Level (RL) of outputs from individual UKCC. Comparison of RL of journals and papers.**

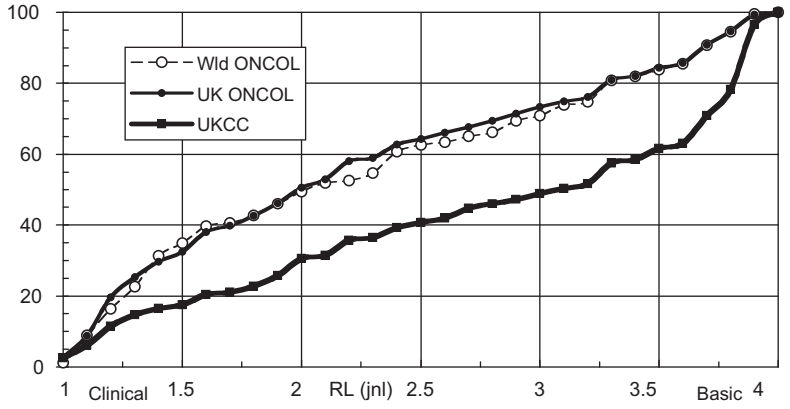


**Fig. 4 – The cumulative research level (1995–2004) aggregated for UKCC compared with overall UK oncology output (UK ONCOL) and world oncology output (Wld ONCOL).**

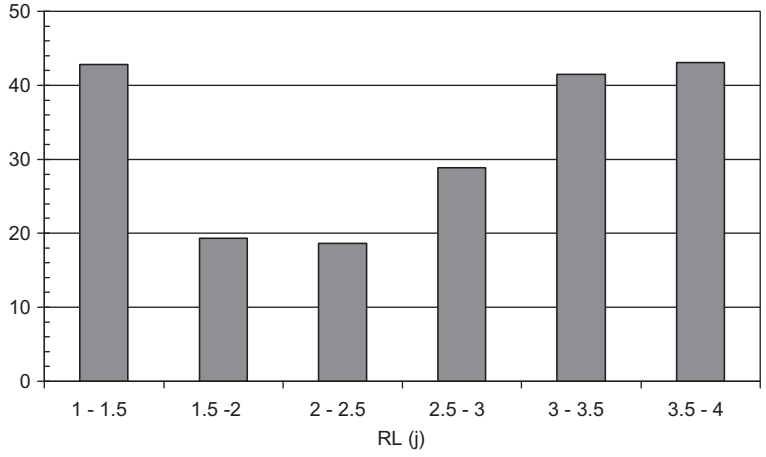


**Fig. 5 – Mean actual citation impact of publications from UK cancer centres by research level of journal of publication (1 = clinical to 4 = fundemental).**

Whilst all the UK cancer centres provide substantial clinical service delivery the focus of their research portfolios varies widely from an aggregate score that places them as predominantly concerned with fundamental cancer science to centres whose aggregate portfolio scores make them very applied. For example, the mean output of one centre at RL $j = 3.6$ corresponds to *Molecular Cancer Research* and of another, at RL $j = 2.1$, to *Anti-Cancer Drugs*, see Fig. 3.

However, in comparison to cancer research activities being conducted in the wider NHS i.e. outside the major centres, in this study the overall research levels of all the centres combined were much more orientated towards basic science, see Fig. 4. The median RL $j$ for the CCCs was 3.2 (*cf. BMC Cancer*) whereas it was RL $j = 2.0$ (*cf. Oral Oncology*) for the whole UK cancer research output.

Aggregating research outputs from all UK cancer centres, we found that those ones focused on either basic cancer biology or highly clinical research (e.g. clinical trials of regimen A versus regimen B) received the highest aggregate citations, Fig. 5. However, translational research as well as prevention and other important areas appeared to fall into a lower 'citation valley'. Although this is only one 'measure' of research quality it demonstrates the difficulty of making value judgements of research based solely on counting citations.

