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Understanding the impact of public policy on cancer research: A bibliometric approach

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ABSTRACT

With global spend on cancer research from the public sector now in excess of 14 billion euro, as well as the increasing burden of disease in market economies and low-middle income countries through changing demographics (ageing and population growth) cancer is now one of the most complex and global public policy issues. Using novel bibliometrics we have sought to investigate changes in research activity (total output), relative commitment and collaborations between countries/regions with similar healthcare and population and development parameters – United Kingdom, France, Germany, Canada and Sweden – to assess the utility of this policy research approach by analysing two different cohorts (1995–1999 and 2000–2004) to study the impact of changes on research publications as a surrogate for overall research activity.

1. Introduction: assessing the impact of public policy on cancer research activity

In 1937 James Ewing asked, in a *Science* editorial, whether public interest in cancer was intelligent and was being addressed along sound lines, or whether it was largely emotional and uncritical, and, of course, he could have added politicised.[1] Some 70 years later cancer is arguably one of the most extensive biomedical research domains, spanning the whole public and private sector(s) with annual global public spend now in excess of 14 billion euros.[2] The questions James Ewing proposed thus remain as important today when funding organisations and countries struggle to fund, organise and understand the societal policies that will shape the direction and impact of cancer research.

Publications, particularly in the public sector, remain one of the most important objective measures of science activity and over the last 10 years their analysis has provided key insights into research activity and impact.[3] However, there have been few attempts to link this with work seeking to understand the conceptual frameworks by which research policy is made, and in particular the context-based,

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Table 1 – Key country indices from UNDP human development index 2007.

	GDP per capita (PPP USD) 2005	Public expenditure on health (% of GDP) 2004	Patents granted to residents (per million people)	R&D expenditure (% of GDP) 2000–2005	Researchers in R&D (per million people) 1990–2005
Canada	33,375	6.8	35	1.93	3597
Sweden	32,525	7.7	166	3.74	5416
France	30,386	8.2	155	2.16	3213
United Kingdom	33,238	7	62	1.89	2706
Germany	29,461	8.2	158	2.49	3261

decision-making.[4] The struggle between the autonomous goals of cancer research and the sponsors' desire to see demonstrable social utility finds parallels in all walks of science.[5] One of the key challenges is how to resolve this 'conflict' through the application of evidence-based policy making in cancer research (oncopolicy) to frame coherent and, ultimately, successful strategies that deploy the full range of levers – cultural, organisational and ethological. We have already successfully used bibliometrics to map out and study the dynamic nature and emergence of translational cancer research[6] and here extend this novel approach to a comparative study of nation–states.

In this study, we focused on the outputs of the United Kingdom (as its devolved regions: England, Scotland, Wales and Northern Ireland) and four other countries – France, Germany, Canada and Sweden – with broadly comparable macroeconomic indicators and healthcare systems (Table 1). Our analysis, based on two different cohorts, 1995–1999, and 2000–2004, seek to address several policy-related questions:

- How do these countries compare with each other in terms of activity and can this be related to specific public policies?
- How have a range of cancer research indicators, for example overall output, and relative commitment, changed over time and can these changes be linked to specific events?
- What has been the impact of cancer research policies in comparison to similar countries?

2. Methodology

2.1. Creation of the filter

Papers in cancer research (restricted to articles and reviews) were selected from the SCI by means of a 'filter' consisting of lists of specialist journals and title keywords. This filter, designated ONCOL, was designed by Dr. Lesley Walker, and revised by Dr. Lynne Davies, both of Cancer Research UK (formerly with the Cancer Research Campaign, CRC); it has a specificity (precision, p) of 0.95 and a sensitivity (recall, r) of 0.90, so that its calibration factor is $p/r = 1.06$. This means that the true total of cancer research papers is estimated to be 6% higher than the number retrieved from the SCI by the filter.

