Study on EU Positioning: An Analysis of the International Positioning of the EU Using Revealed Comparative Advantages and the Control of Key Technologies

Annex

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Directorate-General for Research & Innovation
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Annex 1 – Summary of expert interviews

1. AIMS

The objective of the qualitative assessment is the identification of major foresight variables and drivers for change including possible game changers and disruptive innovation in each of the thematic areas of Horizon 2020. The information gathered feeds into the trend analysis and scenario development.

2. APPROACH AND IMPLEMENTATION

The qualitative assessment is based on in-depth interviews with experts and stakeholders. All in all, 31 interviews were carried out between February 2016 and April 2016.

The interviews were structured by an interview guide covering the following main topics:

- General trends in each area,
- Influencing factors, among these possible disruptive innovation and game changes,
- Existence and location of centres of excellence in the respective areas,
- Strengths and weaknesses of Europe in the respective area and expected changes,
- Potential for cooperation in basic research and close to market activities focussing on most interesting sectors and countries,
- Framework conditions guiding such cooperation.

The results of each interview were summarised in standardised interview fact sheets.

3. RESULTS

In the following, the main results of the interviews are summarised. The results are structured along the main topics covered by the interviews which will be discussed first on a general level, second for societal challenges and third for KETs.

3.1 Trends

3.1.1 General

In the **short term**, experts see budget constraints for innovation at a global level (Table A1.1). Together with the appearance of new actors competition will intensify. This trend also relates to knowledge production which is becoming more global. The globalisation of knowledge production will lead to a **global dispersion of knowledge**. Some important new innovation actors include China, Brazil and Singapore which are are also in a position to merge technologies with lower ends of the market.

Table A1.1: General trends

Short term	Long term
Constraints for innovation funding	Private funders upcoming (e.g. large foundations)
Growing competition for knowledge production	Innovation and employment
Global dispension of knowledge	Growing stress on social care systems
Uncertainty of knowledge credibility	Stronger involvement of civil society in innovation
Reorientation of innovation towards user, society, environment	
RRI getting more important	

The combination of societal needs with technology development and against this background **responsible research and innovation (RRI)** are expected to become more important. Cross-border technologies comprise another trend. Some experts also point to an increasing concentration of innovation in the defence area, leading to innovation activities which are disconnected from the public. Grand Challenges are considered as a continued issue and trend on a global level.

In the **long term**, a stronger involvement of the civil society into innovation activities – not least in the context of RRI – is expected. The relation between innovation and job generation will become a crucial long-term issue in the face of discussions about increasing automation, digitalisation or efficiency gains. Looking at the funding landscape it is expected that new types of funders from the private sector will appear such as foundations initiated by large companies. Ethical issues are considered as upcoming long-term trends, in particular related to the changing way of understanding life and human beings due to advances in biotechnology.

Most important **trends for the European Union** are related to budget constraints due to the increasing challenges of demographic change and migration. This trend could be enhanced by an overloading of European social care systems. In an international comparison European social care systems are highly developed and very well structured. This raises the question how robust such sophisticated systems are against massive changes in the demographic structure, or advances in biomedical research which in a long term could lead to a considerable rise of the average age of the population. The relationship between innovation and employment is considered as very important for Europe. One of the questions is what would happen to the buying power of the middle class if automation is leading to significant job losses. An already present problem for Europe is the very high unemployment rate of the young generation in some countries.

Demographic change also leads to a growing significance of the so-called "silver economy" for Europe. The combination of technology development with societal issues in the framework of responsible research and innovation is seen as another important trend for Europe. Climate change and circular economy are important issues for Europe. Regulation is expected to become smarter and streamlined and adaptable to innovation but also to new challenges by innovation, for example, due to the **massive growth of digitalisation**.

All in all, a **re-orientation of innovation** is called for with a stronger focus on user orientation, and the social and environmental influence on innovation. In addition, the increasing complexity of knowledge leads to a need for implementing concepts which are able to assure knowledge credibility.

3.1.2 Societal challenges

Health, demographic change and well-being

In the **short term**, the following trends are expected in this domain (Table A1.2): demographic change and the aging society, chronic diseases, the uptake of nanotechnology in drug development, better methods for earlier diagnosis and detection of pathologies, the emergence of non-invasive diagnostics, the growing impact of new high-speed technologies for analysing whole genomes or proteomes (all proteins) of humans, the application of artificial intelligence to medical imaging and diagnosis. In addition, changes in the healthcare system are anticipated. For example, patients will stay at home instead at hospitals due to advances in telemedicine. Another trend comprises the increasing significance of preventive maintenance.

In the **long term**, the following technology-driven trends are expected: companion diagnostics based on nanotechnology will be available, regenerative medicine will advance, the causes of diseases will be explored, chronic diseases will stay important, diabetes management will be needed. The general trends towards patient-centred care, telemedicine and mobile care will continue.

Table A1.2**:** Trends in societal challenges

	Short term	Long term
Health	Chronic diseases, high speed analysis and diagnosis, remote care systems, prevention	Chronic diseases, patient control and mobile care
Food agriculture, bioeconomy	Sustainable food-chain, health and nutrition	Consumer trends, personalisation, health
Energy	Electricity storage, zero-energy buildings, demand side management, improved energy efficiency in all sectors, decarbonisation in the electricity sector, harmonisation of energy markets	Electricity and hydrogen-based economy, organic PV, carbon capture and storage (CCS)
Transport	Autonomous vehicles, mobility as service	Smart infrastructures, new role of transport
Climate, environment, resources	Integrated water management, recycling	Circular economy, need for critical materials

These trends are expected on a global level without specific peculiarities for Europe. However, experts point out that European healthcare systems are considered as rather fast adopters of innovation in healthcare compared to systems outside Europe, e.g. in the United States.

Food security, sustainable agriculture and forestry, marine and maritime and inland water research, and the bioeconomy

Sustainability is seen as one of the key short term trends. It covers sustainable food systems and sustainable processing, but also includes improvements of soil fertility, mechanical weed control and the application of new technologies for farming, such as GPS. Mastering food waste is part of this trend. A second trend concerns packaging, which is expected to become smart and intelligent. Waste is another emerging topic in this domain. A closer connection between food science, nutrition, and health is expected. This includes, for example, personalised nutrition but also nutritional solutions in response to an aging population. In the agricultural domain new breeding techniques are expected.

In the long term applications of rRNA technologies are expected and also the use of synthetic biology could contribute to the domain. Consumer trends are considered as most important. Consumer interest in personalisation and health issues will have considerable impact on the demand side of the agrifood chain. Obesity and hunger in society are seen as consisting long-term trends. Safe supply with clean water is another key challenge in the long run.

All these trends are also highly relevant for Europe. In particular, the aging society, health problems such as obesity and the waste generation during food production are mentioned as particular challenges.

Secure, clean and efficient energy

In the **short term**, challenges of second generation ethanol production need to be solved. Electricity storage and related technologies are seen as important. Zero energy buildings are another trend. In the **long term**, gasoline and ethanol mix are seen as main fuel, other trends related to electricity storage and energy efficiency of buildings will sustain.

For Europe, the harmonisation of the European energy market is seen as an important trend.

Smart, green and integrated transport

This section covers mainly trends related to urban transportation and urban construction. In transportation the following trends have been pointed out:

In the short term, self-driving cars and trucks are expected. Challenges are not on the technological side but rather concern the political and legal framework conditions. A second trend pertains to smart infrastructure, which will have strong impact on urban planning and space. On the technology side, this will also lead to massive changes in traffic management and hardware of vehicles. For example, hardware above or beneath the road such as speed advice or traffic lights will become part of vehicle dashboards. Everything will be managed by software and smart infrastructure. Drones and their impact are another trend in transport. Mobility will be perceived as a service and will aggregate different means for achieving transport. Nobody needs to own a car. Citizens will pay for usage of mobility services. The trends of smart infrastructure and new mobility services will also lead to transitions from capital intensive investment to operational investments.

In the long term the expected changes in transport and mobility will have many-fold consequences on travel behaviour and urban spaces. People will be less sensitive for travel time since their activity is where their autonomous car is (key word "driving offices"). This also means that public space will be more intensively used for other activities than for serving mobility. Mobility will not be an interim action between different other activities. Rather, it will be part of other activities. Major operations such as retail, shopping or working will become independent from location.

From a European perspective all these trends are important. The diversity of Europe is considered as an asset. Different approaches to future mobility can be developed in different national settings such as, for example, Copenhagen as the most sustainable city or Estonia as an example for an intensively connected society. It is also expected that the diversity of Europe might even increase since in southern and eastern parts investment into future transportation and mobility is expected to be less compared to the other parts of Europe. Technology and behaviour are very interdependent. Technological changes are expected to move ahead followed by behavioural changes.

In construction, information and communication technologies are expected to exert major impact even in the short term. For example, building information modelling is an important trend or the increased use of microelectronics. In addition, advanced materials are expected there. Construction is anticipated to change to a more industrialised sector where manufacturing of pre-fabricated modules will be important. Integration of construction and energy management is another trend.

