The Knowledge Future: Intelligent policy choices for Europe 2050

Report by an expert group on Foresight on Key Long-term Transformations of European systems: Research, Innovation and Higher Education (KT2050)

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A report to the European Commission

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Chair: Richard Hudson;
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Foreword

Foresight is an important tool to help us face the future with confidence, understand opportunities and risks, and help us develop our medium to long term strategies for research, science and innovation policy. It takes many guises: trends, signals, scenarios, visions, road-maps and plans are all parts of the tool-box for looking to the future. In addition to these tools, using foresight requires an in-depth reflection on the policy implications and related scenarios.

This report 'The Knowledge Future: intelligent policy choices for Europe 2050' is an excellent example of such a reflection. Europe's research, innovation and higher education systems are the foundation of our economic and social prospects, shaping our ability to tackle numerous challenges at both local and international level.

Globalisation, demographic changes and technological advances pose important challenges and opportunities for research and innovation in Europe. By reflecting on the trends and articulating scenarios, this report helps us think differently about European policies in the medium to long term.

In Europe we need to:

- Create the necessary conditions to capitalise on the results of research and innovation;
- Boost excellence in cutting-edge, fundamental research;
- Reinforce our international engagement through science diplomacy.

On this basis, I have set my priorities to be Open Innovation, Open Science, and Open to the World.

I hope that this report will contribute to discussions on how research and innovation can contribute to a stronger economy and a better society for all.

Carlos MOEDAS
Commissioner for Research
Science and Innovation
European Commission

Summary and Policy recommendations

How do ideas become reality? The whole process of transforming knowledge - creating it, sharing it, and using it - has become important to policy makers. They see it as connected somehow with how rich we are, how competitive Europe can be, how healthy or happy our citizens are, and how sustainable our world will be. This report to the European Commission, by a diverse group of academics, policy experts and private-sector representatives, looks at the future of this knowledge engine – towards the challenges of 2050. It recommends steps to ensure that, through maintenance of a robust system for transforming knowledge into action, Europe's citizens are better off, rather than worse off, in that distant future.

Vital to that system is the 'knowledge triangle.' The acts of learning, discovering and innovating all go together, like three pistons in an economic engine. Education, research and innovation; universities, laboratories and companies; academics, researchers and entrepreneurs – all are part of an engine that, if well managed, creates wealth, jobs, growth and, if one is an optimist, social progress. Europe today has many such triangles, of varying strength, specialisation and fecundity. They include very large, multi-disciplinary agglomerations of big universities, companies and agencies; specialised but no-less dynamic sectoral hubs; and rising new centres. Increasingly, they interconnect: Indeed, EU initiatives like the Framework Programmes or, within them, the European Institute of Innovation and Technology, include linkage as an aim. But despite these centres' individual vibrancy, many policy makers share an overriding concern that they aren't enough: That competition from the US, China, India and elsewhere risks leaving Europe behind – and that the difficulties coordinating and managing a European response are enormous.

At least three major trends are destabilising the status quo in Europe's knowledge system. Globalisation is one. As the world gets more inter-connected, and economic competition expands, the way we learn, discover or innovate will change, and the impact will hit home faster and harder. Demographic change is another. The move to cities, the ageing population, the shifts in family size and social norms – all will alter what we expect and can do in education, research and innovation. And technological change is accelerating. Just 35 years ago came text editors. Now: gene editing.

By 2050, what next? Each invention, coming faster and faster, changes not only our society and economy, but also our expectations and the way we work in education, science and business.

How will we cope with these changes? Can we continue to play a key role in the global generation, spread and use of knowledge? Can we use the knowledge system to improve our lives, integrate our societies, preserve and improve our environment? Those are the questions the group asked, as it looked towards 2050. To crystallise the challenges and opportunities, it created two possible views of the future: one positive, one negative. These are not forecasts or formal scenarios. These are plausible sketches of the future with one purpose: To dramatise the importance of making wise policy choices, and to suggest what those choices might be.

Option A: European Success

It is 2050, and Europe and its knowledge economy are competitive. Clusters of well-funded, internationally renowned universities are thriving in many of Europe's important and growing cities, in strong partnerships with regional institutions. Education is 'in'; never before have so many wanted so much from teachers: new skills, new jobs, new capacity to cope with rapid change, new perspectives for leading fulfilled lives – from cradle to grave. This growing demand for continual education has prompted new efficiencies: course modules shared within university clusters, online and artificial intelligence-based teaching, specialisation within institutions public and private. Educational games, at which European designers excel, are a vast market segment. In business, open innovation is now the dominant mode: multinationals, SMEs, universities and many new actors – foundations, NGOs, individuals (many retired) - work together in fast-changing global networks to solve global problems. Europe's mega-cities, with their unique sense of community identity and involvement, are a focus for innovation; 'Paris original' – or Warsaw or Athens – has become a new kind of global brand. Meanwhile, automation and data-intensive science have changed the nature of doing research. We have moved from open science to radical open access: all kinds of new actors are rushing into the research game, especially in astronomy, ecology, climate and other fields that attract strong public interest. Europe's research infrastructures are the new cathedrals of this science: Open to all, supported by all. Frontier science is a competitive, EU-wide affair led by an enlarged European Research Council, while regional disparities in innovation capacities are countered through separately administered regional development funds. Indeed, EU institutions generally are strengthened; as the regions and cities have climbed in importance – Europe's growing laboratories of democracy – so the coordinating role of EU institutions has risen. Multinational tax avoidance is tamed, strengthening public treasuries everywhere. Where Europe once produced 30% of the world's ideas, it has more than held its own as Asia rose; it is moving towards 40%. Many of its industries are competitive, building on healthy SMEs. Its universities are strong, its citizens fulfilled – and its core values, such as equality, openness, social inclusion and environmental responsibility, are upheld.

Option B: Europe misses out

It is 2050, and Europe is a victim of megatrends beyond its control. Automation and globalisation have triggered mass unemployment, social exclusion, discontent. Service bots, machine learning, ubiquitous sensing – what's left for the humans to do? Inequality is higher than ever; new creative jobs are constantly evolving from new technologies, but they are only for the skilled few. Politically, Europe has fragmented into a coalition of rich and poor regions with minimal coordination. A Northern Arc has maintained free movement of goods, services, and people; other parts of Europe are isolated. Multinational companies, and wealthy individuals, use global markets

and digital technologies to avoid tax. Public treasuries are impoverished; and universities and labs depend heavily on private funding – which means new ideas and talent are controlled by the wealthy and powerful. A few great universities dominate; many weaker, regional universities have closed or merged. Automation has also swept across the educational system, with online certifications normal and augmented cognition technologies starting to appear – and finding favour with big companies wanting fast, cheap graduates. In research, the top-cited scientists are in hot demand – often hired by multinationals in a kind of perpetual 'consultancy without borders.' These companies, on which public labs and universities rely for major funding, get early access to the real discoveries and use their influence to steer the remaining public funds towards their projects; that's what makes for jobs and growth, they argue. Asian research is stronger now, and an embattled US has thrown up new trade barriers to Europe. Mobility is diminished. A few European companies are rich and smart enough to stay global champions; but generally Europe's economic base has hollowed out, and the few innovators its universities produce quickly move abroad. Innovation is without borders; supply chains form and dissemble rapidly – making long-term regional development more difficult than ever. Europe looks inward, fears the future, and sees its values gradually discredited.

Looking at what differentiates the two scenarios, three broad principles guide our thinking about what Europe's knowledge institutions and governance must do to prosper: they require openness, experimentation, and cooperation. They are needed to counteract three threats: structural unemployment and inequality, funding shortfalls, and a skills crisis. In what follows, we elaborate on the principles and actions needed to ensure that 2050 is a place worth being – for all Europeans.

Our policy recommendations follow from those principles.

Policy Recommendations

Principle 1: An open knowledge system in Europe

If we are to adapt to coming challenges, our knowledge system must be open. This goes beyond today's open access or open science initiatives, to include the classroom and the marketplace, new infrastructures and a new intellectual property regime.

a. Invest more in research infrastructures. Experiment with different funding models (e.g. programmes for building research infrastructures). Promote openness of research infrastructures for teaching and learning, innovation, and citizen science.

b. Promote open access to data and data literacy – two interrelated goals necessary for, among other things, citizen participation in science and technology policy. Continue to promote public engagement with science. Promote citizen participation in research programmes and develop assessment systems for citizen science. Support models of crowdfunding for research.

c. Create a European Knowledge Space to function as a knowledge pool for addressing societal challenges by making accessible all publicly funded research results (data and publications) from all European labs and teams. An on-line framework open to all citizens for research, analysis, debate and sharing, this will enable policy-makers, business leaders, scientists,

technologists and the general public to access all knowledge available, to exchange information and to deliberate options for addressing societal challenges. An integrated framework of policies, incentives and ICT tools to permit greater sharing, debate and participation in the results and challenges of fast-changing science and technology to address societal challenges, it can form a core objective of Framework Programmes of the future.

d. Rethink intellectual property – opening the debate beyond the small world of IP experts to include researchers, consumers, the developing world and others. While private reward for private investment in knowledge remains a basic principle of our economy, that principle is challenged more and more often by new technologies, globalisation and demographic changes. Time to think again.

Principle 2: Flexibility and experimentation in innovation

Adapting to change also requires greater freedom of action – to experiment locally and regionally, in different social and economic groupings, with new business and social models.

a. Build stronger regional innovation ecosystems piggy-backing on urbanisation processes. Support place-based knowledge triangles, building on open innovation principles. Promote inter-institutional cooperation by encouraging public institutions to make available research infrastructures to firms that need it and develop cooperation with them.

b. Support the autonomy of universities. Strengthen them by encouraging diverse income streams for the diverse activities in which they engage - including collaborations with technology companies to invent new types of education. Encourage regional and national government investment in universities.
c. Stimulate experimentation in the economy and society: name new challenges, create prizes for strategically positioned results between the current state of science and long-range EU policy goals. Stimulate social crowdfunding platforms, and support charities that organise them by, for instance, providing a more favourable VAT status for foundations.

d. Promote experimentation in social and environmental policy. For instance, undertake a major initiative for society to figure out how to move from its obsession with economic growth to a higher regard for sustainability. Create a new regional fund for sustainability to support the experiments. Support new economic analysis, 'well-being' indicators, labelling and other attempts to help change the way we, as a consuming society, think and act. This would require unprecedented engagement of the social sciences and humanities in policy development.

Principle 3: European-level cooperation

A single market of scale requires some form of coordination for policy, regulation and support. Europe's knowledge system will be both a contributor to and a beneficiary of a coherent EU framework. Better to hang together than hang separately.

a. The EU has a role in creating a single market for knowledge – the European Research Area. The ERA needs high levels of public investment, research infrastructures linked to regional smart-specialisation, and a level playing field for competition between researchers and between institutions.

b. Link knowledge-related policy with that for cohesion and social welfare to deal with unemployment and to ensure citizen participation. For example, launch a public education and innovation programme on how to make a living in a sharing economy, or to train retirees to find markets and students for their skills. Such measures, to keep citizens plugged into the fast-changing economy, can make a big difference over the next 35 years.

c. Build the European Research Council into a core institution of the European Research Area: fundamental research is where the public good and European scale intertwine. The ERC, besides funding frontier research, could play a role in science policy and coordinating national, regional and local level funders of basic research. It can be a 'science hub' for Europe.

d. Encourage efforts to update educational curricula and certificate programmes – to adapt them for an age of fast-changing jobs. This would include reinvigorating the Bologna process to modernise educational standards across the Union, while ensuring increasingly flexible curricula. Encourage modular structures for student choice, interdisciplinary learning, and individualised curricula.

e. Identify some truly inspiring Grand Projects for 2050, that really do reflect the aspirations of our citizens. By way of example, this could include such simple, obvious targets as curing dementia or eradicating all infectious diseases. Or it could include a sustainability project of the sort described earlier: Harness the social sciences, humanities, civil society and all other parts of society to discover how to shift our societal focus from eternal growth to sustainable wellbeing.

f. Set ambitious global goals and positions for global problems, building on national and EU research efforts.

Plus: Funding and the tax base

Knowledge isn't cheap. The investments we will need for education, research and innovation over the next 35 years will be substantial – and, as so much of these involve a public good, a public role in financing them will need to continue. Europe needs to safeguard its tax base. Tax-avoidance by multinationals or wealthy individuals is a growing problem, due in part to globalisation and technology.

We urge the creation of better systems to monitor cross-border commerce and taxation. This could be a new initiative within Horizon 2020. But more importantly, we recommend a gradual tightening of the links between fiscal policy and policy for research, innovation and education.

* * *

The principles enumerated above are very broad – but then, the perspective of this group has been broad, and far. When thinking about the future of the knowledge system, one is inevitably drawn into wider considerations: of social structures, environmental impact, Europe's place in the globe. With this regard, far from being a minor corner of EU policy, the combination of research, education and innovation reaches very quickly into every field of policy. Making the right choices will matter very much in the years ahead; our sketches of the future highlight that fact.

In the end, we are what we believe. Despite our many differences, Europeans share some basic values: the rights of the individual, openness to new ideas and peo`ples, égalité and social solidarity, environmental responsibility to future generations – and a respect for knowledge. If we are to prosper in 2050, our policy choices will reinforce those values.

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Introduction

"Rien ne gâte la confiance comme la prévoyance d'un changement."
- Napoléon, Mémoires, 1821

We live in a world of growing unpredictability. Accelerating technological change empowers individuals and organisations to be far more productive, and destructive, than ever before. National and other traditional boundaries are eroding as connections – virtual and physical, for commerce or culture – multiply among individuals, organisations and regions. Demographically, where we live, with whom we live, and how long we live are all changing fast. Even as physical distance becomes less important to us, our growing tendency to cluster in those parts of the planet most challenged for resources in general and for food and energy in particular make it ever harder to forecast anything – from war to peace. Even the problems may change: by 2050 what we view as global challenges may not be as we currently know them.
For Europe, its research, innovation and higher education system - the Knowledge Triangle - lies at the core of its economic and social prospects. It shapes our ability to meet challenges and promote the welfare, security and wellbeing of our citizens. It permits us to adapt to change. From ancient Athens to modern Paris or Cambridge, knowledge defines society; the system by which we create, preserve, share and apply that knowledge is vital. Yet, today, we see that system under mounting stress: of money, technology, demographics, and globalisation.

This report explores how this knowledge system may evolve by 2050. It draws recommendations for immediate policy action in Europe, so that the outcome is what we wish for rather than what we are handed.

Foresight is a growing discipline. At the basis of this report lies a great deal of foresight work by others – a synthesis of current thinking developed under European Union programmes, the Organisation for Economic Cooperation and Development, national agencies and private organisations[1]. This work has underpinned the deliberations of our expert group, a diverse body of academics, policy analysts, and private-sector representatives. Our disciplines include economics,

[1] The group's report builds on work in EU projects: Forward Visions on the European Research Area (VERA) http://eravisions.eu/; Research and Innovation Futures 2030 (RIF) http://www.rif2030.eu/; and on OECD work on the Future of Hihger Education: http://www.oecd.org/edu/skills-beyond-school/ceri-universityfuturesfourscenariosforhighereducation.htm; in the context of globalization: http://www.oecd .org/edu/ceri/hig hereducationto2030volume2 globalisation.htm; and of demographic changes: http:// www.oecd.org/ education/skills-beyond-school highereducationto2030vol1demography.htm. In addition to this background, the Expert Group would like to thank, for their help in surveying the field of foresight, Dominique Guellec of the OECD, Anne Stenros of KONE Corp., Jerome Glenn of the Millennium Project, and Simon Roy and Nikolaos Kastrinos of the European Commission.

computer science, education, science and innovation policy, foresight, journalism and more. We met periodically in Brussels over four months to debate how Europe's knowledge system could evolve through 2050, and what the European Union should do about it.

To capture the spectrum of potential developments and options, the group constructed two scenarios: one of European success in the turbulent world of the next 35 years, and one of Europe missing out on the opportunities of the future. The scenarios are neither quantitative economic modelling nor systems dynamics analysis – although information from modelling exercises has been considered in their construction. They are, rather, narratives that the group finds plausible and instructive. They highlight important decision points and directions – «lines to take» - that could make a difference for the future of research, innovation and higher education in Europe, and through that, for the future of Europe as a whole.

In this report, the first chapter provides a short description of our baseline: What is the Knowledge Triangle today? The second chapter analyses three megatrends that we believe will most influence the knowledge system: globalisation, accelerating technological change, and population change. The third and fourth chapters present our two scenarios. And the final chapters summarise the policy conclusions we draw from the scenarios, and how they relate to our common values as Europeans.

