Turning good science into successful businesses: The technology transfer systems in the UK and Germany

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Abstract In the biotechnology industries, the technology transfer process serves as a crucial bridge linking public science to commercial enterprise. This paper argues that an effective analysis of technology transfer must move beyond a description of the technology transfer offices, and examine how a nation's technology transfer system is embedded within a broader national system of innovation. With this aim the UK and German technology transfer systems are compared.

Important differences exist in the maturity and pattern of subsector specialisation across the two country's biotechnology industries. Germany's relatively late entry into the industry and its new companies' tendency to focus in platform technology and diagnostics segments as opposed to therapeutics (as is the case in the UK) can be linked to the laws governing intellectual property, the incentives for professors and scientists to become entrepreneurs, and the scientific resources available for commercialisation. Given the important differences in the profit and growth profiles of these product segments, the organisation of the technology transfer system together with national factors such as the availability of high-risk finance and skilled managers have a significant impact on the competitive prospects of a country's biotechnology industry.

Keywords: Germany, UK, national systems of innovation, technology transfer

Introduction

In the biotechnology sector, extensive finance and time investments are needed before commercial relevance and market potential of basic life-science research can be externally assessed and confirmed. University laboratories generally lack the human and financial resources needed to develop promising research results into commercial products, and thus, when this is the goal, they must rely on spin-off projects or licensing programmes with established firms. Of the 60 biotechnology products launched between 1982 and 1998, academic organisations discovered less than 5 per cent and marketed none of them (CMR International; G. Ashton, unpublished). Major pharmaceutical companies have also not led the commercialisation of basic biological research, reacting to evidence of potentially marketable new areas rather than leading the search for new opportunities in biomedical research.[1]

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Instead, collaborations between university scientists, entrepreneurs and private funders have emerged to set up new biotechnology firms to commercialise new discoveries and technologies.

In this paper we use evidence from the UK and Germany to examine the link between the technology transfer system on the one hand and the structure of the biotechnology start-up industry in a specific country on the other. Rather than viewing technology transfer as a discrete activity pursued by specialised offices, the technology transfer system is seen as a broader process strongly influenced by a country's national systems of innovation.[2,3] Doing so allows us to focus on the organisation of technology transfer offices and the incentives facing them, as well as their embeddedness within a larger environment, which includes a country's research and business systems. We acknowledge that the strategic and performance outcomes of biotechnology companies are based on a complex set of institutional and global forces of which technology transfer is only one component.[4]

A brief overview of the German and UK biotechnology industries, presented in the next section, reveals important differences in the maturity and size of the companies as well as their product strategies. To help explain these differences we compare technology transfer systems across the two countries, using the USA as a base of reference, with a focus in the following sections on three factors:

- **The quality of basic science**, which powerfully shapes the success of technology transfer through influencing the quantity and types of projects potentially available for commercialisation.
- **The laws and incentives** governing the ownership of university research and motivating scientists to become entrepreneurs.
- **The organisation and resources** available to the technology transfer offices.

Ultimately the effectiveness of the technology transfer system depends on the strength of the supporting network and the offices' ability to connect and work with the actors in this network including business angels and venture capitalists, patent lawyers, city planners, university administrators, pharmaceutical companies and so on. In the concluding section we consider how these networks differ in the UK and Germany and the implications for the performance of the industries.

The structure of national biotechnology industries

The USA is the uncontested global leader in biotechnology. It has more companies than all of Europe and these companies together employ, invest in R&D and earn three to four times more than all of Europe's companies (see Table 1).

Within Europe, the UK industry is the largest and the most mature. As of 1998, Germany had almost as many companies as

Table 1 State of the biotechnology industry, 1998

	USA	Europe	UK	Germany
Number of companies	1,283	1,178	275	225
Number of public companies	327	68	50	2
Employment	153,000	45,823	40,000	4,013
Revenues (Euro million)	15,777	3,709	2,203	293
R&D expenditure (Euro million)	8,398	2,334	449	143
Net loss (Euro million)	4,326	2,107	n/a	35

The financial figures are for public companies only.
UK employment figure is for 1999. The BIA[5] (1999) puts the estimate at 35,000–40,000, a figure that must include service and consulting companies as well as research facilities.
n/a = not available.
Sources: Arthur Andersen,[6] Ernst & Young,[7] Schitag Ernst & Young.[8]

the UK but its companies employed less than a tenth of the people and spent only a quarter as much on R&D. On a biotechnology industry time line that starts in 1976 with the establishment of Genentech, the first established venture capital-backed biotechnology company, and continues through to 2000, the UK enters in 1981 with the founding of Celltech. Germany enters 12 years later, with the amendment of the Genetic Engineering Act in 1993.