2.2. Categorisation of the papers

The bibliographical details of the papers were downloaded to individual Excel files, and papers from publication years other than the nominal CD-ROM year were transferred to the appropriate year file (usually because about 10% of papers from any 1 year are processed for the following year's CD-ROM). The bibliographical source was parsed and the journal name used to characterise the paper by expected citation impact factor and geography.

The research level was determined from counts of the numbers of papers in the journal with one or more of over 100 'clinical' or 'basic' words in their titles. This journal indicator has been developed recently[7] and is better than the CHI system developed back in 1976 as it is transparent, takes account of changes over time in the journal, and is a decimal number so that it can be averaged.

The citation impact factor was based on the average number of citations to papers in the journal in the year of publication and four subsequent years, designated C0-4. This indicator was calculated every 2 years, e.g. for 1996, it was the mean citation score of 1996 papers cited from 1996 through 2000. It should be noted that these values are much higher than the 'standard' journal impact factors, based on citations in 1 year to papers published in the previous 2 years. They are, however, comparable in principle with the expected numbers of citations for papers published in the journal in that year counted over that and the next 4 years.

2.3. Counting methods

There are two possible methods of counting the numbers of papers that can be attributed to a country (or other entity). One is integer counting, in which each paper is counted as unity for each entity that appears amongst the addresses, whether once or many times. The other is fractional counting, in which the numbers of addresses for a particular entity (here, Wales) is divided by the total number of addresses on the paper. Thus a paper with one address in Wales and two in France would count 0.33 for Wales and 0.67 for France. In this report, both methods were used. A case can be made for either method; there is no consensus on which is more truly representative. The world total of papers is, of course, the same on either method, so that integer count percentage presences are always higher than fractional count ones.

As was discussed in the earlier report the oncology filter, while representing satisfactorily the research that can clearly be recognised as relevant to cancer, will omit perhaps one third of the papers supported, as their titles are too general to be identified as cancer-related. This situation is common to the outputs of other disease-specific charities in the UK.

Not all of the papers in the oncology files could be characterised by their citation impact factor, as for some journals

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they had started publication too recently to have 5-year impact factors. However, even in the latest year (2004), only about 2% of the papers had no C0-4 value. These papers were ignored for the purposes of calculation of the mean values. It should be noted that more basic journals tend to have higher citation impact factors; this is one reason why the output of Scotland shows to advantage on this indicator relative to that of the UK as a whole.

2.4. *Relative commitment*

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 their titles. The allocation of journals to research level was performed. By analogy with PCI, the Actual Citation Impact (ACI) is the number of citations received by an individual paper in the 5 years following its publication, analysed on the basis of such words in all the papers that they published that had a biomedical address term, see the reference of Footnote 3. Clinical journals were categorised as RL = 1 and basic research journals as RL = 4, by analogy with the system previously developed by CHI Research Inc. However, journals in the new system have a RL that is a decimal number, not a simple category; it is usually represented to two decimal places, and is re-calculated each 5 years to allow for editorial changes.

2.5. *Potential and actual citation impact*

PCI is 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 Index, based on a file provided originally to City University by Thomson Scientific.

2.6. *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 fraction of the integer count total.

3. Results

Sweden is one of the most research active countries in the world with a high ratio of researchers and spend (as a% of GDP) in comparison to the other countries in this analysis.

Sweden also has nearly double the output per million of population in cancer research publications compared to Canada, Germany and France. Of the four UK devolved regions Scotland is the most research-productive. Germany has seen the biggest rise in outputs (nearly 20%) with small increases by both Canada and Wales (around 7%) when the two cohorts are compared. All other countries have seen marginal declines or static outputs over these two periods (Fig. 1).

Germany is also one of the most committed countries to cancer research relative to outputs in other disease-specific research areas, along with France which has a Relative Commitment of nearly unity. All other countries have low RC to cancer research and the pressure of increasing research activity in other disease-specific areas has continued to place a downward pressure on these figures. The exception has been Canada which has seen a small but significant increase in the country's RC to cancer research (Fig. 2).