The scenarios are not meant to be parts of a binary reality: a menu of two possibilities from which we choose one. Europe is a big place and parts of the positive or negative scenarios may play out simultaneously in different areas. The important point about the scenarios is that they highlight policy choices, and the challenges and opportunities that may derive from them. As always, history is a result partly of events beyond our control, and partly of the choices – smart or stupid – that we make. With this report, we hope for the best.

1. Transforming knowledge

How do you make money from an idea? How do you turn knowledge into wealth, wellbeing and social progress? These questions matter more and more, as economy and society embrace accelerating technological change, and the importance of knowledge rises.

Theories abound. There's the courageous inventor model: A Babbage or Marconi, through force of character chasing a private vision of computation or radio that, sooner or later, proves worthwhile. There's breakthrough science: A Watson and Crick, pointing us down a path that others, more practically minded, develop over 60 years into a new, life-saving industry. There's the invention factory, like Edison's Menlo Park laboratory or Bosch's Stuttgart workshop: Pick an economically important problem, and put a professional team on its solution that draws ideas from wherever they can be bought, borrowed or stolen. There are more theories, but most seem too simplistic – mere cartoons of how knowledge is transformed to action.

In recent years, however, a more complex model has come to dominate policy discussion in Europe: the knowledge triangle. The idea itself is simple: the acts of learning, discovering and innovating all go together, like three pistons in an economic engine. Education, research and innovation; universities, laboratories and companies; teachers, scientists and entrepreneurs – all are part of a system that, if well managed, creates wealth, jobs, growth and, if one is an optimist, social progress. The idea grew from observation of the way universities and companies were interacting in Boston and San Francisco in the 1970s and 1980s, and began to spread in Europe with studies of similar, albeit smaller, phenomena in Cambridge, Gothenburg and a few other university towns[1]. In the first decade of this century, as Europe with its Lisbon Agenda strove (unsuccessfully) to become "the most competitive and dynamic knowledge-based economy in the world,"[2] the triangle model became entrenched in policy circles. By now, it is orthodoxy, a way of thinking embedded in the EU's flagship research and innovation programme, Horizon 2020, as well as policy for education, research and innovation in many member-states.

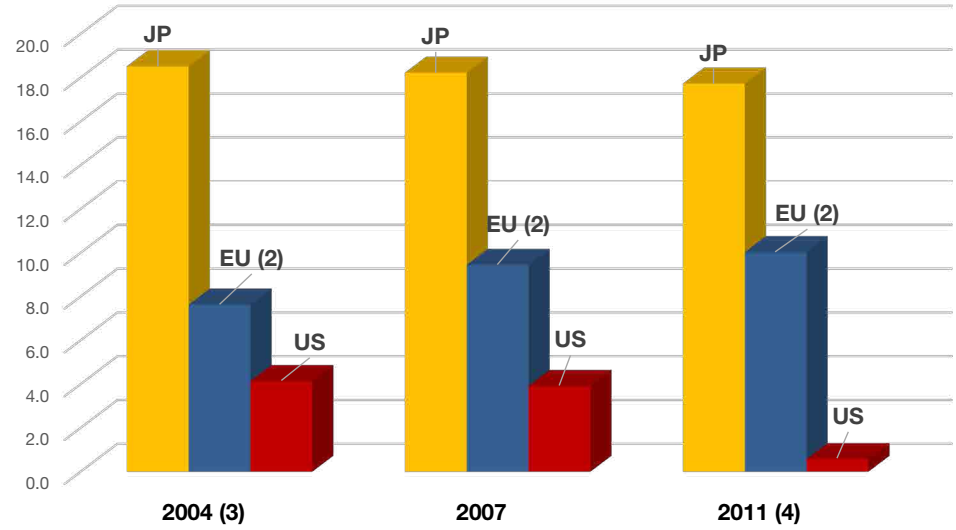
2 See, for instance, "The Cambridge Phenomenon," an influential 1985 report by a UK consulting firm, Segal Quince & Partners, commissioned originally to help promote the city. Similar, smaller studies were done in the 1980s of a few other European cities.
3 European Council. "Presidency Conclusions", 23-24 March 2000. http://www.consilium.europa.eu/en/uedocs/cms_data/docs/pressdata/en/ec/00100-r1.en0.htm

But how does the triangle work, exactly? And what policies would make it work better? These are tough questions.

They are tough, first, because of a widespread view that Europe faces an «innovation gap» with other advanced countries. This perspective is not new. It can be found, for example, in the

Colonna Report published in 1970[3]. But over the last 15 years, it has been documented in a growing number of studies and indicators – of patents, scientific citations, and R&D investment. Like most received wisdom, it isn't a universal truth; in fact, by some measures, Europe is doing better than the US. But the new challengers are China, South Korea, India and other rising economies; as their innovation investments have risen, the US and European share of global R&D has for the first time fallen below 50%. So the innovation gap has risen on the European policy agenda. But the problem isn't just competitiveness. Threats like climate change, energy insecurity, unemployment and inequality in incomes, health and harmful exposures are rising. Politicians strive harder to improve Europe's capacity to innovate its way out of these problems – but the perception persists that something isn't quite right about the way the triangle is working in Europe.

Contribution of knowledge-intensive goods and services (1) to the trade balance



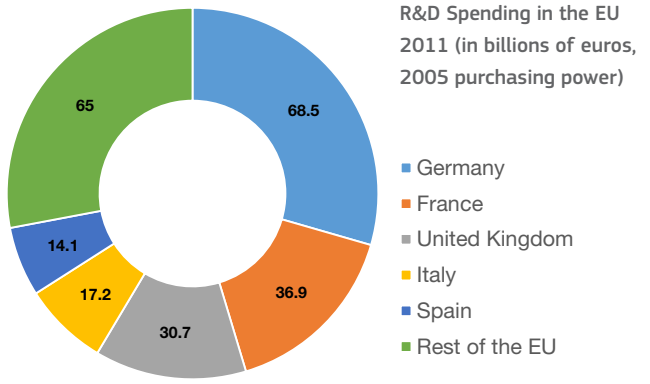
Source: Innovation Union Competitiveness Report 2013; Notes: (1) US, JP: Data were not available for all knowledge intensive sectors for all years. (2) Extra-EU27. (3) US, JP: 2005. (4) US: 2010.

The questions are also tough, however, because the policy levers are hard to grasp in Europe. In research, the EU has some options. It acquired legal competence for research, in parallel with the member-states, in 1986 with approval of the Single European Act that provided the Union with new means to support its own programmes. With the Treaty of Lisbon in 2007 the EU powers were further strengthened by mention of a "European Research Area" – a kind of single market for ideas and their creators. But EU power over higher education is considerably softer: Since the Treaty of Maastricht, education is an explicitly designated national competence. Innovation is mentioned in the EU Treaty in a chapter on industry, as one of the conditions necessary for competitiveness. The result is a complex, ever-changing mix of national, sub-national and EU

3 EC (1970) Industrial Policy of the European Community

policies. Policy makers in Brussels speak of a Knowledge Triangle – but in fact, there are hundreds of them scattered across the EU, big or small, effective or useless, productive or wasteful. What works in one region may fail in another. Finding the right policy mix is difficult.

The knowledge system



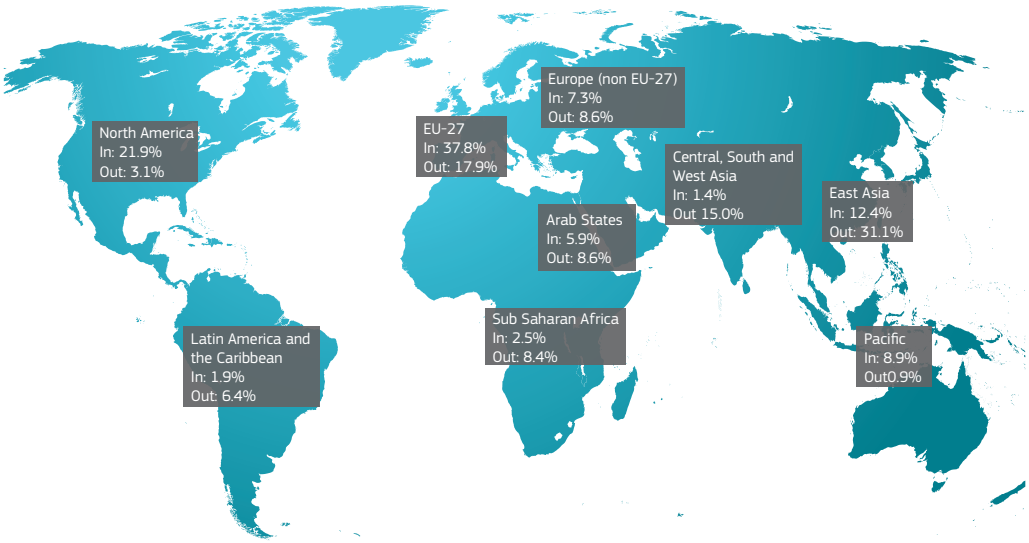
So what is this machine, this engine, efficient or not, that transforms knowledge into action? Start with the most straightforward element, the research capacity. First, European Research is a collection of 28 national research systems with a relatively small overlay of EU coordination. Three countries – Germany, France and the UK – perform more than half the R&D in the EU; the Commission budget is barely 6% of the total. The degree of national commitment to R&D varies wildly, from more than 4% of gross domestic product to a statistically negligible fraction. The structure differs, from strong ministries dictating funding and policy from the top down, to bottom-up, peer-reviewed grant systems administered by politically independent research councils. Some members have politically important academies; some don't. A few trends unite most, however: Among them, a growing interdependence as their researchers collaborate across EU and international borders; high mobility, with 56% of researchers having spent at least three months working abroad ; a growing interest in applying science to global problems like climate and security; and rising political attention to what science does. This can only be good: Witness the rising numbers of "citizen science" web sites and apps, whether counting birds or galaxies. It can also be difficult, as scientific issues from stem cells to genetic modification gain political charge.

Institutionally, the research world is in constant turmoil. The number of research and research funding agencies has risen across Europe, and they often have specific policy missions such as renewable energy or non-communicable diseases. Foundations, patients' groups and other new actors have entered the scene. At the same time, universities have become even more central to research than before, so much so that in Denmark government research centres have been absorbed by the universities. In other countries government labs have been federating under umbrella organisations resembling the German Max Planck, Fraunhofer and Helmholtz societies. Of course, there are exceptions. Austria, for example, has many small, independent research institutes in the social sciences and humanities. And Greece, Spain and Italy do not have national research funding agencies outside government. But there is a slow pressure towards convergence, as member-states compare notes on best practice and EU programmes rise in budget and political importance.

And the nature of research is changing – in Europe as across the world. Individual institutions are challenged by growing competition and new technologies. Money matters more than ever: Research excellence often requires expensive equipment, and generates important income streams. Digital

technologies are changing what it means to publish results or protect ideas. Sharing data and infrastructure are becoming common. Science generally is more open, more collaborative and more productive than ever before; indeed, a whole new idea of research, sometimes called Science 2.0 or more recently "Open Science", is in development – a data-intensive, digitally connected approach to making and testing hypotheses, across borders and disciplines.

Distribution of mobile students in tertiary education by region of origin of the world %, 2010 (inbound and outbound mobility)



Source: European Commission on data from UNESCO

The education system across Europe is similarly diverse. There are about 4,000 higher education institutions in the EU serving more than 20 million students. They range from specialised schools to large universities, with a growing emphasis on training, or retraining, people for jobs in labour markets. Policy is set nationally, with relatively little EU involvement except in defined areas, such as study-abroad programmes or other forms of cross-border collaboration and intergovernmental exchange. Big countries have big educational systems; but, overall, gross national expenditures on higher education range between 1% and 2% of GDP and do not fluctuate much between years, although the squeezing effect of the recent financial crisis on education budgets has been visible, particularly for countries with budgetary deficits[4]. But that doesn't mean it isn't a sector roiled by powerful trends.

Often, education is viewed as a marketplace. Higher education has become ever-more global – and in that evolving market, Europe is No. 1, attracting 38% of international students and 'exporting' 18%. In some European countries cash-strapped universities, no matter how famous, depend on international tuition to balance the books – adding a new tension to immigration policy, which of course can be also important for EU countries where universities do not charge tuition fees. A major trend has been for universities to diversify into innovation, managing intellectual property, spinning out companies and consulting to industry. Again, it helps fill budget gaps; but it also chases after the increasing amount of competitive applied research and innovation funding available from the EC and national governments pushing for faster economic growth.

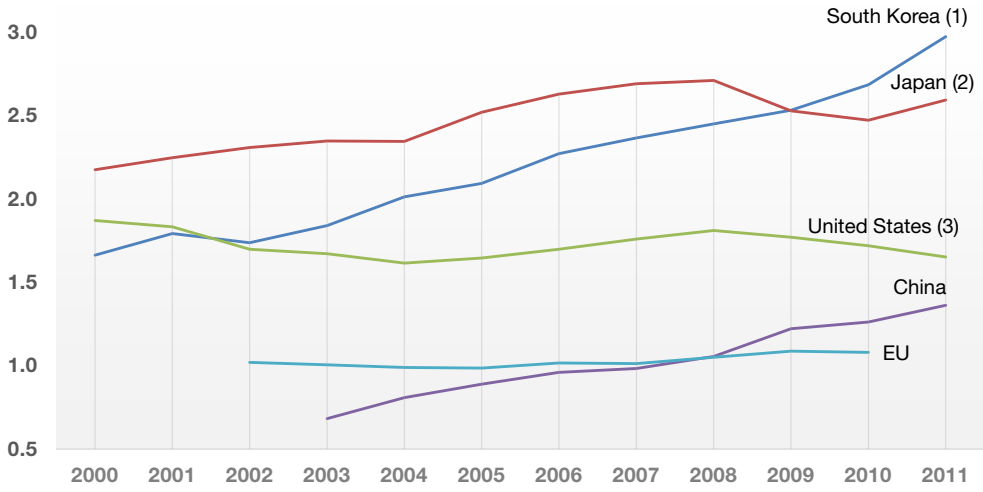
4 See: EURYDICE (2012) Funding of Education in Europe: the impact of the economic crisis http://eacea.ec.europa.eu/education/eurydice/documents/thematic_reports/147EN.pdf

And a combination of technology, labour demand and national policy has made some aspects of education look increasingly commercial. Today educational institutions certify skills to employers, assist in corporate recruitment and train multinational managers. They provide more personalised services to individual, paying students – of any age or background. Some European universities are privately owned, albeit not-for-profit. Indeed, education is even covered by World Trade Organisation rules.

All these trends – viewing education as a market, with strong funding ties to commercial research and innovation – have put universities at the centre of the knowledge systems. In response, they have begun to behave strategically, forming international alliances and satellite campuses. With the arrival of MOOCs, and other forms of online provision, the reach of individual universities and courses grows and the conditions of competition among them changes. Strategies for attracting business investment and engaging in open innovation have become important parts of the identity of competitive universities.

The final, innovation side of the triangle is harder to describe, as it is more diverse. Of course, a big part of it is in business – and that for Europe is a problem: generally speaking, there's less business R&D than in the US, Japan or other major world powers. Indeed, for years, no matter what the prevailing policy, the EU has scraped along with a steadily poor 1% of GDP devoted to R&D funded by business, while China and other rising powers have surpassed it. The industry mix, labour policies, taxation, regulated or anti-competitive markets, foreign tax incentives – many reasons have been suggested for the unresponsiveness of European business. And the problem isn't just with big companies: European start-ups and spin-outs, despite their often-promising technologies, have trouble growing into global colossi. If successful, they are often absorbed by multinationals, for lack of growth capital in Europe.

GERD financed by business enterprise as % of GDP, 2000-2011



Source: DG Research and Innovation - Economic Analysis Unit; Innovation Union Competitiveness Report 2013 Data: Eurostat, OECDNotes: (1) KR: There is a break in series between 2007 and the previous years. (2) JP: There is a break in series etween 2008 and the previous years. (3) US: (i) There is a break in series between 2006 and the previous years; (ii) GERD financed by business enterprise does not include most or all capital expenditure.