Climate action, environment, resource efficiency and raw materials

In this section, a focus will be on water and raw materials.

A main trend in the **water** domain is the development of integrative approaches for water management. This means that the different and traditionally separate operations of water management, such as waste water treatment, fresh water, ground water, surface water, rivers, drinking water, coastal water will be integrated into a whole water management system. In the long term, circular economy and water management will lead to an expansion of the scope of water management. Water will be considered as part of a circular economy.

Raw **materials** will become more important due to the increasing use of portable electronics, the electrification of cars, low carbon energy technologies and catalysts for emission treatment depending on critical materials. Another trend is the need to transform raw materials to advanced materials. In the long term a transformation of the fossile resources based economy to an electricity and hydrogen based economy is expected.

For **Europe** it will be important to keep access to metals. All other trends are also highly relevant for Europe. In particular integrative approaches towards water management and the trends related to raw materials comprising clean energy, clean transportation or portable electronics.

3.1.3 KETs

In general, experts expect that **KETs** will be important almost forevery field and every sector in the economy bringing in additional value.

In **photonics**, there is a growing trend towards making devices more portable. In addition, new materials are needed for integration into photonic systems. Computing devices and sensors will increasingly be used in many different applications, not least due to drifting down of prices. Miniaturisation is another trend which is important among others for the use of photonics in medical applications.

A major continuing trend is **smart manufacturing** in connection with Internet of Things. In particular for Europe this trend is considered as very important.

In general, in the context of the digital society **ICT** is expected to have large influence on the future positioning and competitiveness of Europe and other regions of the world. This is a continuous trend from short to long term. In particular the speed of innovation will accelerate significantly due to accumulative uses of ICT. One of the specific technical trends expected to start already in a short term and continue in the long run is the enfolding of artificial intelligence, again with large impact on many industry sectors.

ICT will also have a strong influence on the administration and service domain. In particular, various e-services are expected. One of the important trends is the wide acceptance of e-signature and the introduction of a broad variety of e-government and e-administration activities. The vision is to combine all the information that exists in different registries about one person and offer this as one complete solution to clients. Estonia is an example where such trends are most advanced. In parallel to the introduction of e-services also the regulatory environment is expected to develop. One example is the implementation of data ownership principles. This means that each citizen can check at any time who is using his or her data, for which purpose and thereby has control over data use. In the long run it is expected to establish consolidated and standardised solutions for different types of e-services, in a sense that one technical block will be set up offering different applications. The data-ownership principle is also expected to advance. Namely online persons should get immediate notification if data is checked by any other person and will have the right to stop the use of personal data. The increasing complexity of ICT and related services and the increasing interconnectedness also has a risk of large incidents which we are not prepared of. An example would be cyber attacks to the energy sector. In this context cyber warfare is another trend expected to become more relevant.

For **Europe** all these trends are important. In particular, experts claim the setting up of a pan-European digital infrastructure also for e-services. On the other hand, there is a strong demand for protection of e-signatures and other services requiring specific regulations. These should be on a European level, so that a harmonised regulatory environment would be available. For the EU it is also expected that an ID code system will be introduced, so that each citizen has one ID code to be used for different administrative services.

3.2 Influencing factors

3.2.1 General

A main **driver** for the trends (Table A1.3) discussed in the previous chapter as seen by the experts firstly is demographic change. Secondly, the trend towards a circular economy in connection with a growing need for improving the sustainability of processes and products is considered as another driver. The demand of society for innovation is expected to change, thereby also driving the way in which innovation is carried out. An improvement of the learning readiness of innovation actors is required. An overarching driving factor is globalisation with broad impact on innovation and competitiveness. For example, sharing of knowledge will become more important, the access to global networks will be crucial. The establishment of communication networks is another driving force. Globalisation also implies that global crime will develop. On the other hand, the green economy on a global level will exert certain impulses. Global scarcity of resources is considered as another driver calling for new solutions.

On the structural level of innovation systems it is expected that the connection between companies and universities will be an important driver for innovation.

Main **impeding factors** are budget pressure and regulation at a European level. Another more general challenge is the ability to scale up. Related to this factor is the current positioning of expertise in some areas in Europe. Experts consider the specialisation as too narrow in some sectors compared to non-European competitors. As an example, robotics is cited. The ability to scale up also depends on the integration of different skills and on language barriers which are perceived as impeding factors in Europe. The political division in different European countries leads to disparities which are also considered as obstacle. Not least the weak ability to translate research into innovation is a hurdle. On a more global scale low oil prices are expected to impede the trend towards circular economy.

Table A1.3: General influencing factors

	Driving	Impeding
General	Demographic change	Pressure on innovation budgets
	Climate change	
	Trend towards circular economy	
	Globalisation - Sharing knowledge	Globalisation - Access to global networks, availability of communication networks - Global crime - Multipolar world: concentration of innovation and economic competence on few global poles
	Innovation policy becoming more strategic: identify strategic areas and concentrate forces	Collapse of social care systems?

In the science and technology domain, new medical technologies, in particular assistive devices for the aging society are considered as **game changers**. Most game changers, however, concern the non-science and technology domain. A first example is the so-called multipolar world. Innovation capacities and economic competition could concentrate on a limited number of poles around the world which raises the question how to organise innovation on such a global scale. In this context also an evolution of competition is considered as a game changer in the following sense. Multi-nationals are expected to become larger and to increasingly acquire innovative SME. In the long run this would lead to a change of control of technology, focussing on a few large industrial actors.

On the policy level it would be game changing if policy decisions would be taken on which areas to focus, on which areas to compete and on which industries to support. Another game changer is the social care system which will come under increasing pressure due to the aging society. There is a fear that the system will not be able to manage these trends. Immigration could also lead to changes if immigration is considered mainly as a source for innovation and not just as a pressure on social systems and national budgets. The idea of level playing fields in Europe is considered as difficult due to the broad diversity and the many differences in the various European regions.

Possible **threats** are catastrophic events which could happen in a number of areas. The continuous rise of China as an economic actor is seen as another threat for Europe. If Europe will not be successful in focussing its innovation capacities and linking required technologies on promising areas, another threat to European competitiveness is expected. Security of energy supply is considered as a problem. Finally, digitalisation is not only seen as a main driver of innovation speed but also as a threat. For example, digitalisation of behaviour and habits will allow establishing activity patterns of people which will lead to a growing predictability of social behaviour.

Disruptive changes are seen in the increasing aging society. On a technology level, the new approaches towards gene editing are also rated as disruptive changes.

3.2.2 Societal challenges

Health, demographic change and well-being

Political forces, societal needs, innovation actors such as private companies and research institutes, regulation and technology push are seen as main **drivers** (Table A1.4). In particular system changes, which would facilitate the translation of research results into products, are considered as supportive forces. Regulatory and ethical issues are considered as **impeding factors**. In addition, the fear of losing employment due to increased automation is seen as hindering. The rising variety of different technological solutions being applied in healthcare requires the establishment of standard procedures. Lacking standards are impeding these trends. The transfer of production capacities of the pharmaceutical industry out of the EU is seen as another impeding factor.

Table A1.4: Influencing factors related to societal challenges

	Driving	Impeding
Societal challenges	Growing digitalisation	Growing influence of large global IT companies
	Better positioning/location systems	Inconsistent policies
	Extended life expectancies	Path dependencies
	Regulation, standards related to environment and energy (e.g. decarbonisation)	Regulation, lacking standards
	Megacities growing (number and size) - Transport, water management healthcare...	

Among possible **game changers** the access to high computing capabilities and cloud technologies are mentioned. In addition, the ability to cure so far uncurable diseases would change the situation. Significantly extended life expectancies and the increased introduction of mobile health services based on telemedicine are perceived as other game changers. On the non-science and technology side, in specific financing and the appearance of new innovation actors are considered as main game changing factors. If large IT companies such as Google and Apple would continue and intensify their engagement in healthcare, this would be a main game changer. From the European perspective it would be important on a political level to focus on patient care as a main goal in the healthcare domain. Another issue is the creation of a common European health market which would be able to compete with large global markets such as the USA and China.

Disruptive innovation is expected from the so-called "-omics" technologies which will have influence on many facets of the healthcare market. These technologies allow high-speed analyses of genomes, proteins and other components at so far unmatched precision. The ability to target specifically cancer cell without any side effects is also considered as disruptive. The availability of large computing power and the growing interconnectedness between different functions of the healthcare system together with improved IT infrastructures enables remote access to a number of healthcare services. In consequence, a lot of healthcare could be provided at home which is considered as a disruptive development. Services for remote healthcare are another disruptive trend. These include, for example, services developed around medical devices or services for smart devices to be used in a home environment. Experience from the consumer market tells that in the long run service providers will be economically more successful than hardware providers.

Radical innovation is driven mainly by the rising use of ICT. This includes, for example, imaging technologies or in general medical devices which are becoming more integrated and cheaper.