The huge increase in% of reviews for Northern Ireland represents a very small sample set. Although highly active, Sweden has a noticeably low percentage of reviews in cancer research outputs, a fact that is also true for Wales, Canada, Germany and France, which have seen their figures decrease substantially. In contrast, England and Scotland produce a high percentage of reviews which they have sustained (Fig. 3).

All countries have seen a rise in their potential 5-year citation impact. Canada and Scotland are above the world mean in both quinquennia; England only in the second and all other countries are below world means, although NI has improved the most. In contrast, the actual 5-year citation impact (ACI) of all the UK regions has increased between the two periods, Canada and to a lesser extent France have decreased their ACI, and it is almost unchanged for Sweden and Germany. With the rising world ACI mean (12.7 in 1998 to 14.4 in 2003), Scotland and Canada are just above this level and England just below. The differences in these two measures reflect the impact of the journal in which the paper is published – PCI and then whether the research is actually cited by others – ACI) (Figs. 4 and 5).

Unsurprisingly, given its proximity and reciprocal flow of researchers, Canada has the highest level of collaboration with USA authors, which has increased substantially between the two quinquennia. England, Germany and France have also seen a substantial increase and to a lesser extent Sweden, although their overall levels of collaboration remain modest (around or below 15% of total activity) (Fig. 6a).

On the other hand, collaboration with EU16 countries has increased dramatically across the board over the two quinquennia. Apart from Wales and Canada approximately a fifth or more of all activity is now part of collaborative work with EU16 countries (Fig. 6b).

4. Discussion

Our previous work has focused on understanding supra-national macro-trends in funding cancer research activity[2], the move to nation-state level assessment is both novel and challenging. Quantitative methods are being used increasingly in research evaluation – at the national level, institutional level and even at individual level, though the latter application is particularly difficult. They are usually based on the numbers

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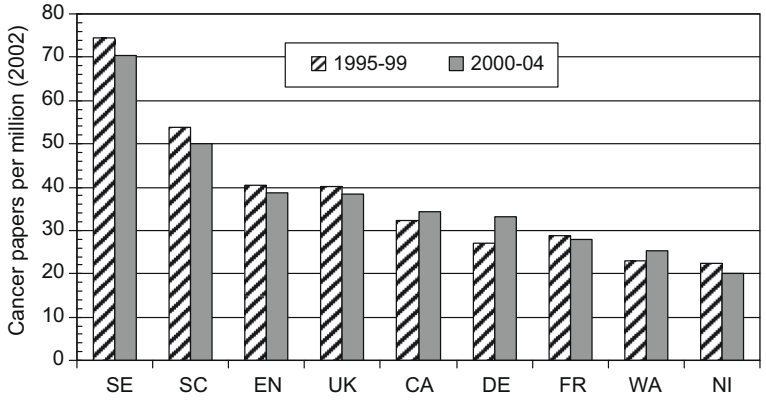

Fig. 1 – Outputs of cancer papers per million population from 1995 to 2004, fractional count basis (Key: SE = Sweden; SC = Scotland; EN = England; CA = Canada; DE = Germany; FR = France; WA = Wales and NI = Northern Ireland).

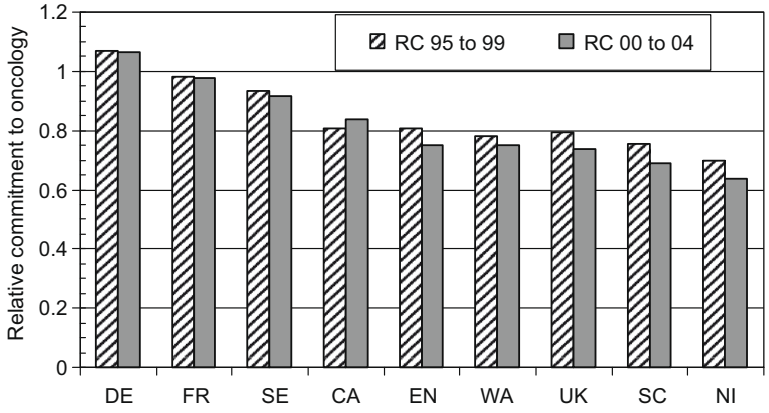

Fig. 2 – Relative commitment to cancer research (oncology) within biomedical research, 1995–2004.