Germany's 'youth' is further demonstrated by the company size and age profiles. Schitag, Ernst & Young[8] estimates that more than 60 per cent of Germany's companies are less than two years old. Of the 173 companies in their survey 98 were founded between 1995 and 1998. A large percentage of UK companies are still in the small and young categories, suggesting a continued start-up dynamic continues here. On the whole, however, the UK sector is more mature; 25 per cent have more than 50 employees and more than half are 5 years or older.[5]

UK and German firms also differ in patterns of sub-market specialisation within biotechnology. Figure 1 shows that more than 50 per cent of German companies concentrate in platform technologies and diagnostics while over a third of UK companies conduct research to develop new therapeutics. Given the different profit and growth profiles of these product segments, the segment patterns have implications for the future structure and competitive success of the two countries' industries. It may take less time and money to get platform technology and diagnostic products to market, making them less risky in some ways. However, the relative ease of entry and opportunities for competing products and technologies to 'outdo' existing ones means that the prospective pay-offs may also be lower. As the market becomes increasingly 'crowded' with new technologies, it may also become more difficult for small companies to attract the attention of large partners for extended contracts. If therapeutics companies are able to overcome the great scientific and financial obstacles of discovery research and clinical trials, the pay off and partnering opportunities are potentially greater.

Germany's date of entry plays a role in the explanation for its companies pattern of specialisation – many have started up just as the opportunities and demands for technology providers industry-wide took off. However, we argue here that important differences in the national systems of innovation across the two countries, including the technology transfer mechanisms, have crucially influenced the dates of entry and specialisation patterns in the UK and Germany.

The strength of a country's life-sciences research base is a critical factor in shaping high-quality start-up firms in biotechnology both as a source of technology and as a source of skilled scientists.[9,10] In the

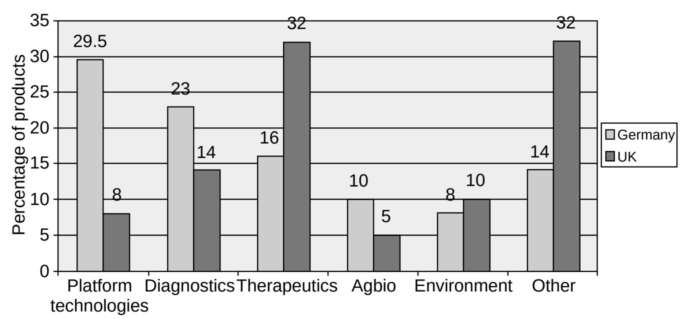

Fig. 1. Product structures in Germany (1998) and the UK (1999) (Sources: Arthur Andersen[6] and Schitag Ernst & Young[8])

next section we use citation indexes as a way to evaluate the quality and size of the sciences bases in Germany and the UK.

Quality of basic science

The US lead in the biomedical basic science fields is also uncontested. In 1999 alone, the National Institutes for Health (NIH) supported US$697.5m worth of awards in bioengineering, almost US$200m more than in 1998.[11] As is the case with private industries, the UK ranks second in the world in biomedical research followed closely by Germany. According to a Science Watch study,[12] Germany had nine institutions ranked in the top class while the UK had eight. UK citations per institution were slightly higher though at 28.4, above Germany's 24 and the USA's 21.9.[10]

To learn more about the areas of strength in biomedical research, we use the Science Citation indexes, published in a recent Wellcome Trust study,[13] as a proxy for research output quality (see Penan[14] for more on using citation data). The report presents statistics on the number of publications in several highly regarded scientific research journals such as *Nature* or *Science* that can be attributed to a specific country's scientists. Table 2 shows the UK and German positions out of 12 advanced industrial countries in terms of the total number of publications in 1988 and in 1996 for 19 therapeutic areas. The aggregate figures in Table 3 sum up the percentage of total publications in all therapeutic categories going for the USA, UK, Japan and Germany for 1988 and 1996.

