Delivering large-scale national science initiatives: Ideals, compromise and stakeholder roles in developing national nanotechnology programmes.

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Introduction

Nanotechnology-"The branch of technology that deals with dimensions and tolerances of less than 100 nanometres, especially the manipulation of individual atoms and molecules." (OED)

The first National Nanotechnology Initiative (NNI) was announced at Caltech by President Clinton at the turn of the twentieth century (The White House, 2000). Since then other national programmes have been created around the globe following "the example set by the NNI [US]" (PCAST in Sargent, 2012: 31) including the German Nano Initiative in 2006/07(Federal Ministry of Education and Research (BMBF), 2011) and the Russian Nano Initiative in 2007 followed by an overarching modernization policy in 2008 (Erawatch, 2008; OECD, 2011). These programs represent a focus of national political agendas onto emerging scientific and technological research. In particular it is a product of interaction prior to the announcement. Policy critics have noted the development of programmes of are influenced by figures with expertise in various positions, as well entrepreneurial figures who encourage development in the policy (Flanagan et al., 2011; Kingdon, 1995). Each party involved in the development of a programme may have particular influences and expectations on the outcomes of science and technology policy and the figures involved in the development of Nanotechnology may offer insights into the development of science policy.

This paper will offer analysis of the concept of Large Scale National Science and how NNI represent the latest formation of this organizational idea. After this, a discussion of research design to develop an understanding of the NNI from the interactions of Policy and Science communities in the USA, Russia and Germany. I will then discuss some of the initial bibliometric work which has been carried out to understand some of the contexts available prior to fieldwork interviews and how these relate to the overall development of NNI and "Large Scale National Science Initiatives".

Framework and conceptualization

What is a “Large Scale National Science Initiative”? Essentially they are the coming together of a national policy makers and scientific expertise to develop a framework for pursuing research and development in line with social, economic or political national agendas (Solingen, 1994). The NNI represents an example of technology based national programmes, formed of a combination of policy and science community interactions and a historical precedent of “Big Science” (Galison and Hevly, 1992).

The interaction between communities interested in the forwarding of science and technology can be conceptualized in a “policy mix” (Flanagan et al., 2011), a view which concerns the influence which different parties have political decisions in relation to an interactive policy views. Instead of considering political decisions as Zero-sum games which involve one party ‘winning’ (Weirich, 1998) the debate and claiming complete domination of the decision. More recent critics of decision making processes are nuanced in their approach, considering the engagement of different parties as collaborative in nature rather than built on individual driving forces (Surowiecki, 2010), instead we can see the science policy as involving the development of the combination of different members in the “policy universe” (Howlett and Ramesh, 2003) or “Policy Mix” (Flanagan et al., 2011). As the figures of the policy interaction, the programme can be made into a coherent policy through the relationship of interaction between these groups.

In the scientific and policy community interaction this coming together can be viewed in terms of “applied” and “basic” scientific research. Some critics have noted the social construction of basic and applied research, tying university to “Basic’ and business sectors to ‘Applied’ research in these two agendas (Pavitt, 1998). However, other critics have seen the position of Government as more influential than Business as it directs initial policy environment in which business develops or in the USA’s case creates something of the “permanent war economy”(Hounshell, 1992) which directs national economic goals. If we see the binary split in this form, we could also see the research area defined by the conceptualization by Stokes (Stokes, 1997) in a representational quadrant model of research with the two axis represented by the degree of work considering basic research and technical application involved in the programme (Table 1).

Table 1: Stokes' Quadrant Model (1997)

	Increase Technological Development?		
Increase Basic Science Knowledge?		**No**	**Yes**
	Yes	Bohr	Pasteur
	No		Edison

In this model there are two influences on research, the aim for basic research to increase scientific knowledge and the aim for technology which may be applied to problems. Research which produces results for scientific discovery but lacks applicability is grouped into the "Bohr" quadrant alluding to the "scholar-scientist engaged in a pure search for understanding"(Stokes, 1997:24, Table 1). Research which deigned to develop technological advances without considering pure scientific knowledge is grouped into the "Edison" quadrant after the inventor who "exemplified the applied investigator wholly uninterested in the deeper scientific implications" (Stokes, 1997: 24) rather than a scientist solely involved in the interest of increasing scientific knowledge .

Between these two quadrants, arises an amalgam of the two, both dealing with basic scientific knowledge and the application of science in novel ways. This quadrant, named after “Pasteur”, is an idealized form of research which engages both basic scientific communities and technology makers in their output (Table 1). In some respects this is ideal as it offers advances by both parties, both Basic Scientists and Inventors of technologies and taking advantage of the opposite party’s work on the development of nanotechnology. Another term for this ‘quadrant’ may be that of “Research and Development”, the “R&D” which is coveted by science and technology policies.