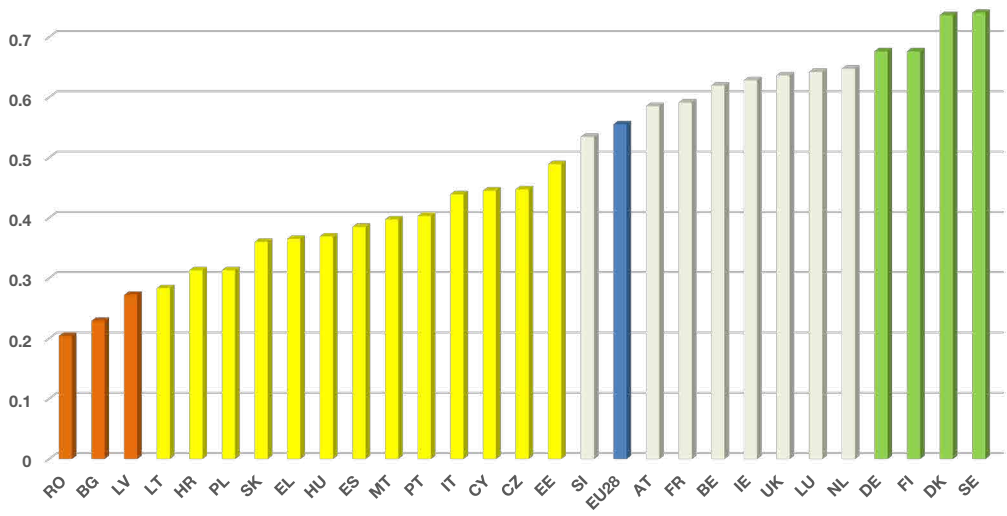
But this picture belies great, and hopeful, ferment. First, innovation is moving 'beyond locality'; multinational networks of suppliers and customers today make our cars, program our computers,

and develop our medicines. Second, new actors enter the picture: micro-companies, foundations, crowd-sourced ventures. With so many players, opportunities for both fruitful cooperation and bitter rivalry abound. On one hand, 'open innovation' has become trendy; closed, centralised corporate labs have given way to networked integrators of others' ideas. On the other hand, intellectual property has never been more hotly defended; the 'smartphone wars' that have pit global ICT companies against one another in court, rather than in the market, are the latest example. Lastly, technology is changing the very definition of innovation. Consider: A Copenhagen architect designs a daring new building in Barcelona, collaborating online with Stuttgart materials experts on thermally efficient windows, Palo Alto programmers on 'smart building' services for automatic control, Tianjin solar engineers for more-efficient power panels – and then innovative new companies from across the world move in as tenants. Which of these is the most important innovator?

The knowledge triangle: Strong partnerships

With apologies to Tolstoy: unhappy countries are all different; happy countries are all the same – at least when it comes to innovation. There is, across Europe, huge regional variation in innovation performance. But the leading countries share a number of strengths in their innovation systems: Resilient economies, dynamic companies, big R&D budgets, open markets, well-trained engineers and scientists and strong schools, to name a few obvious advantages. How much of these advantages are cause, and how much effect, of a strong innovation system is open to debate. But what is clear is that a lot of things have to go fairly right, all around the same time, for success. The combination of factors matters: the innovation leaders have a balanced national research, higher education and innovation system that performs well.

EU innovation performance



Source: Innovation Union Scoreboard 2015

How does that work? They have many, and varied, innovation ecosystems, in which people have incentives to connect, learn, adapt and change – across the conventional boundaries of laboratory, factory and classroom. Universities can be a catalyst for it: training new employees, launching new careers, making new discoveries or helping apply old ones. But it requires a lot more than

just a campus. Also needed are strong local companies with specialities that can succeed in big markets; investors willing to bet on local entrepreneurs; enlightened government; and much more.

Take just one example: the Stockholm/Uppsala region. It is the most R&D-intensive in Sweden, covering all areas of technology – but its life sciences cluster is particularly strong. It includes five universities – most famously, Karolinska Institutet, which names the Nobel Prize in Medicine or Physiology. The region has over 600 life sciences companies, two university hospitals, numerous innovation support services, and dedicated government innovation agencies. The universities train doctors, nurses, researchers and entrepreneurs. They host company offices, large and small, right on campus, making academic/industrial collaboration physically easy. They provide new leads for biomarkers and treatment strategies that the companies can develop into products or services.

They are also extremely well-funded, getting 78% of their budgets in direct grants from the Swedish government. Almost a third of EU-supported life sciences projects have at least one partner from the Stockholm-Uppsala region. The government has invested in supporting technologies including electronic patient records, biobanks and health care databases. There is a distinctive intellectual property regime in Sweden that allows researchers and scientists to retain the patent rights in their work[5]. A number of local investment funds, supported by Sweden's richest families, actively invest seed money in the area.

The outcome? Despite its small size, Sweden ranks 12th in the world in output of clinical trial research and 6th in most-cited papers. Life sciences companies in the capital region employ 23,000, equivalent to 60% of Sweden's workforce in the sector. In 2013, 49 Swedish companies had at least 81 clinical-stage projects, representing a significant pool for potential collaboration.

Of course, Stockholm is unusual – but not impossibly so. World-class innovation clusters thrive around Cambridge University, the University of Oxford and the large group of London universities; around KU Leuven, LMU and TU Munich, TU Eindhoven and many others. Clusters are growing around universities in Prague, Warsaw, Milan and Barcelona. Some have a paramount local industry: Turin is for cars, Toulouse for planes. Some are funded privately, for the most part; others revolve around big government labs or programmes. Some have had decades of growth; others, especially in the East, are only now building or rebuilding.

To what extent are these really knowledge triangles, or just happy clusters of regional innovation? In truth, the dynamics of these systems are not entirely clear – but we can all read in them the effects of a good mix of education, research, entrepreneurship and policy.

The EU role

So what is to be done, if we want more knowledge engines like those? Clearly, national policies matter greatly; but if we wish to spread the success across Europe, the EU institutions are bound to play a role. So, we offer a review of EU policies in this field that have been a key force in the shaping of a European innovation system.

The EU institutions have been pushing to improve Europe's international competitiveness. As mentioned previously, its Lisbon Agenda (later, the Lisbon Strategy) in 2000 set a grand goal of making the EU "the most competitive and dynamic knowledge-based economy in the world capable of sustainable economic growth with more and better jobs and greater social cohesion"

5 There is a long, and so far unresolved, policy debate over whether such 'professor's privilege' IP rules help or hinder innovation in the few countries, such as Sweden, that have them. The more common, American-style model is for the university to own the rights, but give the professor a share of the rewards.

by 2010. It targeted a near-doubling in R&D spending, to 3% of GDP – with projected payback of 0.5% additional GDP growth and 400,000 extra jobs a year. When that strategy failed for lack of investment, in 2010 the EU put forward another initiative, the Europe 2020 Strategy[6] with a number of flagship initiatives to achieve ''smart, sustainable and inclusive growth''. As part of that, Horizon 2020, Europe's framework programme for research and innovation, has boosted European funding for the period 2014-2020 to €77 billion.

A number of policy initiatives go along with these efforts. The Innovation Union flagship initiative, adopting a broad approach to innovation that includes not only bringing to market new products but also new processes, systems and approaches, aims at building on the uniqueness of Europe's values and need for innovation. The European Research Area aims at creating a genuine single market for knowledge, research and – more recently – innovation, enabling researchers, institutions and businesses to circulate, compete and co-operate across borders. Moreover, the new rules for the EU's Regional Cohesion Policy for 2014-2020 aim at making innovation a priority for all European regions, supporting "Smart Specialisation Strategies" to create knowledge-based jobs and growth not only in leading research and innovation hubs but also in less developed and rural areas of Europe.

In education, there are parallel initiatives. Education and Training 2020 has set as targets that at least 40% of those aged 30 to 34 should have completed some form of higher education (also a headline figure for Europe 2020), at least 15% of adults should participate in lifelong learning, and at least 20% of higher education graduates should have spent some time studying abroad. The ERASMUS+ programme supports learning mobility of individuals across EU countries, cooperation for innovation and exchange of good practices across EU higher education institutions and the world of work, and education policy reform. In the context of implementing the Lisbon Strategy, the European Commission has proposed since 2006[7] that the EU should by 2015 devote at least 2% of GDP (including both public and private funding) to a modernised higher education sector. This has been neither attained nor retained as a target. The EU's current Modernisation of Higher Education Agenda[8] has proposed a framework of reforms to improve the quality and quantity of graduates, the governance and funding mechanisms supporting excellence, the knowledge triangle, the mobility of staff and students and the internationalisation of higher education. The intergovernmental Bologna process and the creation of a European Higher Education Area are also important steps towards enhancing the international competitiveness and attractiveness of Europe's higher education and facilitate mobility of students and staff.

In addition to these broad efforts, the European Institute of Innovation and Technology, or EIT, has been an initiative with EU funding to fully integrate all three sides of the Knowledge Triangle (higher education, research and business) by way of so-called Knowledge and Innovation Communities (KICs), international consortia of universities, firms, research organisations and other stakeholders that aim to advance knowledge and innovation in important fields. So far, KICs have been set up in the fields of Climate, Health, ICT, Energy and Raw Materials; more domains are set to follow. Having been founded in 2008 the EIT has become part of the Horizon 2020 package, and constitutes an important experiment in EU research and innovation policy-making, in which the EU gets directly involved with the design of institutional structures of the delivery of research, innovation and higher education in the European Union.

That's a lot of policy. But, as noted earlier, its impact is limited in scope - to areas specifically defined by treaty - and in the total effect: the European economy has yet to innovate itself out of

6 European Commission COM (2010), Europe 2020. A strategy for smart, sustainable and inclusive growth.
7 COM (2006) 30 final of 25/01/06.
8 COM (2011) 567 final

the crisis and investments are stagnating. Across the EU, member-states' budgets and policies dominate. But now, a series of megatrends – disruptive, powerful – are roiling the worlds of education, research and innovation. And the global economic crisis has hurt Europe and its regions. To maintain its economic prosperity and social welfare in 2050, Europe needs to improve its innovation performance, close the innovation gap with competing countries, and reduce regional disparities in innovation performance. Action will require a complex mix of European, national and regional policies, to create successful ecosystems for innovation. But how will these systems evolve in the decades ahead? What is the role of Europe in the future evolutions? And what should Europe do in order not to miss out on the future?

2. Megatrends 2050

A review of major forces shaping Europe's innovation potential

Europe's ability to innovate depends on many things: its universities, companies and research labs, to start. But it also depends, in a more profound way, on its ability to turn the great forces shaping the world to its advantage. Over the past generation, a mini-industry has grown to understand the 'megatrends' reflecting these forces; the list of them varies by forecaster and objective, from the World Bank with an economic slant to the CIA with a security interest. But for knowledge creation and use, a few megatrends seem particularly important:

- **Globalisation.** As the world gets more inter-connected, and economic competition expands, the way we learn, discover or innovate will change, and the impact will hit home faster and harder.
- **Demographic change.** The move to cities, the ageing population, the shifts in family size and social norms – all will change what we expect and can do in education, research and innovation.
- **Accelerating technology.** Just 35 years ago came text editors. Now: gene editing. By 2050, what next? Each invention, coming faster and faster, changes not only our society and economy, but also the way we work in education, science and business.

Here, we present a consensus view – what the experts most often say, from Washington to Paris and Tokyo – about these megatrends. Are they right? Check back in 2050 to find out. But they do appear to identify some of the most powerful forces affecting knowledge transformations in coming years.

1. Globalisation

The world is getting smaller. As it does so, interdependence will rise, power will shift, and new opportunities and risks will open up for individual citizens.

Trade is booming. From 20% in 2010, global exports as a percentage of GDP is expected to increase by 2060 to about 33%, the OECD says.

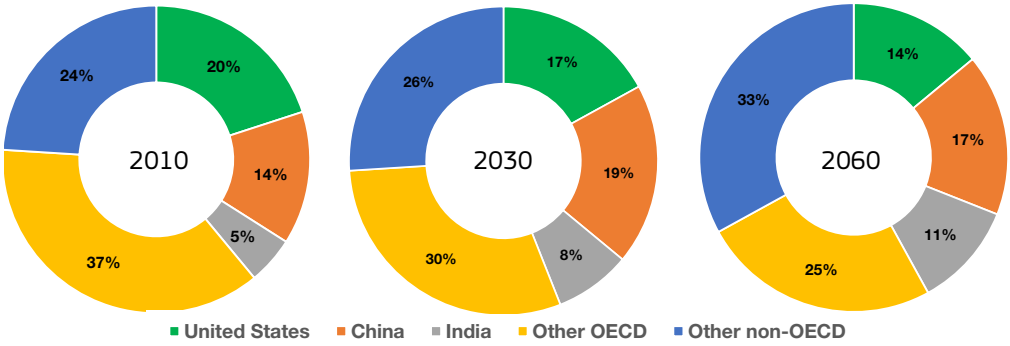
With globalisation comes trade and growth, many economists say. The OECD expects global GDP to triple by 2050. That sounds impressive, but on an average, it actually implies a deceleration in annual growth rates from a peak of 4.3% to just under 2%[1].

1 OECD. "Economic Outlook and Global Interim Economic Assessment," March 2015. http://www.oecd.org/eco/economicoutlook.htm

Resource and population constraints will bite. Still, good government will matter: Those growth rates can increase prosperity, improve living standards, and reduce global poverty – or, if badly managed, can magnify inequalities and destroy the environment.

The OECD expects to see greater global economic convergence, with faster growth in developing regions than in advanced economies. The share in global GDP of advanced economies will fall while China's and India's share will rise by 2060[1].

The global economy becomes multipolar: Shares in global GDP (at current PPPs) fall from 57% to 39%

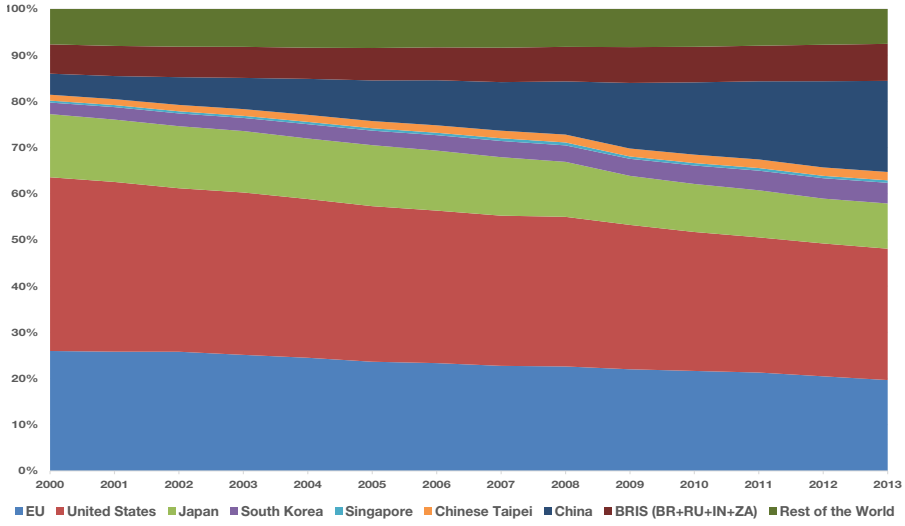


Source: OECD

What if...

Chinese R&D intensity has been rising fast, and it caught up with Europe in 2012. Given that R&D is a high priority for the Chinese Government, we can expect that it may overtake the US, and by 2030 China could be the world's biggest R&D investing country.

Shares of world R&D funding since the year 2000.



Source: E:uropean Commission, DG Research and Innovation

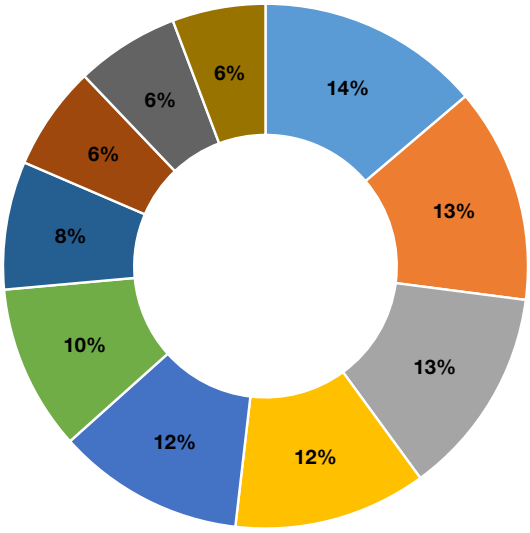
1 OECD. "Looking to 2060: A Global Vision of Long-Term Growth", OECD Economics Department Policy Notes, No. 15, November 2012.

As that happens, economic power will shift from a unipolar to a multipolar system. Trade will also accelerate that shift. The combined contribution to global foreign direct investment of the US, EU, EFTA and Japan has already declined from almost 100% in the 1970s to 60% in 2012, while China's outward investments have grown enormously to reach 12.1% of global FDI in 2012.