Furthermore, as expected, those centres with a greater emphasis in their research portfolios on basic cancer research

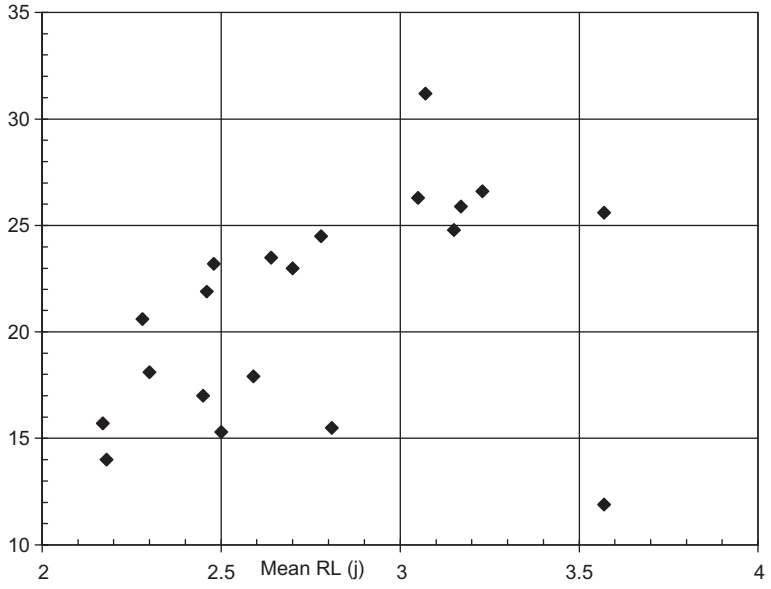


**Fig. 6 – Mean potential citation impact compared to research level: comparison of individual UK cancer centres.**

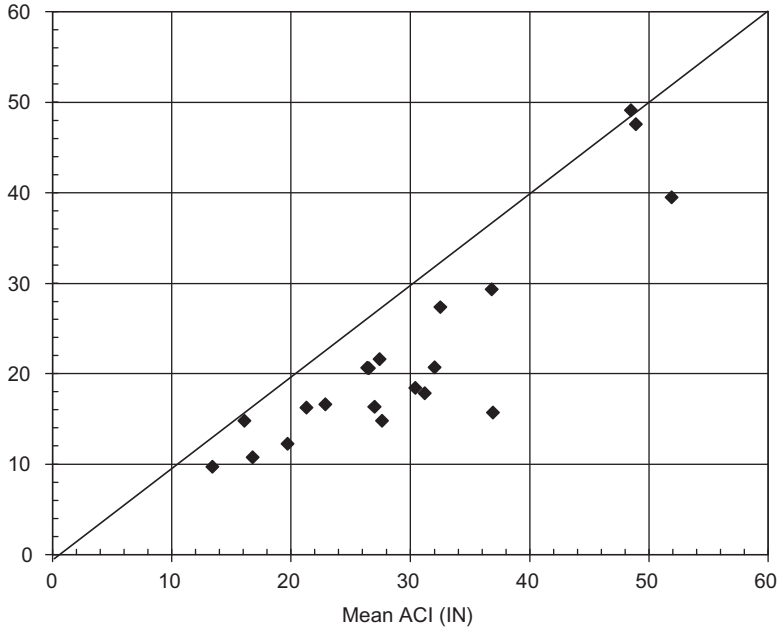


**Fig. 7 – Comparison of actual citation impact by fractional and integer outputs from individual UK cancer centres.**

do much better in terms of their potential citations (PCI) than those with a more translational/clinical focus, with one significant exception. However, there is a large range of citation impact arising from the latters' publications, from 15 to 25 citations over 5 years, see Fig. 6.