Again, the USA dominates biomedical research with roughly 40 per cent of all biomedical-related articles in prestigious

Table 3 Percentage of scientific publications across all therapeutic areas

Country	1988	1996
USA	41.6	39.5
UK	10.1	10.4
Germany	6.5	7.5
Japan	6.9	9.4

Source: Calculated from tables in Wellcome Trust.[13]

Table 2 UK–German biomedical research rankings, 1988 and 1996

	UK ranking		German ranking	
Subfield	1988	1996	1988	1996
Anaesthetics	2	2	3	3
Cardiology	2	3	4	5
Neuroscience	2	3	4	4
Respiratory	2	2	4	5
Arthritis & rheumatism	2	2	6	4
Renal medicine	4	4	2	3
Immunology	2	3	5	4
Gastroenterology	2	3	6	5
Haematology	2	3	4	4
Neonatology	2	2	4	5
Gerontology	2	2	6	5
Tropical medicine	2	2	4	4
Obstetrics/gynaecology	2	2	3	4
Genetics	2	3	4	4
Oncology	3	3	4	4
Histopathology	3	3	4	4
Multiple sclerosis	2	2	3	3
Developmental biology	3	3	4	4
Ophthalmology	2	2	3	3
Average	2.3	2.6	4.1	4.1

The rankings are based on the UK's and Germany's shares of the total papers published on specific therapeutic area in 12 OECD countries: Australia, Canada, Switzerland, Germany, Spain, France, Italy, Japan, Netherlands, Sweden, the UK and the USA.
Source: Calculated from tables in Welcome Trust.[13]

medical journals in both 1988 and 1996. (Though not displayed in Table 2, the USA is also ranked first in all research areas.) The USA has more biomedical research publications than the UK, Germany and Japan combined. The UK is in second place, with a slight decline in its ranking in several leading areas. Germany ranks fourth in the world, slightly behind Japan in most therapeutic areas and in terms of total publications.

The vast lead in US biomedical research should present significant comparative advantages for its commercial biotechnology sector. Its entrepreneurs have easier access to extensive high-quality research ideas to commercialise. The UK's research base is much smaller in absolute terms though compares more favourably if we control for the differences in gross domestic product (GDP) between the two countries – the US economy is about six times larger than that of the UK.

That the UK and Germany have GDPs of similar size and that Germany has relatively fewer publications imply that the total pool of quality research projects from which potential German entrepreneurs may draw is significantly smaller than in the UK. This may contribute to the tendency for the German biotechnology industry to specialise in platform technologies, since these areas of biotechnology depend less on access to therapeutics-related biomedical research. However, this is an area in which more in-depth research needs to be performed.

Laws and incentives for technology transfer

To exploit the science base commercially, institutions to facilitate the transfer of technology from the public to the private sector must be in place. Intellectual property laws, federal rules governing the transfer of public research to the private sectors, and the financing of technology transfer offices within public universities and laboratories each influence how university administrators and scientists develop technology transfer offices. These rules and programmes differ across countries, with important implications for how technology is supplied to biotechnology firms.

Numerous scholars have linked the early development of US biotechnology directly to the high-powered incentives that the 1980-enacted Bayh–Dole Act provided universities to organise technology transfer offices (see Abramson *et al*.[15]). This law cedes ownership of all federally funded research grants from the National Institutes of Health and other funding sources to the universities. Though revenue sharing differs across universities, most technology transfer offices split income between the inventor scientist, his or her department, and the university. The Bayh–Dole Act established 20 per cent as the minimum share in royalties to inventing scientists engaged in federally funded research.[16]

In 1980, the then public National Enterprise Board (now private British Technology Group) founded Celltech, the UK's first biotechnology firm, but this direct government involvement was exceptional. In 1985, the laws regarding the exploitation of publicly funded research were reformed and a systematic intellectual property regime for university research was established, five years after the Bayh–Dole Act. In general, UK technology transfer policies have been based upon the US model.

Under the new laws, the ownership of university intellectual property was transferred from the British Technology Group to the universities.[17] Universities were charged with the development of technology transfer offices to exploit and protect this intellectual property (IP). A number of technology transfer models evolved within UK universities, all of which operate on the basic principle of sharing licensing revenues between individual scientists, university departments and the university. (For an excellent discussion see Arthur Andersen.[17]) The fact that the vast majority of UK biotechnology firms were formed after this change in IP laws took effect is evidence of the need for explicit IP rules. Of the 38 public biotechnology firms listed in the UK in 2000, 35 of them were formed after 1985.

