EUROPEAN COMMISSION
European Research Area
SEVENTH FRAMEWORK PROGRAMME
Funded under Socio-economic Sciences & Humanities

Centre for Economic Policy Research

SCIFI-GLOW: SCience, Innovation, FIrms and markets in a GLObalised World

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Science, Innovation, Firms and Markets in Europe

New Perspectives on Policy

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Luc Soete is Director of the United Nations University research and training institute: UNU-MERIT located in Maastricht, The Netherlands and Professor of Internal Economic Relations and Director-Dean of the Maastricht Graduate School of Governance (MGSoG) at Maastricht University. He is a member of the Advisory Council for Science and Technology Policy (AWT) and the Royal Dutch Academy of Science (KNAW).

Luc Soete graduated in economics from Ghent University, Belgium. He obtained a DPhil in economics from Sussex University where he worked as senior research fellow at the Science Policy Research Unit in the late 70's and 80's. From 1984 till 1985 he was visiting associate professor at the Department of Economics at Stanford University, USA. In 1986 he joined the new Faculty of Economics and Business Administration (now called the School of Business and Economics) at Maastricht University as professor of International Economics Relations. In 2010 he became Director-Dean of the Maastricht Graduate School of Governance of Maastricht University. He is a member of the Board of the Maastricht School of Management (MSM) and the Belgian media company Concentra.

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She is co-promotor for the Flemish Government "Steunpunt" on R&D Statistics, a CEPR Research Fellow (London) and currently an Economic Advisor at the Bureau of European Policy analysis (BEPA) of the European Commission, on leave from the KU Leuven (2004-2008).

Foreword

Science and innovation are central to the European policy agenda. The EU's 'Horizon 2020' initiative for research and innovation, for example, aims to create new growth and jobs and secure Europe's global competitiveness by supporting research and innovation that strengthens the EU's leadership in science and industry. In order to design such policies, we need a better understanding of how knowledge is created and how firms use this knowledge in producing and marketing their products.

Science, Innovation, Firm and Markets in a Globalised World (SCIFI-GLOW) was launched in 2008 to add to our understanding of how firms, markets and institutions transform scientific advances into innovation. Ten research teams from seven European countries came together in SCIFI-GLOW, which was funded by the European Union's 7th Framework Programme.

These research teams were largely comprised of economists, although researchers from other disciplines were involved as well. It is interesting to consider what economics can usefully contribute to discussions of science, technology and innovation. The answer must surely be a focus on markets and incentives, which tend to be underplayed or even ignored in most discussions of technology policy. Two of the contributions to this volume demonstrate this point particularly well.

New products, particularly in information technology and communications, require hundreds of hardware and software components, each protected by its own set of patents. Relying on decentralised bargaining to reach licencing agreements for each of these components will almost certainly not work. One response has been the Standard Setting Organizations (SSOs) analysed by Patrick Legros in his contribution. SSOs constrain the behaviour of intellectual property rights holders in order to allow products to be developed and come to market. While these constraints lead to static gains by reducing opportunistic behaviour, Legros stresses that they also change incentives over the longer term and this may impose dynamic costs, which are typically ignored in policy discussions. While Legros emphasises the importance of incentives, Paul Seabright and his colleagues focus on the relationship between market size and innovation in the pharmaceutical industry. They note an empirical finding: the elasticity of innovation with respect to market size seems to be about 25.2% – for every 1% increase in market size, the number of new drugs will increase by 0.252%. So policies to contain future healthcare costs by squeezing drug prices may result in less innovation.

Mathias Dewatripont, the Centre's Research Director, provided the initial intellectual leadership for SCIFI-GLOW. The design and development of the project benefitted significantly from Mathias' inputs, energy and commitment. When, in 2011, Mathias became a member of the Executive Board of the National Bank of Belgium, his role as Scientific Co-ordinator passed to the capable hands of László Halpern, Senior Research Fellow and Deputy Director at the Institute of Economics of the Hungarian Academy of Sciences in Budapest. We are very grateful to both Mathias and László for the support and direction they have provided.

An important and valuable service was provided by Viv Davies, Chief Operating Officer at CEPR, who designed and organised the final SCIFI-GLOW policy workshop in Brussels in April, 2012, and brought together in this volume some of the key policy results and messages that have emerged from each of the project's work streams. We are also grateful to Bob Denham, who played a crucial role in distilling the research into the 'policy brief' format adopted in this report. Thanks are also due to Anil Shamdasani, Publications Manager at CEPR and our new recruit Charlie Anderson, who together brought this volume to a publishable state with their customary speed and efficiency.

Introduction

Viv Davies
CEPR

In 2000, EU leaders committed to the objective of making Europe "the most dynamic and competitive knowledge-based economy in the world, capable of sustainable economic growth, with more and better jobs, greater social cohesion and respect for the environment." They drew up the Lisbon Agenda to achieve that goal, the central strategy of which was based on policies to encourage investment in knowledge. Knowledge as a public good with potential spillovers is the rationale behind intellectual property protection and subsidies for investments in innovations that could potentially lead to high spillovers – university research that creates basic knowledge is a prime example of this.

However, research also showed that spillovers can be generated from private firms' R&D and that firms can therefore benefit from the presence of more innovative and more productive firms. But which universities and which types of firms are more innovative? And how does globalisation influence the answer to these questions? Furthermore, how could policy help shape and influence the innovation process?

These are some of the questions that the FP7 collaborative project on '*Science, Innovation, Firms and Markets in a Globalised World*' set out to answer in 2008, when a group of economists – based in ten institutions from seven European countries – grouped together to design a research programme that would look simultaneously at the organisation of the 'knowledge sector' and at the behaviour of firms and markets. The aim was to bring together two communities of researchers – those who were interested primarily in the research sector and those who were studying the effect of globalisation in terms of trade flows and the organisation of firms and product and labour market outcomes. It was a diverse group of academics with expertise across a range of topics, including the economics of science and innovation, the economics of incentives and contracts, industrial organisation, international trade, and labour economics. The project combined both theoretical and empirical research and built upon a number of databases, both at the cross-country level and at the national level, in order to highlight interesting and relevant case studies.

The SCIFI-GLOW research programme

The research undertaken during the project was disaggregated into two main parts: the first part was aimed at advancing the frontier of knowledge concerning the production of knowledge in a global world, whilst the second part looked at the effect of globalisation on the organisation of firms, and in particular on their use of knowledge and the implications it has on productivity, employment and competitiveness. The goal was to assess the interactions between science, innovation and production in a unified way. Both Part 1 and Part 2 contained three themes each, as follows:

Part 1: The knowledge sector and the global economy

- **The organisation of science (and creation of knowledge) in the new global era**. Research under this theme analysed in particular the productivity of the science sector, its funding and organisation (internally as well as across institutions, through alliances and networks), and the 'market for scientists'.
- **Industry-science links**. This theme looked at the issue of innovation and considered the role of university-firm collaborations in international R&D alliances. It also looked at industry-science links in terms of local development and addressed the question of the overall complementarity between basic and applied research, with the incentives for sharing knowledge in these two environments.
- **Intellectual property rights and the diffusion of knowledge.** This theme studied the role of patents, licensing, R&D alliances, Standard Setting Organizations,

and scientific communication in the global knowledge society. A particular focus was on the interaction between competition law and intellectual property rights; how strategic behaviour in obtaining and defending IPRs are affected by global competition; and how strategic behaviour of this type affects innovation and the diffusion of knowledge in the international arena, in particular through off-shoring.

Part 2: Globalisation, Innovation and Firms: How knowledge interacts with globalisation and the organisation of the economy

- **The organisation of firms, contracts and markets in the global knowledge society**. Research under this theme analysed how the organisation of firms is currently changing under globalisation, an implication of which is the trend towards the off-shoring of knowledge-intensive activities.
- **Globalisation, the labour market and inequality**. This theme looked at the interaction between innovation, job creation and job destruction; the potential risks on job stability linked to multinational employment compared to 'domestic jobs'; and the 'new international division of labour' in Europe, and the extent to which job migration towards the East concerns knowledge-intensive activities.
- **International trade flows, knowledge creation and diffusion, and innovation.** Work within this theme analysed the impact of trade liberalisation on the innovation process. While theme 4 started from the internal organisation of firms, this theme focused on the 'discipline' that trade imposes on firms, both in the manufacturing and the service sectors.

During its four years of implementation, the SCIFI-GLOW project has produced a number of research working papers and policy papers on each of these themes; it has also convened, via CEPR, a series of policy discussion meetings in Brussels that brought together academics, practitioners and policymakers to discuss a range of issues covering the breadth of the research undertaken during the project. All of these papers, as well as details of the meetings, can be found at *http://scifiglow.cepr.org/*.

The SCIFI-GLOW project brought together leading scholars working at the frontier of academic knowledge on these topics; yet the issues analysed are also highly policy-relevant. This final SCIFI-GLOW policy report is a collection of 'policy briefs' that distil and highlight some of the key research and policy messages that have emerged during the course of the programme.

In the rest of this introductory chapter we briefly describe the policy papers that have been included in the Report.

The organisation of science and creation of knowledge in the new global era

Science is becoming increasingly globalised, with more countries now actively building their scientific capabilities and participating in world science, with scientific knowledge being increasingly created across borders. The opening chapter by **Reinhilde Veugelers**, "Towards a multipolar science world", presents several factors that appear to be driving this increasing globalisation of science. Veugelers is keen to point out however, that within science there are nevertheless forces still working to counterbalance the globalisation.

Veugelers takes stock of the recent evidence available to document the geographic shifts in scientific production and the implications for policy and concludes that despite the continued dominance of the US and the increasing importance of the EU in science, advanced countries are in relative decline and that scientific research from emerging economies is growing in stature – both in quantity and quality. Also, that this catchup in science is a slow but real trend and that the main driving force behind the catchup is China, with many countries still lagging behind. We are not headed towards an integrated science world, but a multipolar one. Finally, for advanced countries, the issue is not how to hide away from the process of global integration of science, but rather how to benefit from it.

The chapter by **Javier Ruiz-Castillo**, "From European Paradox to European Drama: New evidence on citation impact", describes how official EU studies on the research performance of scientists in the EU have regularly highlighted what they call a 'European Paradox' – i.e., whilst Europe is the world leader in scientific excellence in terms of the number of studies published in academic journals, it appears that its ability to transform this into innovation and ultimately growth and jobs lags far behind the US.

Ruiz-Castillo argues that the problem with the European Paradox is that it is exclusively based on the number of publications rather than on the citation impact of each publication, which is a measure of how influential the research is. Ruiz-Castillo concludes that the European Paradox in scientific research is in fact a 'European Drama' and that, based on a measure of how influential the research is, the US dominance over the EU is almost universal. He maintains that research institutions should be rewarded based on their influence rather than on the number of publications they produce, and that European scientists should be encouraged to publish in English in the natural sciences and in some social sciences to help their research reach a wider audience.

Industry-science links

Science is also becoming more and more important for innovation, and with this there is a growing emphasis on the link between science and industry. Despite this global trend, Europe is playing catch-up. Performance in R&D and innovation is disappointing. On the supply side, public and, especially, private investment in R&D still falls short of the goals set by the Lisbon Strategy for EU growth. The framework conditions for innovation fail to provide adequate incentives and rewards and the networks needed for innovation are not well enough developed within the private sector and between the public and private sectors.

The chapter by **Reinhilde Veugelers** on "Improving Europe's industry-science links" highlights the fact that Europe's lagging innovative performance should be a concern for policymakers. Despite the growing emphasis on industry-science linkage and Europe's weakness in this regard, there is a lack of high quality indicators and analysis on the subject. Veugelers maintains that industry-science linkage should be a central part of innovation policy and that policies should aim to stimulate the supply from science and demand from industry; she concludes that research should be provided to inform these policy aims.

Intellectual property rights and the diffusion of knowledge

Research and development (R&D) used to be simple to analyse: once the invention was created, an inventor would bargain face-to-face with a producer in order to develop the invention. This view is slowly becoming something of the past. New products are complex and require the development of multiple inventions – often hundreds – and also need to be compatible with other products or special infrastructures. This is especially true for 'communication' products such as smartphones or in-car communication systems. Bargaining among hundreds is difficult, and it may seem at times something of a miracle that these products get made at all.

Navigating intellectual property rights (IPRs) is an organisational problem as well as a policy challenge. Coordination is required among developers and inventors in order to ease bargaining and development and to avoid the 'tragedy of the anti-commons' where property rights mean that some socially valuable resources are under-utilised. Yet, while the static gains of such constraints reduce opportunistic behaviour and encourage ex-post adoption of the standard, there are potential dynamic costs of these constraints, like a reduced ex-ante participation.

In the chapter on "Organising innovation: Standard Setting Organisations", **Patrick Legros** argues that dynamic gains should receive far more serious attention and that researchers should be encouraged to study the organisational choices by SSOs in order to provide a sound basis for policy that nourishes innovation, while avoiding the threat of over protecting property rights – or under protecting them.

In the chapter on "Innovation in the Pharmaceutical Industry and Market Size", **Paul Seabright** et al describe how pharmaceutical companies are among the most research-oriented in the world and how their innovative research is essential both for individual patients and for the economy as a whole. Recognising the lifesaving benefits from the development of new drugs, one of the key decisions faced by policymakers is how to bolster pharmaceutical innovation.

Seabright looks into the potential effects on drug innovation of policies that affect market size, such as policies towards intellectual property rights, procurement mechanisms and competition policy. The authors conclude that policy makers need to better understand why the productivity of pharmaceutical innovation is declining, in order to see whether public policy can help, and that policies to reduce drug prices may reduce R&D incentives if the expected market size shrinks. Also, when innovation is highly responsive to changes in returns, firms need market power as a reward for their investments in order to help spur the development of new medicines that can bring about major improvements.

The organisation of firms, contracts and markets in the global knowledge society

Over the last 15 years, the nature of the typical multinational company has been evolving. Organisational changes have involved a change in management style to more decentralised, less hierarchical decision-making; greater specialisation in the profitable areas of the business; more emphasis on nurturing employees or 'talent'; and the reorganisation of the company with different stages of production taking place in different countries – including offshoring and outsourcing.

Additionally, trade within firms (for example, components for building a mobile phone travelling from one factory in China to the final factory in the US) are estimated to account for one-third of the increase in world trade since 1970. Indeed, these changes have been so fundamental that we might come to think of these companies as examples of a 'new corporation'

In the chapter on "The New Corporation in Europe", **Dalia Marin** looks at the emergence of this new corporation in Europe, where intra-firm imports account for up to 69% of total imports between old and new Europe. It explores the role of the opening up of the former communist countries as a driving force behind the increase in offshoring and outsourcing within the new corporation. It also examines the challenges these changes in corporate organisation may pose for policymakers.

Marin concludes that globalisation has led to the formation of the 'new corporation' in Europe and that outsourcing and offshoring to Eastern Europe offers huge benefits for German and Austrian firms, with cost savings of up to 70%. And furthermore, that trade policy needs to bear in mind the changing structure of European firms. In future, firm boundaries may become more important than country boundaries for the design of trade policy.