Fig. 7 shows that the centres almost all perform better on their mean ACI when it is calculated on an integer count as compared with a fractional count basis. This is because the most-cited papers tend to be the product of collaborative work, often international. There is a big variation in these ACI values, from 14 to 52 cites in 5 years on an integer basis and from 10 to 49 cites on a fractional count basis.

There are other ways of gauging a centre's impact. One such approach is the use of esteem markers. This is the first of the non-conventional indicators of the centres' 'esteem' and it uses the percentage of reviews (PR) as a surrogate marker for the number and hierarchical ranking of the centres' principal investigators (essentially a judgement of 'reputa-

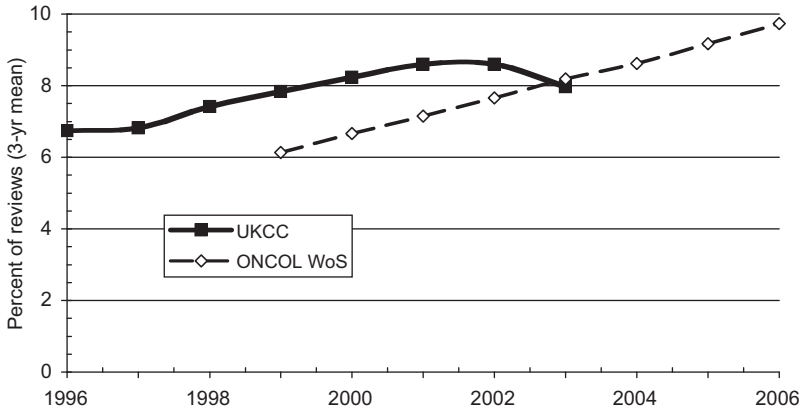


**Fig. 8 – Percentage of cancer research review articles from UK cancer centres compared to overall world output.**

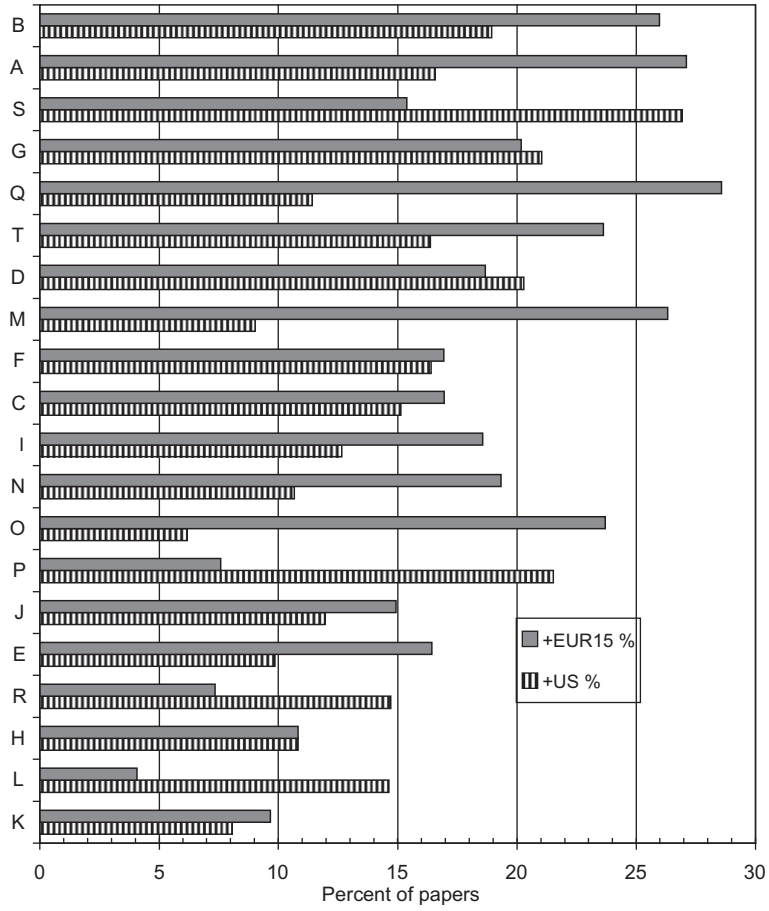


**Fig. 9 – Co-authorship with European (EU-15) and USA (US) collaborators. Analysis of top individual centres (mean percentage between 1995 and 2004).**

tion', Lewison, 2009). Two trends are observed. First this percentage increases steadily with time and second, the value for UK cancer centres is mostly above the world oncology percentage, see Fig. 8.