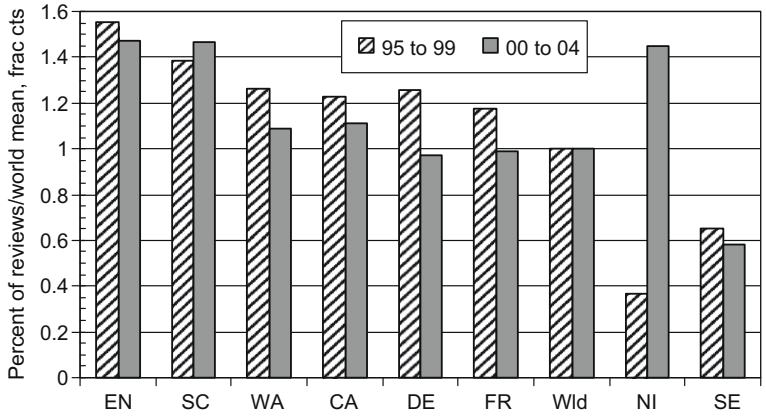

Fig. 3 – Percentage of reviews in the research outputs for cancer research in 1995–2004; relative to world mean percentages (Wld), fractional count basis.

and other parameters of papers in the peer-reviewed serial literature. This may be appropriate for many fields of science, particularly the life sciences including medicine, but not for some other areas of research, such as some branches of engineering, the social sciences and the humanities, where other forms of output are of more importance (e.g. conference papers, artefacts, books). Even in areas where bibliometrics are well established, such as medicine, other parameters such as the successful recruitment of patients to clinical trials is also becoming an important adjunct to quality assessment criteria.[8] Such work aims at understanding the foundational tension between the autonomous goals of cancer research

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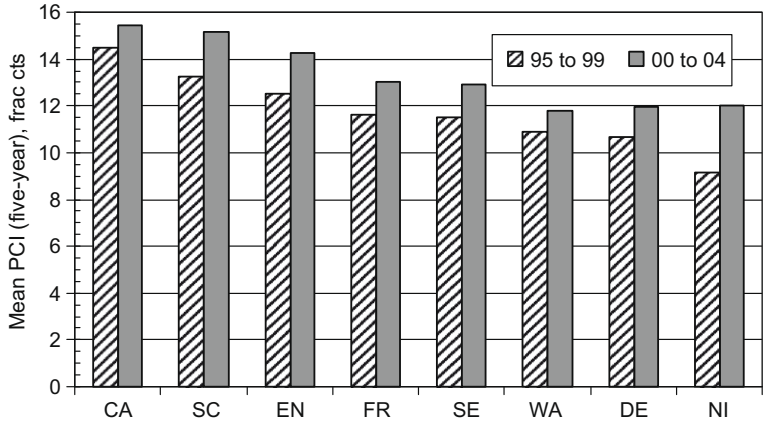

Fig. 4 – Potential 5-year citation impact of cancer papers, 1995–2004, fractional count basis.