The new balances in economic power are already being reflected in global governance, with China, India, Brazil and others playing a more forceful role in international finance, trade, development and climate change deliberations. But this does not necessarily mean that the world will eventually become ''flat''. For one thing, this isn't a static system: As China and India grow, their labour costs are rising and their current competitive advantage could diminish. Also, new actors emerge in the international and global scene, including regions, large cities, regional alliances, multinational enterprises and non-governmental organisations. In this changing context, the EU could see its capacity to control or influence events decline – but it need not be marginalised. That depends partly on the way the EU uses its native strengths in R&D, innovation, education and other factors that affect global competitiveness.

Will borders vanish?

These macro considerations are somewhat theoretical, but on the scale of our daily lives and jobs we already see the very real effects of globalisation. From Amazon to Samsung, global brands and products are in our homes and hands. Migration – and conflict around it – is on the rise. Intellectual property, from music copyright to smartphone patents, is climbing on policy agendas; the White House has an "Intellectual Property Enforcement Coordinator" on staff. Innovation has moved beyond locality; behind any significant new service or product, a global chain of contributors – researchers, engineers, manufacturers, financiers, sales people – is at work. Education, at least at elite universities, is now a multi-cultural affair. In the UK, one of the most international higher



Share of scientific articles internationally co-authored.

- France
- Germany
- United Kingdom
- Canada
- Italy
- Russia
- United States
- Japan
- China
- World

Source: OECD Science and Technology Indicators, 2009. http://dx.doi.org/10.1787/745766770745

education systems in Europe and home to some of the world's top universities, international students already account for 18% of enrolment[2]. Science is most global of all: Today, about a fifth of all scientific articles are co-authored internationally – and for researchers in France, Germany and Britain, it's about half.

2 UK Council for International Student Affairs. http://www.ukcisa.org.uk/Info-for-universities-colleges--schools/Policy-research--statistics/Research--statistics/International-students-in-UK-HE/

Where does this stop? In some respects, it won't: Wherever erasing borders adds value – cutting costs, speeding development, stimulating ideas – the practice will grow and grow. But there is also a countervailing force. Partly in backlash, we see local cultural preferences – in food, entertainment, primary and secondary schools – being asserted. Sustainable living preferences are popular, at least in Europe, in local products and bio agriculture. And regional pride is on the rise, from the Welsh language to Catalan independence movements. We cannot predict how the contradictions between globalisation and local pride will resolve themselves – but they will shape our society, and the way we develop and use knowledge, for generations to come.

2. Demographic change

World population will likely rise beyond 9.6 billion by 2050, despite – as with the economy – a slowing of the growth rate[3]. Most of the increase will occur in the developing world, and particularly in its cities. Age structures are also changing. The world's median age is expected to increase from 28 in 2010 to 36 in 2050; and the proportion of those over 65 will grow from 8% to 16% of the global population. This older population is more often female; women live longer. In developed regions, ageing will cause problems for labour market productivity, and the financing of social security, public health systems and taxation. Developing world regions are already seeing their rising young populations challenge their education systems' capacity and opportunities for employment.

Migration patterns will also change, say the forecasts, as several countries in developing regions attract more people. The economy isn't the only driver: Climate change and environmental degradation will also play a growing role. Projections for climate change-induced migration by 2050 vary significantly, ranging from 25 million to one billion people.

The UN's demographic forecasts for Europe are dire:

- *The share of the EU population under 15 years old will fall from 16.4% in 2004 to 13.4% in 2050.*
- *The share of people 65 and older will rise from 16.4% to 29.9%.*
- *The share of the working age population (between 15 and 64) is expected to decrease from 67.2% to 56.7% - that is, a fall of 52 million working age inhabitants.*

Whereas in 2004 there was one inactive person (young or elderly) for every two persons of working age, in 2050 there could be three inactive persons for every four of working age.

Overall, with other regions growing fast, Europe's share of the world's population will shrink from 11.9% today to 7.7% in 2050.

Urbanisation

Urban areas in developing countries will absorb most of the global population increase, with 67% of people living in cities by 2050, doubling the current 2% of global land area covered by cities. We will see more megacities, informal settlements and, most likely, slums. But we will also see more pressure for efficient and sustainable use, re-use and mixed use of urban space. "Green" will be embraced by "smart" concepts that bring together digital cities, products and technologies. The infrastructure of 2050 will be transformative, enhancing the resilience of cities and of their critical infrastructure systems.

All this has profound political implications. Cities will become more powerful inside and outside their countries. Their revenues will increase and, most likely, they will take a stronger role in investment in research, innovation and higher education.

3 See World population ageing, 2013, The United Nations, Population Division, The Department of Economic and Social Affairs, New York.

A changing Europe

Europe's population is also expected to change by 2050[4]. The total population is expected to increase somewhat and then begin to decrease as the effect of net immigration will no longer outweigh the decrease that is due to the differential fertility and mortality rates. In 2004, Eurostat expected the turning point to be 2025, and in 2050 the population of EU-25 to be 1.5% lower than it was in 2004. Currently Eurostat expects the population of EU-28 to have increased by about 4% by 2050 and then begin to decline. In all forecasts EU population is expected to age considerably, and that raises challenges for European economies and societies. Governments will need to ensure the sustainability of public finances in Europe, in the face of large demographic challenges. In labour markets, the number of workers will shrink, and the ratio of elderly non-workers to workers will rise steeply. Overall, the OECD estimates that demographic trends will contribute to a fall in European annual GDP growth from 1.7% in 2020 to 1.3% in 2050.

The most common household type in the EU-27 in 2011 was the single person living alone, at 31.4% of the population.

Gender dynamics and changing lifestyles

In Europe and other developed countries, changing gender dynamics, lifestyles and attitudes create new economic challenges and opportunities. Women's participation, contribution and purchasing power have significantly increased in recent decades and are expected to grow further. Still, the share of women researchers in science and technology is low in most European countries, while female employees are vastly underrepresented in the workforce of tech companies. A 45% rise of independent professionals across Europe and an increase by 25% of freelancing mothers in the UK in the past two years indicate that casual, temporary work is here to stay.

Lifestyles, preferences and attitudes of younger generations are changing. Household size is shrinking and DINKS (Double Income No Kids) are common. "Millennials" (i.e. those born 1981-1996) appear to care more about having a good job than getting married or owning a house. Millennials say making the world a better place is a priority (64%), prefer self-employment (72%), a collaborative work-culture rather than a competitive one (88%), flexible work schedules (74%), and ''work-life integration''[5].

4 See The Ageing Report, 2009 & 2012, The European Economy Series, European Commission
5 Source: Intelligence Group report, referred to by Anne Stenroos. Also see http://www.forbes.com/ sites/robasghar/2014/01/13/what-millennials-want-in-the-workplace-and-why-you-should-start-giving-it-to-them/

3. Accelerating technological change

What if we can...

- *Grow meat without animals?*
- *Create floating, vertical farms in the sea?*
- *Create avatars to be our cyber-selves?*
- *Wear all day, every day biotech clothing?*
- *Make our growing cities eco-smart?*
- *Create jobs for all, in a global, digital employment marketplace?*
- *Print kidneys and cars?*
- *Develop a digital, collective intelligence?*

It has become a cliché by now: The pace of technological change is picking up. From radio to television to Internet to Web to.... From microbiology to biotech to genomics to synthetic biology to.... These ellipses will doubtless be replaced by an ever-faster sequence of developments: the semantic Web, augmented reality, quantum computing, 4-D printing and 3-D biological printing, nano-robotic manufacturing and more. By 2050, we could have more drones than people. This pace of change is powered partly by the technologies themselves: data-sharing, open science, international collaboration are all made possible by our emerging ICT, for instance. And both governments and companies are pouring more money into R&D, although in Europe this is less so than in other parts of the world. Many multinational corporations now spend more on R&D than most OECD member-states.

But this is all somewhat predictable. More important is the potential of truly disruptive new technologies in society in coming decades. Take one example: artificial intelligence. This can appear an old story, researched since at least the 1970s and producing some impressive demonstrations (for instance, IBM's Watson computer) but not much broad economic impact. That's starting to change. In various projects around the world, researchers are developing expert, tablet computer systems to gather patient histories and symptoms in the waiting room, and offer a suggested diagnosis before the doctor even picks up a stethoscope; the impact of such a system, trained over many years by millions of doctor-patient interactions, would surely change the economics of healthcare globally. Education could be similarly transformed; personalised curricula could be a norm, and the industry of educational games and software could boom.

What if...

The impact of new technologies could be bad, as well as good. Imagine, for instance:

- *Massive structural unemployment of over 50%, due to automation*
- *Lone-wolf terrorists using synthetic biology to deploy killer viruses*
- *New life forms leaking from labs harming agriculture and causing new diseases*
- *Drug-resistant diseases increasing health care costs*
- *Attacks on nuclear power plants, water systems, and electric grids*
- *Cyber-insecurity and information warfare increasing paranoia and costs for all*

Accelerating technological change brings an increasing scale of devices deployed in and around us, the new technologies making us better able to connect our digital and physical worlds through new sensors and communications. With this comes increasing automation to deal with 'big data' and its real-time analysis, a rise of machine-to-machine communication, and an increasing capability to influence the physical from the digital. The adoption of the Web and social media has already shown what happens when there is mass engagement with the digital world, and with it empowerment of individuals who can create new digital products but also new social processes at large scale. We already see the emergence of the digital "crowd", and any planning of a future Europe necessarily includes consideration of its digital counterpart.

That's just the start. How could these and related technologies change the way we think – quite literally? For centuries, eyeglasses, microscopes and telescopes augmented our ability to see. Will chip implants and artificial intelligence one day soon back up memories, speed learning, and start to correct our mistakes and advise our conduct? Will our very understanding of consciousness change?

* * *

All these trends – globalisation, vanishing borders, urbanisation, technological change – will present a bewildering array of policy challenges.

We can, in fact, give ourselves a good scare with all the dire possibilities. Temporary and part-time employment could become the new normal, along with income inequality and regional disparities. Social tensions – between city and country, fully and partly employed, 'native' and immigrant - could rise. Europe could become an ageing, economic colony of China and India. Our shared values – such as individual liberty, social solidarity and democratic openness – could be swept away in a tide of silicon and code.

But equally, we can give ourselves a bright outlook, through wise use of policy levers. Education will be one vital tool: With so much change underway, demand for education – throughout one's life – is likely to soar and re-skilling, "up-skilling" and other forms of flexible, mass vocational training will spread. Our universities and schools could (should) be delivering, not just degrees, but the basic tools a citizen needs for a new labour market of semi-autonomous employment – and, given the importance Europeans place on individual empowerment, this could become a unique European advantage. Likewise, our research labs could be leading, rather than following, new technologies. And our entrepreneurs and innovators could be the owners, rather than customers, of vast new multinational technology companies. New actors will also change our prospects: Foundations, public-private partnerships, crowdsourcing and crowd-financing.

In short, our destiny is in our own hands. The next two chapters present opposing views of our future: one positive, one negative. The difference will be in the policy decisions we take today.

3. A European success

What happens if things go right in 2050? A positive outlook

The scenario, in brief

It's 2050, and through a combination of good luck and good policy, several things have gone right. Europe and its knowledge economy are competitive in global markets; social tensions have diminished as the benefits of innovation-driven growth (technological and social) get spread more evenly; and the knowledge triangle is alive and well.

Since 2015, there has been a change in the political climate. In the face of rising international competition, public funding shortfalls and disruptive technologies, most people support European cooperation: Better to hang together, than hang separately. This means more EU-wide collaboration on taxing multinationals, coordinating research and regional development, and educating citizens. Public finances remain under pressure, but better coordination of regulation and incentives has mobilised more private capital than ever before to help fund research, education and innovation. The knowledge triangle benefits from, and contributes to, sustainable European growth.

At the core of Europe's knowledge economy are clusters of well-funded, internationally renowned universities in some of Europe's important cities, in strong partnerships with regional institutions. The growing demand for continual education and re-training has prompted new efficiencies: course modules shared within university clusters, online and artificial intelligence-based teaching, specialisation within institutions, public and private. Innovation is often open; multinationals, SMEs, universities and other actors, including citizens, work together in fast-changing global networks to solve global problems. Research is, more than ever, a European forte: Frontier science is a competitive, EU-wide affair led by an enlarged European Research Council, while regional disparities in innovation capacities are countered through separately administered regional development funds.

In short, things are looking up. Where Europe once produced 30% of the world's ideas, it has more than held its own as Asia rose; it is moving towards 40%. Many of its industries are competitive, building on healthy SMEs. Its universities are strong, its citizens fulfilled – and its core values, such as equality, openness, social inclusion and environmental responsibility, are upheld.

***

Is this scenario too optimistic? In the beginning of the millennium it would have seemed more like a business-as-usual scenario. Now it feels that a lot has to go right for us to hit 2050 with such brilliant prospects. But achieving that, we believe, is within the means of the European Union.

In part, it requires solving some fundamental problems unrelated to the knowledge triangle: 'a better Europe', multinational taxation, a single market, for example. Solutions are available, and we assume that the inevitable round of crises, economic or otherwise, will provide periodic spurs to our leaders to adopt these answers. Already, we see how the 2008 crisis has prompted a degree of international coordination among central bankers, finance ministers and financial regulators that had not been thought possible before.

But fulfilling these promises also requires a strong knowledge system in Europe. Many futurologists agree: faced with rising competition from China, India and the rest of the world, Europe's strength must come from the culture, skills, creativity and knowledge of its people. If those are ensured, the knowledge triangle of education, innovation and research will power us towards greater prosperity and better lives. So a healthy knowledge triangle isn't just the product of lucky circumstances; it helps create those circumstances.

What follows is our view of what this favourable scenario could look like.

The policy framework: United Europe, strong regions

Looking back from 2050, what economic and political conditions were essential to prosperity? We see a stable and functioning European Union as an important component. It is not so much that a particular form of European governance is required; on that we take no position. But for purely pragmatic and economic reasons, we believe there must be some form of governance that will enable coordination at European level. Our economic and social problems are more easily solved by working together than apart; and the alternative, a dynamic spiral of European disintegration, will have dramatic negative consequences.

The global picture

A positive global context is not a necessary condition for a better Europe, but it would surely help. The EU's AUGUR Project (http://www.augurproject.eu/), which made forecasts for 2030, estimated that global GDP would grow about 0.4% faster from 2010 to 2030 if there was strong regional collaboration on good governance, and 0.9% if there was strong, multipolar global governance.

Another study, by the UK Ministry of Defence, projected:

"The pressures of globalization are likely to mean that individual countries will find it increasingly difficult to act unilaterally – most countries are likely to be less powerful. This could lead to a reduction in conflict. The state is still likely to have the most important voice in international affairs, but out to 2045 the private sector and non-state organisations are likely to become more influential. There is likely to be an increase in the use of private security companies by governments – interdependencies may strengthen, despite their largely separate motivations." ("Strategic Trends Programme: Global Strategic Trends – Out to 2045," 5th edition 2014)

Start with two megatrends: accelerating technological change and globalisation. Since the 1990s we saw them rapidly reducing the importance of physical borders for commerce, innovation and many other aspects of our lives; by 2050, within Europe, only cultural borders remain. From the 2010s, when multinational tax evasion first surfaced as a hot issue, EU member-states found

it easier to tackle the Amazons and Googles of the world together – and now, increasingly, in collaboration with US and other non-EU governments whose tax bases were being eroded by corporate tax dodgers. The switch in VAT rules, to tax in the online customer's home rather than in the supplier's, was a step in that direction. At the same time, the member-states have been cooperating more on regulation and incentives for multinationals: How to induce the investments and socially constructive behaviour that are needed. The addition of most professional services to the Single Market helped, as did cooperation on an Energy Union. The bottom line: government treasuries, while still under pressure, have more room to manoeuvre.

Treasuries would need that flexibility for the many challenges they face. One is staying ahead of the curve on technology: funding basic research and stimulating innovation in personalised medicine, artificial intelligence, advanced manufacturing and other vital fields. European companies, and the economy overall, needs to control these technologies rather than be victimised by them. Another challenge is regional development: It was quickly seen that what used to be called a digital divide cannot extend to these newer technologies without serious negative consequences. Economic growth and social cohesion is better for all if all regions in Europe have a role to play. Complex, well-informed strategies ('Smart specialisation' or 'eco-smart' or...) are now the norm at the regional level. Regions have the capabilities to target their best prospects in a global economy supported by data-intensive techniques to monitor progress and adjust policy regularly.

What if...

A special challenge for Europe in 2050 will be ensuring a fair distribution of new technologies across the region.

Economists have already measured the retarding effect of inadequate bandwidth in regions, poor IT support in industry, and outdated hospitals. As technological change accelerates, the potential for inequity rises – and this, we believe, will be another factor pushing EU member-states towards supporting more coordination for development.