Total factor productivity is expected to change considerably due to innovation in medical technologies. For example, a much larger number of medical imaging diagnoses will be possible by the same number of radiologists. Another factor is the growing personalisation. The more medicines become personalised, the more production is needed.

Food and agriculture

Main **drivers** are related to consumer expectations, needs and demands and to the regulatory frameworks. Stable and reliable regulatory framework conditions could strengthen confidence of companies and researchers to invest in innovation. On the other hand, the lack of coherent policies and suitable regulation are considered as impeding factors. In general, in this domain a huge innovation gap between research and market applications is seen in Europe illustrating the challenge of crossing the valley of death. A weak innovation climate in Europe is considered as one of the reasons for this gap.

Game changers on the science and technology side would include new technologies with the potential to offer solutions for some emerging and growing problems, such as allergies and new pathogens. On the non-science and technology side, policy decisions, financing issues, social trends but also climate change and not least catastrophic events are considered as game changers.

Establishing a **level playing field** is appraised as difficult. Europe wants to have protective measures in place in this domain to safeguard, for example, European farmers. As a side effect this shielding of the European market from other or global markets provides fewer incentives for innovation as market actors can count on the continuation of their market success in Europe. In the long run, such a level playing field would counteract European competitiveness.

Secure, clean and efficient energy

Main **drivers** are related to the political environment. For example, European directives on decarbonisation or efficiency targets for buildings are seen as drivers. On the other hand, national regulations and policy activities related to energy storage could be **impeding**. Another impeding influence is exerted by economic factors. For example, in buildings high initial investment is needed in many cases.

Technologies for new generations of biofuel or new generations of lithium-ion batteries with related cost reductions are considered as a main **game changer**. In buildings, high performance insulation materials would exert an important influence. On the non-science and technology side, policy decisions and financing can change the game. As an example, the decisions of the German government to back out of nuclear energy are considered as game changing events.

A **level playing field** could be established if policy would set control measures for non-environmental friendly technologies at a European level. In the energy domain important framework conditions are set at a national level, so that there is no European playing field. A similar situation is seen for the building market where national configurations are more important.

With respect to possible **disruptive innovation**, energy storage is not considered as a field were radical innovation plays a major role. Rather, incremental advances are more important.

Total factor productivity is considered to be influenced by trends in this domain. In particular any efficiency gains will also improve TFP. This holds true for different energy applications but also for the building sector.

Smart, green and integrated transport

Political and legal factors are **main drivers**. In addition, societal interest and changing needs and behaviour of citizens will push the field. The social trend of citizens becoming less interested in owning and driving own cars goes hand-in-hand with technological developments towards improved connectivity between different transport domains allowing better service for the user. In construction, resource efficiency, climate change and green business are considered as main drivers.

Political and legal frameworks could also act into the opposite direction and become **impeding factors** for progress. As an example, national travel management is considered as a huge risk for investors because national peculiarities on the market, business intelligence, rules and regulation will in the end lead to sub-optimal investment in the sector. Traditional thinking and path dependency are other impeding factors. For example, cities and road administrations traditionally consider transport infrastructure as their own and manage it accordingly. Changing mobility behaviour and not least technological trends like autonomous driving, on the other hand, will lead to a completely new way of appraising public space. The user interest will become much more important, in a sense that citizens have the interest to move from one location to another independently from the infrastructure.

Possible **game changers** on a technological side are related to positioning systems. GPS for autonomous driving is one of these factors, and in particular new more precise location systems based, for example, on WiFi or Bluetooth are considered as crucial. In construction the game is already changing due to revolutions in the use of ICT. On the non-science and technology side a huge consolidation of companies is expected to change the game. These companies will go more global, expand their geographical scope and provide more services. Such companies will also be in a position to master the increasing complexity and the use and managing of big data. Regulation is considered as another game changing factor, for example, establishing new models of payment for mobility depending on different personal specifications and demand preferences. New technological opportunities related to autonomous driving will also offer new chances for people during their mobile activities. While being moved from one place to the other various other operations for work or leisure could be carried out.

For **Europe** the mentioned social trends, financing innovation and climate change are considered as most important. **Level playing fields** are difficult in transports and logistics due to many local and regional peculiarities. In construction benchmarking of state aids is suggested as an approach towards a level playing field.

Digitalisation is expected to exert a huge influence on transportation but also on construction. In this context, data infrastructures are considered as most important and also the management of the open source issue. The balance between governments and the private sector to share control and validate data, in particular if big data are used, is very important. Based on this the power to decide should not be focused only on a few very large companies. This in turn is seen as a main risk if a few big companies would be in a position to share, control and validate data.

A number of technological trends are considered as **disruptive**. These include nanotechnology, big data, soft and smart infrastructures, cheap and precise new tracking systems or drones. Another interesting disruptive trend is the impact of new mobility services on established markets. This includes, for example, real estate, the retail market and traffic in general. In construction the full use of ICT potential is considered as disruptive. In addition, innovative materials of high environmental performance would also transform the sector. They could, for example, lead to a new perception of buildings as a "bank of materials" which is highly recyclable or reusable.

Total factor productivity is expected to decrease as hardware will be replaced continuously by services and software.

Climate action, environment, resource efficiency and raw materials

Main **drivers** are seen in the political domain. Namely setting standards or introducing new regulations would be important. In addition, climate change not surprisingly is one of the main driving factors. With respect to materials also societal trends are cited. In specific the trend towards always being connected increasingly exerts an additional demand for raw materials to be used in the required devices.

In the **water** area, traditional behaviours of important actors and path dependency are seen as **impeding factors**. In addition, an increasing size of companies is expected to lead to a lower propensity to adopt innovation.

With respect to raw materials, cheap conventional energy, and in general the capital intensity of the energy market are seen as impeding factors.

For water management two counteracting **game changing** trends are seen on the science and technology side. On the one hand, the further evolvement of megacities calls for large treatment systems which are able to deal with such environments. On the other hand, small delocalised systems are needed which also would be mobile and could be implemented basically at any place in the world. Obviously, different solutions for both types of applications are needed. Another important game changing trend is the integration of smart approaches towards water management. For example, distribution systems could be monitored and controlled by sensors, providing real time information on quantity and quality of water flows, which in turn would allow much better and also more cost-effective management.

In the material area a trend towards recycling not just material but recycling whole products would be a game changing trend.

Looking at non-science and technology-related game changers in water management the perception of water management not just as a cost-intensive service but rather as a factor improving the competitiveness of the industry would be important. Another game changing trend would be a much stronger involvement of the public in water management, for example, by sharing the experience of individual persons about availability, quality or quantity of water at different sites via mobile apps and IT infrastructures. This would allow a much better monitoring for water management.

In the materials domain a main **threat** expected by experts is that non-European market would develop faster leading in the long run to a displacement of the materials industry to other locations. This in turn implies that end markets for materials should stay in Europe.

3.2.3 KETs

In **nanotechnology** disruptive innovation is expected from new materials with unique properties such as graphene and new metamaterials (Table A1.5). In **photonics** more efficient solar cells and longer lasting batteries are considered as game changers and also as disruptive innovation. Threats in the field of photonics are related to cyber security or catastrophic events. In general, large impact on every aspect of life is expected from photonics, thereby having strong implications for total factor productivity.

Table A1.5: Influencing factors related to KETs

	Driving	Impeding
KETs	Availability of new materials (graphene, metamaterials)	Job losses due to automation
	Better energy storage technologies	
	Digitalisation - Introduction of 5G communication - IoT, additive manufacturing, robotics - Automation of manufacturing and decision making (algorithms) (!)	
	Carbon capture and utilisation	

Advanced manufacturing will be driven by the introduction of 5G technologies for communication. The general fear of cooperation between machines and humans might develop to an impeding factor for the field. 5G technologies and Internet of Things are estimated as game changer. Disruptive innovation is expected from additive manufacturing technologies and also from robotics replacing people. Total factor productivity is seen as being largely influenced by robotics and also nanotechnology.

A main driver for **ICT** in the context of the digital society is an increasing pressure on productivity. This leads to automation of products but also automation of decision-making, both depending on ICT. Concerning e-services the needs and perceptions of citizens could be crucial drivers but also political will and regulation are important. In consequence the understanding of how (IT) technology affects society is an important condition for this area. A prerequisite and thereby also a main driving force is the availability of high quality fast and cheap Internet access.

A general impeding factor for the ICT area is the fear of losing jobs due to increased automation. With respect to e-services traditional thinking and public administration lacking societal acceptance but also low education levels are considered as impeding factors. Experience with the introduction of e-services, in particular in Estonia, tells that IT solutions for e-services should not be introduced in addition to existing systems but rather instead of existing systems.