In his chapter on "Industrial Policy in the Global Knowledge Society", **Marc Ivaldi** also looks at how, over the last few decades, European firms have undergone a dramatic process of reorganisation, driven mainly by the opening of new markets as part of the wider trend towards globalisation. He summarises recent research, undertaken with Olivier Billard and Sébastien Mitraille, that investigates and analyses the causes and consequences of these changes in corporate behaviour (drawing from case studies in the financial audit industry, the banking sector and the rail industry) and explores the ways in which policymakers can keep up with these changes.

Ivaldi stresses that policymakers need to think about designing industrial policy that can face the broad challenges of globalisation and technical changes whilst still remaining focused on individual sectors in order to provide the right incentives for companies to promote welfare – and the right punishments when they do not. In the financial audit industry, policymakers should aim to increase competition either by facilitating entry of competitors or by changing the rules in order to prevent collusion. In the banking sector, policymakers should be sensitive to the possibility that increased market concentration does not always mean less competition. In the rail industry, policymakers should continue with plans for a powerful European rail authority in charge of monitoring the rules and pricing of access to the European rail network.

Globalisation, the labour market and inequality

In 2010, Europe's leaders put together a strategy to help the continent grow out of its current economic crisis – the 'Horizon 2020' strategy – which highlights three key ways in which the EU can "innovate out of the crisis" – (1) through greater investment in research and innovation, both public and private in order to speed up the *rate* of technical change; (2) by improving the *direction* of change to areas that are more environmentally sustainable and socially desirable; and (3) by thinking about ways to use funds to boost local innovation and efficiency in underperforming regions, particularly those in the grip of a sovereign debt crisis.

In his chapter on "Innovating Out of the Crisis", **Luc Soete** argues that all three areas call for more radical structural reforms than are currently being presented by Europe's policymakers in the Annual Growth Strategy 2012. He maintains that there needs to be a much more explicit commitment to public knowledge investment in order to stimulate 'smart growth'; also, that shifting towards sustainable growth – both environmentally and socially – requires a whole range of tools and instruments both domestic and global; and that the aim of achieving inclusive growth is probably most directly challenged by the sovereign debt crisis – but this should be seen as an opportunity. The idea of 'smart specialisation' needs to be broadened to include the public sector.

In the chapter on "ICT and the polarisation of skill demand", **John Van Reenen** describes how job markets in the OECD countries have become more unequal in recent years, and because this has been accompanied by a large increase in the proportion of university-educated people, the inescapable conclusion is that the demand for more highly skilled workers has risen by even more. The consensus among academics is that this increase in demand for high-skilled workers is linked to technological progress driving up the demand for workers who are able to deal with a more complex and challenging workplace. Also, new facts on inequality, or 'polarisation' in the US show that *upper half* inequality – the difference between the richest tenth of the population and the middle – has risen continuously over the last three decades, but after increasing during the 1980s, *lower half* inequality – the difference between the middle and the poorest tenth – has actually fallen since then. This is what is known as 'polarisation'.

Van Reenen concludes that whilst wage inequality in the OECD countries has risen dramatically over the last 30 years, this is not simply a case of the more educated benefiting at the expense of the less educated; rather, it is the middle-skilled who are losing out most. Also, that polarisation is not necessarily bad news for the least skilled – there will be jobs for them even in a high-tech world; but for the middle classes, technology may be endangering their future labour market prospects. And finally, that technical change is the main driving force for these inequality changes. Although trade with lower-wage countries such as China does not increase inequality directly, it may have an indirect effect by speeding up the adoption of new technologies.

International trade flows, knowledge creation and diffusion, and innovation

In the chapter on "Technology Transfer through Capital Imports", **László Halpern** explains how the vast majority of machinery production is concentrated in only a handful of advanced economies. As a result, most other countries rely heavily on machinery imports, which have a wide-ranging impact on the economy. According to several studies, the imported machines contribute to capital accumulation and growth. Yet how do technologies move from one country to another? When firms import capital, do they also import foreign research and development (R&D) as well? And if they do, which firms benefit most from the imported technology?

Halpern suggests that policymakers should be very interested in these questions. Identifying when and how technology diffuses across borders is central to understanding cross-country differences in productivity, with implications for jobs, growth, and welfare. He concludes that technology is increasingly important for economic growth – but much of this technology comes from only a few advanced countries, forcing many countries to import technologies. Detailed data from Hungarian firms suggest that imported technology raises productivity and has contributed to a substantial rise in productivity over the last two decades, both within and across firms; and that imported technology raises demand for skilled workers – a form of 'skill-biased technical change'. In doing so it has contributed substantially to the increase in wage inequality in Hungary.

In the chapter on "R&D Spillovers and Firm Productivity", **Michele Cincera** points out that research and development (R&D) undertaken by one firm can have a significant and positive effect on the productivity of other firms, and that this is particularly the case when these firms are close to one another in a physical sense and even more so in a technological sense. In many cases, firms benefit more from the R&D of other firms than they do from their own R&D.

Knowledge originating in one country or region is increasingly able to cross national boundaries and contribute to the productivity growth of other geographic areas – a process known as 'R&D spillovers'. It is widely recognised that such knowledge flows between regions significantly boost economic growth. Cincera looks at the magnitude of R&D spillover effects on the productivity growth of large international R&D companies. In particular, he studies the extent to which R&D spillover effects are increased when the company is geographically close to the origin of the innovation and when the company is 'close' in the sense of working with similar technologies

Cincera concludes that firms have an incentive to under-invest in R&D in the hope of free-riding from the investments of other companies. Public intervention through subsidies, tax credits or public procurement for R&D projects is therefore needed to bring R&D closer to optimal levels. Further, that regional policies aimed at attracting R&D companies to a given area or encouraging new high-tech clusters are essential; and that policy measures allowing increased concentration in particular industries and technological sectors will help firms get closer to one another in a technological sense.

In the concluding chapter on "The Effectiveness of R&D Tax Incentives", **Pierre Mohnen** argues that given the size of tax incentives for research and development (R&D) in many European countries, it is wise to try to measure their effectiveness – despite this being imprecise and difficult. More and more countries are adopting tax incentives as a way to encourage private spending on research and development. Such tax incentives usually amount to tax breaks or tax credits for spending, so long as firms can demonstrate that money is being spent on R&D. There is consensus among economists that R&D is essential for stimulating economic growth. Compared with direct government support for R&D in the form of grants, research contracts, subsidies or procurement, tax incentives have the advantage of being 'neutral' in that they tend not to favour a particular kind of project or research area. Yet this can also be a disadvantage – indirect support in the form of tax incentives cannot single out specific projects that are judged to have a particularly high social rate of return.

Given the scale of these tax incentives, amounting to close to 0.4% of GDP in France for instance (Figure 1), the immediate question addressed in this chapter is how effective these tax incentives are.

Mohnen concludes that R&D tax credits carry with them a welfare loss: much of the increase in R&D expenditure by the private sector would have taken place anyway, meanwhile the government loses tax revenue. R&D tax credits can, however, be more effective for small credit-constrained firms. Also, that tax credits may lead to a rise in the wages of R&D personnel, increasing the cost of R&D. He recommends that policymakers need to devise a way to stimulate R&D without financing already existing or planned R&D expenditure and that they should compare the effectiveness of tax credits for R&D with subsidies for R&D as well as other forms of direct government assistance.

Concluding remarks

Science and innovation remain central to the European policy agenda. The EU's new 'Horizon 2020' initiative for research and innovation has been designed to help create new growth and jobs in Europe with the aim of securing Europe's global competitiveness. Clearly, and urgently, more research needs to be undertaken on these very important topics in order to inform policy and stimulate growth. It is very much our hope that this collection of essays, or 'policy briefs', from the SCIFI-GLOW project – which is by no means inclusive of the full range of research that was undertaken in the project – will help towards providing a bridge for policy makers to the academic work that is being undertaken in these areas.

Towards a multipolar science world

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Despite the continued dominance of the US and the increasing importance of the EU in science, advanced countries are in relative decline. Scientific research from emerging economies is growing in stature – both in quantity and quality.

This catchup in science is a slow but real trend. The main driving force behind the catchup is China, with many countries still lagging behind. We are not headed towards an integrated science world, but a multipolar one.

For advanced countries, the issue is not how to hide away from the process of global integration of science, but rather how to benefit from it.

Introduction

Science is becoming increasingly more globalised – with more countries now actively building their scientific capabilities and participating in world science and with scientific knowledge increasingly being created across borders.

Several factors are driving the increasing globalisation of science.

- First there is the globalisation of the world economy. Firms are increasingly selling to and sourcing inputs from abroad. This also holds for their research and development (R&D) activities, where firms are looking to access scientific sources outside their local boundaries (Thursby and Thursby 2006).

- Second, scientific talents are more internationally mobile – students as well as scholars. As a result, scientific institutions and firms are competing for talent in a global market.
- Third, the cost of international scientific activities has reduced drastically. The ICT and Internet revolution has particularly lowered the cost of international communication and boosted international exchanges in scientific work.
- Fourth, the research agenda is increasingly being made up of issues that have a global dimension, such as climate change, energy, and pandemics.
- Finally, policymakers are increasingly focusing attention on international cooperation in science and technology. This includes funding programmes to stimulate the 'internationalisation' of higher education and research.

Nevertheless, within science there are still forces counterbalancing the globalisation, such as the resilience of the national dimension in education, science and technology policy and public funding; the importance of face-to-face meetings for informal knowledge transfer; cultural and language barriers; and the inertia of personal and institutional networks.

Globalisation of science and its impact is discussed often and with great animosity. In the US in particular, the decline of its dominant position in science, the rise of the Asian countries, and its dependence on predominantly Asian foreign scientists in the scientific workforce raise deep concerns on the sustainability of US capacity for scientific leadership, innovation, and international competitiveness (see for example King 2004, Segal 2004, and Freeman 2005). But the debate also surfaces in the EU and challenges its hopes of becoming the most knowledge-based economy in a globalising world. Most of the time, these debates are taking place without sound empirical underpinning.

This Policy Brief takes stock of the recent evidence available to document the geographic shifts in scientific production and the implications for policy.[1]

1 This Policy Brief is based on a SCIFI-GLOW CEPR Policy Paper. See Veugelers (2009).

Where are the publications being produced?

An important starting observation is that total number of world scientific publication has been increasing at an average annual growth rate of 2% from 1995 to 2005. Although the size of the global cake has been growing, there are nevertheless important shifts in how the rising cake is being sliced.

The US had been, and remains, the world's largest country in terms of scientific publications, although since 1995 it has been outperformed by the EU, when looking at the whole integrated area.

Table 1 Share of the TRIAD and non-TRIAD in world scientific publications

	1995	2000	2005
USA	34%	31%	29%
EU	25%	35%	33%
Japan	8%	9%	8%
RoWEST*	9.3%	9.0%	9%
TRIAD	**86%**	**84%**	**79%**
Asia (excl. Japan)	5.3%	8.0%	12.8%
C/S America	1.7%	2.4%	2.9%
Other former USSR	4.1%	3.3%	2.5%
Near East/Africa	2.4%	2.4%	2.5%
NON-TRIAD	**14%**	**16%**	**21%**

Notes: *RoWest = Canada, Oceania and other Western Europe.

Sources: NSF, S&E Indicators 2008, S&E articles in all fields, ISI-publications

Nevertheless, the Triad of the US, EU, and Japan has been losing share relative to non-Triad countries. This increase outside the Triad is mostly due to the Asian continent. In Asia, China's scientific growth performance is the most impressive (Hicks 2007 and Zhou and Leydesdorff 2006).

Table 2 Share and growth (AAGR) of the BRICs in world scientific publications

	1995	2000	2005	95-05 AAGR%
BRICs	7.2%	8.2%	11.4%	
China	1.6%	2.9%	5.9%	16.5%
India	1.7%	1.6%	2.1%	4.5%
Russia	3.3%	2.7%	2.0%	-2.5%
Brazil	0.6%	1.0%	1.4%	11.1%

Note: AAGR% = average annual growth rate.

Source: NSF, S&E Indicators 2008.

With an average annual growth rate of 16.5%, China has increased its position in world publications from almost non-existent to ranking fifth in 2005, behind the US, the UK, Japan, and Germany. And in 2006, China became the world's second largest producer of scientific knowledge behind the US (EC-Relex 2007). China's increasing presence is particularly felt in specific scientific fields like Physics, Chemistry, and also Engineering, where China holds a comparative scientific advantage (Glänzel et al. 2008).

Beyond the spectacular rise of China, other emerging scientific nations are also changing the balance of power. South Korea and Turkey have an average annual growth rate of scientific publications of more than 10% and a share in the world total publication output of 1% or more in 2005, and thus represent, together with China and Brazil, the most dynamic countries in terms of science production.

Where is the science workforce located?

Human capital is the most critical input factor in the science process. Unfortunately, there are no internationally and historically comparable data available on the science workforce. However, looking at trends in the geographic distribution of new PhDs degree awarded, with the caveat that not all PhDs are scientists and not all scientists are PhDs, can provide an indication of where the science workforce is located.

For the most recent year available, 2004, Table 3 provides the share of world PhD degrees awarded, broken down by regions and selected individual countries. The last column of Table 4 repeats the share in world publications, for comparison. Although the US is the Number 1 country for numbers of PhD degrees awarded, its top position is less dominant than in world publications. The US is the country with the highest ratio of publications per PhD degree awarded. The EU-27 delivers more than twice the number of US PhD degrees, and also the Asian region and the former USSR countries account for sizeable numbers of PhDs awarded. With the exception of Turkey, all BRICs and emerging science countries have a larger share in world number of PhD degrees awarded than their share in world publications.

Table 3 Doctoral degrees awarded in 2004 by awarding regions and selected countries

Country	Share in world PhD degrees awarded, 2004	Share in world publications, 2005
USA	14.7%	29%
Japan	5.9%	8%
UK	5.3%	6.4%
Germany	9.1%	6.2%
Russia	10.4%	2.0%
China	8.2%	5.9%
INdia	4.8%	2.1%
Brazil	2.8%	1.4%
S. Korea	2.8%	2.3.%
Turkey	0.9%	1.1%
Region	**Share in world PhD degrees awarded, 2004**	**Share in world publications, 2005**
EU-27	33.7%	33%
Asia	23.3%	21%
N. America	16.1%	33%
Other former USSR	13%	2.5%
Near East/Africa	6.7%	2.5%
C/S America	3.9%	3%
RoWest	3.2%	5.4%

Source: Own calculations on the basis of NSF, S&E Indicators 2008.

Is there a process of convergence?

Do these trends imply a more general process of catching-up and convergence? Looking at several indicators to measure concentration/inequality, there is a clear, but nevertheless slow, process of convergence during the period 2000-2005.

The Theil coefficient – a measure of economic inequality – allows the decomposing the total world inequality into subgroups: the Triad and the non-Triad countries. This decomposition allows us to analyse whether the trend in overall convergence is due to convergence *between* these two groups, which is the catching-up process of the non-Triad countries, and/or *because* of convergence within each of these two groups (Table 4).