At the same time, the long-running trend of urbanisation has made regional policy ever more important. Take London: 350 years ago, it comprised 10% of the UK population. Just before World War II, it was nearly 20%. A century later, it is still growing as the opportunities and infrastructure of a megalopolis draw more and more citizens. Such cities are powerful hubs of education, research and innovation – and of sustainability. In 2013 London was home to four of the top 40 universities in the world[1]. European policy has made ''smart eco-cities'' a research priority, making local companies global leaders in the new energy and environmental technologies the world is seeking. Consequently, regions have gained more powers devolving from nation-states, over education, research and innovation policy. Knowledge triangle institutions have shifted their attention to, and increased their interactions with, regional authorities as new loci of regulation and power.

This paradoxical situation – strong regional authorities, embedded in a strong European and global framework – is a source of stability, a new manifestation of the old benefits of European diversity. It promotes citizen involvement in policy, empowerment, creativity, culture. Education has become a near-continuous activity, so people can adapt to change faster and lead more-fulfilled lives. An educated population also means more support for research, education and innovation.

1 See http://www.timeshighereducation.co.uk/world-university-rankings/2014-15/world-ranking

The research angle: Strong labs, citizen science

Automation and data-intensive science have changed the nature and economics of doing research. Whereas in the past science was a matter of gathering specific data to test hypotheses, now the vast stores of data accessible over networks around the world make research a more dynamic process: data mining can suggest hypotheses, citizen- scientists contribute in new and unpredictable ways, and scientific conclusions are expressed in often-changing degrees of confidence. All this takes expertise, of course – making academic specialists, and the universities at which they work, vital. It also takes capital, for computer networks, data repositories, archives and more. So those are forces for concentration.

On the other hand, all kinds of new actors are rushing into the research game. Millions of citizens, benefitting from the continual university contacts that ubiquitous lifelong learning has created, are getting onto networks to add their own insights, data and hypotheses to science.

This is especially true in astronomy, ecology and climate research (finally, people can do something about the weather, rather than just talk about it.) This isn't merely open science; it's radical open access. And it's facilitated by Europe's prestigious Research Infrastructure – CERN, the European Southern Observatory, online environmental monitoring institutes – opening their networks to students, amateurs and companies; it's the only way they could justify their continued public funding. This is not without risks. With synthetic biology now mainstream, for instance, the potential for bio-hacking is terrifying; much government R&D investment now goes into security systems that protect without constraining liberties. But overall, new research frontiers are spurring all kinds of new institutions, virtual and physical – some financed privately, some publicly, some by charities, and some by crowdfunding. People are voting for science with their own money – building public support for research across the EU.

The new science

Something fundamental is changing in the way science happens – though exactly what and how is still uncertain. In a public consultation in 2014, the European Commission called it Science 2.0, and now refers to as Open Science:

"(Open Science) defines systemic changes that are currently taking place in the way the science and research system functions. It is characterised by an open, collaborative networked way of doing research, that has been referred to as Facebook for scientists. While the feedstock is big data, it requires many people to make inputs.

(Open Science) is enabled by digital technologies and driven by the globalisation and growth of the scientific community, providing the means to address the Grand Challenges of our times. (Open science) has impacts on the entire research cycle, from the inception of research to its publication, and on the way this cycle is organised. It also affects the evaluation of the quality and impact of research."

A key part of this balancing act, between centralised and distributed research, is in a new, stronger definition of 'public good' that has emerged in the past half-century. Fundamental research is for the benefit of all citizens; from cosmology to quantum physics, it's widely recognized that the private sector won't pay enough and the public – whether through national treasuries, charities or crowd-funding – must[2]. Here, the European Research Council has evolved as a vital force, ensuring continent-wide competition for the smartest minds and strongest results. Indeed, it has become the "European Research Area" for fundamental research, a hub for national research councils with matching governance structures. Its own ruling Council has been broadened beyond scientists to include government, business and citizen members in response to pressure to address societal

2 As mentioned earlier, companies support fundamental research indirectly, through taxation. Collaboration among tax authorities makes it much harder for multinationals to shop for favourable tax climes.

challenges. Its funding, and that of the national councils, focuses on societal challenges, as citizens get more engaged in research policy.

EU investments - through coordinated but separate ERC and regional funding - aim to develop an ecosystem of urban or regional innovation hubs across Europe, north to south, east to west. At the same time, new forms of public-private partnerships in research are blurring the lines between Research and Innovation.

Thus, the old debate over the right level of R&D investment – 3% of GDP or more? – has become irrelevant. There's more of it everywhere, but the "it" is harder for an economist to define. The bottom line is that Europe's open institutions, educated population and world-famous labs and universities maintain its position as a global powerhouse in knowledge, however you measure it.

What if...

This scenario implies a proliferation of purpose-driven research funding agencies at all levels of government from local to global. Perhaps, a Global Climate Council, a European Agency for Social Research, a Munich Institute for Machine Learning – and so it goes.

How many? In which fields? Will they exist in all countries?

Another scenario could be the proliferation of missions inside existing national institutions, and a change in the character of research councils to include greater international collaboration and more focused missions.

Which way? We can see pressures for specialisation and targeted missions, but the politics of it are unpredictable.

The innovation angle: fast-changing ecosystems, new opportunities

By 2050, open innovation has become the dominant mode. Both large and small companies cannot afford to rely entirely on their own R&D; with so much capital involved – for networks, data analysis, research infrastructure and background knowledge – high-impact product and service development, the kind that creates winners in global markets, is prohibitively expensive for all but the very biggest conglomerates to handle on their own. Instead, companies extensively encourage, explore and use external, or exchange internal, ideas to advance their technology. In contrast to the rigid supply chains of multinationals at the start of the century, by 2050 companies are operating in 'innovation ecosystems.' Suppliers, academics, government programmes, individual consumers – all contribute to fast-changing networks for innovation, thrown up and taken down rapidly to suit changing market needs; all this is enabled by global networking and artificial intelligence. As a result of these innovation alliances, collaborative undergraduate, postgraduate and doctoral study programmes with placements, joint training and supervision, have become important recruitment routes allowing small companies to grow and expand. The European Institute of Innovation and Technology and initiatives like it have become successful incubators of effective knowledge triangles, although they have evolved substantially. Dynamic ecosystems can be brutal for incumbents; and adaptation is the name of the game even for policy programmes.

Into these dynamic ecosystems comes a bewildering variety of innovators, many of them new players. Some ideas are crowd-sourced, from individuals anywhere in the world; and some of the funding also comes from the crowd. Some innovators, especially in healthcare and the environment, are backed by charitable foundations. Vanishing borders opened new opportunities for firms, universities and labs, leading to further strategic differentiation. The knowledge triangle of research, innovation and higher education has become a terrain of great institutional variety, where some institutions, mostly universities, are active on all sides of the triangle, while innovation and companies are increasingly present in higher education. At the same time, public financial incentives have succeeded in bringing small entrepreneurs together with higher education

and research institutions; they often focus on projects important to the economic and social well-being of their cities. This reflects the growing importance of Europe's booming cities, and a sense of community involvement. It also yields hot products and services that, on the global market, enrich these communities and strengthen Europe's position in the global economy; a 'Paris original' – or Warsaw or Athens – has taken on a whole new meaning in the international marketplace, as powerful brands in their own right.

For the individual, the outcome is both exhilarating and frightening. The new technologies, themselves, have opened new possibilities. Lives are much longer and healthier. Manual tasks at home and at work are easier (except for back-to-naturists who resist the trend). Cities are stronger and comfortable and healthy places to live ("eco-smart"). Countless work opportunities, for part-time or temporary projects, can be found online or in the mega-cities. But gone is the idea of a job for life; and even full-time employee status is rare. It's the 'do-it-yourself' economy.
This has made social support, for people in transition from one task to another, essential – and no longer a social stigma to receive. This kind of support was, in accordance with European social history from Bismarck onwards, pioneered in Europe; it draws on the continent's special values of social solidarity and égalité. But it is reinforced by new demographic trends. People have been forced to think about ways to mobilise and better use existing and neglected resources – and that includes the knowledge and skills of the ageing population, of immigrants and other formerly marginalised parts of society. Education supported by ICT is enabling new social movements – for sustainable food production, inclusion of all social group, privacy and security of data, and more. Overall, individuals have greater power than ever before to improve their own communities and environment. This new altruism has political impact, as well: For starters, it has led to an expectation that companies – especially large ones – engage in more socially constructive behaviour than in the past.

What if...

Who will own all these new ideas in 2050? It depends.

Economics will force companies towards more open innovation. But there could be many different shades of 'open.' As we see already in, for instance, the flexible intellectual property framework of the European Institute of Innovation and Technology, the specific rules can vary by project and group. Also, the strength and length of IP protection could vary by sector or product category; for some, 20 years, for others, three years. IP protection could be tuned to the technology and circumstances, rather than one-size-fits-all.

One consequence would be stronger partnerships between universities and companies for specific tasks; you trust your friends not to double-cross you. More corporate support for universities could come from consulting or joint ventures, meaning the universities will care less about individual patents, and today's IP conflicts between corporate and university lawyers could diminish.

Of course, whatever happens, we will still have lawyers. IP litigation, between rival innovation eco-systems if not within them, is bound to be a growth profession throughout this century.

This also translates into more and more public entrepreneurship, for example social innovation or participation in crowd-funding schemes. The latter can socialise both risks and benefits of entrepreneurial ventures within particular communities. Indeed, the complex inter-relations of innovators - public and private, collective and individual - have created a feedback loop between technological change and policy development. Policy is constantly adjusting, calibrating, correcting as technology and other forces change society. The EU institutions, with their bird's-eye view of trends, are especially important in spurring and helping shape these policies in the member-states and regions.

The education angle: Always learning, on-line and off

Education is "in." Never before have so many wanted so much from teachers. And never before have so many been empowered to become teachers. Longer, healthier lives permit more career changes; education needed. Globalisation and shifting innovation networks permit new opportunities for those with skills; education needed. New technologies require constant re-training; education needed. Lifelong learning is no longer a term for policy wonks only; in 2050, it's reality for empowered citizens who shift in and out of education in teacher and student roles.

Studying involves a large amount of online learning. The massive online courses pioneered in the 2010s have been improved, and are now standard, specialised parts of the teaching portfolio. Indeed, new artificial intelligence technologies go a step further, using expert systems and learning 'chips' to speed the learning process for key skills. The learning-game market is huge. The very idea that billions were once spent on making games with flying birds or cartoon warriors is quaint; the real money is in educational games, and the EU has made development of the indigenous game industry a priority of industrial policy. All these technologies are adjuncts, rather than replacements, for human teachers. With this variety of methods available, education is increasingly self-directed. Overall, this expansion of education has created unheard-of opportunities for people to learn, change, and grow.

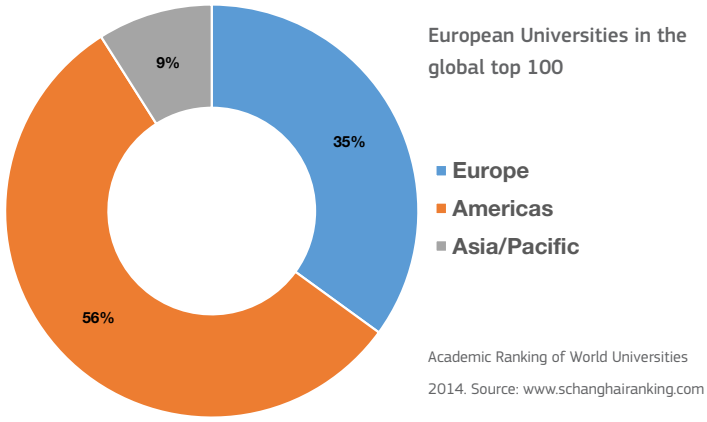
Private companies supplement the educational offering with specialised vocational training – some for their own job recruits, and some as a profit centre. European private and public universities compete for students globally. The increased competition has not resulted in a crisis in the European university sector; the growing demand has simply enlarged the market for all. At the same time, a strong policy division has developed between the "public good" aspects of education, and private benefit. Having an educated electorate is a public good; public funding, from a range of sources European and local, is tight but still manages to support 13 years, from Kindergarten to Bachelor. Some PhD programmes are also publicly supported. But most education beyond the tertiary level has a big element of private funding – by companies who want trained employees, or by the students who want new horizons. Private gain, private expense, is the rule.

Europe's top 50 universities combine international reach in education and research with strong partners in key multinationals. These ''world class'' institutions have concentrated their institutional strategies on being globally competitive, retaining and attracting top researchers and students worldwide, and attracting funding from sources beyond their city or country. They enjoy extensive financial and organisational autonomy from national states. They work in dynamic clusters with other universities which are increasingly specialised rather than trying to do everything for everybody. Funding constraints, while manageable, force all the institutions to focus on efficiency: Within their clusters, they co-develop teaching modules and tools, and they swap students (often online) to maximise efficiency. If the Technical University of Darmstadt has the best courses on geothermal energy, that's where the students go – virtually, at least (and translation technologies have broken down most language barriers for online education.) It's a good time for education; but the emphasis is on outcomes, rather than process. At the end of the day, people expect jobs and opportunities from what they learn, and employers demand it even more. The old "CE" mark has found a new market.

In short, in 2050 Europe remains a great place to study, offering world-class higher education in all member states, accessible to all irrespective of their financial situation.

* * *

In this scenario, the knowledge triangle is thriving – and with it, European society. The potentially destabilising trends of globalisation, technology and demography have been turned to our advantage, in part through wise policy, and in part through the natural strengths of Europe: Its diversity, its values and the vast resources of its people. Many European universities are recognised as world leading; they all work in clusters, and offer unprecedented ways and opportunities to learn and grow. Its research is radically open to citizens and companies to join in, even when it takes place in centres of excellence. Its innovators benefit from close links to research and education centres, providing the tools to excel in global markets. And a clear structure for the articulation between public and private good has emerged in education, as in research; economists, and taxpayers, are pleased with the balance.



Above all, this is a scenario that sees an "intelligent Europe" as an essential element in a prosperous knowledge triangle: for economies of scale, efficiency, and social impact. Given today's political climate, we don't imagine this conclusion will come quickly or easily; there will be crises to precipitate it. Assuming we survive them, the outcome will be a stronger knowledge economy.

4. Europe misses out

What if we make the wrong choices? A dystopian view of 2050

The scenario, in brief

It is 2050, and Europe's capacity to innovate, educate and research is in decline. The cause: an inability, during the first half of the century, to be a leader rather than a victim of globalisation, technology and demographic megatrends. Two generations of inaction, bad luck and bad decisions have taken their toll. Europe's population is now less than 10% of the world's total 9 billion and its share of the world's GDP is 15%.

Politically, Europe has fragmented into a coalition of rich and poor regions with minimal coordination. A Northern Arc has maintained free movement of goods, services, and people; other parts of Europe are fragmented. Multinational companies, and wealthy individuals, use global markets and digital technologies to avoid tax. Public treasuries are impoverished; and universities and labs depend heavily on private funding – new ideas and talent are controlled by the wealthy and powerful.

A few great universities dominate; many weaker, regional universities have closed or merged. A few European companies are rich and smart enough to stay global champions, mainly by being able to dominate new global value chains in healthcare, transport and engineering; but generally Europe's economic base has hollowed out, and the few innovators its universities produce quickly move to Beijing, Sao Paolo, Lagos, Singapore or Boston. Automation has moved beyond physical tasks to knowledge creation and exploitation; and with other regions of the world leading and controlling those technologies, millions of Europeans find themselves underemployed and in difficulty making ends meet. For the dominant multinational companies, Europe is now 'outsourcee', rather than outsourcer; most European companies have not grasped the new global economy.

Where once Europe produced 30% of all new ideas in the world, it now struggles to yield even half that. It looks inward, fears the future, and sees its values – such as individual freedom, equality, openness, social security – gradually discredited.

* * *

What are the conditions under which Europe could miss out on the future? As the dystopian scenario above suggests, they aren't that hard to imagine.

That globalisation, technological acceleration, and demographic change are happening is indisputable; how we deal with them is what matters for our future. This chapter tries to paint one probable, unfavourable outcome for Europe, in which its basic values are swept aside by trends it does not, cannot or will not control. For the sake of clarity, we start with the possible political framework and then explore its ramifications for the education, innovation and research activities of Europe. But in fact it would not be a simple cause-and-effect process; declines in Europe's innovative capacity would also spur political turmoil, rather than simply follow on from it.

We are certainly not predicting this as Europe's likely future. But like all dystopias, from Brave New World to Fahrenheit 451, this scenario is based on close observation of real world facts and trends around us – and is offered as a cautionary tale to urge action.

What if...