This model helps view the relationship between Policy and Scientific communities in the creation of “Large Scale National Science Initiatives” as they offer the coming together of science and technological development for a national agenda. In the case of Government and Policy Makers we can interpret “Large Scale National Science Initiatives” as synonymous with the application of national assets for the national interest. Early science over the last 400 years was predominantly funded by wealthy donors (Christianson, 1999) while corporate funding appeared more frequently in the nineteenth century. From the 1940’s, “Large Scale Science” could be defined in terms of “Big Science” (Galison and Hevly, 1992), programmes which were often spurred by warfare and ideological conflict during the Cold War. The Manhattan Project harnessed the use of the atom to military application and also civilian power generation. The program was developed during the Second World War and essentially had a financial ‘blank cheque’ (Hughes, 2002; Kelly, 2007) which implies the programme was potentially less regulated than other science projects tied to single grants. We could interpret application of research for the government leaning towards the Edison approach, driving technological application rather than necessarily increasing scientific basic knowledge. In other interpretations, the programme encouraged increased research in nuclear physics, but lacked the traditions of academic diffusion, brought on by wartime secrecy. The lack of information sharing may influence the degree to which basic science knowledge was increased. By organizing science in secrecy, there is a reduction of information sharing and thus increasing the basic knowledge according to the “Bohr” definition of scientific research which is concerned with the development of knowledge rather than technological application and the potential for market which has become more important in recent years (Atkinson and Ezell, 2012).

Out of the “Big Science” research and development from the Second World War, figures such as Weinberg and Bush (Bush, 1945; Weinberg, 1967; Zachary, 1997) developed the notion of large scale science programs in policy literature and saw the potential which organized systems of science bringing together different expertise from a variety of disciplines to work on a technological problem. Some critics have noted the notion of national science came into its own in the 1960’s with standardized political interpretations of national research agendas in the OECD (Henriques and Larédo, 2013) and the competition offered between them appear to be more . What is notable is that by the 1960’s there was a shift from explicitly warfare based big science projects, and began offering development of civilian science as well as public relations exercises (Kauffman, 1991). National programmes were developed by other countries after the initial binary opposition of the USA and USSR during the Cold War, including France and the UK (Oakley, 1990; Sastry and Siegel, 1999).

“Big Science” is an interpretation of the application of national interests. However, it does not truly define present technology and science development in the later 20th century. “Big Science” implies programmes which held more policy and ideological influences over the development of technology. “Large Scale Science Initiatives” represent a change in program goals towards economic development as well as ideological ones. By the 1980’s the National Science Program had gained another element, that of industry influence in programmes such as the Human Genome Project (Tripp and Grueber, 2011), the civilian nuclear research (Sastry and Siegel, 1999) and the Alvey Program (Clery, 1991; “Looking into Alvey’s future,” 1985). In effect the science and policy communities moved towards markets as a form of national competition. Critics have noted that economic competition is at the heart of innovative activity, being both the “creative destruction” (Schumpeter, 1962) which drives future economic development (Atkinson and Ezell, 2012).The aims of Big Science or “Large Scale National Science Programmes” developed to encompass economic competition such as the Human Genome Project which “allegedly created

310 000 jobs and launched the genomic revolution" (Tripp and Grueber, 2011). In innovation models, this ties in with the triple helix model of innovation developed which sees science policy as the coming together of science and policy communities and smaller influences from the business community (Etzkowitz and Leydesdorff, 2000, 1998; Leydesdorff, 2000). However, as pointed out earlier, the third interest group made of industrial players could be subsumed by the directions of the policy and science communities. In this sense, this coming together of the science and policy community offer the environment from which industrial activities can develop.

The coming together of science and policy groups can be taken from the triple helix (Leydesdorff, 2000) interpretation and applied to the Stokes quadrant model of application and basic research (Stokes, 1997). The Large Scale National Science Initiatives aim to encompass the Pasteur approach to science which scientific communities as essentially interested in the development and distribution of knowledge to explain previously obscure phenomena. In the development of an NNI there needs to be involved in the development of basic knowledge and the application of technology for the national interest. The science and policy communities present two focusses for the ideal "Large Scale National Science Initiative" in this interpretative view of NNI.

Key figures and policy groups in the development of science policy have been researched in the past. They have considered the rational policy cycle and the development of programmes based on technical knowhow and administrative expertise (Dror, 1973; Howlett and Ramesh, 2003; Kingdon, 1995). As an interpretive grouping, the science and policy communities will be addressed as they offer the most diametrically opposed groupings which need to be in communication with each other in order to develop a coherent policy based in scientific knowledge and bureaucratic handling. There are figures of this within the "Policy Mix" (Flanagan et al., 2011) which develop the notion of nuanced influences between communities, and this can involve major groups as well as main groupings and policy leanings. In this case, I would argue that the science and administrative groups are the most relevant stakeholders in this programme since they represent technical experts in their field, and they also represent other stakeholders by proxy. For example, policy and government may represent business and community concerns, and the scientific community is also engaged in the ethical debate and wider higher education structures. Their positions are not simplistic, but under these umbrellas the figures may be loosely interpreted as a binary opposition in overall dynamic I wish to interpret.