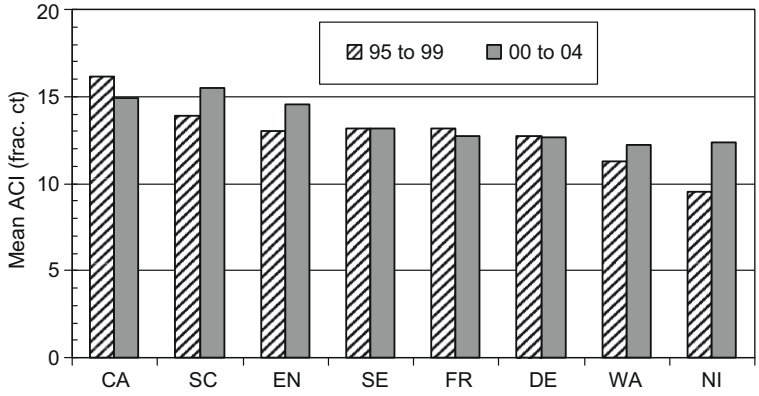

Fig. 5 – Actual 5-year citation impact of cancer papers, 1995–2004, fractional count basis.

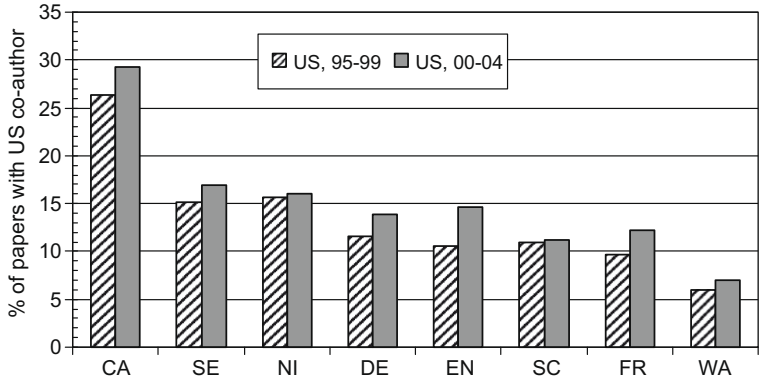

Fig. 6a – Collaboration with the USA in cancer research, 1995–2004; based on integer counts.

as a science community and the sponsors'/funders' desire for results of demonstrable public utility as part of policy setting.

In this study we have sought to understand the link between cancer R&D public policy development and metrics derived from research publications (bibliometrics). At the outset it should be noted that the outputs in any given year (or cohort) reflect public policies towards funding, organisation, from between 3 and 7 years prior to the data, in other words there is a lag period between policy and bibliometrics. Why is this understanding important? For two reasons, firstly to create a greater evidence base for policy development towards cancer and secondly, because research assessment metrics in many countries are, already moving towards a heavy reliance on outputs (publications). This will fundamentally alter many of the public policies and therefore understanding the pros and cons of this approach is essential.

Cancer research worldwide now comprises about 40,000 papers per year and this is growing at just over 2% per year. Global funding for cancer research is also growing at some 5.7% CAGR, with major contributions from both the private

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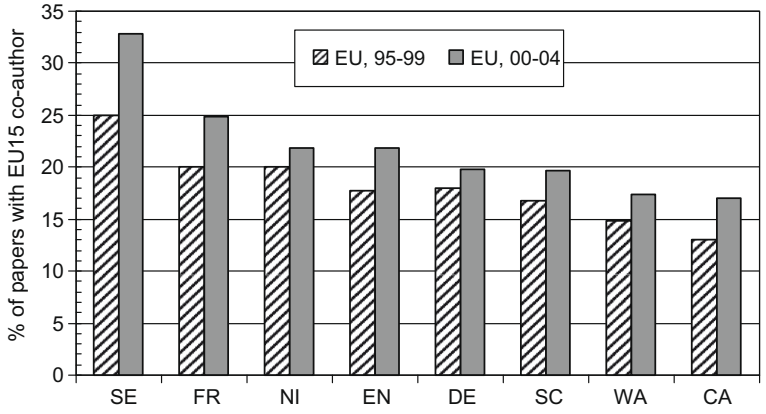

Fig. 6b – Collaboration with the EU16 countries in cancer research, 1995–2004; based on integer counts.