The essence of this scenario is that automation triggers unemployment, social exclusion, discontent, and a disintegration of governance. We could pick other trends as possible bad-news triggers – but, as described in the accompanying utopian scenario, every megatrend can as well be a source of strength as weakness. Advanced automation, if mastered in Europe, could provide citizens with new freedoms, new jobs, and new opportunities in the global economy.

There are some encouraging signs of this: Many EU member-states, as well as the EU's Horizon 2020 programme, are devoting new resources towards developing automation and advanced manufacturing technologies, and Europe's engineering industry remains a strong, global player absorbing new ideas.

The political framework: fragmentation rules the day

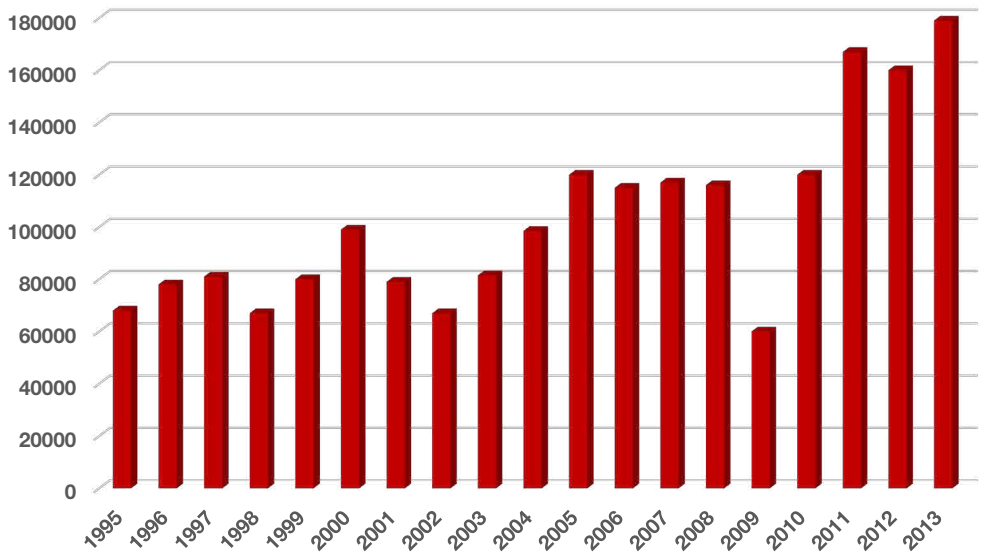
Our story begins with a technology trend: By 2050 automation has moved beyond the factory to nearly every aspect of our lives, focused on artificial cognition, ubiquitous sensing, big data analytics and machine learning. Service bots, flexible robots, handle goods and material[1]. Fruit and vegetable picking, as well as processing and delivering food, is fully automated; the notion of a 'family farm' or le terroir are quaint artefacts of history. Maintaining offices, hospitals and schools is taken over by robots; transport is fully automated. Most information-intensive tasks have been automated. Pattern recognition and intelligent machines supplant many former office jobs. New creative jobs are constantly evolving from new technologies – but only for the skilled few. The labour market shrinks, and high levels of structural unemployment become normal. In this environment the trend towards greater inequality continues to build as returns to capital accelerate. Employment in service-related industries has not been able to keep up with the number of jobs lost to machines. Many people, whether white or blue collar, are out of work or under-employed; and part-time, distributed jobs – in a global, digitally managed job bazaar – become the norm.

A growing portion of these people are living in cities; these are dynamic hubs for commerce, innovation – and discontent. In the countryside, agriculture has intensified to avoid imports and to maintain self-sufficiency. Especially in Eastern Europe, many nature reserves and farmland areas with high natural value are lost. The lack of innovation capacity in Europe makes things worse because no new technologies are developed to decouple intensification of agriculture and

1 http://www.ifr.org/industrial-robots/statistics/

environmental strain. On the other hand the reduced per capita income also results in reduced municipal waste and CO2 emissions.

Estimated worldwide annual shipments of industrial robots.



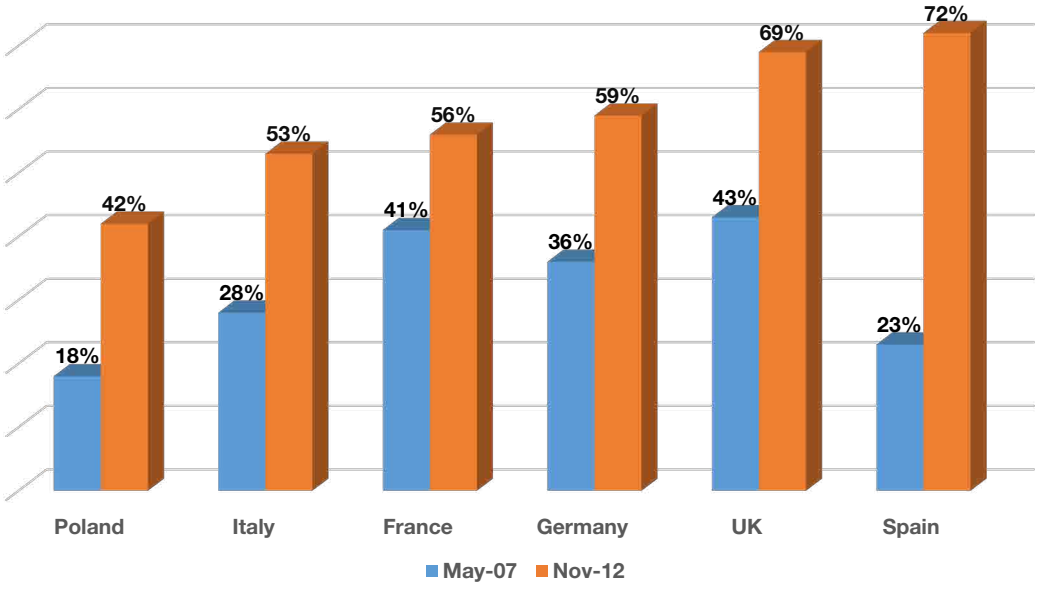
Source: World Robotics 2014

Under these difficult economic and social circumstances, nationalist and anti-European movements - reactions to the feeling that borders no longer protect the community - become dominant. European coordination struggles for democratic legitimacy, as the costs of 'Europe' are seen as unjustifiable. Limited resources and conflict over their distribution fuels national egoisms. Every nation – and, increasingly, every region - seeks a ''fair return'' on its investments in each and every one of the European or international agreements it has entered. The governance landscape has become extremely complicated since 2020, when nations and regions started to opt in or out of treaties and organisations. European policies are fragmented and captured by different stakeholders – particularly, those with the financial and knowledge capital to exercise power[2].

Thus, European diversity, a source of past strength, gives way to fragmentation: a source of weakness. The use of domestic policies to compete directly with European neighbours becomes widespread, and includes "competitive" fiscal frameworks and devaluations, and regulatory and practical constraints to mobility of people and goods. Regional disparities across Europe widen; increasingly, where you are born determines how well you will live and work. A few countries may benefit, but the EU overall struggles. Multinational corporations play off national and regional governments against one another. As information becomes the biggest part of added value, the location of «production» becomes very difficult to identify and companies can optimise «production» in states with low taxes. As a result, national governments become poorer and less able to offer social protections. This fuels social tensions and conflict. Of course, new forms of cooperation between the public and the private sectors have emerged to deal with the problems, including extensive use of surveillance technologies and predictive technologies based on data analytics. But civil liberties suffer as a result.

2 Project Augur calculated that a break –up of the Eurozone is likely to cost about 16% GDP points in 2030 (starting with a 5% drop the year after the break-up). See http://www.augurproject.eu/IMG/pdf/Executive_summary_final.pdf

Lack of trust in the EU: Percentage of nationals who say they tended not to trust the EU, as an institution.



Source: EU, Eurobarometer

The bottom line: The role of joint European action in shaping global rules and governance diminishes. Gradually, power in the global economy continues to shift towards the more-dynamic East and South. And a few global players control the flow of data and material, as well as the processes within globally organised value chains.

The innovation angle: Multinational control, an SME deficit

In the early 19th century, British economist David Ricardo developed a theory of 'comparative advantage', in which each trading nation specialises in what it does best and all benefit. In our dystopian scenario, this specialisation has gone farther than anyone could have imagined: Not just nations, but regions, companies, and individuals struggle to find their place in global markets managed by digital communications. It doesn't matter anymore where an innovation occurs; mammoth corporations can stitch together their own far-ranging networks of suppliers and customers, to suit their own interests. Ideas are co-developed across borders. Supply chains are built and disassembled at will, and business relationships are more often temporary and narrowly targeted than in the past. Manufacturing is all 3-D printing; components are made wherever they're best and cheapest, and assembled wherever it's most efficient. Capital flows across borders, with minimal government restraint or knowledge. The global economy has become amazingly efficient at innovating services, products and methods. The borders to commerce have all but vanished. Of course, there are frequent financial crises, as the interconnectedness and complexity of the global economy have risen; but people are resigned to it.

For some – world-class artists and professionals, low-cost suppliers, engineering powerhouses or mega-banks – this is all good news. An expert, in whatever field or country, commands top pay and privileges. Lucky investors in the dominant companies enjoy fat dividends (and expert accountants help them skip the tax; this is at least one European specialty in the global economy.) But a key

difference between winners and losers in this world is the value of their knowledge 'assets'; how much of the new technologies and ideas can they master and control? The old battles over intellectual property rights continue: The global Internet has long favoured winner-takes-all strategies (who wants to buy the second-best app?) but at the same time it has enabled community ownership of ideas. A bewildering range of IPR models has resulted, specialised to different industries and needs and varying from a collaborative commons to corporate concentration. But the general trend favours consolidation in sectors where multinationals operate. This all puts Europe at a disadvantage: it is generating a smaller share of the world's ideas than in the past, and its influence on global standards – a vital aspect of international trade – has diminished.

What if...

Leading companies are able to combine open innovation, open data, open access and competitive open innovation platforms with protection of their intellectual property rights.

Would Europe be the base of such companies? Or, would European companies struggle to use such platforms because of lack of infrastructure and established IPR positions?

The consequences are severe for smaller companies, which find it difficult to keep up with the rate of change - especially as the big companies find they have to move R&D to the hottest innovation clusters outside Europe to remain competitive. The diminishing local access to top technologies worsens the long-standing European deficit in entrepreneurship[3]. Legal systems that punish failure too hard, rigid labour markets, and business cultures and corporate structures that make EU firms slower to react to technological opportunities combine with a lack of commitment of public investment to strong, high quality basic science. This leads to a failure to tap into new sources of growth. The trend has been described by a 2014 World Economic Forum paper:

Will EU businesses stay in the global R&D charts?

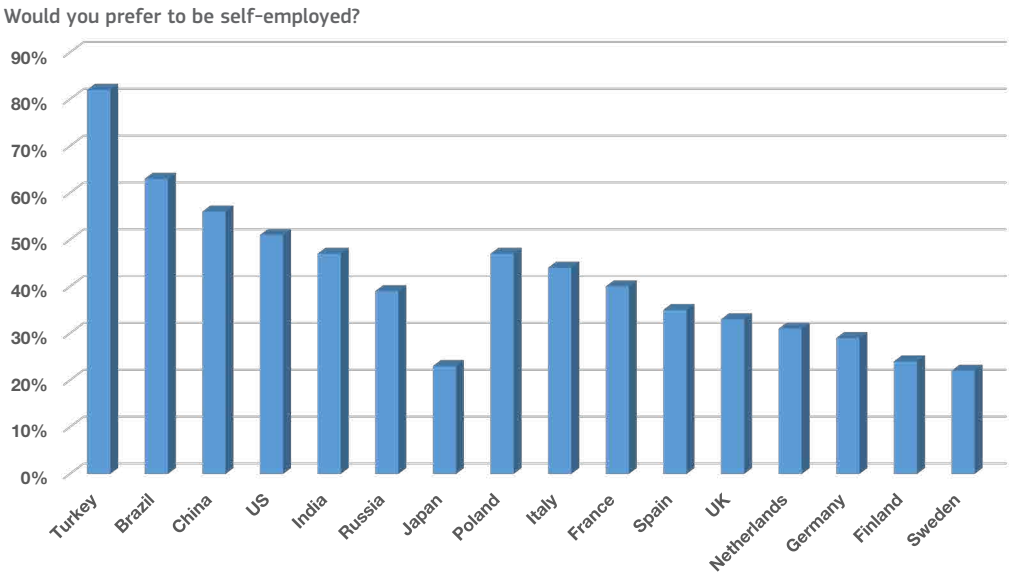
In 2013, Europe was the base of 633 of the world's top 2,500 R&D investing companies. German automotive manufacturers and Swiss chemical and pharmaceutical companies figure amongst the world's top 10, together with ICT companies from the US and South Korea. But over the last 10 years this list has witnessed the rise of East Asia. Taiwan's electronics industries are most noteworthy, but so too is industry in China and South Korea.

How will European companies fare in these statistics in 2050? In this scenario the position of existing companies is eroded and there are few, if any new European entrants in the lists of the world's highest R&D spenders.

«The EU is increasingly falling behind globally in building the digital infrastructure and innovative capacity that would allow its economies to unlock new sources of growth[4]».

Of course, the pain is not evenly spread across Europe. Some states invest heavily in high quality basic science and have strong entrepreneurial cultures and traditions. Yet, even they find it difficult to sustain their economic and innovation performance as markets around them decline.

3 http://ec.europa.eu/public_opinion/flash/fl_354_en.pdf
4 The Europe 2020 Competitiveness Report: Building a More Competitive Europe http://www3.weforum.org/docs/WEF_Europe2020_CompetitivenessReport_2014.pdf



Source: Eurobarometer survey 2012 (%)

The research angle: Poorer, weaker, fragmented

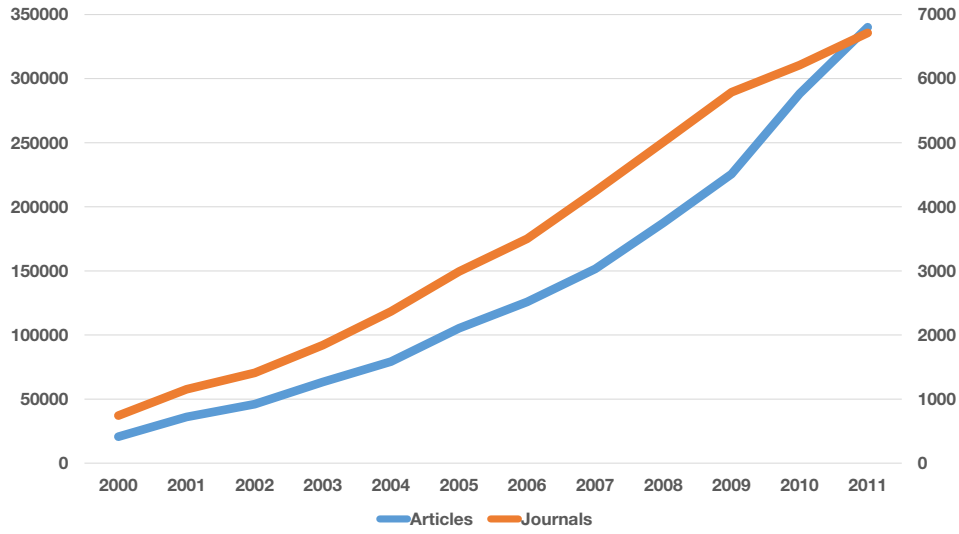
The research side of Europe's knowledge triangle will also be strongly affected by evolving economic and political conditions. These are brought about by high unemployment across all EU regions, conflicts in East and South East borders, separatist terrorism, and increasing refugees. Researchers' mobility has decreased and collaboration across borders is more difficult. International scientific infrastructures face challenges of legitimacy; and the drive for economies of scale in European research is lost. Yet, the biggest challenge is the funding shortfall for public research in a number of countries. Many research institutions, especially from smaller and weaker economies, find it increasingly difficult to produce knowledge that is relevant and important in the global economy, and become less and less competitive. In the wealthier and more advanced European economies the budget gaps are smaller, but even there the competitiveness of top institutions against faster-growing US, Chinese and other competitors is eroded.

The move towards open science becomes a double-edged sword for Europe. On one hand, it makes research more efficient and global collaboration the norm – essential for such fields as climate change and biodiversity. It also brings opportunities for everyone to pursue their curiosities. Sensors, open research infrastructures and virtually free computer power enable many citizens to be part of the knowledge generation process; and thus research ceases to be only for specialists. Indeed, public engagement in research is redefining the concept of literacy.