Game changers on the science and technology side are big data and artificial intelligence. Non-science and technology-related game changing events include catastrophic cyber incidence or policy decisions, for example, in favour of insurance companies which want to get extensive data access. With an increasing diffusion of IT into all parts of the society more and more decisions will be taken by algorithms leading to the question who takes responsibility for such decisions. Lacking answers to these questions will certainly exert a threat. Advancements of digitalisation are considered as disruptive changes in the public sector. Basically every administration will be able to work on cloud-based information. This will allow massive parallel working. On the other hand, such cyber infrastructures will be vulnerable to attacks. Disruptive trends would be technologies which are able to attack or defend cyber infrastructures autonomously. Learning algorithms would be a basis for such systems.

3.3 Centres of Excellence

3.3.1 General

For general issues of innovation research or foresight in the EU centres of excellence are seen mainly in the United Kingdom. Sussex, Manchester and Edinburgh are cited by experts. In the USA the universities at Harvard and Berkeley, and in addition the Georgia Institute of Technology in Atlanta and Carnegie Mellon are considered as centres of excellence (CoE). In Asia the IPM in China has a reputation as COE. Interesting trends in this field are seen in countries like Singapore, Brazil or South Korea.

3.3.2 Societal challenges

In the **health** area many centres of excellence active in medical devices are seen in European countries. These are mainly universities in the United Kingdom, France, Spain, Italy or Germany. Also in the US well-known universities in Boston (MIT, Boston Medical Center) or Houston (Texas medical Center) or John Hopkins, Baltimore, are cited. In general, the reasons for these locations are seen mainly in their ability to attract talented and motivated people. In Europe changes are expected not least due to funding activities of the EU within Horizon 2020. A stronger grouping and coordination between centres in this context is observed.

A general issue in the medical devices field are the very high cost of research and innovation activities. Therefore, smaller players cannot afford to be active. Cooperation with large companies is one of the ways to deal with this problem. In some countries huge governmental subsidies have played an important role.

In the area **food, agriculture and forestry**, centres of excellence for food are seen in the Netherlands (Wageningen), Belgium (Gent, Leuven), Denmark, Sweden (Oresund region) and in France (Montpellier and Paris). In agricultural biotechnology Gent is mentioned and in the Netherlands Wageningen. INRA in France is also considered as an important player here. Important changes are expected in the European landscape due to the upcoming KIC on food starting in 2017. This will lead to a more pan-European approach, so that more countries will be involved in the topic.

In the **energy** area centres of excellence depend on the specific topic, for example, in the field of biofuels companies are considered to play an important role such as DSM in Heerlen (NL), Novozymes in Bagsvaerd (DK), Clariant Biotechnology Group in Planegg (DE). In the USA the North Carolina biotechnology cluster is mentioned and in Brazil the Bioethanol Science and Technology Laboratory, CTBE, in Sao Paolo.

With respect to energy storage the universities of Oxford and Imperial College in London are mentioned as centres of excellence. In the United States Berkeley is considered important.

In **transport** the European automotive industry is also playing an important role with regard to centres of excellence. In addition, Fraunhofer Institutes and the KICs are cited. With respect to logistics, Kühne Logistics University in Hamburg (DE) and the KTH Royal Institute of Technology in Stockholm (SE) are emphasised. Changes are expected in particular in Germany and Scandinavia which will move forward quickly. Other changes are seen in the context of public-private cooperation. The trends towards autonomous vehicles will catalyse more public-private partnerships.

In the **climate and resources** area important centres of excellence for water management are the KWR Water Cycle research Institute in Niuwegein (NL), EAWAG in Duebendorf (CH), SINTEF in Trondheim (NO). The Potsdam Climate Institute (DE) is seen as a CoE for climate research. At a global level, some of the Asian regions are expected to become more important. For example, Singapore has a strategy of being autonomous also in water management, fuelling a number of important innovation activities. Similar trends are expected for South Korea.

3.3.3 KETs

In **nanotechnology**, currently centres of excellence in Europe are seen, for example, in Grenoble (FR) (MINATEC). In the USA Stanford and MIT are mentioned. Expected changes refer mainly to the Asian region, where Singapore and China will move forward.

In **photonics** mainly the United States are cited as a location for centres of excellence, for example, the University of Central Florida or the National Institute of Aerospace, Hampton VA. In New York a cluster has been established consisting of more than 200 companies active in the field.

Important centres of excellence in **advanced manufacturing** in Europe are seen in Belgium (e.g. Ghent University) or Germany (e.g. Aachen, Dortmund University). On a global level Japan and South Korea are cited. Also in Taiwan semiconductor clusters have been set up which are relevant for advanced manufacturing. Expected changes again refer mainly to the Asian region. In particular China is expected to become stronger in all activities related to Internet of Things.

In **ICT** in the context of digital societies, cyber security is an important topic. Centres of excellence in this area are seen within the Fraunhofer Society and the Centre for Advanced Security Research (CASED), Darmstadt.

3.4 Europe's position

3.4.1 General

General current **strengths** of Europe in terms of innovation competitiveness are seen in Europe's excellence in basic research, in the availability of skilled workforce and also in the variety of different institutions which potentially can contribute to the configuration of innovation systems. Besides these diversities the "guiding hand" via the European Commission is mentioned as strength. In addition, the sensibility for social and environmental issues is considered to lead to better governance arrangements compared to other parts of the world. Stable and reliable political framework conditions are other assets of Europe.

Learning points for Europe concern firstly the improvement of university-industry collaboration, in particular compared to the USA. As another topic the ability to learn from southern countries is pointed out. Upcoming themes like frugal innovation or grass route innovation currently are more relevant and explored in southern regions, and Europe as a whole could learn from such trends.

Main **weaknesses** of Europe in general are the ability to commercialise research results, entrepreneurship and a too pronounced fragmentation. Also the aforementioned little attention to low tech or local needs oriented innovation in the context of a frugal innovation concept is noted as a weakness.

3.4.2 Societal challenges

In the **health** area Europe together with the United States and Japan is appraised as a leading region. Particular **strengths** of Europe are seen in biomaterials, regenerative medicines, medical devices, but also in the existence of centres of translational research. The strong pharmaceutical sector in some European countries (in particular Switzerland), is also considered as a European strength. In medical devices also new trends such as the increased use of sensors is seen as favourable for Europe since the respective industries are present. The current overall perception is that the starting position for Europe today is favourable since all relevant industries and companies are present.

European **weaknesses** in the health area first of all are related to funding. In Europe funding is based largely on public organisations, while for example in the United States a lot of private funding and venture capital is available. This strong private engagement in the USA is seen as a clear advantage in terms of providing favourable conditions for start-up companies. Public funding in Europe, suffers from difficult implementation hurdles. The funding mechanisms are considered as far too slow. In particular in the health area speed is an important factor when it comes to advancing innovative developments. The funding issue also relates to European companies. Compared to their counterparts in the United States and in Asian countries, they are seen as relying more on public funding in a sense that they wait until public funds are available. Companies in other regions of the world tend to invest into new projects by themselves.

In consequence **learning points** in Europe are seen mainly in the need to change the mind set and remove barriers and separation between academia and industry.

In the **food and agricultural** field Europe is assessed as a leading region in only food. In agricultural innovation the United States and Asian countries such as China are perceived as outperforming Europe. Current **strengths** of Europe are seen in financial support for the agricultural sector from the European Commission. Also food research in Europe is ranked very high. Looking at the specific topic of organic farming, Europe seems to be in a favourable position since consumer demand is driving the topic considerably.

A main European **weakness** in food research is the lacking ability to cross the valley of death by translating research into new products. In agricultural research potential business opportunities are not in the focus. Rather the gap between academia, industry and regulation is considered as widening. All in all, the innovation climate in the food and agricultural area is rated as weak. It is expected that this weakness of Europe will continue also in the long term and the USA and China are expected to improve their competitive position.

In the **energy** area according to expert assessments, Europe holds a strong position. In addition, the USA and also China are mentioned. Current **strengths** of Europe include among others the existence of strong research programmes and a strong private sector providing high level technologies. In addition, the political climate is seen as favourable, for example, for the field of energy storage. In the area of efficient buildings Europe is rated at the forefront since, not least due to high energy prices and a motivation to develop new technologies and not least regulatory framework conditions, innovations in the building sector towards increasing efficiency are well developed in Europe. As a general **weakness** in Europe also in this sector the ability to translate research into commercial applications is cited despite the rather favourable political climate.

In the **transport and mobility** area some European countries belong to the international leading ones such as Scandinavian countries (Sweden and in particular Finland), the Netherlands, Austria, or Poland. At a global level China is perceived as a key competitor not least to the sheer size of their innovation activities. But also other regions such as Brazil, Russia, India, Mexico, Indonesia and also Turkey are considered as promising advancing regions. Accordingly, a main learning point for Europe is that is should realise that other countries are improving their positions.

In the **construction** area current European strengths are seen in the availability of research infrastructure, the huge market size and the initiatives via Horizon 2020 to boost international cooperation. As a weakness the lacking awareness of business issues among policy-makers is cited. Some experts expect that the export shares of Europe in this area will decrease in the long run due to the growing competition from global actors.