In the build up to the creation of a National Science Initiative there is a need for an interpretation of this dialogue between both of these two groups as they each hold expertise and community influence which can be brought into the development of a national program. This relationship between science and policy in the development of NNI is a worth investigating as it offers insights into the initial program creation and how these parties initially influence the outcomes of the final program. They also show the opposition of technical knowhow and the bureaucratic handling of programmes to pass it through the government and policy machines into fruition. These relatively contemporary policy decisions may offer some guidance for future decisions to the relationship between science and policy communities.

Research Design

By adopting this critical lens of policy and science communities I aim to design a research piece which considers these two groups and how they make an NNI in different political contexts. These groupings offer the initial entry into the development of a programme, but other stakeholders may well become evident as the research progresses.

This research aims to take a mixed methods approach (Tashakkori and Teddlie, 2003; Teddlie and Tashakkori, 2012) employing statistical and bibliometric data and case study interviews. Initially this will involve data on R&D funding and outputs along with the policy documents on the development of NNI. This aims to show how indicators and policy documents show some of the development of NNI and one angle from which to “triangulate”(Yin, 2011) the overall appearance of NNI. I have begun to develop some interpretations of the programs up to the present along with some bibliometric datasets I have been working with from the ESRC funded Rising Powers research project at MIOIR.

From these indicators I will develop a case study for each context from these sources and produce some initial interpretation of the development of these programs. This case study approach (Yin, 2011) aims to show some of the potential markers of similarities between science policies of the different national contexts. As a secondary point of triangulation, I will take a set of prepared interview questions to policy and science community members in the different country contexts involved in NNI. The protocol will be influenced by the data gleaned from the bibliometric and other source material, taking into account salient dates and events in the national and international development of NNI. I predict that the policy and science communities in these different contexts are the most dominant figures in the development of NNI although other figures may become apparent during the research. In effect this stage is developed out of the initial findings.

The aim of the research is to compare responses on the development of NNI between the statistical information and policy documents available and the policy and science figures opinions. This triangulation is two-fold as the comparison may be made between the data collected and interviews made as well as comparing these different contexts in each stage. Under this comparative approach of mixed methods using case studies, the aim is to compare information and opinion available on the programmes and show how the collaboration of these two groups.

The national comparison is useful in the national innovation context (Nelson, 1993; Samara et al., 2012) since national programmes may be compared against one another to offer potential ideals and failures of forms of "Large Scale National Science Programmes". However, this approach may be time consuming and have some linguistic issues with gaining information in the interview phase depending on the level of English of the interviewees.

The main research questions are whether the interactions of science and policy communities are considered important in the development of an NNI, and whether policy direction can inhibit or encourage the development of research and the development of nanotechnologies.

Initial Research

Since the completion of the research training program in August I have been able to begin moving from research design to empirical work. Although interviews have yet to take place, I have been able to gain access to some bibliometric information and policy documents on the development and funding of Nanotechnology in Russia. In the future I will be collecting similar databases for Germany and the USA.

The Russian database was initially collected for an ESRC project on the “Rising Powers” focusing on the development of Nanotechnology in Russia and China in comparison to the UK. The Russian database holds over 30 000 publications and over 3000 patents around publications with a link to nanotechnology and the Russian Federation from 1990 to 2012. The database was collected using the keyword method approach outlined in Arora et al (Arora et al., 2013) from Web of Science (WOS) and Derwent Patent Database. These databases involve records which are formed from research and patenting activity in Nanotechnology. This data was cleaned and grouped by Maria Karaulova, Weishu Liu and Oliver Shackleton in the research group for a project. This analysis is developed out this database.

Bibliometric data can offer insights into the development of a technology or innovation as the they show markers into the overall activity or inactivity of companies and parties involved in the development of a technology (Hall et al., 2013). While this information is reported by other parties, rather than initially collected by researchers, it also offers signs of activity which may be evidence of general themes in the technology and research patterns (Okubo, 1997). Programs may not be completely illustrated by publication and patent data, instead it aids the overall “Triangulation” (Yin, 2011) of information which is the hallmark of a the case-study approach offered by Yin.

These outputs are examples of the research work done in the Nanotechnology and may offer examples of the scientific research agendas as well as the government interest in the funding of science over time.