and public sector. Indeed, in terms of disease-specific research, cancer is one of the major areas for global research focus both at country and regional levels. Finally, cancer is one of the most important diseases for developed countries and, increasingly, for transitional/developing countries and is a key plank of national cancer control programmes (NCCP). However, whereas areas such as screening within NCCP's are constructed using an empirical evidence base, there has been little scrutiny of the implementation and effectiveness of public policies aimed at research. This is, partly, a result of the often 'given' belief that research is beneficial, i.e. a public good in itself and, partly, representative of a lack of methodological tools as well as R&D into the process of public policy development for cancer research. The exception to this is the USA which has seen a major Federal programme in cancer research since the early 1970s, however, as we have previously shown even here the focus in public policy making has been around the political process.[9]

Here we have utilised scientometrics to compare cancer research activities in countries with, (a) similar healthcare systems and, (b) broadly similar socio-economic indices (although there are important differences, which we shall discuss). Each of these countries has also had unique trajectories in terms of their development of cancer research public policies (or lack of them).

In terms of productivity (per capita) Sweden has constantly maintained high outputs. Clearly such a dramatically higher level of output cannot be related to cancer-specific policies, instead the data suggest that the overall higher commitment to R&D per se (a greater% of expenditure for GDP on science and technology as well as a higher proportion of researchers) has had a major impact on cancer productivity. A similar relationship can also be found for other Northern European countries with high R&D expenditures in science and technology which cements the conclusion that strong national base in cancer R&D is sensitive to broad public policy towards S&T. Wales, Germany and Canada have all seen significant increases in productivity, with Germany experiencing the greatest growth. Interestingly Germany has, and indeed maintained the highest relative commitment to cancer over this 10-year period. In part this can be explained by public policies put in place following re-unification to deal with the chronic disease burden brought about by the 'East-West Gap'.[10] Canada has also seen an increase in its relative commitment. The UK (across all Devolved nations) has, however, seen a decrease in its relative commitment to cancer research between 1995–1999 and 2000–2004. Although cancer has led the way in the UK in terms of disease-specific public policy – the creation of the National Cancer Research Institute and its associated research networks across the Devolved nations, the UK has also been quick to follow up on these successes with new disease-specific research networks across a number of domains, such as the Experimental Cancer Medicine Centres.[11] The influx of new funding and a broadening of opportunities in these other areas, e.g. UK Clinical Research Networks has translated, in relative terms to the downward pressure on research outputs in cancer. The question that arises is whether relative commitment should be seen as 'underinvestment' in public policy terms? An analysis of countries, e.g. USA that have a top-down 'iron triangle' approach to R&D public policy tend to have RC's close to unity, i.e. in terms of research outputs the portfolio is balanced. The difficulty in countries which have developed 'bottom up' public policy is that there is a more complicated connection between public policies, funding and research activity, i.e. there is less hypothecation along disease specific boundaries. What is clear, however, is that funding for cancer research in the early 1990s in the UK and Canada was much lower than Germany and France which had already embarked upon new cancer-specific public policies. By the late 1990s to 2005 the situation in the UK dramatically reversed with a huge change in public policy and a major influx of new funding which has made the UK, in terms of% of GDP or per capita, one of the best publicly funded countries for cancer research. A re-analysis for 2010 will be interesting to see whether the downward trend on RC has been reversed.

Percentage of review (a marker of researcher esteem), and the citation impacts (potential and actual) of outputs bring together some important metrics to understand how public policy might be affecting the 'quality' of research. The use of metrics for this purpose is very controversial and numerous weighted and unweighted approaches exist. The reality is that taken together they do provide a sense of how much a country's research influences global thinking and progress in the fight against cancer. However, this benchmarking must be taken with other factors. There is a strong correlation