Table 4 Decomposing the world's scientific inequality: Triad versus non-Triad (2000-2005)

	Rel T_{World} (1)	Rel T_{Triad} (2)	Rel $T_{Non\text{-}Triad}$ (3)	$Share_{Triad}$ (4)	Share of world inequality due	
					Between-group (5)	Within-group (6)
2000	0.26	02.6	0.14	0.84	23%	77%
2005	0.23	0.25	0.17	0.78	16%	84%

Source: Own calculations on the basis of NSF, S&E Indicators, 2008.

The *'between-group' inequality* only accounted for 23% of overall inequality. But this 'between-group' component has decreased significantly over the period 2000-2005. This is clear evidence of the catching-up process of the non-Triad countries.

The *inequality within the non-Triad countries*, displayed in column (3) is markedly smaller than the inequality within the Triad countries displayed in column (2). But it has increased over time. This suggests that the catchup process of the non-Triad countries has been very unequal. In other words, the dramatic rise of China has not been matched by other non-Triad countries. China has increased its share of non-Triad publications from 18% in 2000 to 27.5% in 2005.

To conclude, almost all of the reduction in world scientific inequality is due to the non-Triad countries catching up. This catchup is particularly a reflection of China's growth, which has at the same time been responsible for an increase in the inequality among the non-Triad countries.

Globalisation of science and the movement of people

What does this mean for the movement of people? A first important observation is that, overall, the number of students and scholars moving internationally has increased. In 2005, there were 2.7 million foreign students enrolled in higher education outside their country of origin (undergraduates and postgraduates). This is a 50% increase as compared with 2000 (OECD 2007).

As Table 5 shows, the most important country of origin of these mobile students is, not surprisingly, China, followed by India. Korea (3.8%) and Japan (2.5%) further complement the Asian window. The other BRICs (Russia and Brazil) are less significant sources of foreign students. The most favoured destination for these foreign students is the US. There are however some marked differences for the BRICs in terms of countries of destination, with India's extreme focus on the US and Russia's strong favour for Germany and relative neglect of the UK and the US.

Table 5 Distribution of foreign students from BRICs to Triad destinations, 2005

Country of origin		Country of destination			
		US	UK	Germany	France
China	**16%**	*23%*	*13%*	*7%*	*4%*
India	**5.5%**	*60%*	*12%*	*3%*	*0.4%*
Brazil	**0.7%**	*38%*	*6%*	*9%*	*9%*
Russia	**1.6%**	*12%*	*5%*	*28%*	*6%*
		27%	**17%**	**14%**	**6%**

Notes: Numbers in italics are the shares in row country's total number of students enrolled abroad. Shaded cells represent cases of "overrepresentation", i.e. where the share of the row country in the column country is larger than the total column country's share.

Source: OECD, Education at a Glance (2007).

International co-production of scientific publications

Has the rise in the number of scientists from non-traditional countries led to changing patterns of international scientific collaboration? A first important observation is an overall increase in international scientific collaborations (see Table 6 and Glänzel et al. 2008). However, for the fast emerging science countries, as their own science base grows, the share of international collaboration does not intensify over time, it even has declined in relative terms – see Brazil and China.

Table 6 Trends in share of international publications in total number of publications for BRICs and fast-growing science countries

Country	1988	1996	2003
Russia		26.8%	40.5%
India	10.4%	16.1%	21.9%
Brazil	29.6%	41.8%	36.2%
China	22.5%	28.0%	26.8%
S. Korea	27.4%	26.8%	28.0%
Turkey	22.4%	226%	21.5

Source: NSF, Science and Engineering Indicators 2006.

Looking at partnerships in international co-publications for 2005 (Table 7), we see that the most important dyads still involve the US with a large Triad partner (Germany, the UK, Canada, Japan, and then France). Nevertheless, the China-US dyad comes in 6th position; close behind US-France.

Ties between the EU and the BRICs and other emerging science countries are still very modest and often historically and geographically marked. For example, for almost all EU countries, Russia is the most important partner, while Brazil's ties with Portugal and Spain carry a cultural and historical imprint.

Overall, the EU is not a strong science partner for BRICs, with the exception of Russia. Not only is the EU not very high on the radar screen for Chinese collaborative efforts, the share of the EU27 in total Chinese international co-publications has even been declining over time. This does not hold for the US, whose share as partner for Chinese international collaboration has remained dominant over time. This correlates with the large and stable flow of Chinese human capital into the US, which forms the basis on which stable international US-Chinese networks are built. With the EU lacking this Chinese human capital circulation, it is more difficult to build up similar strong and stable networks. The same holds true for Korea and Turkey, where the dominance of the US as international partner for scientific co-publications also mirrors the strength of the flows of human capital from these countries to the US.

Table 7 Share of Top-10 dyads in total number of international co-publications (2005)

	DYAD	Share in world international publications	International Collaboration Index
1	US-GER	5.9%	0.69
2	US-UK	5.8%	0.72
3	US-CAN	5.2%	1.19
4	US-JAP	4.0%	0.91
5	US-FRA	3.7%	0.59
6	US-CHINA	3.3%	0.91
7	US-ITA	3.1%	0.76
8	UK-GER	2.9%	0.79
9	GER-FRA	2.4%	0.86
10	US-AUS	2.1%	0.80
11	US-SKorea	2.0%	1.25
12	US-Nethl	2.0%	0.70
13	US-ESP	1.8%	0.61
14	US-SUI	1.7%	0.70
15	GER-RUS	1.6%	1.41

Notes: Shares do not add up to 100%; Articles are no whole-count basis, i.e. each collaborating country credited one count. To account for unequal country sizes, the International Collaboration Index (ICI) is also given. It is calculated by dividing a country's rate of collaboration with another country by the other country's rate of international co-authorship: (ICPij/ICPj)/ ICPi/ICP). A number higher than 1 represents a larger than expected co-publication dyad. Shaded cells have ICI > 1.

Source: Own calculations on baisis of NSF, S&E Indicators 2008.

Has co-authorship led to scientific catchup?

Has the growth in international collaboration been used by non-Triad emerging countries to fuel their catching up process? As Table 8 illustrates, international co-publications have higher than expected citations for all countries considered, including for the catch-up countries. When considering trends over time, the Triad's international collaborative research quality has stagnated. By contrast, research quality of co-publications involving emerging countries have risen sharply. With most of their international collaborations with top Triad countries, the increase in the quality of their international collaborative research has helped these fast emerging countries to catch up. But since the share of international collaboration is not on the rise, the catching-up in overall quality of these countries, seems not only due to the higher quality of international collaborative research, but also has to be based on an increase in the quality of nationally produced research.

Table 8 Evolution of the relative citation rate of internationally co-authored papers

	1991		1997		2003	
	All papers	Int Coll	All papers	Int Coll	All papers	Int Coll
EU15	1.04	1.21	1.05	1.22	1.04	1.18
US	1.07	1.22	1.09	1.24	1.10	1.21
Japan	0.97	1.19	0.97	1.20	0.94	1.10
China	0.67	0.85	0.79	0.95	1.02	1.11
S.Korea	0.72	0.91	0.88	1.06	0.94	1.10
Brazil	0.75	1.00	0.76	0.90	0.86	1.05
Turkey	0.62	0.85	0.70	1.03	0.90	1.17

Source: Glänzel et al. (2006).

Conclusion

The evidence on scientific publications and workforce clearly demonstrates that despite the continued dominance of the US and the increasing importance of the EU, the Triad is in relative decline. Other geographic sources of science outside the Triad are rising, in quantity but also, to a lesser extent, in quality. China is the main driver of this non-Triad growth.

The data show a slow but real process of increasing convergence, with the catchup of non-Triad countries and the sources of new scientific knowledge more evenly spread across the globe. This global convergence nevertheless leaves a less equal non-Triad science community, as the growth of some emerging countries, such as China, is not matched by other non-Triad countries. The process of growing international integration can not yet be associated with the shaping of a truly global integrated research community, but rather a multi-polar one.

What does the rise of non-Triad countries, and particularly China's rise in the global science community, mean for the scientific and economic position of advanced countries? Will the erosion of the Triad dominance in science diminish its advantage in knowledge-based value creation? In any case, the issue will not be how to hide away from the process of global integration of science, but rather how to benefit from it as much as possible. Countries will need not only to improve the competitiveness of their national science and innovation systems in a global environment, but to learn better how to connect into global science networks to achieve national benefits.

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From 'European Paradox' to European Drama: New evidence on citation impact

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The 'European Paradox' in scientific research is in fact a European Drama. Based on a measure of how influential the research is – the number of citations an article receives – the US dominance over the EU is almost universal.

- *Research institutions should be rewarded based on their influence rather than on the number of publications they produce.*
- *European scientists should be encouraged to publish in English in the natural sciences and in some social sciences to help their research reach a wider audience.*

Introduction

In science, as elsewhere, there is no good policy without an appropriate diagnosis. Official EU studies on the research performance of scientists in the EU have regularly highlighted what they call a 'European Paradox'. The problem is as follows: If we look at the number of studies published in academic journals, Europe is the world leader in scientific excellence. And yet if we look at its ability to transform this into innovation and ultimately growth and jobs, it lags far behind the US.

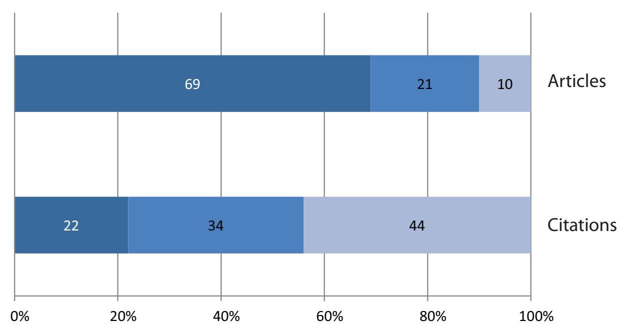
But is this really a paradox? This Policy Brief argues that the problem with the European Paradox is that it is exclusively based on the number of *publications*. Since the mid-1990s the EU has indeed published more scientific papers than the US. However, as soon as we take into account the *citation* impact of each publication – a measure of how influential the research is – the US comes out on top by a distance. Moreover, articles produced in the EU perform particularly poorly among highly cited research papers.[1]

Challenging the European Paradox

The study looks at 3.6 million articles between 1998 and 2002 published in more than 8,000 academic or professional journals in 36 languages. It also looks at the approximately 28 million citations to these within five years of being published. It then divides these articles into three places of origin: the US, the EU, and the rest of the world.

The first finding is that citation distributions are highly skewed, with the mean at about the 69th percentile of the distribution. It shows that most articles are hardly cited at all, while a small number are responsible for a disproportional percentage of all citations (see Figure 1).

Figure 1 Articles and citations



The main finding is that forces explaining publication efforts across different scientific fields are different from those explaining relative *success*, as measured by citation impact. Thus the European Paradox hides a truly *European Drama*: judging from

1 This Policy Brief is based on a SCIFI-GLOW CEPR Policy Paper. See Ruiz-Castillo (2012).

citation impact in the periodical literature, the dominance of the US over the EU is almost universal at all aggregation levels.

The study evaluates citation distributions using two indicators. A *high-impact indicator* for articles with citations above a certain critical level of citations, and a *low-impact indicator* for articles with citations below that level. The high-impact level in the EU is greater than the US in 30 out of 219 sub-fields, three out of 80 disciplines, and none out of 22 fields. However, the US/EU high-impact gap is greater than 100% in 71 sub-fields, 27 disciplines, and eight fields. This confirms that there is no connection between publication shares and whether this research has a high or low impact.

The study then looks at a larger dataset of 4.4 million articles published

between 1998 and 2003. It divides these articles among 38 countries and eight geographical areas of origin. It finds that the UK and six small continental countries (Austria, Belgium, Denmark, Finland, Netherlands and Sweden) perform relatively well. As a result, the explanation of the European Drama must be found in the relative poor performance of Germany, France and, above all, Italy and Spain – the four large continental countries. Greece and Portugal are also poor performers.

Of the most successful research articles – those with the top 10% of citations compared with the average for that field – many of those from Europe are internationally co-authored. In the six small European countries, between 58% and 69% are internationally co-authored. In the four larger continental countries the percentage is between 55% and 60%. In the UK it is 51%. In the US, on the other hand, only 29% of the top research articles are internationally co-authored. The global average is around 45%. This suggests that future research, taking into account international co-authoring, may further question the European Paradox, as well as the relative responsibility of small continental EU countries versus large ones.

The results from this study concur with previous research (see for example Dosi et al. 2006, Glänzel and Schubert 2001, Glänzel et al. 2002, and Veugelers and Van der Ploeg

2008). The value added by this study lies in the method and the sheer amount of data analysed.

Two direct policy implications

1. The evidence indicates that the EU publishes many articles with little impact. As a result, it would be better to reward citation impact rather than the number of publications.
2. One reason for the relatively poor performance of the four large continental countries – Germany, France, Spain and Italy – is that they publish articles in their own languages. This reduces the likelihood that academics in other countries will access their research and as a result damages the potential for influence. It would therefore be better to incentivise or somehow reward publishing in English in the natural sciences and in some social sciences (see Drèze and Estevan 2007 for a discussion of language and influence in the field of economics).

Areas for further consideration

In order to learn more about centres of excellence within the EU, it would be helpful to extend the empirical analysis to individual institutions. Also, the study of success stories within the EU or other non-US areas will be useful for policymakers before making any further policy recommendations.

While the skewed influence of scientific research towards the top 10% is to be expected as it reveals the skewed talent in these fields in all countries, it is worth investigating the role that incentives play in encouraging scientists to produce world class research.

Given the observed concentration of talent in the US, several authors have found the more important differences in the following two dimensions:

- **Governance of scientific institutions.** This includes their autonomy, recruitment and promotion policy, accountability and competition.

- **Resources**. Private resources should be increased through tuition, gifts, and private/public matching grants. Moreover, there should be more attention paid to the endowments of institutions rather than just flows. It is worth noting that the US spends far more on education as a percentage of its GDP than many countries in Europe but also that many institutions in the US have far larger endowments.

Conclusion

The main point of the study is to question the European Paradox. It finds that the problem is more of a *European Drama*. Judging from citation impact, the dominance of the US over the EU in the basic and applied research published in the periodical literature is almost universal.

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Improving Europe's industry-science links

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Europe's lagging innovative performance should be a concern for policymakers. Despite the growing emphasis on industry-science linkage and Europe's weakness in this regard, there is a lack of high quality indicators and analysis on the subject.

Industry-science linkage should be a central part of innovation policy. Policies should aim to stimulate the supply from science and demand from industry. New research should be provided to inform these policy aims.

Introduction

Science is becoming more and more important for innovation, and with this there is a growing emphasis on the link between science and industry. Despite this global trend, Europe is playing catch-up. Performance in R&D and innovation is disappointing. On the supply side, public and, especially, private investment in R&D still falls short of the goals set by the Lisbon Strategy for EU growth. The framework conditions for innovation fail to provide adequate incentives and rewards and the networks needed for innovation are not well enough developed within the private sector and between the public and private sectors.