The German case presents an even clearer illustration of the importance of adequate legal incentives supporting technology transfer. Until an explicit biotechnology industry policy was introduced in 1993, the start-up dynamic, commonplace in the USA and increasingly in the UK, did not take place.

Under German law, professors own most IP derived from publicly funded research. Because universities do not own the IP, they had little incentive to establish technology transfer offices. (One exception is the Max Planck Society[18] which has a separate legal status and its own technology transfer office, Garching Innovation, which organises licensing schemes for Max Planck-funded research based on the US model. Since it was reorganised in 1979, Garching Innovation has backed patent applications for 1469 inventions and concluded 827 licensing agreements with non-German firms. Since 1995, Garching Innovation has also organised a separate programme to help spin-offs firms from Max Planck laboratories. More than 20 companies have been established, the majority of them in the biomedical field.) At the same time, professors did not have resources to obtain patents for this research and those seeking an external outlet to commercialise their work tended to develop long-term relationships with established pharmaceutical companies. (This paragraph relies strongly on the extensive review of German technology transfer practices in Abramson *et al*.;[15] see also Momma and Sharp[10] and Schmoch.[19]) Under these collaborations, the IP and research were transferred from the university laboratories to the large firms at minimal cost in exchange for generous fees paid to professors.

There is, therefore, a history of university/industry relationships in Germany, but the primary technology link has been with large firms. Abramson *et al*.[15] have argued that this system works well in applied fields where research can be easily commercialised by large firms and links these technology transfer practices to the success of German firms in engineering-related industries. However, in scientific areas where basic research ideas need extensive additional research before commercialisation is possible, this intellectual property regime proves inadequate. German pharmaceutical companies are more interested in establishing alliances with US biotechnology companies where the commercialisation process has already taken place than buying 'raw' research ideas from the universities.[1] This leaves German universities without the resources or an established vehicle to commercialise German-derived biotechnology research. At the same time, professors and large established firms are resistant to changes in the IP ownership system.

Rather than reform the laws in 1995, the German government introduced industry-specific initiatives designed to try to encourage universities to transfer technology and set up entrepreneurial spin-offs. Biotechnology was explicitly targeted. Under the federally funded 'BioRegio' competition, 17 regions established biotechnology promotion offices, a prerequisite for consideration in the competition where three winners would get DM50m in federal grants over a five year period. Specifically, the government funds were to be used to finance the development of local technology transfer offices and fund 'pre-commercial' research and development projects in local start-up firms. Regions had also to demonstrate access to matched funds from state and local grants as well as contributions from prominent local businesses and publicly managed venture capital funds.

The winners of the federal funds were Munich, the Neckar Rhein region (centred especially in and around Heidelberg) and Nordland Westphalen (primarily the Cologne area) but many other BioRegions have also flourished using state and local grants. The Berlin programme, which has been able to tap into funds designated for post-unification restructure, is the best example of a thriving, non-winning region. Jena in east Germany has also had access to post-unification restructure funds. Table 4 shows the number of small and medium enterprises (SMEs) (in all industry segments) for the 17 regions that originally applied for the BioRegio funds as of July 1998, according a UK Department of Trade and Industry survey. The winning regions are highlighted in bold.

In total the BioRegio offices have overseen the establishment of more than 200 usually very small biotechnology firms. This success, in terms of sheer numbers at least, indicates the importance of incentives to motivate universities to transfer technology and also suggests that alternatives to university-run systems can be effective. Most of the BioRegio offices are public or para-public organisations (privately run with some public ownership). With the exception of Freiburg, direct university involvement is minimal.

The types of projects technology transfer offices can support depend on their resources and organisational structures. We explore these issues in the next section.

The organisation and resources of technology transfer offices

In the biotechnology industry, technology transfer practices involve more than licensing university research. Tasks include the development of incubator laboratories and technology parks in and around the research campuses, as well as the provision of financial and consulting services to help university scientists patent research, develop business plans for their own spin-offs, or to arrange collaborations with existing biotechnology firms. Technology transfer offices require resources to support and oversee these activities and qualified personnel to evaluate potential projects and help establish contacts between professors and external experts.