The understanding of research relationships is another advantage of bibliometrics. There are somewhat more papers co-authored with EUR15 [i.e. the EU15, minus the UK and plus Switzerland] than with the USA but this is not so for all centres, see Fig. 9. Co-authorship with the USA shows one measure of esteem; co-authorship with the EUR15 countries is probably based on competitive EU programmes and is therefore also a useful mark of influence. Many of these collaborations are very durable and show no 'strategic' pattern, i.e. they emerge as a result of some institutional and/or research funding organisational strategy, or from personal links and contacts, often resulting from the European Commission's 'co-ordinated action' programmes.

Fig. 10 introduces two new indicators of a centre's impact, namely the percentages of their papers that are cited on a set of 43 UK cancer clinical guidelines and in stories appearing on the BBC website. These show the relative impact of the centres' research on recommended clinical practice both in England and Wales and in Scotland, and on public perceptions of cancer research, which are of increasing importance. We have found substantial variation in the propensity of papers originating from UK cancer centres to be cited on guidelines and in the media. There does not appear to be a correlation with the conventional citation impact of the papers, nor indeed with the size of the centre.

## 4. Discussion

The UK has seen major socio-political changes to the cancer funding and organisational landscape in the last 15 years. Until the late nineties service was delivered through a framework set by the Calman-Hine report.[11] Research was a networked function loosely organised through the UKCCR and funded through two charities (the Cancer Research Campaign [CRC] and the Imperial Cancer Research Fund [ICRF]) and one governmental funder (mostly Medical Research Council with some Department of Health). With the change of government in 1997 there was a radical re-structuring of the landscape both from a service perspective – the NHS Cancer Plan etc. – and from the funders with the creation of Cancer Research-UK (a merger between the ICRF and the CRC) and the formation of the National Cancer Research Institute. Although there has been no national cancer centre strategy the UK has seen the growth of cancer centres and there is evidence that the broad and substantial changes to research funding in 2000/1 helped this process along. However, what is clear is that other market forces, a sort of Adam Smith 'Invisible Hand' effect, have mostly driven the emergence and development of UK cancer centres. This cancer 'invisible hand' has also been identified in the context of the emer-