This Policy Brief focuses on Europe's lagging innovative performance, arguing that it is at least partly related to deficiencies in industry-science linkage. It then explores the question of how policy can improve this.[1]

1 This Policy Brief is based on Veugelers et al. (2012).

Measurement of industry-science linkage

Science-industry linkage can arise through a number of channels. Scientists and scientific institutions can 'engage actively', either by patenting their research or by starting up technology-oriented enterprises based on the science generated by their research. They can also collaborate by engaging in joint research projects, contract research, or know-how-based consulting.

Science-industry linkage can also occur through the job market. Firms can recruit graduate and postgraduate students or cooperate with universities in graduate education. Universities can provide advanced training for enterprise staff, or install open information access policies. Companies and universities can agree to systematically exchange research staff. Moreover, researchers are known to be mobile between the public and private sectors, and can help the informal transfer of knowledge between sectors.

Since industry-science linkage can occur on multiple levels, it can be measured in multiple ways. A first way to study science-industry linkage is by looking at the number of patents applied for by universities. Table 1 shows the share of European Patent Office (EPO) patents applied for by each assignee category between 1980 and 2007. Companies account for 85% to 89% of all patents, followed by individuals (6% to 12%) and government and non-profit organisations (2%). Yet while universities accounted for only 2.66% of EPO patents between 2001 and 2007, this is more than three times larger than its share in the early 1980s.

Table 1 Trends in university patenting in technology development (university assignees, EPO)

Sector	1980–1985	1986–1990	1991–1995	1996–2000	2001–2007
Company	84.90%	87.04%	88.5%	88.42%	89.20%
Government/non-profit	2.41%	2.36%	1.98%	2.09%	2.29%
Hospital	0.07%	0.15%	0.19%	0.22%	0.19%
Individual person	11.84%	9.30%	7.70%	7.00%	5.84%
University	0.79%	1.16%	1.57%	2.28%	2.66%
	100.00%	100.00%	100.00%	100.00%	100.00%

Source: Veugelers et al. (2012)

Another way to assess the role played by universities in technology development is through the measurement of citations from corporate patents to university patents. As patent citations are an indication of knowledge flows, citations from corporate patents to university patents indicate that technologies developed at universities have served as a technological base for further innovation by the private sector. Table 2 makes the comparison between the US, the EU15, and Japan. While the US has the highest share in university patenting and corporate citations received by university patents, the EU15 receives more citations per university patent than the US. In terms of impact of cited university patents, however, the US outperforms both Japan, and the EU15.

Table 2 University citations and their impact

	US	EU-15	JP
Share in university patenting	68%	21%	1.4%
Share in corporate citations received by university patents	67%	23%	3.8%
Citation Intensity Index*	0.98	1.08	2.67
% university patents cited	14%	28%	49%
Impact of cited university patents	6.03	3.74	4.77

Notes: *Citation Intensity Index measures a country's share in corporate citations received by university patents, relative to its share in university patenting. A value larger than 1 indicates that the country received a higher number of citations per university patents than the world average.

Source: Veugelers et al. (2012)

Other ways of measuring the industry-science linkages include:Patents and start-ups from universities. These measures show that while European universities and research institutes are ahead of the US in terms of patent applications and patent grants per million spent on research (in purchasing-power adjusted dollars), the US outperforms Europe in terms of executed licenses and established start-ups (Conti and Gaulé 2009).

- *Public-Private co-publications.* One of the ways to quantify cooperation between the public and private sectors in scientific activity is through the number of scientific publications that are co-authored by people from both sectors. This indicator is used in the European Commission's Innovation Union Competitiveness Report 2011 (European Commission 2011). The US and Japan publish much more co-publications per million of population: in 2008 the US reached 70 co-publications per million, while the number was around 55 in Japan and 35 in the EU. However, both the EU and the US are increasing the amount of public-private co-publications.
- *Public-Private cooperation in innovation.* Private firms often cooperate with the public sector in the development of innovative products and services. Universities (and other higher education institutions) are involved as the main cooperative partner in a significant share of innovative enterprises: ranging from around 5% in Spain to around 30% in Finland.

Because industry-science linkage manifests itself through many channels, policymakers should be careful to avoid biasing their selection of indicators towards formal and measureable links or indicators for which data are easily available – those links that are available and measurable are not necessarily the most relevant ones. The question then arises: Which links are the most important for policy? Moreover, do industry-science links matter for performance?

Supply side industry-science links

Research by Lach and Schankerman (2008) finds that universities that give higher royalty shares to academic scientists generate more inventions and higher licensing income. Bercovitz et al. (2001), meanwhile, find that universities with high records in industry-science linkage tend to have a decentralised model of technology transfer, such as technology transfer offices (TTOs).

Technology transfer offices at universities are dedicated to identifying research findings with commercial potential and then developing strategies for how to exploit these. For instance, a research finding may be of scientific and commercial interest, but patents are normally only granted for practical processes, and so someone at the technology transfer office will typically come up with a specific practical process to boost the patent application.

Technology transfer offices at universities have both advantages and disadvantages. The primary disadvantages of these offices concern the running costs and cost of set up. A secondary issue is the potential for 'principal-agent problems' between the office and the university, as well as between the office and researchers. That is, the office may set incentives for the production of commercially-viable research but because the researchers have more information about their research, they can choose to only put in low effort if the incentives are too generous.

The prime advantage of technology transfer offices, meanwhile, is that they specialise in supporting services, such as the screening of projects and searching for potential buyers and financers, allowing universities interested in patenting their research to operate more efficiently.

Empirical evidence has shown that technology transfer offices at US universities enjoy *constant* returns to scale with regard to licensing activities, but *increasing* returns to scale with regard to licensing revenue. This suggests that, if the quality of inventions transferred rather than the quantity matters, technology transfer offices need to reach a critical scale to reap the full benefits.

Other studies suggest that the productivity of TTOs further depends on organisational practices, the most critical of which are the ways faculty are rewarded for their research, such as royalty distribution, and the ways in which the staff of the TTOs themselves are rewarded.

A cause of concern for the EU is that there are too many small technology transfer offices that fail to reach the critical mass required to provide the best quality service. Moreover, publicly-supported TTOs crowd out private services, and unclear regulations (such as professor's privilege) and tax treatments further hamper TTO effectiveness.

There are, however, some best practices in the EU. These include maintaining close proximity with research teams, allowing enough autonomy for research teams to develop relationships with the private sector themselves, centralising specialised supporting services (such as contract management, intellectual property rights management, and business development), and the presence of remuneration packages which reward successful transfer.

Demand-side science-industry links

Are firms engaged in seeking industry-science links and, if so, which firms? Are linkages having a positive effect on firm performance, particularly with regard to innovation?

A study by Mansfield (1998) shows that 15% of new products and 11% of new processes, representing about 5% of total sales in a sample of major firms in the US, could not have been developed without the backing of academic research. However, other sources have questioned this finding. The results of Eurostat's Community Innovation Surveys, for example, show that more than two-thirds of firms see universities as *not at all* important sources of information, leading many to argue that industry-science linkages benefit only a section of firms.

While there is not enough evidence to dispute this claim, there are a number of studies showing the positive effects of industry-science linkage:

- Cockburn and Henderson (1998) find that co-authorship with university employees increases the R&D productivity of pharmaceutical firms.

- Several studies find the presence of leading scientists ('star scientists') in firms is associated with firm entry and new product development in biotech as well as nanotech (Zucker et al. 1998, Zucker et al. 2005, Stephan et al. 2007).
- Meanwhile, recruiting university scientists is shown to lead to higher research productivity for the firm (Kim et al. 2005).
- Firm patents, which have been developed in teams including academic inventors, have a higher 'value' than others (measured through the number of forward citations) (Toole and Czarnitzki 2010, Cassiman et al. 2011).
- The most productive inventors are publishing researchers, firm researchers co-publishing with university researchers, and inventors mobile between universities and firms (Azoulay et al. 2007, Dietz and Bozeman 2005, Fabrizio 2004, Gittelman and Kogut 2003, Hoisl 2007, Palomeras and Melero 2010).
- The presence of universities with strong publication records in relevant science fields attracts R&D investments by multinational firms. This pattern is observed both at the country level (Belderbos et al. 2011) and at the regional level (Belderbos and Van Roy 2011). In particular, active collaboration between local firms and universities, as indicated by local co-publications, appears to attract R&D activities.

At the same time, some firms are more enthusiastic than others about the presence of universities and collaboration potential. Multinational firms with stronger scientific orientation tend to weight countries' academic research strengths significantly stronger, highlighting the importance of an 'absorptive capacity' to understand, assimilate, and build on university research. Firms with this absorptive capacity can reap the rewards of direct collaboration with universities. In the absence of these capabilities, however, establishing 'indirect' ties to academic research by linking up with intermediary or 'brokerage' firms – firms with strong ties to academia such as dedicated biotech firms in the biopharmaceutical industry – is more effective (Belderbos et al. 2011).

Conclusion

Despite these findings, economists are still far from providing enough help to policymakers looking to improve industry-science linkage. Nevertheless, some helpful insights have been collected here.

First, industry-science linkages should be the central focus of overall innovation policy. Policies should aim to simultaneously affect the supply from science and the demand from industry, as well as the interlinking actors.

Second, efforts should be made to support industry-science linkage policy with data, building a diverse set of indicators, and more analyses should be performed to assess the private and social effectiveness of industry-science linkage. This in turn will stimulate more effective policy.

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Organising innovation: Standard setting organisations

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As technologies have advanced, the way we invent has become much more complicated, with many hundreds of intellectual property rights now involved in innovations.

An example of the difficulties with organising innovation in the 21st century can be found by looking at the functioning of Standard Setting Organisations (SSO) – what is a good for the short term may have detrimental effects in the long term.

Researchers should be encouraged to study the organisational choices by SSOs in order to provide a sound basis for policy that nourishes innovation while avoiding the threat of overprotecting property rights – or underprotecting them.

Introduction

Research and development (R&D) used to be simple to analyse: once the invention was created, an inventor would bargain face-to-face with a producer in order to develop the invention. This view is slowly becoming something of the past. New products are complex, require the development of multiple inventions – often hundreds, and also need to be compatible with other products or special infrastructures. This is especially true for 'communication' products such as smartphones or in-car communication systems. Bargaining among hundreds is difficult, and it may seem at times something of a miracle that these products get made at all.

Navigating intellectual property rights (IPRs) is an organisational problem as well as a policy challenge.

- On one hand, some form of coordination among developers and inventors should be allowed in order to ease bargaining and development, and avoid the ‘tragedy of the anti-commons’ where property rights mean that some socially valuable resources are under-utilised. This coordination may require agreements between the participants that constrain the behaviour of intellectual property rights holders.
- On the other hand, while the *static* gains of such constraints reduce opportunistic behaviour and encourage ex-post adoption of the standard, there are potential *dynamic* costs of these constraints, like a reduced ex-ante participation.

In the policy debate, and also often in the academic literature, much of the focus is aimed at the *static* rather than *dynamic* effects of different organisational structures. This Policy Brief argues that dynamic gains should receive far more serious attention.

Case study: Standard Setting Organisations

An example of the difficulties with organising innovation in the 21st century can be found by looking at the functioning of Standard Setting Organisations (SSO). These organisations develop and coordinate technical standards that are intended to be used by companies throughout the world and cover most areas of industry. One example is the International Organisation for Standardisation(ISO), which is composed of national standard setting organisations and among many other things is responsible for the classification of photographic film based on its sensitivity to light – hence the term ‘ISO number’. Other examples include the World Wide Web Consortium (W3C), whose standards for HTML, CSS, and XML are used universally throughout the world, the European Telecommunications Standards Institute (ETSI) for the development of ICT standards or 3rd Generation Partnership Project (3GPP), an SSO specifically created for the development of the “3G” standard for mobile telephony Standard Setting Organisations illustrate the difficulties in organising innovation for increasingly complicated technologies:

1. There is a wide variety of participants in any ‘standard’. Some participants are national standard organisations that specialise in inventions, others specialise in production and development while others do both. There are also infrastructure developers, such as telecom operators, and representatives of consumer groups, consultancy groups, administrations, or other government bodies. Their ‘size’ is also different: there are large and small manufacturers, as well as organisations from small and large countries. Agreeing on standards among such a diverse group poses huge challenges.
2. The process of creation of the standard is *ongoing*, with inventions added to the standard often by voting within the Standard Setting Organisation.
3. Prices and royalties for use of the intellectual property are mainly determined *after* the standard has been introduced through two-way or round-table bargaining (known as *ex-post* bargaining).
4. In order for the R&D to eventually lead to gains, other market participants beyond manufacturers may have to invest: for instance, in the case of mobile telephony, smartphones using a new standard for transmission (such as 4G) will improve on the previous generation of products only if the operators invest in order to make their networks compatible with the new standard.

Reasonable and non-discriminatory licensing

With ex-post bargaining, Standard Setting Organisations face the risk of opportunistic behaviour by holders of the property rights. The holders can potentially extract huge profits from users once the standard is adopted, by which time it is difficult to go back to the old technology. For this reason, SSO participants agree to follow the rules set by so-called RAND (Reasonable And Non-Discriminatory licensing) in the US or FRAND (Fair, Reasonable, And Non-Discriminatory licensing) in the EU. These rules include:

- Intellectual property right holders should disclose all the patents that may be essential for the standard.

- Participants agree to use “fair, reasonable and non-discriminatory” royalties.

These two clauses prevent or limit the ‘hold-up effect’. The first clause makes it impossible, or difficult, to engage in ‘patent ambush’, whereby firms only disclose their patent after the standard has been accepted in order to receive high royalties. The second clause puts a limit on excessive royalties.

Because coordination between technologies that complement each other is generally not seen as detrimental to competition, regulators have taken a lenient stance with respect to SSOs and their RAND and FRAND agreements. In fact, their guidelines often provide exemptions for such agreements and encourage them to be negotiated before any standards are set.

The direction of the static effects is reasonably easy to assess: by having RAND and FRAND, the hold-up and patent ambush problems should indeed be less pronounced. As already noted, however, *dynamic effects* of FRAND or other types of rules are less well understood.

Reducing the delays

An important source of inefficiency in SSOs is the delay in producing a standard because of haggling between competing holders of intellectual property rights (Simcoe 2012). For instance, many firms may have competing inventions for a technology but only one of them will be incorporated in the standard. What is less well understood is whether certain rules on collective choice can help to reduce these delays. It is also unclear whether delays would be less important in the absence of SSOs, when bargaining takes place in the open market.

A natural source of delay is due to the large number of patents that are disclosed in SSOs. The sheer number of disclosures raises a practical problem for the SSO since they have to navigate through a larger set of patents. Recent research (Dewatripont and Legros forthcoming), considers the incentives to invent when SSOs are governed by

FRAND agreements and where and the holders of patents and property rights expect, because of the "fair and non-discriminatory" feature of FRAND, to get a share of the total future value of the standard – a share that increases in the number of patents that the holder contributes to the standard.