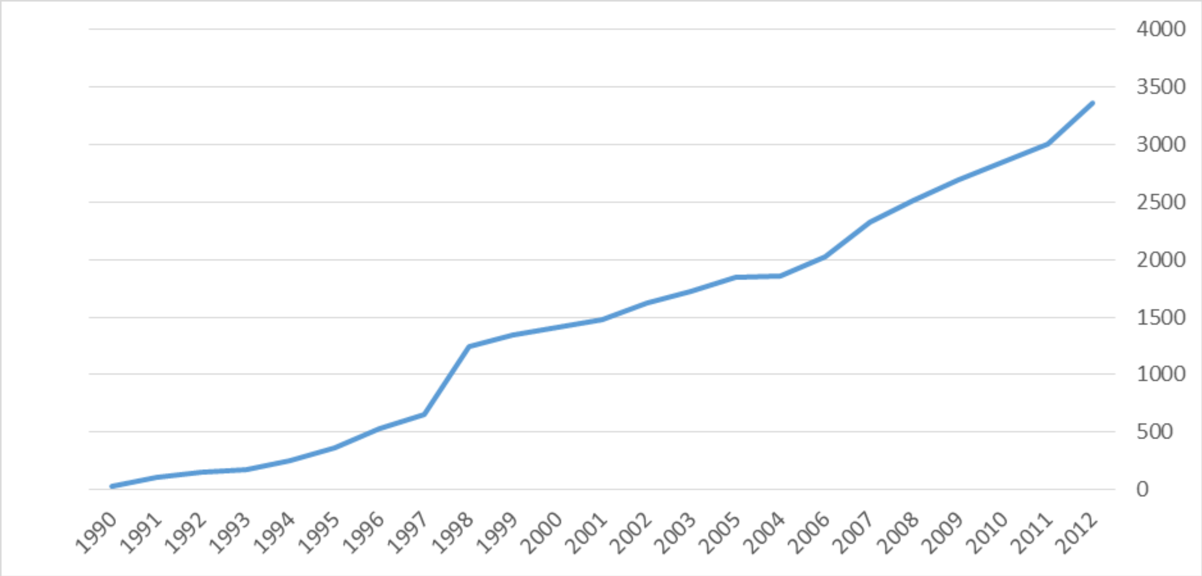

Figure 1: Time Series Nanotechnology Russian Publications

Initially, the publication database implies that nanotechnology research on nanotechnology have increased over time and could be linked with policy events which occurred. The yearly increases in publications can be interpreted as interest from the scientific communities and show an upward trend in interest prior to the development of NNI in Russia in 2006/7. Russian research can also be seen to be increasing in line with other internationally collaborated research in the database, implying that Russia's work is comparable to other international research in Nanotechnology (Figure 2).