The lack of adequate resources is commonly sited in studies of the UK technology transfer system.[4,21] Under the university-based technology transfer systems in the USA and UK, offices aim to pay for their activities through a combination of licensing fees and funds raised through holding shares in spin-offs they sponsor. However, it takes a long time to become self-financing by this route, particularly in the biotechnology case where start-ups typically fail, and even for successful cases profitability is many years off. As a result, technology transfer offices need large cash infusions during their formative years. In the USA most large research universities, both public and private, enjoy extremely large (i.e. billion

Table 4 The BioRegio competition-driven start-up dynamic

Region	Number of SMEs (1998)	Start-ups since 1996
Berlin–Brandenburg	40	30
Braunschweig, Goettingen, Hanover	>30	25
Bremen	2	1
Freiburg	30	11
Greifswald–Rostock	17	7
Halle–Leipzig	13	7
Jena	>20	14
Mittelhessen	7	2
Munich	**36**	**16**
Nord (Hamburg, Kiel)	30	12
NW Niedersachsen	5	5
Regensburg	13	11
Rhineland (Cologne, Dusseldorf)	**50**	**11 (plus 8 company expansions)**
Rhine–Main Hessen	24	8
Rhine–Main Mainz	24	8
Rhine–Neckar Triangle (Heidelberg)	**20**	**9**
Stuttgart	11	7
Ulm	8	4

Sources: DTI/ British Embassy in Germany.[20]

dollar plus for several of the largest universities) endowments raised through extensive fund-raising among wealthy alumni. Technology transfer offices have been allowed to dip into these endowments to set up venture capital funds for start-ups as well as to obtain seed capital with which personnel with expertise in both particular scientific fields and patenting and consulting expertise can be obtained.[15] Many large US universities, following Stanford's early example, have also raised funds to finance nearby technology parks and incubator parks to foster prolonged collaboration between university departments and spin-off firms.

Though similar in design to the USA, the results of the UK government technology transfer policies have lagged well behind because of differences in the financial organisation of universities. UK universities generally lack the large private endowments generated by alumni and corporate sponsors within large American research universities. This leads to much less available funding available from university coffers to fund technology transfer offices.[17] With insufficient funds, these offices struggle to recruit enough quality staff and to provide the seed capital needed for investments in the development of many projects. A more generalist orientation creates difficulties in appraising proposals, which could lead to the funding of potentially poor business plans. Universities also lack resources to fund incubator laboratories or science parks, and instead have relied on private market entrepreneurs or in some cases local governments to undertake such ventures.[17]

Recent government initiatives could lead to more cohesion within UK technology transfer offices. The most important of these programmes is the University Challenge Fund (UCF), introduced in 1998. This programme invites university technology transfer offices to submit bids for between £1m and £5m of funding to be applied to the provision of seed capital for start-up firm projects organised through university technology transfer offices. It requires each university to obtain matching grants of 25 per cent of the total requested from government funds, ideally from venture capitalists, industry angels and firms. While the UCF is open to all technological areas, the Wellcome Trust, a substantial private sponsor of biomedical research in the UK, has promised to match the initial governmental funding of £20m, ensuring that substantial UCF-generated resources will flow to biotechnology projects.

Compared with the UK, most German technology transfer offices formed through the BioRegio programme are relatively well funded. The government-funded technology programmes have developed many of the functions typically seen in university technology transfer offices in the USA. In return for services, most fledgling start-ups cede small equity stakes to either the local BioRegio office itself, or in some cases to para-public venture capital organisations operating in conjunction with local programmes. The BioRegio offices then draw upon a number of publicly funded programmes to help scientists and local entrepreneurs organise virtually every phase of start-up formation within the biotechnology sector. This includes the hiring of consultants to help university professors or their students make decisions about commercialising their research and design viable business plans, subsidies to help defray the costs of patenting intellectual property, and the provision of management consulting and partnering activities new firms can draw on. Most of the BioRegio programmes have also used public funds to create 'incubator laboratories' to house fledgling start-ups in and around universities or public research laboratories, and several areas also have created technology parks where firms entering into expansion phases can locate.[22]

A second major advantage of German technology transfer offices compared with the UK is their exclusive focus on biotechnology. This allows them to hire personnel exclusively for expertise in this area.