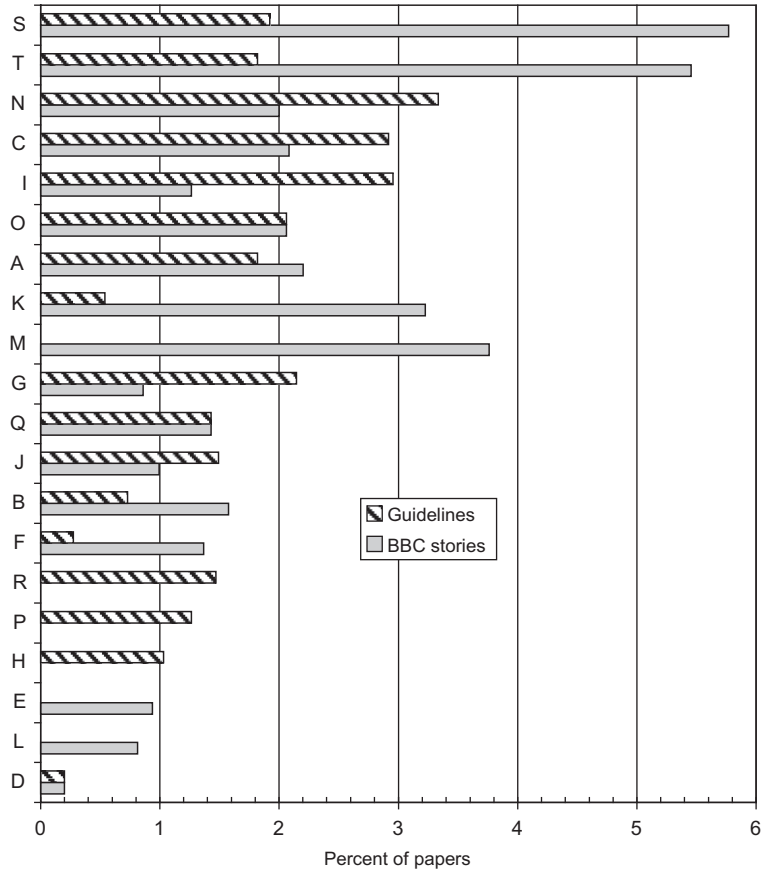


**Fig. 10 – Citation of research from individual UKCC on UK cancer clinical guidelines (Guidelines) and BBC website (BBC stories) as a percentage of overall output (1995–2004).**

gence of translational cancer research which found this science domain emerging long before any national or supranational policies.[12] What could be the drivers for the increasing centralisation of cancer research? There are likely to be several, from the economics of scale and human resources to cultural shifts in the way research *per se* is assessed and rewarded through the UK university system. It is these broader forces that appear to be the critical drivers to the organisation of cancer research.

We have found substantial diversity in both the overall levels of research activity (despite the fact that all the centres had within a 1.5 order broadly similar clinical service activity) and the types of research being conducted. Furthermore, taken as a collective the type of research activity being undertaken within centres is far more fundamental, i.e. orientated towards the basic biology end of the research spectrum. This is perhaps not surprising because of the close integration of universities and hospitals. However, it provides a warning that in order to deliver a broad national research programme that improves patient outcomes the development and support of networks are of equal importance. The recent devastating report on the state of clinical trials in the USA testifies as to what happens when there is an excessive focus on 'centres' at the expense of networks/communities.[13] The role of centres in delivering a broad research agenda also needs to be sense checked against the fact that despite what one might perceive with the over-coverage of medicines and molecules by the media, health is still social.[14] With centres mostly driven by basic cancer biology, policy-makers needs to ensure that this is balanced with complementary social and community-based research.

With an eightfold difference in their overall research outputs as well as their diverse portfolios, UK cancer centres are very heterogeneous. However, by all other measures, patient recruitment, peer-recognition etc, these are all major research, training and clinical service centres. Furthermore the trajectories (in terms of critical mass) can change rapidly depending on the emigration and immigration of academic faculty. However, what appears more resilient to change is the overall research level. This suggests that despite policy-making that focuses on specific domains, its downstream effect on the actual cancer research activity base is relatively small. Top-down national research strategies appear to make very little difference. This is not a surprise if one understands that the intellectual underpinnings of cancer research are radically different from a straightforward input–output model and that, as Daryl Chubin and colleague have articulated,[15] we are dealing with a scientific nexus that is rarely, if ever, affected by individual factors such as funding.

One of the key policy areas to affect research within cancer centres is the national approach to assessing the quality of the host institutions' science base through a research assessment framework.[16] Increasingly, bibliometrics are playing an ever larger role in this assessment.[17] However, we have found clear evidence that using 'quality' indicators such as citation impact could have detrimental effects not only on the breadth of research portfolio but also on key cancer public health domains. Cancer centres that focus more on basic biology have higher citation impact scores; furthermore, there appears to be a 'bibliometric valley of citation death' for the types of research that sit in between very applied (large scale randomised clinical trials, for example) and laboratory-based cancer sciences. Policy-making around research assessment framework could, paradoxically, work against a patient-centred research ethos by driving centres into focusing and recruiting ever more laboratory-based faculty, thus narrowing the national cancer research base. This view has been echoed previously by James Ewing who also recognised the danger of poorly thought-through policy on the breadth and depth of cancer research.[18] Descriptions of the intended impact of cancer research are an increasingly important component of funding applications. They are also essential for helping the public understand how charitable donations and tax spent on cancer research actually improve cancer control. Frameworks that incorporate policy, service (health and inter-sectoral) and socio-economic impacts are already being developed,[19] although their use by cancer centres is still in the early stages.