Because the importance of patents is difficult to assess, there is a co-variation between the number of essential patents and the number of inessential patents a firm contributes. This generates a natural force towards over-investment in patent creation by firms, as well as an increase in the number of patents disclosed, as is indeed observed in the data. The co-variation makes policy recommendations subtle. A better screening of inessential patents would help reduce "padding" but will also lead firms to invest less in the creation of essential patents, eventually leading to a decrease in the quality of the standard. A middle ground has to be struck that will not overly distort the quality of the standard.

High royalties

High royalties are natural impediments to the development of products: product prices increase, making consumers less likely to buy them, and operators who may need to make additional investments (in infrastructure, for instance) may be reluctant to do so since there is less demand for the standard itself. For this reason, industry participants are opening the door for agreements on caps on royalties. Here also, while the static effects of caps are relatively easy to assess, their dynamic effects are less so.[1]

For instance, one dynamic effect is related to the interaction between investment for invention (before the standard is agreed) and investment for development (after the standard is agreed). The expectation of high royalties decreases development incentives but may increase inventive activity. Inventors who could commit to royalties would internalise both effects, and 'bring on board' developers and encourage them to invest

1 These results are part of ongoing work, see Dewatripont and Legros (2012a,b).

for their benefit. If as in SSOs, such commitment is not possible, bringing on board developers has to take another channel, that of changing the quality or the number of inventions that are brought to the bargaining table, or agree to a cap on royalties. If the intellectual property rights holders are heterogenous, some specialising in inventions, others being also developers, some form of discrimination between them is necessary in order for all of them to agree to a cap on royalties. There is therefore a tension between the "ND" part of FRAND and the ability of SSOs to induce its members to commit ex-ante to caps on royalties.

Conclusion

Standards are a good thing. They avoid duplication of efforts, facilitate compatibility and reduce switching costs for consumers. As we have seen, organisational details of SSOs are important if they are to bring about these benefits, and bring on board all the stakeholders. One message from this Policy Brief is that what is good organisation from a static perspective may have detrimental dynamic effects; it is therefore important to enrich the analysis of organisational choices by SSOs in order to provide a sound basis for policy.

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Innovation in the pharmaceutical industry and market size

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Policymakers recognise the importance of new medicines for both the health of individuals and the health of the economy. Indeed, encouraging innovation in the pharmaceutical industry is one of the key challenges of our time.

- *We need to better understand why the productivity of pharmaceutical innovation is declining, to see whether public policy can help.*
- *Price regulation of drugs is no free lunch. Policies to reduce drug prices may reduce R&D incentives if the expected market size shrinks. If governments wish to stimulate more R&D, it is worthwhile looking into policies that increase potential market size such as orphan drug exclusivity.*
- *When innovation is highly responsive to changes in returns, firms need market power as a reward for their investments. This will help spur the development of new medicines that bring about major improvements.*

Introduction

Pharmaceutical companies are among the most research-oriented in the world. Their innovative research is essential both for individual patients and for the economy as a whole. The discovery of new drugs may help to treat diseases that were once damaging, incurable, or even fatal. According to several studies, drug innovation has a significant and positive average effect on longevity and quality of life, with knock-on effects for the economy.

Recognising the lifesaving benefits from the development of new drugs, one of the key decisions faced by policymakers is how to bolster pharmaceutical innovation. This Policy Brief looks into the potential effects on drug innovation of policies that affect market size, such as policies towards intellectual property rights, procurement mechanisms and competition policy.[1]

Pharmaceutical innovation and market size

Intuitively, a larger market size will attract more firms and more innovation. Using new data from Intercontinental Marketing Services and the World Health Organisation, a recent study finds a positive relationship between potential market size and the number of new pharmaceutical products in the market (Dubois et al. 2011). It finds an average 'elasticity' of 25.2% – this means that that for each 1% change in market size, the number of new drugs will change in the same direction by 0.252%. This finding is relevant to policy discussion in three ways.

- First, it implies that policies to contain future healthcare costs by squeezing procurement prices may have adverse effects on innovation. For instance, we have been hearing for some years about the continual pressure on government healthcare providers to spend less on drugs. However, it is important to remember that there is a social cost in doing so. If the expected market size shrinks, then the incentives to engage in the development of new medicines will be weakened. Indeed, a 1% decrease in potential market size will reduce the number of novel drugs being developed by 0.252%.

  This may be particularly important in areas where existing therapies are proving increasingly inadequate, as in the growth of antibiotic resistance.

  That being said, this does not mean that cost containment is undesirable, but that the potential disincentive effects on innovation should not be ignored.

1 This Policy Brief is based on a SCIFI-GLOW CEPR Policy Paper. See Dubois et al. (2011).

- Second, it is worthwhile looking into policies that increase potential market size, keeping in mind that one potential benefit is encouraging biomedical innovation. An example of a successful policy in this area is 'orphan drug exclusivity' in the US. There the developer of drugs to combat rare diseases enjoys market exclusivity for seven years following the date of approval.

  Without this exclusivity, pharmaceutical companies are reluctant to undertake research on new therapeutic treatments that affect relatively few people because they might not be able to recover their R&D investments. By contrast, orphan drug exclusivity encourages innovations in this area because pharmaceutical firms will anticipate an increase in sales revenue for the orphan drug during the exclusive marketing period.

  Nevertheless, without assessing the cost of implementing this provision, a positive relation between the market size and new drugs does not imply that we should extend the length of these intellectual property protections indefinitely.

- Third, the importance of the elasticity of innovation with respect to market size has been widely debated (Dubois et al. 2011, Weyl and Tirole 2010). One of the central findings of recent research is that when elasticity of innovation is large, innovations *need* market power as a reward since it incentivises the development of new medicines that bring about major improvements. The size of the elasticities is therefore central to this debate and informs the choice of different institutions for encouraging innovations such as patent protection, prize system and research subsidies.

Pharmaceutical productivity in decline

A further concern raised by this research is the productivity of pharmaceutical research. To put these findings in numbers, over the lifecycle of a drug, an average market size of around $1.8 billion is needed to launch an additional drug (or a constant annual revenue of $148 million that lasts for 20 years). Since this is well above the average cost of R&D, this implies that the marginal productivity of pharmaceutical research is declining. In other words, €1 spent on R&D is yielding less return and pharmaceutical companies therefore require a larger market size to justify their investment.

It is not clear to what extent this fall in productivity is because of intrinsically diminishing returns to research activity (sometimes described as the hypothesis that the pharmaceutical industry has been running out of "low-hanging fruit", see Cowen 2011), and to what extent it is due to steeply rising costs of regulatory approval such as the 'patent thicket', though it seems plausible that both factors have contributed. This fall in productivity is an area in dire need of further research to see if and how policy can help.

Conclusion

Recognising the welfare benefits of pharmaceutical innovation, it is important to understand what factors drive these inventions. This Policy Brief emphasises that care should be taken when designing policies that affect expected market size. Reducing the market size could be particularly harmful as it reduces incentives for investment in R&D.

We need to also have a better understanding of why the productivity of pharmaceutical innovation is declining. This is particularly concerning when the efficacy of existing drugs is declining, for instance because of antibiotic resistance. It is worthwhile looking into policies that increase potential market size such as orphan drug exclusivity, keeping in mind that one potential benefit is encouraging further innovation. When the elasticity of innovation is large, innovations deserve market power as a reward since it incentivises the development of new medicines that bring about major improvements.

Getting drug regulation right is one of the key challenges of our time. This body of research aims to be a valuable resource for thinking through policymaking in the pharmaceutical industry.

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Industrial policy in the global knowledge society

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Policymakers need to think about designing industrial policy that can face the broad challenges of globalisation while still remaining focused on individual sectors in order to provide the right incentives for companies to promote welfare – and the right punishments when they do not.

- *In the financial audit industry, policymakers should aim to increase competition either by facilitating entry of competitors or by changing the rules in order to prevent collusion.*
- *In the banking sector, policymakers should be sensitive to the possibility that increased market concentration does not always mean less competition.*
- *In the rail industry, policymakers should continue with plans for a powerful European rail authority in charge of monitoring the rules and pricing of access to the European rail network.*

Introduction

Over the last few decades, European firms have gone through a dramatic process of reorganisation, mainly driven by the opening of new markets as part of the wider trend towards globalisation. This Policy Brief summarises three recent investigations into the causes and consequences of these changes in corporate behaviour and explores the ways in which policymakers can keep up with these changes.

1. Competition in the audit industry in France

For many, the credit-rating agencies and statutory auditors have a lot to answer for. Many observers point to the failure of these financial intermediaries to first identify high-risk assets and second to prevent their use throughout the global economy – factors that they argue contributed to the global financial crisis.

Indeed, both credit-rating agencies and statutory auditors failed to flag the real level of risks financial institutions were undertaking. This eventually led to dramatic tensions on the interbank credit markets that then spread throughout the financial markets when information on the *actual* risks became available. For many investors, this was only after the bankruptcy of Lehman Brothers.

One reason given for why these external auditors and rating agencies may have failed in their duty is the conflicting incentives they faced. The former are paid by the companies they audit and therefore may have been completely objective, while the latter may have chosen rating systems that were potentially 'disconnected' from the value of the audited companies, with a view to promoting their reputation or raising short-term profits.

Despite the criticisms, these intermediaries do provide extremely important services to the entire economy. By analysing and certifying the value of companies for investors, they help the financial system operate much more efficiently. The goal for policymakers, then, is to make sure these intermediaries are transparent and able to provide the best service from the viewpoint of the economy as a whole.

One way of promoting this is through market pressure. By providing policies that support competition, these firms are more likely to focus on serving their clients rather than co-ordinating among themselves to raise prices or lower their quality of service. Without market pressure, coordination or collusion among auditors could lead to being overly indulgent in their opinions on the financial statements of their clients. They might do this in order to stabilise their market share, gain customer loyalty, or prevent rival firms from the fringe from gaining access to or growing within the market.

Whereas the strategy of economic agents investing in a listed company is based in whole or in part of the opinions of auditors or rating agencies, the revenues or losses of these agents are not fully internalised by these financial intermediaries. A difference may therefore arise between what society as a whole would like to get as an opinion on the financial health of listed companies and what the financial intermediary provides.

A recent study (Billard et al. 2011) proposes an evaluation of the risks of collective dominance in the statutory audit market in France. In particular, it analyses how regulatory obligations governing statutory auditors may favour the emergence of tacit collusion among auditors. The analysis suggests that there is very little preventing collective dominance of the auditing market by the big auditing companies – something that could be damaging for the economy as a whole.

These results suggest that the regulators and the authorities should increase competition either by facilitating entry of competitors or by changing the rules in order to prevent collusion. In particular, an intermediary could be created between the firms to be audited and the auditors, with the objective of monitoring transparency.

2. The impact of mergers on competition in the banking industry

Back in 1992, one of the outcomes of the Second European Directive was a set of policies designed to promote competition in the banking sector. It is well documented that while this directive did, almost instantaneously, restore competition among banks after years of tight regulatory constraints, it has also indirectly prompted a wave of mergers within national borders. As a result, the degree of concentration in the banking industry, measured in terms of market shares, has risen in almost all European countries. Since deregulation was aimed at promoting competition, this rise in concentration raises the concern that these policies may be backfiring.

A recent study (Cerasi et al. 2010) proposes a way of measuring the degree of competition in the banking industry. It originates from a model where entry is ‘endogenous’ – in other words, determined by forces outside of the model. The model captures the fact that banks compete in retail markets by setting interest rates and have the ability to translate an enlargement of their network of branches into higher profits. It proposes that the more rivalry there is in interest rates, the less ability the bank has to enlarge, thus revealing greater competition.

The advantage of this measure of competition is that it requires very little information. All that is needed is a measure of the size of local markets and data on branching market shares of individual banks in these local markets, without any need for accounting data – even when it is publicly available. (These are the same informational requirements used to compute the Herfindahl-Hirschman Index, which is the measure of concentration commonly used in antitrust cases.)

The study shows that the impact of mergers cannot be fully captured by measuring the change in market concentration only. When, for instance, the market structure is fragmented with a single dominant firm, a horizontal merger between medium-size players might restore competitive conditions by generating a rival for the dominant firm in the market. In this case, greater concentration in market shares is accompanied by greater competition, breaking down the intuitive inverse relation between concentration and competition.

3. Industry structure for international rail transportation

International rail services – services from one country to another – have recently been opened up to competition within the EU. This decision, part of the so-called 'Third Railway Package', is aimed at fostering international rail travel, which represents a significant part of railways' revenues and market shares. Indeed, international rail travel accounts for 10% of railway companies' passenger turnover and 20% of overall international travel.

While international rail services face fierce competition from low-cost airlines, many argue that they would profit from the enlargement of the European high-speed network and its interconnection if greater competition were allowed. For the high-speed network to be enlarged, however, all EU member states must grant the right of access to their rail infrastructure – a policy that raises many questions.

One key question raised is what would be the optimal organisation of the European rail industry. From a policymaker's perspective, the 'optimal organisation' is one that best serves consumers.

The traditional option for railway organisation in Europe involves a single firm in charge of both the fixed infrastructure – that is, the network of rail tracks and its associated equipment of signals and stations – and the rolling stock management, i.e. the operational services. In the jargon, the firm is vertically integrated. The main reason put forward to support this form of organisation is that there are high 'returns to scale' from doing so – that is, the more services provided by a railway organisation, the cheaper it becomes to provide each additional service. This suggests that the market may be best served by one provider – what economists call a 'natural' monopolist.

A number of detailed analyses of railroad costs highlight the strong cost complementarities between infrastructure and operations. They also indicate that vertical integration might be costly from a technical point of view. The gains must therefore be balanced against the gains that could be expected from managing the rail infrastructure separately from the different rail service operations.

The other option for rail organisation is the separation into separate providers for different areas. Separation is viewed as a way to foster competition to the benefit of customers. However, a well-known advantage of vertical integration is that it diminishes incentives for 'double marginalisation' – that is, replacing two monopolies with just one – so it may be that some kinds of anti-competitive behaviour become less likely under integration even though the authorities' ability to monitor them is diminished. This is probably why most countries – apart a few examples such as France, Japan, the

Netherlands and the UK – have still maintained an integrated industry or have adopted a partial disintegration where the vertically integrated incumbent is challenged by new entrants.

With these results and facts in mind, one might question the relevance of the European reform of the international rail service contained in the Third Railway Package. Recent research (Friebel et al. 2011) aims to shed light on the working of competition for the international rail services. It provides a theoretical setup to help understand and explain the issues at stake. In particular it looks at the possible effect of the EU directives on liberalisation and unbundling, which, in particular, allow for different degrees of separation.

The analysis focuses on returns to scale, which are usually used to justify the existence of monopolies because they are seen as natural monopolies. It finds that when the share of international services becomes greater with respect to the total level of transport services, some kind of separation tends to be preferred when the infrastructure is characterised by decreasing returns to scale. By contrast, integration would be optimal under increasing returns to scale at the infrastructure level. Importantly, the competitive environment must be taken into account in such reasoning.