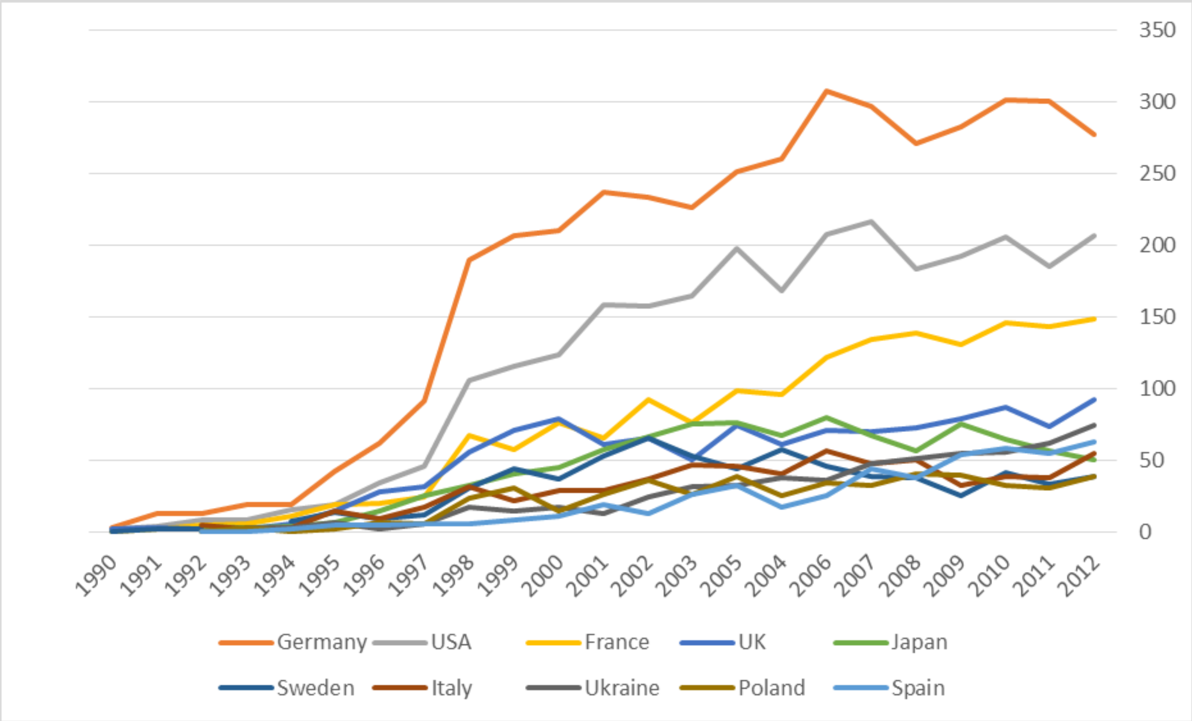

Figure 2: Publications over Time minus Russia

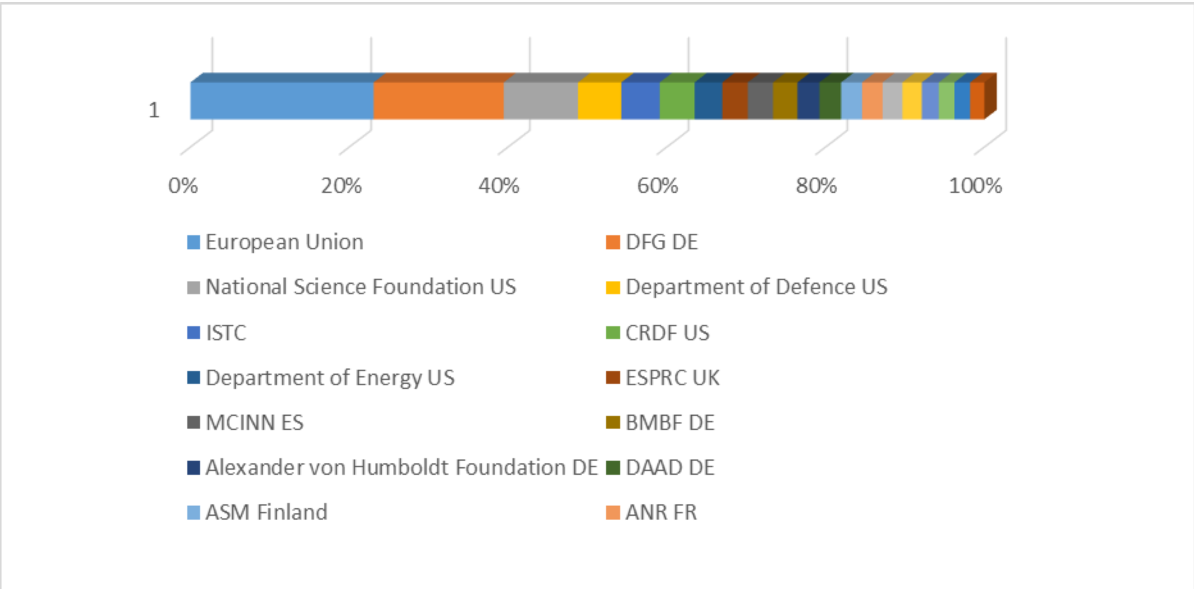

Figure 3: Top 20 International Funding Bodies in Russian Dataset.

As well as basic publication data, the funding perspective can be investigated which may offer some perspective on government and other bodies influences on research. The database reports data in this category from 2008-2012 and shows increased funding from all interested parties. In Russia it appears that governmental bodies are the largest funders of Nano research. The funding of research in nanotechnology is not as complete as the overall database, so unfortunately we are unable to interpret the development of funding prior to 2008. However, the records can be used to show interests of sectors and major institutions over a shorter time period.

From a funding perspective in particular, the international funding links with Russian research in nanotechnology appear to be dominated by 1.) The EU and Germany and 2.) US government departments. From a funding perspective, these groups appear to be the most influential groups in Nanotechnology research in a Russian funding context (Figure 3). These initial indicators are encouraging and imply that the next step in data collection and analysis will be fruitful.

R&D funding in Nanotechnology has followed a similar course to the policy, creating a "large scale national science initiative" outlining national agendas and trying to

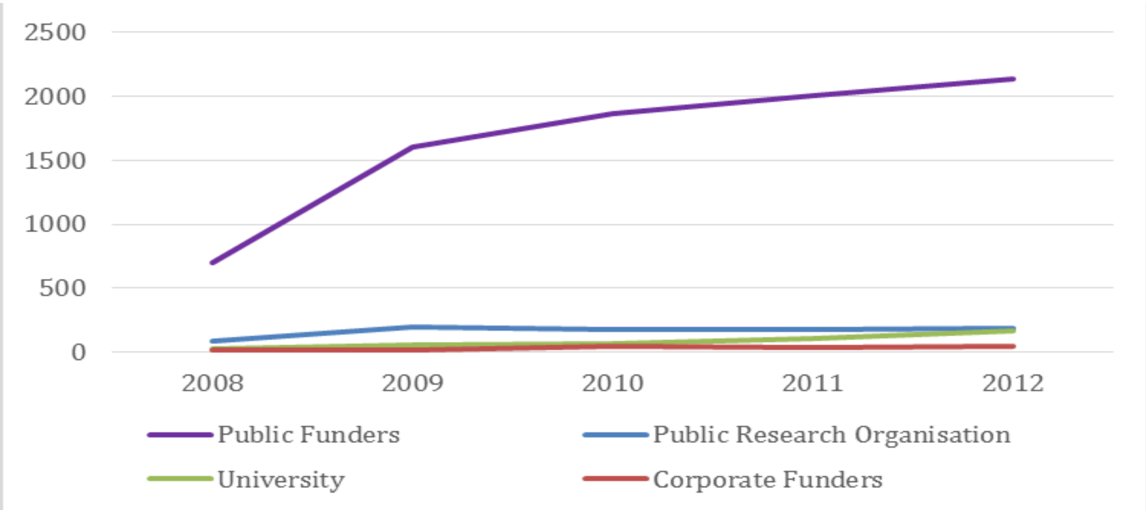

Figure 4: Funding Sectors in Russia

shape targets and environments for the development of said technology.