In the area of **climate action environment and resource efficiency** with respect to **water** management besides the EU also Singapore and South Korea are perceived as leading countries. In **materials** a number of European countries is seen as leading including Germany, France, Belgium, Italy, the United Kingdom and the Netherlands. Outside Europe mainly Asian countries (Japan, South Korea, China) and the United States are considered as leading. China and Korea are expected to become even stronger in the future, also in science. In the water domain Europe could learn from other regions in the world, in particular with respect to water management in megacities.

European strengths in the material sector are seen on the one hand in well-developed research activities. On the other hand, the tradition of the relevant industries in Europe is also a strong point. Europe is still a leading region in chemistry.

Like in other areas a lacking focus of European innovation activities is perceived as a **weakness**. This relates, for example, to the materials area. Accordingly, a main learning point would be to set strategic priorities, such as other countries like the USA or Japan are used to do. With respect to **export** shares, decreases are expected if markets for materials will develop outside Europe.

3.4.3 KETs

Among the different KETs experts only provided additional assessment going beyond those already mentioned in the preceding chapters for the area of **ICT and digital society**. With respect to e-service solutions, the leading country in Europe is Estonia. Outside Europe South Korea, Singapore and Israel are considered as foremost. Future changes include Finland and Denmark as well as Poland which are expected to improve their position.

In the area of cyber security Israel and the USA are seen as the leading regions. Also governmental activities in Russia, China and India are considered as very relevant. However, details about such activities are not widely known in the public domain. Expected changes in cyber security relate to China and Russia where an improvement of their positions is expected.

A main learning point, in particular for e-services made not only in Estonia, is that novel e-solutions should be designed as substitute technologies for conventional systems and not as add-on approaches.

European **strengths** are seen in the social, political and cultural system: there exists an ability to agree on regulations and directives. This is considered as an important prerequisite for developing harmonised solutions. In addition, strong standardisation organisations are mentioned, such as CEN, CENELECT or ETSI. Regulation on the other hand, is also perceived as a weakness, in particular looking at the national differences, for example, with respect to rules for data protection.

Export opportunities could emerge in the area of cyber security, where at least some European countries could sell their cyber security solutions.

3.5 Cooperations

3.5.1 General

According to expert assessments the following framework conditions would be supportive to stimulate further cooperation between Europe and partners outside of Europe. Establishing joint research institutes between the EU and the USA is seen as an interesting instrument for enhancing cooperation. In general, university and industry collaboration should be perceived as more important. In areas being influenced increasingly by digitalisation, the UN is considered as an actor which could also get involved more intensively into innovation activities related to security. Finally, it was recommended to have a closer look at the funding system in Taiwan which seems to be favourable for cooperation.

3.5.2 Societal challenges

In **health**, demographic change and well-being an important topic for global cooperation concerns the regulatory systems. Since the FDA is the key authority worldwide and the EMA the respective authority in Europe harmonisation and standardisation between these agencies would be important. This might also help to overcome at least to some extent the diversity of regulatory systems in the European Member States which are governing approval procedures for new products. Another topic for cooperation would be large databanks and biobanks which would include not only biological samples but also images.

It is expected that Europe could benefit from such global biobanks in terms of knowledge availability and finally changing the paradigm of medicine, for example, by facilitating the discovery of new phenotypes. Another benefit of transatlantic cooperation would be learning experience from translation activities in the United States.

In general, the instruments for facilitating cooperation within the EU are perceived as quite good, in particular Horizon 2020 is mentioned. In order to bring science closer to industry, more private investment in terms of venture capital and also intensified standardisation activities in Europe would be favourable. With respect to consortia applying for European funds, some funding rules are perceived as less favourable, for example, when a certain composition of the team is expected. This would lead to artificial consortia which might not be the best-suited ones for the particular topic.

In the area of **food and agriculture**, topics for cooperation relate to different biotechnology tools where Europe is rated as an interesting partner providing a lot of expertise, for example markers, sequencing tools, imaging technologies, and proteomics. In general, big societal food-related challenges are seen as important topics for global cooperation.

With respect to framework conditions and incentives, the support activities at the European Commission such as joint programming are assessed as important and favourable. Another useful example is the EU cost programme (COST).

In the **energy** domain new approaches towards developing biofuels would be interesting topics for cooperation, but also smart energy storage systems or solar heating and cooling issues in buildings. Europe could learn from leading regions such as California with respect to energy storage. Required framework conditions for cooperation basically are in place. However, better coordination of exchange of researchers between different universities on a national and European level would be appreciated.

In the area of **transport**, interesting topics for cooperation relate to autonomous vehicles and include information and communication technologies and connectivity concepts, standards or security issues. In the area of construction, CO2 reduction and climate change are important challenges. This calls for cooperation in construction with a goal to reduce the environmental impact of the "built environment". Energy savings is another topic for cooperation.

Many governments are seen to prefer cooperating with large companies where the required knowledge for such cooperation is present. This would hinder innovation generated by small and medium enterprises in the respective markets. Another challenge for SMEs is seen in the participation in European research programmes. For these companies on the one hand it is necessary to focus on the respective research programme. This perspective on the other hand violates the core interest of the SME to focus on its clients. So there is an intrinsic split of requirements.

In the **climate and resources** field, water management in megacities is considered as an important topic for global cooperation. Europe could learn from experience in Asian megacities such as Singapore. On the other hand, water management also offers cooperation configuration, where European expertise meets demands in foreign regions, for example, South America.

In the **materials** area different energy applications and in general technologies for decarbonisation, energy storage or renewables are seen as interesting.

F**ramework conditions** firstly concern the awareness of foreign cultures. In addition it is important to understand the local organisation and function of the innovation system in cooperating regions. Secondly, establishing long-term partnerships would be important, which would be facilitated by stable framework conditions. In general experience with private-public partnerships is positive. In water management it would be helpful to integrate cities not only as an administrative body for water management projects, but also as an innovation actor.

3.5.3 KETs

In addition to the issues mentioned in the previous chapters, only a few topics were raised by the experts. In nanotechnology, for example, security issues and environmental issues are considered as important topics for global cooperation. In photonics, applications in solar cells, batteries, healthcare defence and security would be suited for cooperation. With respect to the digital society the setting up of connected company registers is seen as a worthwhile target.

Annex 2 – The scenarios

1. AIM AND METHODOLOGY

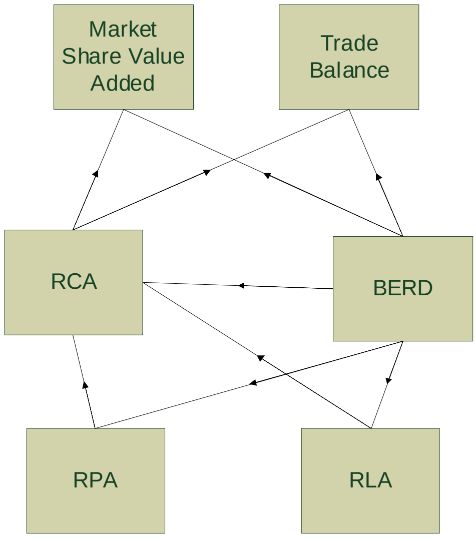
In this appendix we describe the methodology underlying the scenario analysis in the main report. The scenario results build on estimating a structural model linking business R&D expenditures, scientific, technological, and economic specialisation patterns to measures of economic success, in particular the trade balance and the share of world production, in each of the KETs/SGCs (compare Section 2 of this appendix).

The structural relationships between the core variables will be exploited in the scenario analyses to forecast the future positioning of the European economy with respect to the KETs and the SGCs. The estimated relationships can be used to determine the likely impacts of a change of e.g. the economic specialisation as measured by the Revealed Comparative Advantage (RCA) in a KET on the future world market share held by the EU countries in this field: supposing that the interview data would suggest that the RCA in Europe will increase in a certain KET by a certain percentage amount, we can use the prognostic change as feeding into the structural quantitative model. Based on this we can obtain an estimate on future world market share in this field and the trade balance.

Based on the data collection exercises described in the main report we created a unique panel dataset on the level the individual KETs and SGCs disaggregated at the country-level. The dataset encompasses the time period from 2004-2014 and in principle covers all of the variables described in Table A2.1. So there is in particular information on the share of world market for each country/region in a specific KET/SGC, the trade balance in this field, the Revealed Comparative Advantage (RCA) as a measure of economic specialisation resulting from relative production advantages, the Revealed Literature Advantage (RLA) as a measure of scientific specialisation, the Revealed Patent Advantage (RPA) as a measure of technological advantage. Further measures include the R&D shares, the citation rate for scientific publications, and the average family size of the patents measuring average market reach in each KET/SGC.

In order to link these variables in a structural model, we rely on a three-step sequential model. A schematic representation is contained in Figure 1–1. On the first level we determine how the RCA, RPA, and RLA depend on business R&D expenditures. In a second step, we allow the RCA to depend on the RPA and RLA. This direction of causality seems reasonable because scientific and technological specialisation patterns are usually a precursor of economic specialisation. In the third and final step we let the eventual economic outcome variables depend on the RCA as well as business R&D. Based on the empirical dataset we can estimate this model both determining the direction and the strength of association of represented by each of the links. This information will be used later in order to forecast the position of the European economy in the KETs/SCGs vis-à-vis other competing countries.