Because of the complexities involved in gauging which is the best way to organise the rail industry, these findings support the idea of a policy that reinforces the power of a European rail authority in charge of monitoring the rules and pricing of access to the European rail network.

Final Comment

These three examples sketch out some of the ways in which Europe can develop industrial policy that faces the challenges of globalisation and technical changes, while also providing companies with the right incentives and punishments to ensure their behaviour is best for the economy and society as a whole.

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The 'New Corporation' in Europe

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Globalisation has led to the formation of a 'new corporation' in Europe, with many choosing to outsource and offshore areas of their production to other countries.

Outsourcing and offshoring to Eastern Europe offers huge benefits for German and Austrian firms, with cost savings of up to 70%.

Trade policy needs to bear in mind the changing structure of European firms. In future, firm boundaries may become more important than country boundaries for the design of trade policy.

Introduction

Over the last 15 years, the nature of the typical multinational company has been changing. These organisational changes involve: a change in management style to more decentralised, less hierarchical decision-making; greater specialisation in the profitable areas of the business; more emphasis on nurturing employees or 'talent'; and the reorganisation of the company with different stages of production taking place in different countries – including offshoring and outsourcing.

Trade within firms (for example, components for building a mobile phone travelling from one factory in China to the final factory in the US) are estimated to account for one-third of the increase in world trade since 1970 (see Hummels et al. 2001).

Indeed, these changes have been so fundamental that we might come to think of these companies as examples of a 'new corporation' (Economist 2006).[1]

This Policy Brief looks at the emergence of this new corporation in Europe, where intra-firm imports account for up to 69% of total imports between old and new Europe. It explores the role of the opening up of the former communist countries as a driving force behind the increase in offshoring and outsourcing within the new corporation. It further examines the challenges these changes in corporate organisation may pose for policymakers.[2]

Lessons from Germany and Austria

How trade and investment integration are transforming European corporations can be best studied by looking at Germany and Austria. Not only are Germany and Austria among the European countries most integrated into the world economy, but as direct neighbours of Eastern Europe, firms in these two countries have been most affected by the opening up of the former communist countries.

Between 1994 and 2006, exports and imports to former Eastern European states (now members of the EU) increased from 2% of GDP to 7% in Germany, and from 4% to 11% in Austria. Furthermore, in 2000-1 Eastern Europe (including Russia and Ukraine) accounted for 64% of Austrian foreign direct investment (FDI). German investment-led integration with Eastern Europe started later, but nevertheless accounted for 32% of German FDI direct investment by 2003.

In a recent study (Marin 2010), I look at changes in corporate organisation among 660 global corporations in Germany (460 firms) and Austria (200 firms). I examine 2,200 investment projects from German and Austrian investors in Eastern Europe between

1 Other terms for that aim to explain the 'new corporation' phenomenon include: 'slicing the value chain', 'vertical specialisation', and 'trade in tasks'.

2 This Policy Brief is based on a SCIFI-GLOW Policy Paper. See Marin (2010).

1990 and 2001. These investments account for 80% of German investments and 100% of Austrian investments in Eastern Europe during that period.

Offshoring and outsourcing: Who benefits?

With the enlargement of Europe to include the East, European firms have reorganised and have moved several stages of production to Eastern Europe, where the costs are generally thought to be lower. There are two ways firms can do this:

- Inside the firm - production can be set up a subsidiary in another Eastern European country (offshoring).
- Outside the firm - production can be allocated to an independent input supplier located in Eastern Europe (outsourcing).

The benefit of organising production activity inside the firm is that the headquarters have more control over the activity and stronger incentives to provide headquarter services like R&D. One of the drawbacks from such a set up, however, is the loss of the initiative of managers and workers. The benefit of organising an activity outside the firm by outsourcing to an independent input supplier is that it promotes the incentives and the initiative of the input supplier. The drawback of this set up is that it involves contracts that can be difficult to design properly and to enforce, and there may be opportunities for either firm to exploit the other. Picture the situation where the parent firm refuses to buy a certain component from their supplier at the given price, or the reverse situation where an outsourcing company raises the price of production of a vital component.

Does moving to Eastern Europe help to cut costs for German and Austrian firms?

Comparing relative wages and relative productivity between Germany and Austria, on the one hand, and Eastern Europe on the other shows how beneficial moving to Eastern Europe can be.

- Wages in the countries that joined the EU in 2004[3] are around one quarter of those of Germany. Yet because the productivity of these Eastern European firms is also around one quarter that of German companies, outsourcing to Eastern Europe does not save German companies any money. With offshoring, however, German companies can set up subsidiaries in these countries allowing them to bridge the gap in productivity while benefitting from the lower wages – overall this leads to a cost reduction of around 70%.
- Looking at the countries that joined the EU in 2007 as well as countries from the former Yugoslavia[4], German companies can reduce their costs by 10% by outsourcing and 50% by offshoring.
- Finally, with countries from the CIS[5], including Russia, German companies can reduce costs by 33% with outsourcing and around 70% with offshoring.
- The benefits are similar for Austrian firms.

How important is offshoring to Eastern Europe?

One way to look at whether offshoring benefits Eastern Europe is to look at intra-firm trade – international trade that takes place inside the multinational corporation between parent firms in Europe and their affiliates in Eastern Europe. Between 1997 and 2000, intra-firm trade with Eastern Europe is a dominant phenomenon in Austria's trade with Eastern Europe, while less so in Germany. In Austria, 69% of imports from Eastern Europe are goods from Austrian affiliates in that region. For Germany, the proportion is lower but still significant at around 22%. Yet there is considerable variation across individual countries. Imports to Germany from Slovakia and Hungary for example are

3 Countries that joined the EU in 2004 are: Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, and Slovenia.

4 Countries that joined in 2007 are: Bulgaria and Romania. The former Yugoslavian countries are: Albania, Bosnia and Herzegovina, Croatia, Macedonia, Montenegro, and Serbia.

5 Countries in the Commonwealth of Independent States are: Armenia, Azerbaijan, Belarus, Kazakhstan, Kyrgyzstan, Moldova, Russia, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan

65% and 40% from German affiliates respectively. In short, offshoring has become an important phenomenon within Eastern European.

Who are the outsourcers and offshorers?

Is outsourcing and offshoring then primarily undertaken by firms with a large share of labour in production? The data indeed show that the more labour-intensive firms and the firms with lower wages in Germany are more likely to be moving production to Eastern Europe. But the picture is more complex. As predicted by the theory (Antras and Helpman 2004), R&D intensive firms in Germany tend to prefer offshoring to outsourcing as they save money on wages but maintain more control.

Almost 60% of total German investment to Eastern Europe is undertaken by the manufacturing sector, of which machinery and transport is the most important sector. German affiliates in Eastern Europe are on average more R&D-intensive compared with their parent firms in Germany, they also tend to have more workers working on R&D compared with German parent companies. Austrian investment in Eastern Europe, meanwhile, is predominantly involved in services (more than 70% of total investment in Eastern Europe), in particular in banking and financial intermediation.

The differences between Germany and Austria can be illustrated by the importance of one single multinational firm in each of these countries. Siemens, a manufacturing firm, and Bank Austria each account for about 10% of Germany’s and Austria’s investment in Eastern Europe, respectively.

Challenges for policymakers

Why does it matter how firms organise? It matters for several reasons.

- First, recent research suggests that organisation is an important source of competitive advantage. Firms with ‘better’ organisation tend to introduce IT faster and to show a better performance in productivity, market shares, and profits. The difference in IT capital between US and European firms might explain why Europe has been lagging recently in productivity growth relative to the US (see Bloom and Van Reenen 2006).

- Second, how successful European firms reorganise their international value chain may determine how well they adjust to an increasingly competitive global environment. The best example is Germany's super competitiveness. In the course of Europe's enlargement to the East after the fall of communism, German firms have offshored part of firm activities to Eastern Europe, which helped these firms to lower their global production costs, on the one hand, and to deal with a skill shortage in Germany on the other. The adjustment to the shock of the fall in communism took place inside corporations rather than across sectors. As a result, German firms became more competitive in all sectors and increased their market share in export markets with only a small rise in unemployment. According to a recent estimate, job losses due to offshoring to Eastern Europe have remained below 1% of total employment in Germany.

Do the fundamental changes in the organisation of the corporate sector in Europe require new policies?

With the international organisation of production of European firms, the conflict of interest with respect to the design of trade policy is no longer across sectors (import competing against export sectors) or across groups (capital versus labour), as in the old days, but rather takes place within sectors, at the level of firms based on how they are organised (input-importing firms versus import-competing firms) or within groups (tasks undertaken by workers which are easily transferable to other countries versus tasks not easily transferable). Hence, firm boundaries may become more important than country boundaries for the design of future trade policy.

Two recent examples illustrate how the global organisation of European firms is affecting European trade policy with China.

- One example is the battle between Osram, the German light bulb producing firm, and Philips, a company from the Netherlands. Osram opposes lifting tariffs on imports of energy saving lights bulbs from China, while Philips – which offshores to China – is in favour of it.

- Another example is the conflicting interests between the European Confederation of Iron and Steel Industries (Eurofer), who are asking the European Commission to impose a 25% to 40% tariff on cold-rolled and galvanised steel imports from China, and Orgalime, representing the engineering industries who oppose the tariff by arguing that they have difficulties sourcing raw materials, including steel.

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Innovating out of the crisis

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Europe's latest Annual Growth Strategy needs radical updating if the continent is to "innovate out the crisis" – as policymakers hoped it would back in 2010.

- *There needs to be a much more explicit commitment to public knowledge investment in order to stimulate 'smart growth'.*
- *Shifting towards sustainable growth – both environmentally and socially – requires a whole range of tools and instruments both domestic and global.*
- *The aim of achieving inclusive growth is probably most directly challenged by the sovereign debt crisis. But this should be seen as an opportunity. The idea of 'smart specialisation' needs to be broadened to include the public sector.*

Introduction

Back in 2010, Europe's leaders put together a strategy to help the continent grow out of its current economic crisis: the 'Europe 2020' strategy. It highlights three key ways in which the EU can "innovate out of the crisis".

- First, through greater investment in research and innovation, both public and private in order to speed up the *rate* of technical change.
- Second, by improving the *direction* of change to areas that are more environmentally sustainable and socially desirable.
- Third, by thinking about ways to use funds to boost local innovation and efficiency in underperforming regions, particularly those in the grip of a sovereign debt crisis.

Yet, all three areas call for more radical structural reforms than are currently being presented by Europe's policymakers in the *Annual Growth Strategy 2012*.[1]

What is missing in Europe's innovation strategy?

By far the most important factor behind economic growth – and the area where most has still yet to be done – is the integration of knowledge in its different forms. The integration of knowledge is essential for the development of new technologies and for combining these with old technologies across countries, sectors, and industries.

Yet despite the apparent European-wide strategy, in practice the policies aimed at growing the knowledge economy, such as research and development (R&D), patents and licensing, attracting foreign direct investment (FDI), and policies aimed at telecoms, internet and more broadly the use of ICT, all remain first and foremost governed by each national member states policies and concerns.

The result has been that technology, social cohesion, ICT, and innovation have not played a significant role in enhancing European growth 'at the European level' – instead they have done so only at the national and regional levels. This has been damaging for Europe. For instance, from a technologically leading position in mobile phones, the EU has become more of a laggard.

Undoubtedly, the Europe 2020 strategy addresses the right issues: achieving in Europe over the current decade a process of smart, sustainable and inclusive growth. However, it provides little insight into how to achieve this in the coming few years.

Three ways to innovate out of the crisis

This policy brief address the three smart, sustainable and inclusive growth areas where the innovation strategy needs to be revamped.

1 This policy brief is based on a SCIFI-GLOW CEPR Policy Paper. See Soete 2012.

1. A much more explicit quantitative commitment to public knowledge investment to speed up the rate of change.

It has been too easy for European member states to propose a knowledge investment target – for instance the 2002 Barcelona 3% R&D target – which put the efforts of knowledge investment primarily with the private sector: the economic sector which is the least in need of being incentivised by investment targets given the growing market pressure from the US, Japan and the emerging markets.

It is not just the total amount of R&D investments that will count, but also whether those additional investments are 'matched' by institutional reforms. Companies need to feel confident that investment in R&D will yield sufficient returns – in areas where such confidence is lacking, the public sector will have to step in. These reforms represent a major challenge for public policies.

But how to pay for this in time of crisis? A first proposal is to separate public investments in higher education, research and innovation from national budgets while keeping other government spending under stringent fiscal consolidation rules. We could then see growth in private R&D investment as firms feel assured about the long-term national public commitment towards research and higher education.

A second proposal would focus on the effectiveness of R&D support policies. While some countries such as France, the Netherlands, the UK, and Belgium have stimulated private R&D investments through R&D tax credit systems, there is evidence to suggest that such policies result in a 'net welfare loss' to the economy and also lead to a beggar-thy-neighbour effect as tax credits have risen across Europe. In a period of fiscal consolidation, it is worth asking whether countries should continue to provide such tax exemptions. Indeed, Finland and Germany have rejected such tax systems, and prefer to focus instead on R&D subsidies.

2. Sustainable growth – influencing the direction of technological change.

Shifting the emphasis on sustainability as the new direction for European research and innovation growth requires a whole smart range of tools and instruments both domestic and global.

A green economy will require a major commitment from the private sector to create more efficient green technology options. Yet, putting the current financial uncertainties to one side, private sector investment is unlikely to be forthcoming as long as there is no clear and full commitment to setting an effective price on greenhouse gas emissions – and this requires setting tight caps that will not be quietly loosened by the issuance of additional-emissions permits to alleviate industrial 'distress'.

As a result, publicly funded R&D is absolutely necessary to share the risks of developing such new technologies: this would provide the private sector with the opportunity to build on these technologies through less risky, applied R&D (Mazzucato 2011).

3. Safeguarding social cohesion in a crisis.

The aim of achieving inclusive growth is probably most directly challenged by the sovereign debt crisis. There is a need to rethink how structural funds are used to help all regions to unleash their growth potential. The idea of 'smart specialisation' needs to be broadened to include the public sector.

One of the most robust results from modern growth theory is the strong positive impact of public investments in, above all, intangibles such as education and R&D, which boost overall productivity growth (De Grauwe 2011). Yet, as in the case of the knowledge intangibles production factor, most if not all public services have, largely, remained nationally run. It is this widespread divergence in the efficacy and efficiency of the public sector that has been one of the most stifling bottlenecks restricting higher growth and productivity in Europe and has been a major cause of the current euro and sovereign debt crisis.