But on the other hand, open science is a huge challenge for research funders and research institutions, as it undermines their former, professional prerogatives; the definition of 'scientist' has changed more in the past half-century than at any time since its coinage in the early 19th century. Important scientific disciplines have become part of popular culture, whilst new emerging disciplines find it difficult to institutionalise; the definition of 'state of the art' research keeps

changing, faster and faster, as the pace of science accelerates. Indeed, knowledge production in many fields is already fully automated through big data collection and artificial intelligence. This requires capital, and so research data and infrastructures are controlled by a few powerful organisations.

Estimated annual article and journal counts in full immediate open access journals.



Source: Laakso and Björk BMC Medicine 2012 10:124 doi:10.1186/1741-7015-10-124

Of course, there are parts of science that are not open because of the importance of confidentiality and technological advantage – for example, for military or high-value industrial research. These fields are also highly automated, but data and infrastructures are strongly protected. Top talent is prized; the most valuable researchers are tracked by global expert consultancies and often hired by global investors, expanding the notion of 'consultancy without borders.' Top institutions are also prized. These include government labs and universities; universities, in particular, can work under the secrecy and IP conditions imposed by industrial firms. But these winning universities will be few. Public funding has dried up in Europe's weaker countries, undercutting their universities and their ability to produce employable graduates. In rich and poor countries alike, researchers depend heavily on private funding. Multinationals collaborate with national research councils and institutions, imposing their own research agendas and policy priorities. They get early access to ground-breaking research, and steer public funding towards helping them commercialise it; that's what makes jobs and growth, they argue.

The result: public funding for frontier research has shrunk. The European Research Council is a shell of its former self. Europe's technological innovation is increasingly dependent on Asian science. The Americans, themselves embattled in global markets as never before, have thrown up barriers to EU-US collaboration; talk of trans-Atlantic trade deals is long past. The European science system has lost its position in an increasingly Asian-centric world; whereas once Europe produced a third of all scientific publications, it now accounts for barely a sixth.

What if...

As public engagement in science increases, the risk of anti-science cultural movements also increases. Creationists, climate deniers, and other fringe groups can gather strength from social media, exploiting scientific mistakes or failures or public panic over extreme events. Can the scientific establishment find an answer to such challenges? What if it can't?

As a result of political fragmentation, Europe's role in addressing global challenges has weakened, while disparities in scientific and technological capacities across Europe have widened. Europe has some global centres of excellence – in climate change, bio and medical research, social sciences and humanities – but they are losing ground as their public funding shrinks. ''Brain drain'' to other global centres, in other continents, has accelerated since 2020; and within Europe, lack of support for trans-European knowledge networks impedes mobility of ideas and researchers.

The education angle: Winner takes all

The good news for education: Demand has never been higher. Besides conventional secondary and tertiary education, a vast range of continuing education, specialised certificates and re-skilling is on offer – and eagerly sought by a population in need of new skills, new jobs and new opportunities as technology and globalisation accelerate. The bad news: with public budgets under pressure, Europe fragmented and the levers for research and innovation consolidating into a few wealthy hands, higher education in Europe is in crisis. The private sector has stepped in to fill some of the gaps, but not all; and private education is for those able to pay, not the general population. The Bologna system of progressive degrees is breaking down; people are learning more, but more often in informal, ad hoc settings – to learn a specific skill or get a job.

National budget constraints have hurt education funding and the number of higher education institutions has halved to around 2,000. As graduate unemployment rises, universities are finding it more difficult to pay teachers, at least for undergraduate courses (what private company wants to invest in a bunch of unskilled 18-year-olds?) Different universities have adopted different strategies to survive. The research component is emphasised by the top-ranked universities, as it allows them to form lucrative links with firms. Others emphasise individually tailored programmes and certificates, to attract students and funding. Some are focused on their local communities – a good strategy for the universities lucky enough to be sited in Europe's fast-growing urban mega-cities. Others, with the best reputations and biggest treasuries, operate in a global market and compete for the smartest students and the most active corporate recruiters. That some are in Europe is historical coincidence, not the new economic or social reality.

What if....

Some member-states may resist the trends, and spend more on their national education systems rather than less – for cultural or political reasons. That's certainly possible for Germany, the UK and some other wealthy countries with a history of strong university funding.

But tough economic conditions will make such policies difficult to sustain, and will eventually lead to concentration in public university systems – especially in poorer countries. We can imagine that by 2030 concentration trends will be already apparent, and that by 2050 there could be fewer than 2,000 traditional universities across the EU – about half the number today. The private actors that replace them in training are unlikely to link it with research; those are separate businesses, outside a university. Graduate education will suffer as Europe's research system concentrates and so will the competitiveness of large sections of Europe and the quality of life of its citizens.

Virtual reality is common for online, distance learning and testing. Online education including MOOCs, after an initially rocky start 35 years earlier, is now standard for all universities; the kinks have been ironed out, and these huge courses now dominate mass provision of skills and research knowledge. Effective on-line certification has made virtual training normal. Automation also brings corporate practice into education. Companies are deeply involved in skills training, either for recruitment or as a profit centre in its own right. Augmented cognition technologies, now starting to appear on the market, are popular with the multinationals: why waste money on a year-long

master's programme when these clever technologies can force-feed the needed knowledge in a few months, without having to take time off from work? Large companies have developed their own instruments for recruiting, testing and training employees, and sell these new products to specialised consultancies and smaller companies. Lifelong learning in public institutions is a luxury reserved for those who can afford it.

In 2050 a few European countries have managed to maintain a small number of world class universities – the ones, again, whose research strengths, international reputation, and deep private pockets have made them winners. International rankings have proliferated; and they dominate funding and recruitment decisions. Below the top universities, a wide range of state or private institutions offer varied programmes and specialties, with a mostly local focus; many are linked in networks to the fewer, stronger universities, as both suppliers and customers to them. Learning outcomes for employment and entrepreneurship are the main goals for graduates, who are increasingly hunting globally to find employment. Large social groups become marginalised without the skills needed.

* * *

In this scenario, the knowledge triangle suffers from fragmentation and decline. The 19th century, Humboldt vision of a university combining research and teaching has faded; only the top universities can sustain it, while the rest scramble to get by as best they can in local markets. A comparatively few mega-multinationals are picking and choosing how they recruit employees and train them, and with whom and how they do R&D. Frontier research is withering for lack of public funding – meaning that, eventually, technological change will slow down; but that's decades ahead. And, with Europe's political cohesion long since destroyed, it's every state, region and citizen for itself in a global market. The knowledge triangle is more of a knowledge Web or network, with the rich and powerful controlling the central nodes. European values are history.

Yes, this is a pretty depressing outlook. And yes, none of us know how these trends will really play out. But we need to look at a worst-case scenario of the future to see just how important the policy choices of today will be.

5. Making the right choices

What will 2050 be like? Faster, most likely.

Already, technological change is accelerating. In energy, the generations of succeeding technologies have shortened - from wood to coal to oil to nuclear to renewables; what next? In life sciences, we have moved from a theory of natural selection (1854), to a structural picture of DNA (1953), to reading the entire human genome (1998), to editing it (2015); what next? This isn't just a matter of speed; with faster technological change comes a new dimension – a greater volume – of change throughout society. We see this today in information and communications technologies. In the span of one life we have moved from transistor to chip to Web to smartphone to cyber-warfare – and with it our social and economic lives have moved into the kind of virtual dimensions that were once science fiction. What's next? Big data is becoming a crucial resource for science, economy and society. Computational science may accelerate the growth of knowledge. Artificial intelligence may re-write its own code, based on feedback from global sensor networks. The very nature of intelligence – human or machine – may change.

Accelerating technological change is not a natural law. It is the product of important processes in human society; and mankind can, if it so wills, restrain it. Already, we see a backlash in parts of Europe against some technological 'advances' – particularly when they impinge upon long-held European values such as individual privacy. And there are many other major trends affecting us – some enabled by technology. Globalisation sweeps us ever-faster towards new economic systems, cultural contexts, and opportunities for personal fulfilment – or abnegation, depending on how things evolve. Demographic trends affect us all: the ageing EU population, the move to cities, the splintering of family units. Altogether these and other forces have profound implications: they affect the environment, climate, economies, jobs, health – our very definition of the rights and responsibilities of a civilisation. Knowledge production, absorption and use; research, education and innovation; all working together define our ability to manage the resulting opportunities and challenges. An "intelligent" Europe will be a richer, safer, healthier, happier Europe.

But will we be intelligent? Will we make the right policy choices? Will we make them quickly enough? As everything speeds up – technological change, demographic shifts, global interactions – entire industries can be created or destroyed in a few years, and fortunes gained or lost in a few exchange-trading seconds. Our policy responses must be faster than before, and wiser.

These are the issues we have tried to raise in the preceding chapters, painting two pictures of 2050. Depending on the nature and timing of our policy choices, Europeans will be better educated, and more in demand in global job markets, than ever before; or, they will be unemployed. They will be leaders in new technologies, applying knowledge to improve the economy, preserve and improve the environment, and strengthen social bonds; or, they will be victims of technologies they cannot master. They will have well-financed, public knowledge institutions and clear policies distinguishing public good and private gain; or, they will be bankrupt. They will be intelligently governed, employing EU-level coordination when it makes sense (and not, when it doesn't); or, they will be fractious.

Looking at what differentiates the two scenarios, we have identified three broad principles that guide our thinking about what Europe's knowledge institutions and governance must do to prosper. They are, in themselves, opportunities to grasp or, to use a homely metaphor, trains not to be missed.

1. Openness. An open system adapts better to change. It includes open access to science – but goes far beyond: open markets, open debate, open government. In short, openness in all the ways knowledge is created, transmitted and applied will empower European citizens.

2. Experimentation and flexibility. To adapt, one must experiment – to find what works and where it works, to discover new business models and technologies, to grasp new knowledge and market opportunities. That requires regional, local and individual autonomy, and support for experimentation, in our knowledge systems.

3. European-level cooperation. Fragmentation can become chaos. Some form of supra-regional coordination and support for the knowledge system will be needed. This includes creating the framework conditions for a single European market in ideas and talent, supporting research infrastructure and fundamental science (a public good), and enabling open participation of citizens everywhere.

In pursuing those opportunities, there are some important challenges to be overcome. Each of them risks propelling Europe towards the negative scenario, by setting off cycles of discontent and fragmentation. We are thinking of:

1. Structural unemployment and greater inequality
2. Funding shortfalls and shrinking tax bases
3. Talent crises as universities suffer and the smart leave Europe.

The opportunities and challenges form the backdrop for our policy recommendations.

Principle 1. An open knowledge system in Europe

The negative vision showed the rich and privileged, whether corporate or individual, controlling the future; the positive vision showed all citizens sharing in it. We want a future in which all citizens can join in the process of research, education and innovation – because they want a better job, a healthier body, a cleaner environment, a richer community or a happier, more fulfilled life. We want a future in which it's easy for new players with new ideas to enter a market, and not get blocked by excessive regulation or protected monopolies; a future in which knowledge can circulate freely,

in classrooms, online, in markets, across borders. The reason: An open society adapts more easily to rapid change. Its members can sense opportunities and threats faster, experiment with possible responses more easily, and, gradually and noisily, change and adapt. We don't know what 2050 will be like – but we don't have to know if we can adapt.

By openness, we mean something far beyond conventional talk of 'open access' in scientific publishing. We mean openness in every part of our knowledge system, from lab to classroom to marketplace. Of course, there is already a trend towards openness. It is enabled by ICT, accelerates knowledge production, and challenges institutions. Research institutions, because they value open science, become facilities managers for shared resources – often open internationally. Libraries find their role as spaces for reading becomes less important than their role in knowledge management and publishing. Universities compete with one another, globally. More large companies do their R&D in semi-open networks, in collaboration with universities, suppliers, customers and governments. These institutional transitions need encouragement; they can be threatening to incumbents. Policy makers must embrace openness, avoiding the temptation to "protect" established institutions (academic or corporate), ensuring a level playing-field, and providing appropriate investment in infrastructures across the European Union.

To this end, we identify a few broad areas for action: supporting infrastructure, ensuring data access and literacy, reforming intellectual property rules, opening markets and programmes, and enabling citizen participation.

Investment in research infrastructures. It may seem odd to start a discussion of openness with brick and mortar institutions; but such are the realities of the knowledge system. As research costs rise, economies of scale force more sharing – of costly lab equipment, databases and knowledge. That, by definition, requires openness. CERN, with 12,000 participating researchers in 21 countries, is an extreme example, but representative nonetheless. Europe has long understood that no individual country can cover all these needs, and created bodies – such as the European Strategy Forum on Research Infrastructures, or ESFRI – to help coordinate funding. This is a good start, but more is needed: more money, more installations, more collaboration. And these should not be limited to Europe: Initiatives like the Square Kilometre Array, the world's largest radio telescope to be spread over Africa and Australia but managed from Europe, demonstrate the value of international partnership in infrastructure. As the US and China compete for world leadership in infrastructures, Europe cannot afford to stay out of the race, for, at a minimum it needs to be involved in the process of defining the rules of openness and sharing at a global scale. All this requires investment – more than we have, so far, been willing to accept.

Of particular importance here are systems for open science: the platforms used for research collaborations, communication of results, and archiving of data and publication. These systems, while essential scientific tools, also affect who gets credited with discoveries, and who can profit from them. In the international arena, for example, they exacerbate problems stemming from differences in IPR regimes - for example by offering advantages to those who are "first to file" or "first to invent". Increasingly, we see them also spurring controversies over privacy and security. Solutions to these problems will be found, but should be guided by two principles. The first is that open access to data is important for progress in science and industry, and that it should be supported at every opportunity. The second is that data literacy is essential to our society. Faced with a bombardment of data and data-based arguments, individuals need to be able to understand and critically evaluate information to function in society, in their jobs, and in the polity. The two ideas – train people to work with data, and make it open for them to work with – are basic. Data literacy would have another effect: encouraging greater citizen participation in science and

innovation. We already see 'citizen-science' at work in astronomy, ornithology, and many branches of the social sciences and humanities. Open science, as it expands with more standardised and user-friendly interfaces, will involve more and more citizens. It will spur more citizens' support for scientific endeavours, not only with their votes but also their money (through crowd-funding or charities.) What's needed now is a step change.

We urge the creation of a European Knowledge Space – an online framework open to all citizens for research, analysis, debate and sharing, to function as a knowledge pool to underpin the search for solutions to societal challenges. It is not some specific pieces of ICT technology we have in mind – though it would certainly include those. Rather, this would be a living, evolving set of policies, incentives and tools making it easier, across the EU, for all to share and debate knowledge. It would permit citizens to join in those searches, and have a say in which challenges matter most, through fora for policy debate linked to all relevant data and knowledge pools. It would be a strong force for social inclusion, across all EU regions and interest groups. It would permit policy makers to exchange information on new approaches and technology assessment methods. It would paint a big, integrated picture of European knowledge in various domains – for teaching, researching or innovating. It would be open to links beyond Europe. Some key elements of the idea exist already. Social media and other online tools permit far more sharing of knowledge than ever before imagined. Big Data tools are rapidly appearing to analyse this knowledge. EU initiatives, such as the Commission-sponsored Research Data Alliance to promote global cooperation in data sharing, are working to improve online collaboration within the research community. And the European Research Area is already promoting greater mobility of ideas and knowledge-workers across the EU.

But we are urging something bigger – a broader way of thinking about how knowledge can move – building on open science and on the public demand for open access to research processes funded by public funds to address societal challenges. This effort would create the policies and infrastructure for all citizens to participate openly in research and innovation – to move out of the conventional policy silos and become a mainstream, job-creating objective for Europe. For research to solve societal challenges, the knowledge it produces must become part of the knowledge base used for policy decisions. The EU is mandated by the current Treaty for the European Union to finance research in order to support its policies as described in the Treaty. This can be Big Data for policy. It can be the explicit goal of EU Framework Programmes of the future.

Openness also applies to markets. Officially, Europe's old policies of 'national champions' have been discredited, and competition enforcement has greatly expanded; but in practice, many local barriers to new entrants remain – especially in the knowledge system. Academic appointments are often politicised; transferring professional credentials from one country to another remain difficult; disruptive new products or services can be easily barred (viz., the controversial Uber ride-sharing service.) Even EU programmes, while officially targeting broader participation than ever before, are difficult for a small, disruptive company to access; the barriers to entry need taking down.