Figure A2.1: A schematic illustration of the structural quantitative model



In order to describe the model in Figure A2.1 formally, we translate it into estimable regression equations. On the first level, we are interested in how BERD affects the RPA, and RLA. We describe this by the following three generic equations:[1]

$$\log RPA_{ijt} = \vartheta_0 + \vartheta_1 \log BERD_{ijt} + x_{ijt}\pi + c_{ij} + \sigma_{ijt}$$

$$\log RLA_{ijt} = \kappa_0 + \kappa_1 \log BERD_{ijt} + x_{ijt}\xi + c_{ij} + \tau_{ijt} \qquad \text{(1a, b)}$$

where x is a vector of control variables and c is country sector specific unobserved effect. We discuss estimation techniques subsequently, while for now we continue with presenting the overall structural features of the model. On the second level, we model the link between RCA and RPA, RLA, and BERD in a similar way:

$$\log RCA_{ijt} = \alpha_0 + \alpha_1 \log RPA_{ijt} + \alpha_2 \log RLA_{ijt} + \mu_1 \log BERD_{ijt} + x_{ijt}\beta + c_{ij} + u_{ijt} \qquad (2)$$

This equation then obviously treats economic specialisation as a function of the RPA, RLA and again of BERD as well as other control variables. In a third step we intend to relate the RCA to eventual economic outcomes, which we on the one hand measure by the share of world production in the respective KETs and SGCs. On the other hand we use the trade balance a country achieves in any of the KETs/SGCs. In specific, we propose the following two generic models:

$$\log shareWP_{ijt} = \delta_0 + \delta_1 \log RCA_{ijt} + \delta_2 \log BERD_{ijt} + x_{ijt}\gamma + c_{ij} + v_{ijt}$$

$$\log trade\_balance_{ijt} = \varphi_0 + \varphi_1 \log RCA_{ijt} + \varphi_2 \log BERD_{ijt} + x_{ijt}\lambda + c_{ij} + \varepsilon_{ijt} \qquad \text{(3a, b)}$$

It is important to note that in Eq. (1a-c), Eq (2), and Eq (3a, b) the core variables appear on the left-hand-side in some equations and on the right-hand-side in others. But they do so in a restricted way, because variables on higher levels never appear as explaining variables on lower levels. Such models are called recursive or triangular. Triangular models

[1] The log-log-transformation is used because the parameters $\vartheta_1, \kappa_1, \mu_1$ can then be interpreted as elasticities, which facilitates feeding the qualitative interview information into the model.

have two important features. First, because the models are interlinked, we can trace how an effect of e.g. the lowest level impacts (BERD) runs through to variables on the highest level (e.g. trade-balance).

To see this analytically, consider the impact of BERD on share of the world market. BERD affects the RCA, RPA, and RLA, where again RPA and RLA determine RCA. The latter variable finally transmits the combined effects to share on the world market. Thus the overall impact of the BERD on the share of the world market can be written as follows:

$$\frac{\partial \mathrm{E}(shareVA_{ijt} \mid \cdot)}{\partial BERD} = \frac{\partial \mathrm{E}(shareVA_{ijt} \mid \cdot)}{\partial RCA}\left(\frac{\partial RCA}{\partial BERD} + \frac{\partial RCA}{\partial RPA}\frac{\partial RPA}{\partial BERD} + \frac{\partial RCA}{\partial RLA}\frac{\partial RLA}{\partial BERD}\right)$$
$$= \delta_1\left(\mu_1 + \alpha_1\kappa_1 + \alpha_2\vartheta_1\right) + \delta_2 \quad (4)$$

It becomes obvious that in such a model set-up we can estimate how BERD affects value added both directly and indirectly through affecting RCA, RPA, and RLA, which in turn have influence on the trade-balance and the share of world production. Since the model allows for a variety of sequential interactions, we can determine complex patterns, which can deliver quite detailed accounts of the structural relationships between the variables in Figure A2.1. This knowledge will later on be used to derive prognostic impacts of trends and predictions e.g. of the evolution of BERD on the final market outcomes in the future.

The second implication of recursive and triangular models concerns the estimation of the regressions. Principally, including variables both as explaining and explained variables can induce endogeneity biases. Triangularity, despite its flexibility in relating variables ion various sequential levels, however can lead to consistent estimation of individual equations under the assumption that the bivariate cross-correlations between the error terms are zero. In this case resorting to more complex systems-estimator relying on instrumental variables is not necessary (see Wooldridge 2002). In this respect, triangular models are both quite powerful by including complex relationships and are still econometrically tractable.

Individual estimation of e.g. Eq. (2) can be achieved in several ways.[2] If we assume that $\mathrm{E}(\mathrm{c},(x,RLA,RPA))=0$, we can achieve a consistent and efficient estimator based on random effects (RE) regression. This assumption however is usually too restrictive because it precludes the possibility that the unobserved heterogeneity is in some way systematically related to the other observed variables. A less restrictive approach is based on the so-called fixed effects (FE) estimator which transforms Eq. (2) by subtracting the intra-observation time average.

$$RCA_{ijt} - \overline{RCA_{ij}} = \alpha_1\left(RPA_{ijt} - \overline{RPA_{ij}}\right) + \alpha_2\left(RLA_{ij} - \overline{RLA_{ij}}\right) + \left(x_{ijt} - \overline{x_{ij}}\right)\beta + \left(u_{ijt} - \overline{u_{ij}}\right) \quad (2)$$

This equation does no longer contain the time constant unobserved heterogeneity, implying that Eq. (2) is generally estimable by straightforward regression.

[2] The methodology is analogous for (2a) and (2b).

2. ESTIMATION RESULTS FOR THE STRUCTURAL MODEL

In Table A2.1 we present the descriptive statistics for the core variables that we use in the regression models throughout this section. We see, for example, that the average specialisation ratios RCA, RPA, and RLA are all close to unity.[3] This is an expected result because on average over- and underspecialisation across sector-country-pairs should approximately balance each other. The same reasoning holds for the trade-balance average across countries. In fact, if we had included all countries in the world, the average value would by definition have been exactly zero, because positive values in one country appear as negative values in others. The average number of citations per paper is 2.09. The average family size of a patent, i.e. the average number of national offices a patent is filed at amounts to 3.43. Finally, the BERD expenditures measured as shares of world R&D in the specific field hovers between 0% and about 70%. For the GBERD shares these figures are 0% and 21%.

Table A2.1: Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
RCA	21480	0.9615	0.3651	0.0289	3.4967
RPA	22360	0.8603	2.0816	0.0000	196.8060
RCA	21480	0.9615	0.3651	0.0289	3.4967
Trade balance	21480	-461.6460	9267.2500	-172725.0000	136665.0000
Share of world production	7540	0.0292	0.0523	0.0001	0.5092
Publications: average citation rate	11000	2.0940	2.3083	0.0000	39.0000
Patents: average family size	24000	3.4300	2.9820	0.0000	31.0000
BERD shares	5740	0.0279	0.0854	0.0000	0.7008
GBERD shares	2002	0.0050	0.0125	0.0000	0.2112

In Table A2.2 we present the results for the first level regression linking the logarithm of BERD to the logarithm of RCA, RPA, and RLA. In this table we have not made a distinction between KETs/SGCs despite the overlap that potentially exists in particular between KETs on the one hand and SGCs on the other. A distinction between KETs and SGCs is implemented in Table A2.4. In general, we see that BERD does not influence RPA and RLA, but there is a positive and significant effect on share of world BERD on the RCA, where the coefficient implies that increasing the business R&D expenditure in a KET/SGC by 1% will lead to a 0.024% increase in the economic specialisation in this field as measured by the RCA. This suggests that one of the major angles for policies trying to increase the specialisation in these core fields is indeed to increase the business R&D. We also see that the RPA and RLA significantly increase the economic specialisation as measured by the RCA (Column 1). Note also that the results in Table A2.4 giving an account differentiated by KETs and SGCs are quite similar both in terms of direction and in terms of size of the relationships. We therefore decided to summarise the main results for the overarching model pooling KETs and SGCs in Table A2.6.

[3] Note that we did not use the log-tanhyp transformation in order to avoid compression of the values. This makes these variables less useful in descriptive meaning but it allows us to obtain more reliable estimators because the spread of the values is higher.