Hence two concrete proposals:

- First, why not allow the best-performing national public services to take the lead across Europe? As a result the performance of the public sector in Europe, still responsible for the largest part of GDP, will receive a major boost in efficacy and efficiency. We all know the typical European joke of the Brussels dinner organised by an Italian, prepared by a Briton and with a German giving the after-dinner speech. But, of course, the ideal picture also exists. Think of the Dutch tax-paying office taking on the responsibility for earning tax revenues in Greece, Italy or even Belgium. Or using the approach of Belgium's social security bank[2] to manage social security payments in every member state.
- Second, the large sovereign debt in some of the peripheral European countries should be viewed as potential pilot cases for triggering innovation in public procurement with the help of the private sector. For example, now is the time for public spending on lighting in offices, schools and hospitals to switch to new technologies such as LEDs that use up to 80% less energy, have a much longer life and would reduce the cost of air conditioning. This is the sort of investment that could be supported by institutions such as the European Investment Bank.

Conclusion

Crises are also periods of structural change; of creative destruction both at the level of sectors and of firms on both the supply and demand side. Despite the concerns about Europe's future integration process, these are exciting times. Times for stronger policy emphasis on knowledge investments in sectors such as the public sector, which might offer new opportunities to address the lack of growth convergence within the Eurozone. All are areas that fall outside the scope of the current financial firefighting but which will need to be addressed if we want to strengthen Europe's long-term cohesive growth.

2 The so-called "Kruispuntbank Sociale Zekerheid" (KSZ) is an electronic network between Belgian institutions of social security and the state register. It is considered as a government 'best practice' case.

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ICT and the polarisation of skill demand

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Wage inequality in the OECD countries has risen dramatically over the last 30 years. But this is not simply a case of the more educated benefiting at the expense of the less educated; rather, it is the middle-skilled who are losing out most.

Polarisation is not necessarily bad news for the least skilled – there will be jobs for them even in a high-tech world. But for the middle classes, technology may be endangering their future labour market prospects.

Technical change is the main driving force for these inequality changes. Although trade with lower-wage countries such as China does not increase inequality directly, it may have an indirect effect by speeding up the adoption of new technologies.

Introduction

Job markets in the OECD have become more unequal in recent years. In the UK, for instance, the top 10% of male earners receive almost four times as much as the lowest 10%; 30 years ago they only earned twice as much. Because this has been accompanied by a large increase in the proportion of university-educated people, the inescapable conclusion is that the demand for more highly skilled workers has risen by even more. Indeed, since the early 1980s, returns to a university education have risen significantly in the US, UK, and many other nations (Machin and Van Reenen 2008).

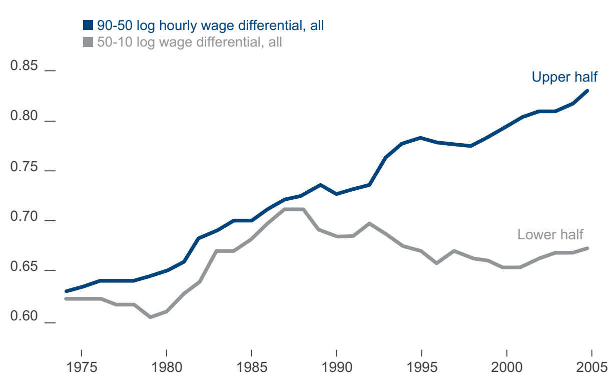
Rather than blame increased trade with low-wage countries, the consensus among academics is that this increase in demand for high-skilled workers is linked to technological progress, driving up the demand for workers who are able to deal with a more complex and challenging workplace (see for instance Goldin and Katz 2008 and Krugman 2008).

But that's not the whole story – new facts on inequality have recently emerged. In the US, 'upper half' inequality – the difference between the richest tenth of the population and the middle – has risen continuously over the last three decades. But after increasing during the 1980s, 'lower half' inequality – the difference between the middle and the poorest tenth – has actually fallen since then (see Figure 1). This is what is known as 'polarisation'.

And while university graduates' wages have continued to increase relative to those of non-graduates, high school graduates' wages (the wages of those who leave school at age 18) have ceased to increase relative to those of high-school dropouts (those who leave at age 16) since the 1990s. It also seems that jobs in middle-skilled occupations have decreased relative to both high-skilled and low-skilled occupations across Europe and North America.

This Policy Brief seeks to understand why this is the case.

Figure 1 The divergence of upper half and lower half inequality in the United States, 1975–2005



Why the polarisation?

What could account for this polarisation, in which the prospects of the middle-skilled have been declining? One explanation can be found by looking at the tasks that new technologies are performing. What new technologies – such as information and communication technologies (ICT) – are very good at doing is replacing repetitive, boring, 'routine' tasks (Autor et al. 2003, Goos and Manning 2007). Tasks that require responding rapidly to unfamiliar situations (such as driving or cleaning), on the other hand, are not easy for robots to reproduce. Repetitive activities that were traditionally performed by less educated workers, such as assembly workers in a car factory, have been good candidates for job destruction by new technology.

But it isn't only this group that has been affected. ICT has also reduced the need for middle-educated workers carrying out routine tasks. Bank clerks, for example, have found demand for their services plummeting as a result of computerisation – ATMs, online banking, and so on.

More educated workers making analytical, non-routine use of ICT – such as management consultants, advertising executives and physicians – have actually found that their jobs have been made easier by ICT rather than threatened by it. Nor has ICT reduced the demand for less educated workers carrying out non-routine manual tasks – such as janitors and cab drivers – contrary to claims that low-skilled jobs are disappearing.

Since the number of routine jobs in the traditional manufacturing sectors (such as car assembly) declined substantially in the 1970s, the subsequent growth of computerisation may have primarily increased demand for highly educated workers at the expense of those in the middle of the educational distribution, leaving the least educated (mainly working in non-routine manual jobs) largely unaffected.

Is technology really replacing the middle-skilled?

Although this theory sounds convincing there is currently little direct international evidence to back it up. A recent study (Michaels et al. 2010) seeks to plug this gap. It looks at whether technology is indeed reducing demand for those in the middle, by conducting a simple test using 25 years of data across 11 countries and all sectors of the economy.

It makes use of the new EUKLEMS database, which provides data on university graduates and disaggregates non-graduate workers into two groups: those with low education and those with “middle level” education. In the US, for example, the middle education group includes those with some university and high school graduates, but excludes high school drop-outs (see Timmer et al. 2007).

The EUKLEMS database covers 11 developed economies (the US, Japan, and nine countries in Western Europe) from 1980-2004 and also contains data on ICT capital. The research considers not only the potential role of ICT becoming cheaper and more easily available, but also several alternative explanations. In particular, it examines whether the role of trade in changing skill demand could have become more important in recent years (most of the early studies on wage inequality pre-date the growth of China and India as major players).

If the above theory is correct, we would expect industries that had a faster growth of ICT to have also had an increase in demand for university-educated workers relative to workers with middle levels of education, leaving the least skilled unaffected. The findings suggest this has indeed been the case.

After 1980, countries with faster upgrading of ICT (Finland, the Netherlands, the UK and the US) also saw the most rapid increase in high-skilled workers. Across different countries, similar industries – for example, financial services, telecommunications, and electrical equipment manufacturers – replaced middle-skilled workers with high-skilled workers at the fastest rate.

The change in demand reflected an increase in both the wages and the hours worked by high-skilled workers relative to middle-skilled workers. The study documents this finding not only for the full sample of countries together, but also separately for the US and for continental Europe.

There is also evidence of technology polarising the demand for skills through other means. Industries that engage in more research and development (R&D) also show the same pattern of substitution of middle-skilled workers by high-skilled workers. Taken together, ICT upgrading and R&D account for about a quarter of the growth in demand for the university educated since 1980.

What about trade?

An alternative explanation for the falling demand for non-university workers is globalisation. The idea is that increased trade with low-wage countries such as China has lowered the wages and taken the jobs of the less skilled. The study finds that the positive correlation between trade openness and the increased demand for high-skilled relative to middle-skilled disappears once we control for technological change. This could either mean no role for trade or a more subtle effect whereby trade has an indirect effect by inducing faster technical change. There is evidence for the latter effect in Bloom, Draca and Van Reenen (2011). They find that increases of trade with China (e.g. after membership of the World Trade Organization in 2001) increased the speed of technological upgrading in the West which then had a knock-on effect increasing the demand for skills.

Room for more research

Although the study method is simple and transparent, there are many extensions that need to be made.

- First, there is no compelling 'natural experiment' to exploit. As the study did not take place in a laboratory, with real world data there is always that – despite best efforts – there is some factor that is causing both a rise in ICT expenditure and an increase in demand for the highly skilled. To help minimise these risks, more variables and richer data would help better identify the causal impact of ICT.
- Second, although the study finds no direct role for trade variables, there may be other ways in which globalisation influences the labour market, for example by causing firms to 'defensively innovate' (Acemoglu 2003).
- Third, there are alternative explanations for the improved performance of the least skilled group through, for example, greater demand from richer skilled workers for the services they provide, including work around the house that no longer seems worthwhile when skilled wages are so high, such as childcare, eating out in restaurants, home improvements, and so on. These explanations may complement the ICT explanation in this study.
- Finally, the study has not used richer data that focuses on the skill content of tasks, due to the need to have international comparability across countries. The work of Autor and Dorn (2009) is an important contribution here.

Conclusion

Using industry level data on the US, Japan, and nine European countries 1980-2004, the study finds that technology – both ICT and R&D – has raised relative demand for university-educated workers and, consistent with the ICT-based polarisation hypothesis, this increase has come mainly from reducing the relative demand for middle-skilled workers rather than low-skilled worker.

This polarisation is not bad news for the least skilled – there will be jobs for them even in a high-tech world. But for the middle classes, technology may be endangering their future labourmarket prospects.

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Technology transfer through capital imports

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Technology is increasingly important for economic growth – but much of this technology comes from only a few advanced countries, forcing many countries to import technologies.

Detailed data from Hungarian firms suggest that:

- *Imported technology raises productivity and has contributed to a substantial rise in productivity over the last two decades, both within and across firms.*
- *Imported technology raises demand for skilled workers – a form of 'skill-biased technical change'. In doing so it has contributed substantially to the increase in wage inequality in Hungary.*

Introduction

The vast majority of machinery production is concentrated in only a handful of advanced economies. As a result, most other countries rely heavily on machinery imports, which have a wide-ranging impact on the economy. According to several studies, the imported machines contribute to capital accumulation and growth.[1]

1 On the reliance on imported machinery, see Eaton and Kortum (2001) and Caselli and Wilson (2004). On the contributions to economic growth, see De Long and Summers (1991), Alfaro and Hammel (2007).

Yet how do technologies move from one country to another? When firms import capital, do they also import foreign research and development (R&D) as well? And if they do, which firms benefit most from the imported technology?

Policymakers should be interested in these questions. Identifying when and how technology diffuses across borders is central to understanding cross-country differences in productivity, with implications for jobs, growth, and welfare.[2]

Capital imports and productivity

While several studies point towards a positive association between capital imports and improvements in productivity, there remain doubts about whether one is really *causing* the other. [3] These studies may, for example, be missing some crucial factor that might explain both the rise in capital imports and the rise in productivity and are therefore drawing biased conclusions.

A recent study (Halpern et al. 2012) takes a micro-level approach to international technology diffusion. The starting point for the analysis is a unique dataset that contains detailed information on imported capital and intermediate goods for essentially all Hungarian manufacturing firms between 1992 and 2003, a total of over 30,000 firms.

In particular, for every importer and every year there is data on each imported good, the amount of money spent on the good, and the source country. This allows the research to look at performance in years when a firm has imported more new technologies compared to normal – and because the data are so detailed, this can be done while controlling for other factors, such as the workforce and time of year.

2 This Policy Brief is based on two SCIFI-GLOW Papers. See Halpern et al. (2012) and Koren and Csillag (2011).

3 Coe and Helpman (1995) find that countries importing from R&D abundant trade partners are more productive, while Keller (2002), Keller and Yeaple (2009), Acharya and Keller (2009) obtain similar findings at the industry level. For doubts on the accuracy of these studies, see Keller (2004).

The central finding is that imported capital that includes new technologies is strongly associated with a rise in firm sales. This result cannot be explained by the business cycle, industry-specific trade costs, or industry-level profitability – three major factors that raise doubts about previous research (Keller, 2004).

It could be that firms that start importing foreign capital also simultaneously become more productive for reasons unrelated to capital imports. This could happen for example if the firm hires a talented manager who both starts to import foreign capital and streamlines the production process in other ways. While the analysis is not immune to such criticism, the fact that this finding remains the same when other factors are considered suggests that capital imports do affect productivity at the very least.

If the results are to be accepted, the estimates imply that the role of imported capital for technology diffusion is large. For example, if in 2003 all firms in the Hungarian economy replaced their capital stock with German capital, the study predicts that manufacturing value added would grow by 6%. Moreover, a simple back-of-the-envelope calculation suggests that the actual imports of foreign capital during 1996-2003 increased aggregate productivity in the Hungarian manufacturing sector by 2% over the period.

Skill-biased technological change

Using similarly detailed data from Hungary, this time between 1994 and 2004, recent research by Koren and Csillag (2011) argues that imported capital also increases the demand for skilled labour.

The starting point for the study is that machines produced in advanced economies are more sophisticated and of a higher quality than those produced in a less developed country. For example, most Indian users find computer numerically controlled (CNC) machine tools imported from Japan and Taiwan to be more reliable, more accurate, and more productive than similar Indian machines (Sutton 2000). Sophisticated machines, in turn, require highly trained, skilful and attentive operators. Operating CNC lathes, for example, requires more training than operating traditional lathes. More broadly, computerisation has increased the demand for complex skills, even within the same occupation (Autor et al. 2003 and Spitz-Oener 2006). In other words, the technology embodied in up-to-date sophisticated machines is skill biased. Taken together, the paper argues that importing machines from advanced economies amounts to importing 'skill-biased technical change'.

The study finds that workers at firms that import machinery specific to their job earn 10.5% more than workers with no access to imported machinery. Some of this wage difference may be due to omitted firm characteristics. Importing firms may be more productive, better managed, and may be able to attract more skilled workers. When the research contrasts operators, such as printing machine operators, working at firms that import their specific machines, such as offset printing machines, to those working at firms that import machines unrelated to their occupation, it finds a wage gap of around 8%.

The difference in wages reflects differences in skill as well as differences in the returns to skill. Among workers operating domestic machines, the wage gap between those with a high school education and those with only primary schooling is around 7%. Among those working on imported machines, the return to a secondary education is around 11%. This suggests that imported machines increase the returns to education (and skills) substantially. However, many of the skills of machine operators are unobservable and only partially explained by formal schooling. This is important, because imported machines are operated by more skilled workers than domestic ones, and hence the estimated wage differential is the combined effect of increased returns to skill and unobserved skill differences. This suggests that imported capital and worker skill are complementary.

This is perhaps the first study to provide micro evidence on how imported technology changes the demand for skills. It is related to several studies that show that technology transfers are embodied in imports (see for instance Coe and Helpman 1995, Acharya and Keller 2009, and Halpern et al. 2011).