A special case for the knowledge market is the intellectual property regime: it needs urgent reform. As a general rule, private investment in knowledge should reward the investor in some way; that has been a principle on which every major industry of the 20th Century was built, from automobiles to computers. But that general rule is being challenged by new technologies, globalisation and the demographic trends discussed earlier. How much should a drug company be able to charge for, and protect, its patent on a life-saving medicine? Should a teenager streaming

a song without paying really constitute theft? Or, especially urgent for research, who owns data? You can own a database today, but not the information in it. You can patent a computer chip, but (at least at the European Patent Office) not the software it encodes. We have IP systems the basic principles of which have not changed in four centuries. And the digital world is throwing once-marginal controversies into the centre of our economic and social models. With the Digital Single Market, the EU is currently opening a door into a very important terrain of law-making, one where it is critical to get the principles and the politics right, and to keep at pace with the development of technology. Rather than spend 30 years trying to agree on a European Patent, would it not have been better to redefine what a patent is, in the first place, to reflect the accelerating pace of technological change? We urge a new initiative to rethink the basic principles of intellectual property – one that opens the debate beyond the small world of IP experts, and includes researchers, consumers, the developing world and others.

Lastly, we should consider the impact of openness. In the scientific profession, it will be profound. As more citizens get involved in science – for debate, entrepreneurship, or direct participation – the role of the white-coated researcher is going to change. There will always be a need for certified experts and full-time professionals; but in other fields, such as the media and journalism, we have already seen how an opening of the online gates to new actors has rendered obsolescent the old ways of working and thinking. In science, careers will become more diverse, employment more precarious. At the same time, openness will also affect our institutions and regions. If we allow untrammelled competition, red in tooth and claw, to hit our public sector labs and universities, we will have many losers – more than, as a society, we are willing to accept. Here, the European Research Area can provide a framework for balancing open competition with regional and institutional support. This may seem to contradict a call for openness. But the solution lies with a combination of EU-level framework conditions that support enterprise and innovation, a highly skilled and educated population that can adapt to change – and an adequate system of social safeguards and regional support to correct any unwanted side-effects.

Principle 2. Flexibility and experimentation for innovation

When comparing our alternate views of 2050, we can see that with openness must come greater flexibility. When a new technology arises, Europe cannot go through yet another late, muddled response as happened in the early days of the Web. A strong knowledge system in Europe would be able to generate and absorb ideas quickly, foster start-ups and future Googles that would act on them, and train the young and old quickly to use them. It would also play on its greatest strength: Its diversity. That means that it would provide the means and freedom for our growing cities and regions to pioneer new ideas – in smart cities, education and training, culture and more. Let a thousand flowers bloom.

For this purpose, Europe's regions are its gardens. They often boast excellent, dynamic universities and strong research infrastructures; with sufficient funding, they form ecosystems of innovation that attract private investment from around the world. The investment to build these ecosystems can already tap the regional development funds of the EU; we applaud the recent addition of 'strings' to some of that funding to require it be spent on innovation-related projects. The growing EU focus on 'smart city' and other regional initiatives marrying technology with urban planning is also good.
But along with this, local and national authorities must give their institutions, especially universities, greater autonomy. Ministries can't teach, research or invent; they must allow freedom for those who can. This can be through changing national laws, or by expanding the range of funding

sources available to universities. The formation of partnerships with multinationals is one such source – but that comes with a caveat, in light of our negative vision: These partnerships need to bring in investment without subverting the character of the institutions. But there must be plenty of room for experimentation in online instruction, specialised career training, expert systems and artificial intelligence for education – even educational gaming. It is just possible that "the next Google" won't be in search or cloud or anything we commonly expect; it could be in educational gaming, at a level and sophistication that would make today's interactive gaming look antique. This is exactly the kind of new frontier that is ideal for a university to explore with a technology company – and for that, both sides need full flexibility to try, fail, and try again. We urge the Commission and member-states to support university/industry experimentation of this kind.

Another framework for experimentation can be provided by open innovation. The benefits of more-open collaboration in R&D have been well documented: multinationals increasingly use expanding networks of research institutes, suppliers, and other partners to speed innovation cost-effectively, and the EU has pioneered subsidised forms of collaboration in its Framework Programmes. The EIT is a noteworthy example of that, stimulating open innovation in specific thematic areas, on a continental scale. Several Research Infrastructures, such as the DESY synchrotron in Germany and CERN in Geneva, have also been pioneering new open innovation methods – often in collaboration with universities.

But there are many obstacles to open innovation. Confusion about intellectual property rights is one, mentioned earlier. Another is the lack of sufficient critical mass of world-class research institutions to form the core of an open innovation cluster; Europe has many but, as discussed earlier, its shared research infrastructure needs more support.
Another obstacle is financial: small companies, especially those with disruptive technologies, are usually poor. The EU and member-states have been expanding grant and loan programmes for early-stage companies – but much more is needed. For a model to copy, the EU could look more closely at the way Norway's SINTEF makes available infrastructure and know-how that SMEs cannot afford, by centralising it. There needs also to be more financial incentives for small enterprises to form partnerships with higher education, research institutions and societal actors. Why all this concern about little companies? Because entrepreneurs and SMEs are likely to be the main motors of city or regional development and competitiveness, given the anticipated shift to more self-employment and personalised service provision.

Experimentation is also needed in social, environmental and other 'socially constructive' initiatives. As the reach of education broadens across society, new social movements are developing that target a multitude of issues, such as sustainable food production, engagement with disadvantaged groups or environmental protection. Sometimes, they take the nature of a 'challenge' – a goal to be met. While they may scale up to a European dimension, they usually start with local initiatives, local ideas and local energy; people tend to help those closest to home. EU and national governments can stimulate more of these initiatives, by naming new challenges, creating prizes, stimulating social crowdfunding platforms, or supporting charities that organise them by, for instance, providing a more favourable VAT status for foundations. The EU can further support these efforts in its regional development and research and innovation programmes, making social impact a funding criterion for a larger share of the grants and loans than at present.
As a society, to solve our most difficult problems will require bold experiments. For instance, a growing number of voices are pointing to a basic fallacy in our macroeconomic systems: That growth is ever and always good. Rather, they argue, if we are as a species to survive this century, we will have to shift our focus to sustainability. How?

Can we come up with the technological and social innovations for environmentally responsible lifestyles, for manufacturing that doesn't deplete resources, for energy that doesn't warm the planet? There are many possible tools for this. We can invent a new kind of EU regional fund focused on sustainability, rather than economic recovery and growth. We can fund economic research in to end-to-end accounting methodologies, incorporating indirect environmental and social costs and benefits. We can move beyond conventional GDP and growth indicators, to new sustainability or 'well-being' indicators. We can improve EU labelling for products and companies that support sustainability. This is a huge area – already much-discussed, but to which policies for research, education and innovation have been only haphazardly linked. Providing society with the knowledge to move from growth to sustainability should be a headline priority – and that requires systematic support for experimentation.

Principle 3. European-level cooperation

These considerations bring us to the overall framework in which experimentation and openness will take place: The single market.

For people to travel freely down a road, there must be rules to avoid collisions – and the same goes for the European knowledge system. The financial markets that support innovation – or, more often, fail to do so - need flexible but harmonised rules across Europe to work. The regulations that govern technology products and trade must stretch across member-state borders. Trading partners demand clarity of standards and interfaces across Europe. A common European approach to degrees and certification make it easier for people to move from one job or country to another. The importance of this kind of European regulatory role was illustrated in our positive and negative scenarios: In one case Europe guides, and in the other it falls apart. In a single market of scale, there needs to be some form of coordination for policy, regulation and selective and collective support. The specific form can vary: Sometimes more intervention, sometimes less. The individual cases are a matter of political choices. That's the case today, and we believe it should continue to be so tomorrow. To use the commonly accepted policy phrase: **Europe provides the framework conditions.**

But the EU role goes beyond setting ground-rules only. We have suggested above a number of specific examples of EU 'activism': Support for research infrastructure, pilot initiatives for modular and core educational qualifications, prizes and challenges for innovators, support for regional innovation development. It can also scale up those local experiments that show promise in solving one of the biggest dilemmas we identified for 2050: How to stay employed, healthy and integrated into society roiled by technology, globalisation and social change. For example, it can launch a public education programme on making a living in a 'sharing' economy, or to train retirees to find students and markets for their skills so their years of painfully acquired knowledge isn't lost to society. This could make a big difference over the next 35 years.

The EU can also lead where European scale and the public good are most intertwined – for instance, in the funding of fundamental research. Breakthrough science is, clearly, a public good; who, if not the state, would pay for fundamental discoveries like graphene, CRISPR gene-editing, or the Higgs Boson? The European Research Council has already demonstrated its importance as one important EU-scale funder. We recommend that it should be strengthened and play a greater important role in Europe's scientific affairs, advising on matters of science policy and coordinating national, regional and local level funders of fundamental research. It can evolve to be a science 'hub' for Europe.

Education will also need more investment – at both an EU and national level. Any leap forward, or backward, in European innovation will depend on our schools and universities. Today, it is widely understood that a generic compulsory secondary education is no longer enough. Depending upon the sector, different kinds of tertiary training are the new normal. In biotechnology, a minimum is already an MSc; soon it will be a PhD. Who will pay for this? Who will set the curricula? There will be a core or base qualification for higher education, and we urge the Commission to reinvigorate the intergovernmental Bologna process to update it. There must also be a modular structure for student choice, interdisciplinary learning, and the development of individualised, or personalised, curricula. Diversity of gender, culture and value systems also depends on our education systems: They must be open to young and old, native and immigrant, employed and unemployed, rich or poor. This takes money: Europe's spending, nationally and regionally, on education will have to rise, and that will require new funding models, both public and private. The Commission can stimulate experimentation by supporting new, bottom-up pilots of core and modular education qualifications. But whatever the goal, in education it boils down to money, and the freedom to spend it well. The EU can support useful cooperation among member-states in this field.

The EU can also lead in another form of large-scale public good: The grand project. The US model of the Apollo Program is often cited as an example of what government can achieve, to mobilise research and inspire citizens; but the European Space Agency's recent scientific and PR success with its Rosetta mission is a timely reminder that Europe can play that game, too. In Horizon 2020, the Commission has launched a few 'flagship' programmes intended to inspire; they have yet to do so. We urge a bottom-up effort to identify some truly inspiring Grand Projects, with a 2050 horizon, that can be simply described and directly relevant to all citizens. For instance:

- Ban Dementia: Target a cure or prevention for Alzheimer's by 2050
- Sustainable Europe: Invent the society, not just technology, to be self-sustaining by 2050
- Epidemic Busters: Target the eradication of all infectious diseases by 2050

We list these simply by way of illustration. Some would build on existing EU initiatives, such as the flagship brain project. All are of a grand scale and inspiring nature. All involve multiple disciplines and actors: the sustainability project, for instance, would require a level of social sciences and humanities research that has never been attempted. It would have to integrate societal voices on a regular basis, find new ways to support collaboration among civil society organisations, and educate all citizens. In essence, a challenge such as this isn't so much about citizen science or technological fixes; it's about permitting all Europeans to make and express their own choices – to co-develop their visions of tomorrow. In all these grand projects, our general point is that, if the EU is to matter in the knowledge system, it must be bolder, smarter and better-connected with the fears and hopes of its citizens. It must involve all of us. It must inspire.

One final important role for the EU is the articulation of European positions towards global problems, and a coordination of the participation of its member-states in international research efforts to address these global problems. There is no area where this is more evident than in global climate change. European leadership in environmental responsibility represents an important direction for the future of Europe, one that enables appropriate choices between alternative technological directions, and provides for economic and innovation models that can bring sustainability to the world, and wellbeing to the people of Europe.

The challenges ahead: funding and the tax base

Accelerating technological change is likely to change the employment situation of most people. Companies rise and fall at an increasing pace and the automation of many functions risks making many occupations redundant; already, to cite one small example, we see technology driving conventional post-carriers into retirement. Will automation increase total unemployment? Optimists point to the experience with previous technological transitions in which new professions were created even as old ones died. Pessimists argue that there has not been another transition like this one. However, there is no doubt that jobs will move around faster than people, and that countries and regions will have to deal with unemployment situations which may be temporary or may become a structural feature of our societies in the near future.

This raises challenges for higher education, which would have to bear the weight of retraining people to re-enter employment or enterprise. The greatest challenge will be to prevent long-term unemployment from leading to discontent and social disintegration - the key trigger for the negative scenario. Publicly funded higher education may need, in the near future, to expand massively towards lifelong learning for social integration, rather than purely for reskilling. Stimulating curiosity about science and technology through higher education should be a function that is encouraged in education systems in Europe.

At the risk of repeating ourselves: We must spend more on research and education. The private sector can do much, but it, too, depends on public goods: An educated population, a skilled workforce, fundamental knowledge, breakthrough discoveries. Public funding shortfalls will trigger shrinkage of our science and education base. One might argue this is just an inevitable rationalisation of our knowledge-generating industries – a kind of market-based privatisation of formerly public functions, such as rail service or health insurance in some countries. But knowledge labour is different. It is extremely mobile. Countries compete for talented scientists and engineers. Current and near-term funding shortfalls in Europe can send waves of skilled migrants towards the US and China, and aggravate the challenges posed by globalisation in Europe in the medium and long term. Funding shortfalls and brain-drain are important triggers of our negative scenario. But this isn't just another plea for public cash; we wish to highlight the solution that has, so far, been outside the conventional run of research or education budget debate.

To safeguard public funding, Europe needs to safeguard its tax base. The connection between healthy treasuries and healthy universities and labs is obvious to most of us – but often, it appears, not to policy makers. One threat to that tax base is in headlines today: the tax-avoidance behaviour of many multinationals. Large companies, able to move their profits at will across the globe, are skilled at shopping for the most favourable tax venues; while some EU member-states have proven adept at playing that game, the EU overall, with its high social charges, is bound to be a net loser in a global market for tax holidays. It should wish to see this better regulated. In part, this is an informational problem: It's impossible for individual governments to grasp the full picture of what a multinational is doing. Cooperation among tax authorities, within and without the EU, is on the rise. Another worthwhile EU-inspired, Big Data initiative could be creating systems to better monitor cross-border commerce and taxation by large companies – another new direction for the EU Framework Programmes (and one that might win friends in Europe's finance ministries.)

There is also an economic reason for linking fiscal and research policies. A good knowledge-production system, sooner or later, produces economic growth, jobs, and tax revenues. It also produces a more educated, better-informed electorate. Citizens who don't understand or are

daunted by the 2050 world of fast-evolving science and technology will find the economy a rotten place to be. Innovation will be brought about by others; our citizens will find it harder to get a job, find housing, get cured or obtain what we regard as the minimum requirements for a good life. Our treasuries will empty, and the entire system break down. We are recommending a natural and gradual tightening of the links between fiscal policy and policy for research, innovation and education. If there is one 'big idea' from our work, it would be this.

In conclusion

Europe's greatest strength is in its diversity: Its mind-boggling profusion of languages, cultures, religions and opinions; of universities, laboratories and companies; of institutions, foundations and organisations; of villages, cities, regions and nation-states.

Despite this diversity, however, most of us do share some common values; it is what makes a European, well, European. They include our sense of openness – to new ideas and peoples; whether in government or commerce or culture, we rebel against any kind of imposed uniformity. There is our belief in égalité and social solidarity; that we have a responsibility to the well-being of our fellow-citizens, and to ensure that there is equality of opportunity, at the least, for all. As well, there is our deep support for the rights of the individual – to speak freely, worship or think freely, move about Europe freely. More recently in our history, we have also developed a common sense of the importance of sustainability: to preserve the planet and its life for future generations. Our scenarios of 2050 are, at root, premised on how well we do or do not sustain these fundamental European values. They should guide our policy choices today.

There is also another kind of value built into us all: The value that we, as Europeans, place on knowledge in all its forms: in research, education, innovation. In the meritocratic society we aspire to – but may not always achieve – what you know helps define who you are. Thus, the system for creating, conveying and applying knowledge is core to our being as Europeans. It is a complex policy area unlike any other – cutting across disciplines, regions, sectors and ministries.

Our two visions of 2050 were not meant as forecasts; they are projections of what Europe could look like in 2050 if it does, or doesn't, manage its system of knowledge transformation well. We urge speedy action by EU leaders – starting with those in the European institutions who supervise knowledge policies in their many forms. Thirty-five years may seem like a long way in the future. But taking the steps now, to ensure a bright future, will also pay back immediately to our prosperity, health and happiness right now.

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We live in a world of increasing and systemic unpredictability. Accelerating technological change empowers individuals and organizations to be far more productive and destructive than ever before. National and other boundaries are eroded as links between individuals, between collectives and between countries multiply at an unprecedented pace. And whilst physical distance becomes less and less significant, vast and rapidly expanding populations are located in parts of the planet that are challenged for resources, food and energy. In this context, Europe's research, innovation and higher education system lies at the core of its economic and social prospects. The report «The Knowledge Future: intelligent policy choices for Europe 2050» elaborates on challenges and opportunities that three «Megatrends» - globalization, demographic change and technological change - represent for Europe's research, innovation and higher education system, and suggests a number of ideas that could find a place in EU policy for Research and Innovation.

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