Table A2.2: The effect of business expenditures on R&D on scientific, technological, and economic specialisation (fixed effects)

	(1)	(2)	(3)
	Log RCA	Log RPA	Log RLA
Log BERD shares	0.02386***	-0.03300	0.00787
	(5.10)	(-1.30)	(0.37)
Log RPA	0.00301*		
	(1.69)		
Log RLA	0.00673**		
	(1.97)		
Publications: average citation rate	0.00138*	-0.00316	-0.01047***
	(1.93)	(-0.81)	(-3.47)
Patents: average family size	0.00156	0.03490***	0.01149***
	(1.45)	(6.16)	(2.64)
2006bn.year	.	.	.
	.	.	.
2007.year	-0.01140***	0.02905	-0.03070*
	(-2.98)	(1.38)	(-1.69)
2008.year	0.00116	0.03964*	-0.00992
	(0.30)	(1.85)	(-0.54)
2009.year	0.00114	0.06513***	-0.06548***
	(0.29)	(2.98)	(-3.54)
2010.year	-0.00696*	0.01843	-0.05368***
	(-1.74)	(0.83)	(-2.86)
2011.year	0.00109	0.01987	-0.05607***
	(0.27)	(0.89)	(-2.97)
2012.year	-0.00777*	0.07618***	-0.04826**
	(-1.86)	(3.33)	(-2.52)
2013.year	-0.01371***	0.10744***	-0.07727***
	(-2.96)	(4.26)	(-3.79)
Constant	0.06944***	-0.52348***	-0.06789
	(2.63)	(-3.57)	(-0.54)
Observations	4432	4812	4877
N_g	658.00000	696.00000	688.00000
r2_o	0.00232	0.01009	0.00031

t statistics in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$
t statistics in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

In Table A2.3 we present the regression results for the third level (linking the RCA to the trade balance and the share of the world market). Again in this table we do not differentiate between KETs and SGCs. The results for this distinction can be found in Table A2.5. In any case, we can observe that there is a positive effect of the RCA on the trade balance and the share of the world market. Most importantly this implies that the RPA and RLA have a positive indirect effect on the trade balance on the world market share, where this effect is channelled through the RCA, which means that increasing both the RLA and the RPA will eventually have an effect on the trade balance in these fields.

Table A2.3: The role of scientific, technological, and economic specialisation (fixed effects)

	(1) Log trade balance	(2) Log share of world production (value added)
Log RCA	2.36755***	-0.04123
	(9.60)	(-1.03)
Log BERD shares	0.66711***	0.15270***
	(8.82)	(10.83)
Publications: average citation rate	0.00453	-0.00040
	(0.46)	(-0.21)
Patents: average family size	0.03221*	-0.00166
	(1.86)	(-0.67)
2006.year	0.00155	-0.00222
	(0.03)	(-0.19)
2007.year	0.17686***	0.02871**
	(2.91)	(2.45)
2008.year	0.22109***	0.33528***
	(3.59)	(27.91)
2009.year	0.10777*	0.27083***
	(1.77)	(22.33)
2010.year	0.20033***	0.25625***
	(3.17)	(20.92)
2011.year	0.29477***	0.63026***
	(4.56)	(50.75)
2012.year	0.30854***	0.77473***
	(4.49)	(60.20)
Constant	9.32753***	-4.12175***
	(22.34)	(-46.89)
Observations	1953	5300
N_g	322.00000	720.00000
r2_o	0.26200	0.57877

t statistics in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

In Table A2.6 we summarise the main coefficients of our structural model described in Figure A2.1 and Eqs. (1a, b), (2), and (3a,b), respectively. These coefficients will be used to assess the likely future impacts of different scenarios for the development of the core variables RCA, RPA, RLA, and BERD on the two outcome variables, i.e. the trade balance and the share of world value added. Alternatively, to these coefficients, we have also computed the effects based on the coefficients separated by KETs and SGCs as a measure of robustness. The results were however quite similar, because of which we present only the results from the simpler model without distinction between KETs and SGCs.

Table A2.4: The effect of business expenditures on R&D on scientific, technological, and economic specialisation for KETs and SGCs (fixed effects)

	(1)	(2)	(3)	(4)	(5)	(6)
	Log RCA (KETs)	Log RCA (SGCs)	Log RPA (KETs)	Log RPA (SGCs)	Log RLA (KETs)	Log RLA (SGCs)
Log BERD shares	0.02974***	0.01228*	-0.00253	-0.08427**	0.01695	-0.01251
	(4.83)	(1.87)	(-0.08)	(-2.34)	(0.65)	(-0.35)
Log RPA	0.00246	0.00358				
	(0.68)	(0.71)				
Log RLA	0.01171***	-0.00402				
	(2.59)	(-0.80)				
Publications: average citation rate	0.00197**	-0.00033	-0.00278	-0.00542	-0.01055***	-0.01088*
	(2.21)	(-0.30)	(-0.56)	(-0.87)	(-3.00)	(-1.78)
Patents: average family size	0.00151	0.00268*	0.04629***	0.01755**	0.01667***	0.00086
	(1.04)	(1.82)	(6.07)	(2.21)	(3.08)	(0.11)
2007.year	-0.01264**	-0.00854	0.03659	0.01225	-0.03492	-0.02221
	(-2.49)	(-1.63)	(1.30)	(0.41)	(-1.54)	(-0.75)
2008.year	0.00802	-0.01112**	0.03875	0.03378	-0.02512	0.01839
	(1.57)	(-2.09)	(1.37)	(1.11)	(-1.10)	(0.61)
2009.year	0.00198	0.00124	0.07083**	0.04848	-0.08591***	-0.02399
	(0.38)	(0.23)	(2.44)	(1.57)	(-3.72)	(-0.78)
2010.year	-0.01066**	0.00107	0.00554	0.03915	-0.05714**	-0.05013
	(-2.01)	(0.19)	(0.19)	(1.26)	(-2.44)	(-1.62)
2011.year	0.00341	-0.00209	-0.01335	0.07886**	-0.06523***	-0.04100
	(0.64)	(-0.37)	(-0.45)	(2.48)	(-2.78)	(-1.31)
2012.year	-0.01009*	-0.00070	0.05893**	0.10215***	-0.05636**	-0.03897
	(-1.85)	(-0.12)	(1.97)	(3.05)	(-2.39)	(-1.18)
2013.year	-0.02100***	0.00380	0.11016***	0.09571**	-0.08098***	-0.07998**
	(-3.53)	(0.56)	(3.38)	(2.54)	(-3.28)	(-2.18)
Constant	0.06427*	0.07302*	-0.48715***	-0.56835***	-0.02692	-0.14761
	(1.89)	(1.89)	(-2.58)	(-2.60)	(-0.18)	(-0.69)
Observa-tions	2957	1475	3191	1621	3366	1511
N_g	449.00000	209.00000	480.00000	216.00000	478.00000	210.00000
r2_o	0.00584	0.00151	0.00166	0.00001	0.00010	0.00100

t statistics in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A2.5: The role of scientific, technological, and economic specialisation for KETs and SGCs (fixed effects)

	(1)	(2)	(3)	(4)
	Log trade balance (KETs)	Log trade balance (KETs)	Log share world production (value added) (SGCs)	Log share world production (value added) (SGCs)
Log RCA	2.39545***	1.32638*	-0.04002	-0.03399
	(8.88)	(1.96)	(-0.85)	(-0.44)
Log BERD shares	0.77463***	0.33542**	0.14133***	0.18749***
	(8.86)	(2.20)	(8.14)	(8.16)
Patents: average family size	0.05242***	-0.03954	-0.00016	-0.00272
	(2.69)	(-1.00)	(-0.05)	(-0.68)
Publications: average citation rate	0.00327	0.00539	0.00124	-0.00668*
	(0.29)	(0.27)	(0.54)	(-1.91)
2005bn.year	.	.	.	.
	.	.	.	.
2006.year	-0.00772	0.01453	0.00682	-0.02126
	(-0.11)	(0.14)	(0.47)	(-1.21)
2007.year	0.19383***	0.11728	0.04544***	-0.00960
	(2.65)	(1.08)	(3.07)	(-0.54)
2008.year	0.25205***	0.12324	0.32046***	0.37042***
	(3.43)	(1.09)	(21.21)	(20.00)
2009.year	0.10423	0.08746	0.25007***	0.32184***
	(1.45)	(0.75)	(16.39)	(17.22)
2010.year	0.18862**	0.19994*	0.22833***	0.32542***
	(2.50)	(1.69)	(14.80)	(17.26)
2011.year	0.27603***	0.30209**	0.61596***	0.66828***
	(3.60)	(2.41)	(39.52)	(34.64)
2012.year	0.25246***	0.35768**	0.76971***	0.79174***
	(3.12)	(2.57)	(47.96)	(38.64)
Constant	9.31634***	9.32947***	-4.21371***	-3.85927***
	(19.31)	(11.10)	(-38.84)	(-27.17)
Observations	1372	581	3710	1590
N_g	227.00000	95.00000	504.00000	216.00000
r2_o	0.24998	0.32703	0.56227	0.62523

t statistics in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A2.6: Summary of the effects for the total model

Effect from to	Trade Balance	Share world market (value added)	RCA	RPA	RLA
RCA	1% increase leads to 2.3675% increase	No effect			
RPA			1% increase leads to 0.003% increase		
RLA			1% increase leads to 0.007% increase		
BERD	1% increase leads to 0.6671% increase	1% increase leads to 0.1527% increase	1% increase in BERD increases RCA 0.023%	No effect	No effect

The scenarios in the final report are then calculated based on the results in Table A2.6, which are plugged into Eq. (4) and the respective version for share of the world production.