Understanding machine imports as a source of technology transfer can shed light on why wage and income inequality has increased dramatically in developing countries, and why these increases have mostly coincided with periods of trade liberalisation (Goldberg and Pavcnik 2007). Most researchers point to 'skill-biased technical change' as an explanation. Given, however, that most skill-biased technologies are developed in advanced economies, the liberalisation of capital imports is a necessary condition for skill-biased technological change to reach developing countries.

The finding that machine quality and worker skills are complementary lends support to the view that complementarities are an important feature of the development process (Kremer 1993 and Jones 2008). If skilled workers are required to operate new, more advanced technologies, then the lack of adequate education and training is a barrier to the spillover of technologies. Moreover, if labour market institutions do not facilitate the efficient matching of workers with machines, aggregate productivity will be substantially lower (Bénabou 1996). Both effects make it harder for poor countries to catch up with the productivity frontier, magnifying differences in income per capita.

Conclusion

What is the effect of imported technology on productivity and jobs? Detailed data from Hungarian firms suggest that:

- Imported technology raises productivity and has contributed to a substantial rise in productivity over the last two decades, both within and across firms.
- Imported technology raises demand for skilled workers – a form of 'skill-biased technical change'. In doing so it has contributed substantially to the increase in wage inequality in Hungary.

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R&D spillovers and firm productivity

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Research and development (R&D) undertaken by one firm can have a significant and positive effect on the productivity of other firms. This is particularly the case when these firms are close to one another in a physical sense and even more so in a technological sense. In many cases, firms benefit more from the R&D of other firms than they do from their own R&D.

- *Firms have an incentive to under-invest in R&D in the hope of free-riding from the investments of other companies. Public intervention through subsidies, tax credits or public procurement for R&D projects is therefore needed to bring R&D closer to optimal levels.*
- *Regional policies aimed at attracting R&D companies to a given area or encouraging new high-tech clusters are essential.*
- *Policy measures allowing increased concentration in particular industries and technological sectors will help firms get closer to one another in a technological sense.*

Introduction

Knowledge originating in one country or region is increasingly able to cross national boundaries and contribute to the productivity growth of other geographic areas – a process known as ‘R&D spillovers’. It is widely recognised that such knowledge flows between regions significantly boost economic growth (see for instance Grossman and Helpman 1991).

This Policy Brief looks at the magnitude of R&D spillover effects on the productivity growth of large international R&D companies. In particular, it looks at the extent to which R&D spillover effects are increased when the company is geographically close to the origin of the innovation and when the company is 'close' in the sense of working with similar technologies.[1]

What drives R&D spillovers?

Knowledge spillovers may be driven by a variety of channels such as workers moving across companies and countries, the exchange of information at technical conferences, or knowledge available within the scientific and technological community, including scientific papers and patent documents. These R&D spillovers can benefit competitors' R&D by lowering the costs of their own R&D activities and in turn can help raise their productivity.

Part of the problem with this spillover effect is that firms will have less of an incentive to invest in knowledge generation themselves, instead preferring to copy the innovation once it has been released into the market. For this reason, R&D will always be underprovided if left exclusively to the private sector, leaving a role for government intervention to support R&D through such means as subsidies, fiscal incentives, and public procurements.

Over the last few decades, several studies have examined the geographical dimension of R&D spillovers, finding that most spillovers tend to be concentrated among firms close to each other (Jaffe 1989; Jaffe et al. 1993). At the same time, other studies have shown evidence of the positive impact of a firm's R&D on the productivity of other firms if those firms are 'technological neighbours' – that is, companies that use similar technologies (Jaffe 1986, 1988).

1 This Policy Brief is based on a SCIFI-GLOW CEPR Policy Paper. See Cincera (2011).

Geography- and technology-based benefits from R&D

While very important for economic growth, the effects of geography- and technology-based R&D spillovers on firm productivity have rarely been investigated together (Orlando 2000). A recent study provides such an investigation (Aldieri and Cincera 2009).

- It looks at the firm locations by taking the latitude and longitude coordinates of corporate headquarters.
- In the technological space it looks at company patents to see how 'close' they are technologically (Orlando 2000).
- The study then looks at the 'absorptive capacity' of firms – that is, the ability for firms to identify and make use of the new knowledge they are acquiring, which depends heavily on the firm's own R&D activities.

The study examines how all three factors determine the productivity of a representative sample of over 800 worldwide R&D-intensive manufacturing firms between 1988 and 1997.

Positive elasticities

The results show a strong link between R&D spillovers and a firm's productivity performance.

- The study estimates the 'elasticity' of technology-based R&D spillovers at 0.61, suggesting that a 1% rise in R&D undertaken by a technologically 'close' company raises productivity by 0.61%.
- For geography-based R&D spillovers, the estimated elasticity is slightly less at about 0.41.

- Remarkably, both these elasticities are higher than for a firm's own R&D stock, which is less than 0.2. This means that R&D from other companies has more of an effect on productivity than a company's own R&D.

Assuming that the stock of own R&D is a proxy for absorptive capacity, the study then analyses the extent to which this capacity interacts with both geographic and technological sources of R&D spillovers. The findings suggest that while firms seem to benefit more from outside R&D than from their own R&D, they will benefit *even more* from outside R&D if they are investing in R&D themselves.

Further research

In order to further explore the drivers of productivity growth, further research is needed. Among the suggestions for future work are:

- Using information on patent citations to construct a more direct measure for R&D spillovers. Backward citations – that is, references in patent documents to former patents – can be used as evidence of spillover effects.
- In order to further analyse the interplay between geographic and technological 'closeness' for the diffusion of knowledge, both types of R&D spillovers could be split into a national and an international component. This would allow testing for the presence of country borders effects, such as institutional settings, national policies, language, and history (Maurseth and Verspagen 2002).
- Finally, the analysis could be enriched by considering alternative measures of absorptive capacities and their impact on firm economic performance, such as the level of education of the workforce.

Conclusions

Both the geography- and technology-based R&D spillovers have an important and positive impact on the productivity growth of firms. The effects of the pure technological spillovers on firms' economic performance appear to be higher than the geographic spillovers. This finding suggests that technological proximity is more important than geographic proximity for the impact of R&D spillovers on firm productivity growth.

From a policy point of view, there are a number of implications:

- First, the estimated effects on firm productivity of both geography- and technology-based R&D spillovers are positive and quite large. Crucially, they are higher than the effects of the firm's own R&D. As a result, firms have an incentive to under-invest in R&D in the hope of free-riding from the investments of other companies. Public intervention through subsidies, tax credits or public procurement for R&D projects is therefore needed to bring R&D closer to optimal levels. Another option is direct funding of R&D and more generally of Science and Technology (S&T) collaborations. This would allow firms to internalise some of the spillover effects associated with their research activities.
- Second, since geographic proximity matters for R&D spillovers, regional policies aimed at attracting R&D companies to a given territory or space are essential (Audretsch and Feldman 1996). Besides the traditional policies discussed above, all measures aimed at supporting existing knowledge-based clusters as well stimulating the emergence of new high-tech clusters represent another major policy instrument (Karlsson 2007).

Another option in the policy toolkit is to make geography less of an issue. Providing easier access to financial and human capital and to markets and knowledge at the national and international level will help here. As will policies aimed at reducing geographical transaction costs, such as transport and infrastructure policies.

- Third, as technological distance appears to be an even more important determinant of knowledge spillovers between companies located in narrowly defined sectors, policy measures allowing increased concentration in particular industries and technological sectors are highly desirable (Orlando 2000). Here also, measures to support S&T collaborations between similar firms from a technological point of view could be another way to achieve greater technological spillovers.

- Finally, given the role of a company's own R&D activities to enhance the absorptive capacity of firms to identify, assimilate, and exploit external knowledge, policies promoting this specific absorptive function of R&D, such as R&D subsidies or measures that help improve in-house company knowledge, or that upgrade the skills of the company's research personnel, such as vocational training, should be explored further.

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The effectiveness of R&D tax incentives

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Given the size of tax incentives for research and development (R&D) in many European countries, it is wise to try to measure their effectiveness – despite this being imprecise and difficult.

- *R&D tax credits carry with them a welfare loss: much of the increase in R&D expenditure by the private sector would have taken place anyway, meanwhile the government loses tax revenue. R&D tax credits can, however, be more effective for small credit-constrained firms.*
- *Tax credits may lead to a rise in the wages of R&D personnel, increasing the cost of R&D.*
- *Policymakers need to devise a way to stimulate R&D without financing already existing or planned R&D expenditure.*
- *Policymakers should compare the effectiveness of tax credits for R&D with subsidies for R&D as well as other forms of direct government assistance.*

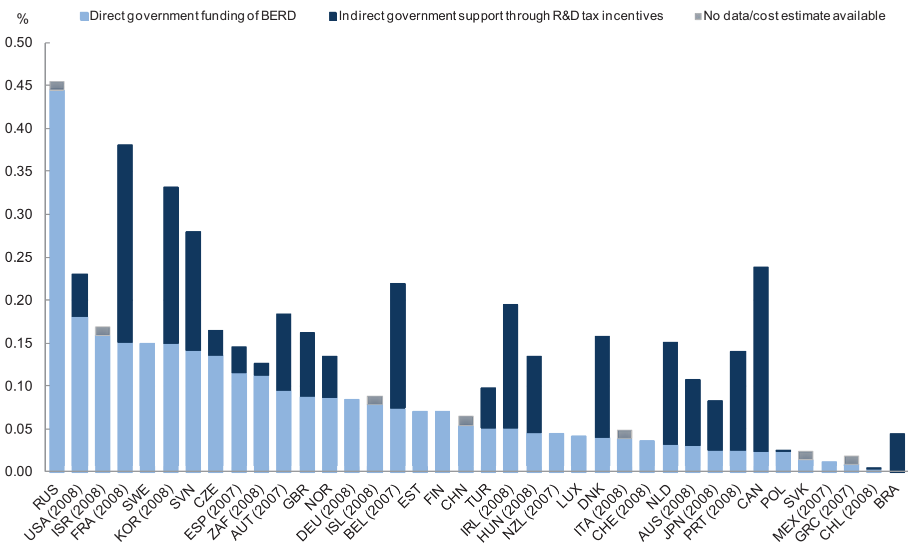
Introduction

More and more countries are adopting tax incentives as a way to encourage private spending on research and development (R&D) (OECD 2011). These tax incentives usually amount to tax breaks or tax credits for spending so long as firms can demonstrate that money is being spent on R&D. There is consensus among economists that R&D is essential for stimulating economic growth.

Compared with direct government support for R&D in the form of grants, research contracts, subsidies or procurement, tax incentives have the advantage of being 'neutral' in that they tend not to favour a particular kind of project or research area. Yet this can also be a disadvantage – indirect support in the form of tax incentives cannot single out specific projects that are judged to have a particularly high social rate of return.

Given the scale of these tax incentives, amounting to close to 0.4% of GDP in France for instance (Figure 1), the immediate question addressed in this Policy Brief is how effective these tax incentives are.[1]

Figure 1. Government support for R&D



Source: OECD 2011

Measuring the effect

The typical way of evaluating such a policy would be to compare the R&D expenditure of firms that receive tax incentives with that of those that do not receive any tax incentives.

1 This Policy Brief is based on a SCIFI-GLOW CEPR Policy Paper. See Mohnen 2012.

However, because in principle every firm doing R&D can claim R&D tax credits, there is no dividing line between receivers and non-receivers across which to compare. In this case, the only possibility would be to compare the R&D of firms that apply for tax credits with the R&D of firms that do not, controlling for 'selectivity'. By controlling for selectivity, we try to remove the possibility that there is some factor explaining why firms choose to invest in R&D that also explains their R&D expenditure and that is separate from the tax incentives. Because it is difficult to know what this factor might be, such estimates are prone to bias.

The more appropriate method is instead to use a structural model specifying R&D investment as a function of:

- The 'user cost' of R&D, composed of the usual two opportunity costs – interest rate and depreciation rate – and,
- An index of R&D tax incentives known as the B-index. This should include the various types of R&D tax incentives available in a given country. For example, expensing, accelerated depreciation of R&D equipment, R&D tax credits, allowances, carry forward and carry backward provisions, refundability of unused tax credits, and so on (OECD 2002).

The next question to then ask is how sensitive R&D expenditures are to variations in tax incentives. Various studies have estimated this 'elasticity' of R&D (Mohnen and Lokshin 2010) – how much a 1% change in tax affects R&D expenditure. The estimates vary across studies because of different time horizons, different levels of aggregation (firm, industry, country data), differences in firm size or differences in econometric methods.

In general, small firms are found to be more responsive to tax incentives because they are more 'credit constrained' – that is, because they have difficulty borrowing, much of the savings from a tax break are quickly invested.

Studies also find that short-run elasticities tend to be smaller than long-run elasticities, suggesting that firms will take time to change their investment decisions to take into account the changes in taxes. There may also be adjustment costs that prevent a quick change, such as contracts and commitments to spending elsewhere.

Do tax incentives crowd out other spending?

One possibility is that R&D tax incentives ‘crowd out’ other spending on R&D. In other words, instead of spending more money on R&D as a result of the tax incentives, firms simply use the money they save elsewhere. The net result would be that tax incentives have no overall effect on R&D spending in the economy.

It is possible to test this by seeing whether €1 of R&D tax expenditure generates at least €1 of additional R&D. If it does not then we cannot rule out the possibility of at least some crowding out. Ideally, to get an even better idea of the return on tax incentives – the so-called ‘bang for the buck’ – we should also look at the spillover effects on firms and the rest of the economy, such as the making workers more productive.

Two recent studies try to look at the bang for the buck from R&D tax incentives: one looks at over 1,100 firms in the Netherlands between 1996 and 2004; the other at nearly 1,400 firms in Quebec between 1998 and 2004 (see Lokshin and Mohnen 2009 and Baghana and Mohnen 2009). Three lessons come out of this analysis.

- First, in the Netherlands, the accumulated benefit-cost ratio starts above 1 for small firms but drops below 1 after a few years, whereas for large firms it is below 1 from the beginning (because of large initial amounts of R&D expenditure) and deteriorates even further afterwards (Lokshin and Mohnen 2010).
- Second, in Quebec, the bang-for-the-buck stays above 1 for small firms but drops below 1 for large firms.

These results also suggest that R&D tax credits incur a deadweight loss. Public funding through R&D tax credits ends up supporting R&D expenditure that would have taken place anyway or that was already planned before the introduction of tax credits.

Third, the R&D tax credits could also produce general equilibrium effects. One of those could be a price rise in R&D due to a rise in the wages of R&D personnel. This could be due to rigid supply or increased negotiating power of R&D personnel. For the Netherlands the study finds an increase in R&D wages of 10% to 13% following a 10% decrease in the 'user cost' of R&D due to R&D tax credits.

Conclusion

The net cost or benefit of R&D tax incentives depends on a number of parameters about which we have only an imprecise estimate. That said, these studies suggest that the challenge for economists is to devise a way to stimulate R&D without financing already existing or planned R&D expenditure, if at all possible. It may well be that in the face of imperfect information only a second-best support policy can be found to stimulate more R&D. Policymakers should however keep comparing the effectiveness of tax credits with that of direct government support for R&D, including subsidies.

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