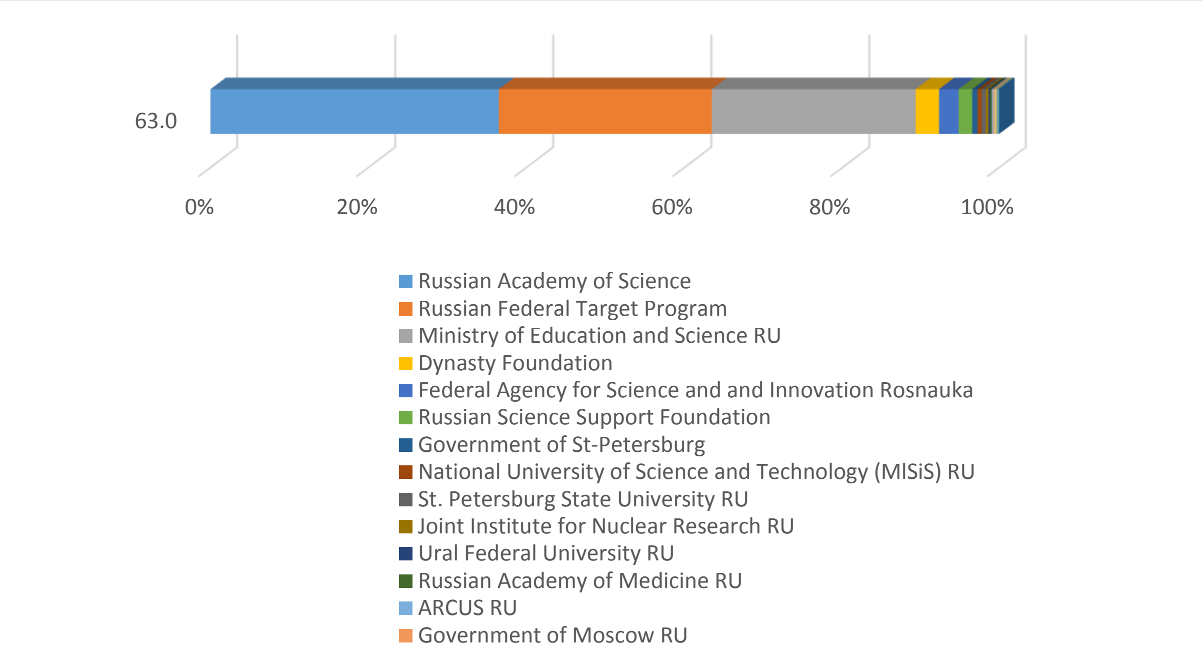

Figure 5: Top 20 Russian Research Funders.

From the database the development of the nanotechnology is tied with Russian National Agenda as the top 20 publishers are by an overwhelming majority funded by Russian Government bodies and quasi-independent bodies associated with it (Figure 5). In the Russian context at least, the state is particularly influential in nanotechnology. It appears national nanotechnology programmes in Russia have an influence on the programs by funding of research. Funding from a sectoral perspective also puts the Public funders far above all other sectors since 2008 (Figure 4) When we consider the number of corporate, university and Public Research Organizations, they have minimal instances of funding compared to the government bodies. This would imply that the interpretive framework offered, considering science and policy communities may be useful, since government is by far the largest and what may be the scientific community “University” funding involved a significant increase in recent years.

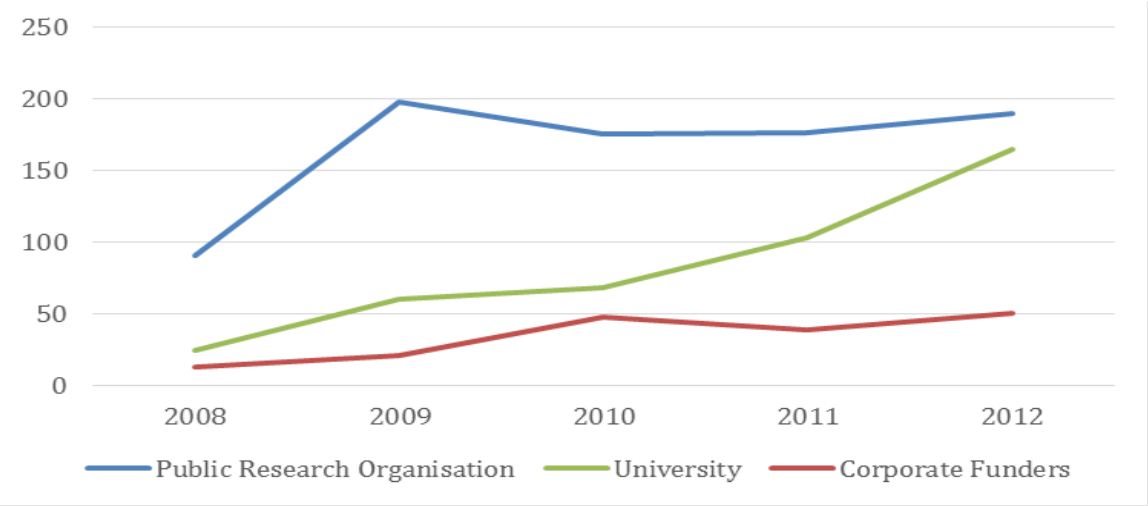

Figure 6:Funding Sectors in Russia (Minus Govt)

Patenting in Nanotechnology appears to include Corporate and Public Funders as well as Individuals. Corporate interest in patenting may be difficult to pin to national contexts and instead represents globalization of research as an undercurrent of national interest as companies often have Joint Stock ventures with the state. In effect, the development of nanotechnology is tied to the national agenda rather than led by a free market.