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between a country's performance in terms of percentage of reviews and the absolute numbers of key research leaders active in that country. The major increase in NI is due to public policy changes, which saw the recruitment of key opinion leaders into the cancer research system. Sweden, England and Scotland have remained relatively stable (with a small but non-significant increase for Scotland) whereas the data suggests that Wales, Canada, Germany and France have all significantly decreased their percentage of reviews. Mobility, recruitment and retention are complex demographical indices in cancer. Further complexity flows through the additional dimensionality of general policies aimed at science and technology (S&T) human resources. In terms of numbers of overall S&T researchers and associated annual growth rates, countries such as Sweden have clearly developed policies with growth rates of between 4% and 5% per annum (OECD, 1997–2003 data) whereas Germany has struggled (1.5% pa). Our data are able to go beyond the aggregate data to ask questions not only of critical mass but also productivity of the academic cancer faculty at nation-state level.

In all the countries studied, the cancer research community has been publishing in higher impact journals, with outputs from Scotland, England, Wales and Northern Ireland all being cited more (actual citation counts). So why then does the research of these four countries appear to have greater influence on global cancer knowledge? It is not due to greater international collaboration (this is true of all countries studied), neither does it appear to have any relationship with productivity or the countries relative commitment. Interestingly all the increases occurred in the UK's four Devolved regions and the suggestion is that this is linked to some major global change in public policy. During the two periods under study all four Devolved regions of the UK underwent a significant shift in the structure, organisation and funding of cancer research.[12] Such major public policy shifts have already been noted as creating strong outward facing *de novo* structures, furthermore the competition for the additional funding is likely to have driven such externalities. The prediction for this interpretation is that, once the zenith had been reached in terms of the research culture shifting from one equilibrium to another then the ACI should stabilize out. The broad impact of cancer research outputs across the full spectrum of research activity (laboratory to population) should also be seen as a cautionary point to those countries seeking to establish a distinction between 'blue skies' and 'strategic' policies towards cancer research. Our evidence supports Keith Pavitt's findings that '*policies advocating more detailed central management and choice based on foresight should be resisted, because our understanding of the complexities of the knowledge bases that underlie future technological knowledge is limited, and . . . our ability to predict the future abysmal*' [13].

Public policy also has a major effect on research collaboration and competition.[14] In terms of collaboration with the USA, Canada, almost certainly due to its geographical and historical links, has the most collaborative research. Across Europe, Germany, England and France have also increased their collaborative research with USA investigators. In all three countries there has been a strong public policy focused towards junior and middle faculty working at major cancer centres in the USA. Although this study is not of sufficient resolution to determine whether collaborators have indeed spent time in each others' countries at the institutional level the pro-exchange policies are clearly there. There has also been a major increase in trans-European/intra-European collaboration. Whilst the public policies driving this at country level are less clear to identify, at European level the European Research Area has been a significant driver. This is perhaps the first clear evidence that we have to show that funding dating back to the end of Framework 5 Programme has seeded intra-European collaboration.[15] Interestingly, the cancer public policy development at European level continues to be driven in an *ad hoc* manner, whilst research, although starting to make an appearance in official European public policy, continues to take a back seat despite its integral position with national cancer control programmes.[16]

Finally we need to recognise that cancer research is part of a much larger process of global socio-industrial innovation to which public policy is mainly aimed.[8] Understanding the rate and extent of international co-operation is essential for national public policy. Those countries ignorant of such relationships and trends, or indeed simply too parochial in their attitude to cancer research will invariably waste resources.[17] Whilst the topography and dynamics of complex networks in cancer research may seem daunting, new tools[18] allow policymakers to study the evolution of such networks with a degree of independence and impartiality akin to Adam Smith's 'impartial spectator'[19]. In the pursuit of fair and equitable cancer research policies the application of scientometrics provides an important perspective.

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Contributors

R.S. initiated this study. G.L. was responsible for data collection, database design and collation of data. G.L. was involved in the analysis of the data. G.L., A.P., M.M., G.Mc.V. and R.S. were involved in its interpretation and the writing of this paper. R.S. and G.L. are the guarantors.

Conflict of interest statement

None declared.

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