We have found that bibliometrics can and should be used to address some of these other areas, for example reviews in journals as a simple measure of research esteem[20] and as an objective measure of the centres' research impact on the mass media[7] and national clinical management (as measured by citations on cancer clinical guidelines.[8] As a group, UK cancer centres have a high global impact both in terms of their 'esteem measure' (high percentage of reviews) and the percentage of their papers cited on UK cancer clinical guidelines and media. In the latter case these surrogate measures of societal impact will become more important as institutions seek to justify research funding and also use their research outputs to influence their local fundraising options.

Whilst every scientific idea is an intellectual structure, it arises within boundaries and relationships set by social tribes.[21] At their simplest level these tribes are formed into centres and into networked groups. UK cancer centres have established substantial international collaborations with both the EUR15 countries and the USA. In most centres EUR15 collaborations are the main ones but the overall level of overseas collaboration is substantial. In comparison to other areas within natural and physical sciences, the levels of international collaboration are very high for the centres, e.g. clinical medicine has around 2% of outputs as international collaborations. Whilst collaboration is the norm and most research policy-makers (and this includes strategic leaders at centres) make the assumption that international collaborations positively promote productivity and quality, studies in other domains of science have not found a linear relationship.[22] Instead such collaborations are driven by multiple factors including the need for expanding faculty, training, scientific problems that require large teams and/or specialised technology approaches, etc, and, furthermore, they are not without cost. Research into the social science of research collaboration has found that complex collaborations, particularly across national boundaries, can have substantial process and outcome costs.[23] Whilst UK cancer centres appear to increasing their international collaboration there is no guarantee that this will lead to better returns in terms of research quality, speed or cost-effectiveness. There needs to be careful consideration of the merits and disadvantages of such organisational approaches.

One of the key policy drivers of the development of cancer centres since their inception by the National Cancer Institute in 1971 was that they would provide a focus and stimulus to innovation.[24] A large body of literature exists on this topic through the prism of epistemic, geographical, organisational and empirical network studies. Whilst substantial differences in conclusions are evident, one of the key areas of commonality is the highly distributed nature of medical innovation. Studies have found innovation to be 'a complex process that unfolds unevenly in time and space. . .characterised by radical uncertainty. . . .[and is] . . . highly distributed across countries, competences and organisations'.[25] Indeed the seminal paper by Leonard Read, *I Pencil,* describing the thousands of different and completely independent technological processes and innovations that take place to create a pencil highlights the fact that no one organisational structure(s) is anything more than a piece in the jigsaw.[26] This vast corpus of data points clearly to the fact that, as Keith Pavitt articulates, 'our capacity to predict future technological applications [is] therefore abysmal'.[27] Policies that advocate more reductionist central management and choice based on foresight should thus be strongly resisted. Key to understanding the fundamental importance of cancer centres is to regard them as hubs of creativity. Free-flowing hierarchies and broadly-distributed interacting faculty appear to be key to stimulating and nurturing this creativity.[28]

A broad understanding of cancer centres based on objective measures is only the first step to a system of evidence-based policymaking that promotes and supports their development. If we think about centres as an organisational skeleton for the culture of cancer research, we need a far better understanding of what does (and what does not) work. An understanding of the cancer research organisation is essential in order to identify the factors that engender creativity, productivity and the host of other emergent properties that define success and value.

## Conflict of interest statement

None declare.

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