Nanotechnology publication output appears to develop prior to the creation of NNI in 2003 for USA and 2007/08 for Germany and Russia. .This implies that the science community is working on the technology prior to the development of the Large Scale Science Initiative.

Patent data offers another perspective on the research and development of NNI and the outputs which have been developed.

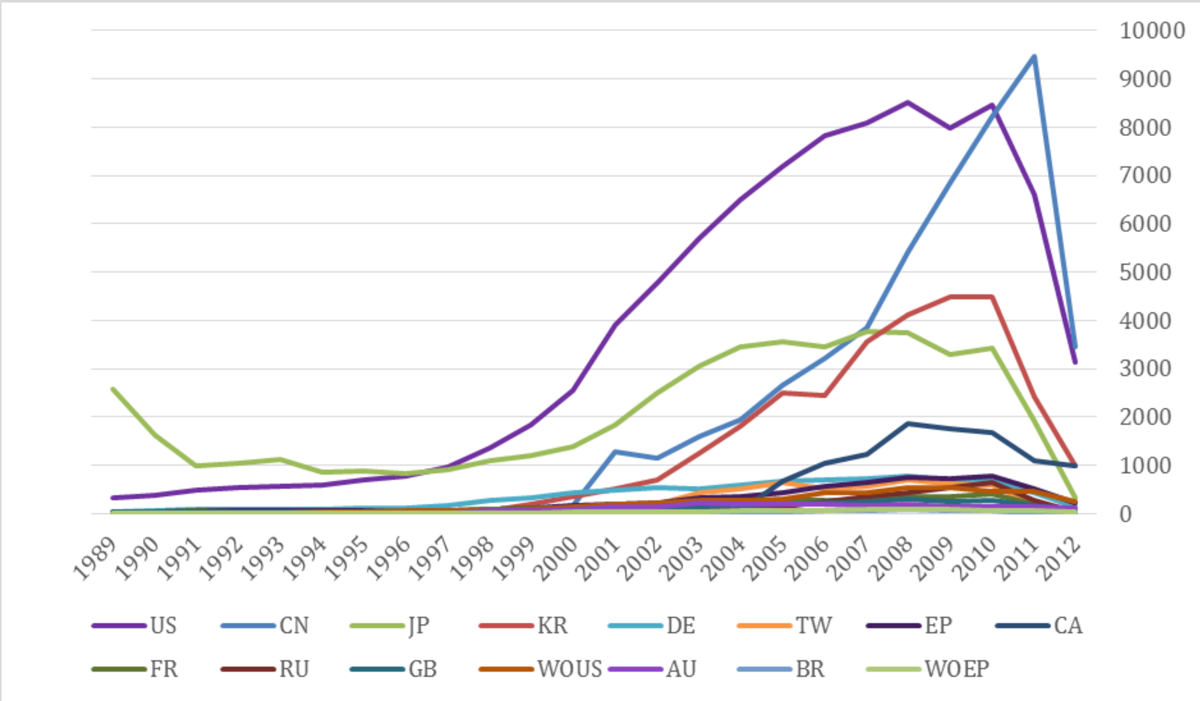

Figure 7: Nanotechnology Patenting (World)

Patenting within nanotechnology appears to have increased over time and the USA has remained until the last few years as the leading country for Nano patenting. More recently, Chinese patenting has increased dramatically (Figure 7). In effect, since the first NNI pronounced in 2001 nanotechnology patenting has increased significantly. Whether this is inherently linked to NNI development is one question which aims to be addressed by triangulating information from research interviews with policy and science communities.

Russian Patenting in particular appears to accelerate around the creation of NNI in 2006-2007 and may imply some interest from the state. Considering the sectoral make-up of the patenting output may offer further insight into the development of NNI. One thing that can be understood from this simple descriptive analysis is that Nanotechnology research in both publication and patent databases increased dramatically over the past 20 years and is an emergent technology.