However, German offices face potential problems stemming from their public status.

The focus, especially by politicians, has up until now been on the aggregate number of firms created rather than the quality or success of these firms. Of the 200 or so firms created in association with the BioRegio programme, the vast majority are tiny firms that would not exist were it not for generous public funding. Officials interviewed at several of the largest German BioRegio offices in 1999 repeatedly expressed concern about a political backlash should large numbers of firms fail. One reason why most German biotechnology firms have specialised in platform technologies is that these segments have much lower risk profiles than therapeutics.[23] While other factors pertaining to the science base and a generally inexperienced venture capital sector[4] also have played roles, political factors have unquestionably shaped the emerging structure of the German biotechnology industry.

Conclusions

The technology transfer systems are a key component in a broader institutional system that supports and promotes the biotechnology industries. In this paper we have explored the links between the types of companies that exist in Germany and the UK and the technology transfer systems that helped create them. In the UK, the starting date of the entrepreneurial start-up dynamic corresponds closely with the establishment of specific laws giving universities explicit control over intellectual property developed with public research funds. In Germany, sector-focused policies to help fund technology transfer offices were needed to get around otherwise restrictive IP laws.

We have argued that in addition to facilitating the establishment of start-ups, the organisation and financing of technology transfer systems and their ability to coordinate start-up companies' access to other resources affect what kind of technology is commercialised and what product strategies these companies develop. Finally, the quality of the country's science base and the incentives professors and top researchers have to involve their research in commercial projects is important for the strategic position and longer-term sustainability of the start-up companies. There is a key difference, however, between the risk profiles of the kinds of technology and projects spinning-out in the German and in the UK. Though more evidence is needed to affirm our position, we suggest that the tendency of German companies to concentrate in platform technologies seems to be linked to both the types of research underway in the universities and the scientists who are responding positively to the incentives created by the BioRegio offices.

In the UK, recent government studies[24] have called for sector-specific 'cluster' policies to strengthen the ties between the academic and the private biotechnology sectors. The German 'BioRegio' policy has been put forward as a possible model. Our analysis of how the technology transfer systems operate in Germany and the UK raises questions, however, about how appropriate or necessary this kind of government intervention is for the UK case. Most of the components of the technology transfer system and supporting network exist in the UK. The scientists are allowed and have incentives to work in both the university and private sectors. A mature and extensive venture capital market exists as do markets for business services such as business plan consultants, patent lawyers and technology parks.

More important than 'coordinating' interventions may be the pumping in of additional resources. Technology transfer offices often lack the resources to hire top staff or to maintain adequate connections with other services. Given the evidence of moderate decline in the UK science base, further research is also needed to explore whether the science base in the UK requires additional resources to maintain and boost its world class position. Representatives of the pharmaceutical and biotechnology industries, looking for partners and new staff, have, for example, expressed concerns about the limited number of skilled UK scientists and researchers in key technology areas such as genomics, bioinformatics, toxicology and animal pharmacology.

In Germany, key questions remain about what, if anything, the government will have to do to continue to support its new industry as the companies mature and seek additional resources, especially labour and finance. Professors in Germany can license research results and engage in limited consulting activities but cannot work directly for a start-up firm without giving up their university post. Thus, post-docs have founded the majority of companies. In the short term, if one assumes that the commercialisation of basic scientific ideas requires the direct inputs of top scientists, this may affect the development of top-quality science in the German companies. There is also concern about the long-term supply of experienced scientists coming through the German university system that will be qualified and available to work in German companies.

The venture capital market in Germany is also relatively immature though the money available to start-ups has increased significantly over the past five years.[22] Until now, much of that money has gone into less risky, platform technology companies than therapeutics projects but that trend may be determined by the types of research being commercialised. In general, the BioRegio programmes have been successful in jump-starting the commercialisation process of the German industry. What remains to be seen is if the multiplier effects into the required private supporting sectors will suffice to support enough of the new companies to give credibility to the direct public involvement in their establishment.

With detailed research of the resource demands of different subsectors, especially for platform technologies and therapeutics, the hypotheses developed here can be more vigorously tested. In particular, such work could further support our position that the national specific institutions, incentives and networks, a key component of which is the technology transfer system, help explain company product strategic decisions and ultimately, companies' opportunities for success.

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