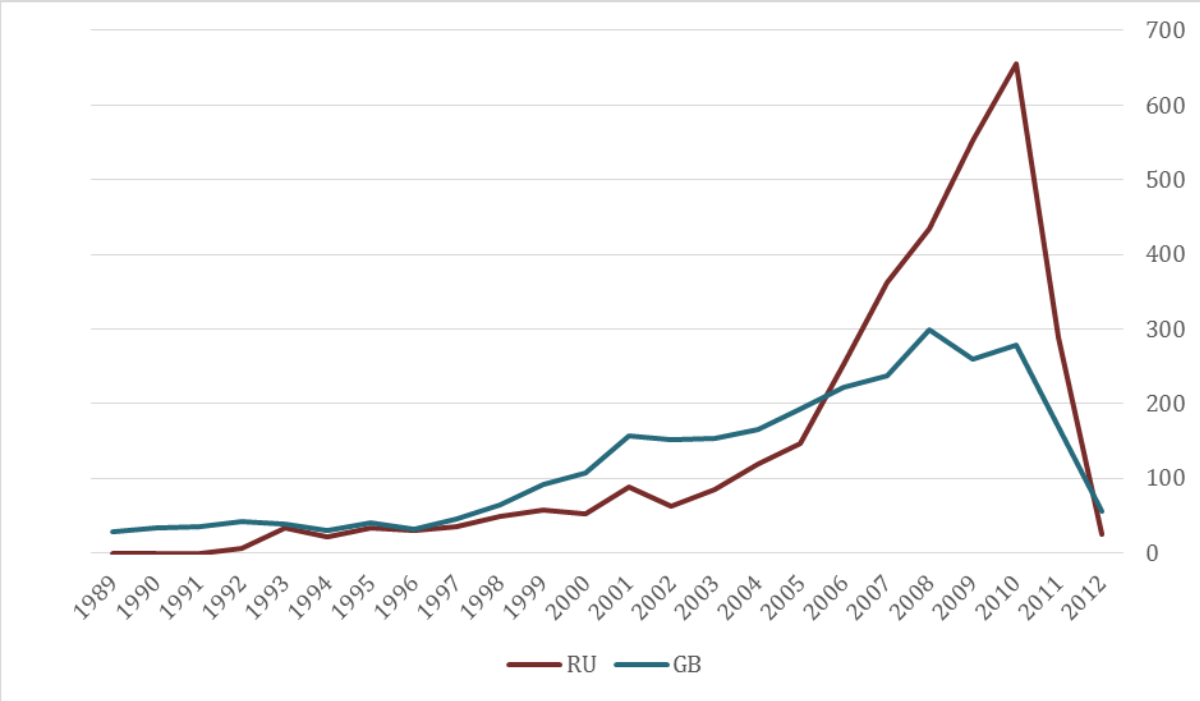

Figure 8: Russian UK Patenting

The patent and publication databases give one perspective of development of research in a particular area and if there are other potential databases which are available, I will be taking advantage of them to develop the case study element of the research which will influence the question framework for the case study interviews.

Initial Observations

The patent and publication databases give some initial insights into the development of NNI programmes and show the general development of nanotechnology in a sectoral as well as national setting. The dynamic of patenting and publication information may be one way to consider the development of Basic research and applied technology. Research articles could appear to be evidence of basic research agenda and the interests prior to a programme made by the research communities in Universities and Research Institutes. Patents can similarly be regarded as the could represent application and by extension, national agenda interests in 'applied' technology as earlier highlighted with the Stokes quadrant model (Stokes, 1997).

These two sources could be used to point towards the coming together of basic science and technological application in what Stokes calls the "Pasteur Quadrant" (Stokes, 1997) which is a focus of both agendas. Both of these influences offer some insight into the Pasteur Quadrant of technology and basic science development and give indicators as to whether large scale national science programmes can be seen in terms of this quadrant.

Some sectoral insight into patents and publications shows a leaning towards national funding and thus national agenda in a Russian context. Sectoral leanings of funding in publications appear to show how technology has become an interest of policy makers in Russia and influenced through large bodies including Federal Target Programmes and Ministries.

This research will need to develop a larger database to incorporate German and US publications. Both patenting and publication work will need to be considered in more detail in order to develop an interpretation of NNI between different contexts. However, we can see from the international collaboration which occurs with Russian Nanotechnology and Science research appears to lean towards these two contexts. Developing further interpretations from national context databases will further aid the triangulation of research

Whether there are the same instances of research and development of nanotechnology by NNI in Germany, Russia and the USA will become evident once a larger dataset is developed. I will also have to consider other economic factors and databases which may be available.

Other elements to include will be the development of NNI policy documents and this will be combined with the other statistical data to develop some readings of the NNI and then develop some case study questions which can be addressed to policy makers and scientists involved in the development of NNI. The case studies will hopefully offer some similarities and differences to compare and will reflect on the previous bibliometric and other statistical data available.

Overall, this research requires further development and once sufficient information has been gleaned from an increased selection of publication and patent data, interviews will ideally begin with some initial pilot interviews in late 2013.The main interviews aim to be taken during 2014. The spread of different countries may offer some challenges in the execution of interviews, however, the research will offer enough information from many different sources to gain sufficient insight into the development of NNI and the policy and science communities. This triangulation of methods will ideally result in a research piece which takes both statistical and interview data to consider how these programmes are formed and whether similarities and differences may be gleaned from the programmes showing markers of how productive or unproductive they may be.

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