3. REFERENCE

Wooldridge, J.M. (2002): Econometric Analysis of Cross-Section and Panel Data. London: MIT Press, 735 pp.

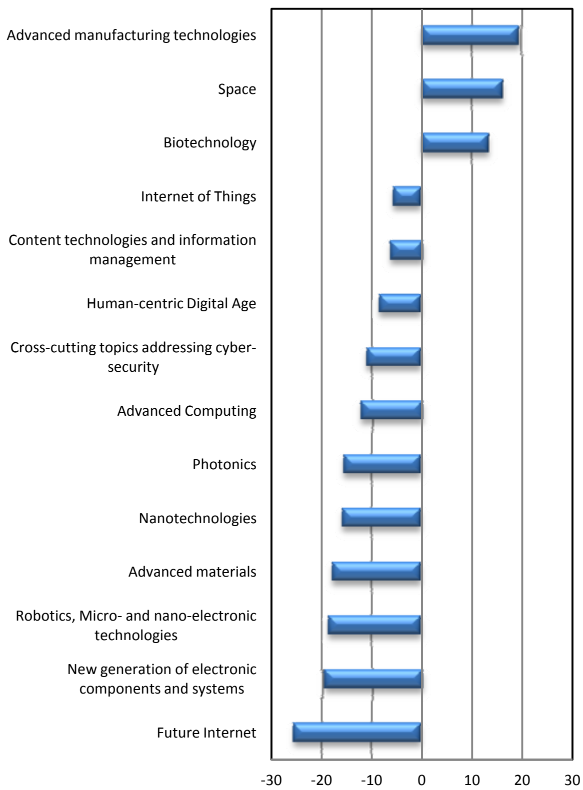
Annex 3 – Export and export-import specialisations excluding intra-EU trade

In this annex, we show the Revealed Trade Advantage (RTA) and the Revealed Comparative Advantage (RCA) based on data where intra-EU trade is excluded. The data we use in this study is based on OECD-STAN Trade bilateral database, using ISIC sector classifications, which are then recalculated according to KETs and SGCs employing the method described in section 2 of the final report. This data, however, is not able to exclude or separately provide intra EU-trade. To exclude the intra-EU trade, we employed the following method to the OECD-STAN data. First we aggregated the product classes to the two digit NACE classes. Next we identified the share of intra-EU trade per 2-digit product group. The share of extra-EU trade for each product group was applied to the OECD-STAND data, so that the extra-EU trade was left over. In additions, we subtracted the difference between the newly calculated extra-EU and total-EU trade from the worldwide total trade. After applying the conversion method to KETs/SGCs, we calculated the RTA and the RCA accordingly. It was not possible to directly employ the PRODCOM data as we lack a concordance between technologies and products. Therefore we had to stick with the concordance between technologies and sectors and the method for their conversion described above.

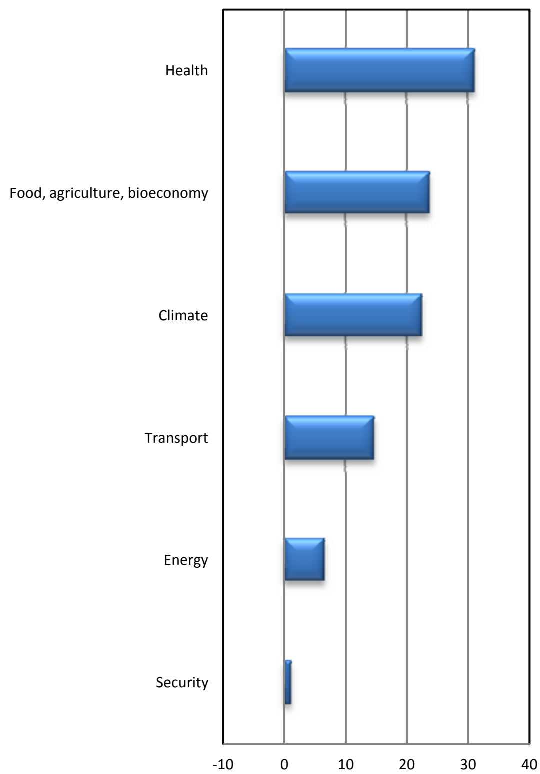
It needs to be kept in mind that the extra-EU trade is only about 1/3 of total EU trade, if intra-EU trade is taken into account as well. This means that the export volume is considerably decreased when intra-EU trade is ignored.

Figure A3.1: The output perspective – current exports (world trade specialisation, RTA) in 2010-2014

KETs



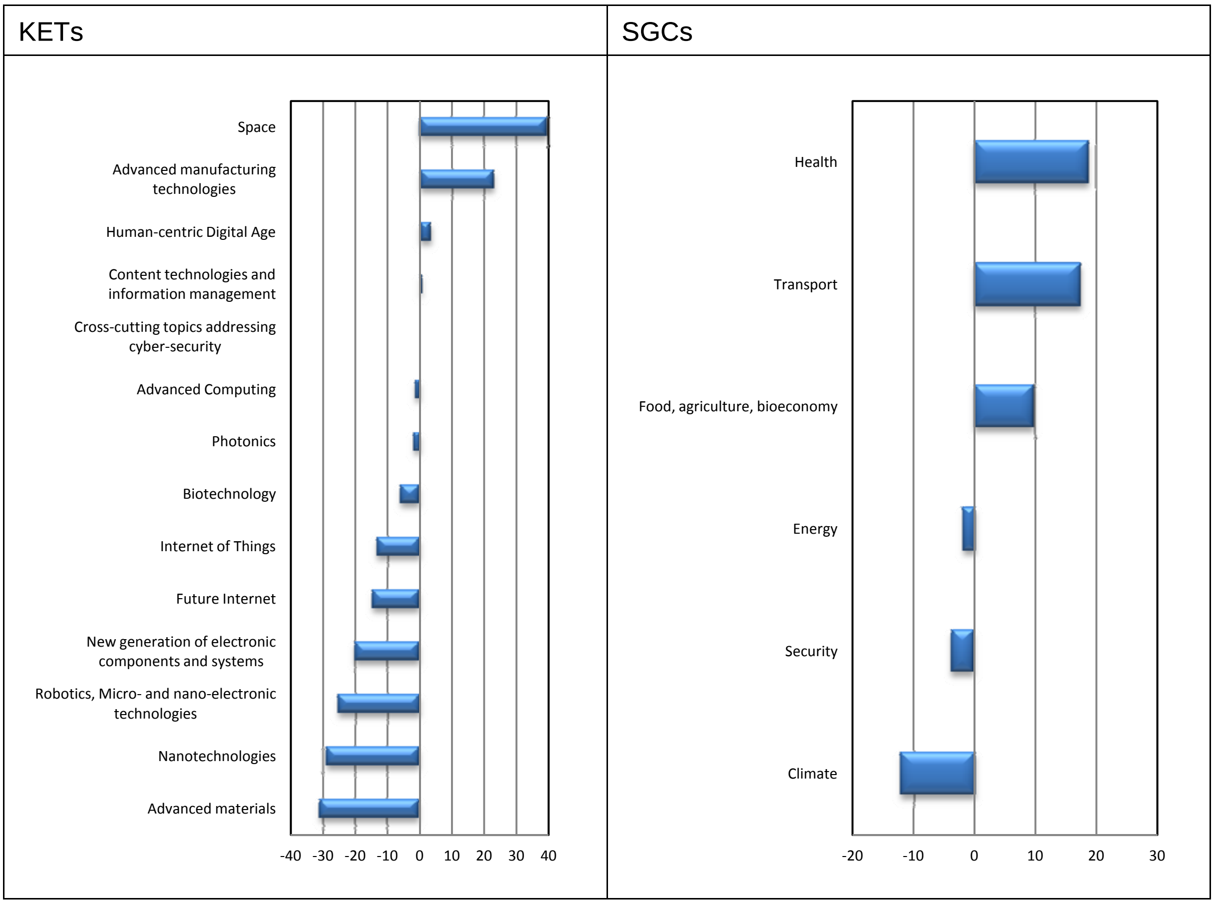
SGCs



The results of the export specialisation profile of EU-28 by KETs and SGCs for the years 2010-2014 only relying on extra-EU trade is depicted in Figure A3.1. In the case of KETs, we see a very similar pattern like the profile including intra-EU trade as it was presented in section 3 of the final report, but with higher values, both in positive and in negative directions. AMT is at the top, followed by space and biotechnology, which all show stronger positive values, especially for AMT. In the case of the underspecialsed fields we find only minor differences for example for advanced computing or nanotechnologies. The most outstanding effect can be found for advanced materials, which reaches a value of -9 if intra-EU is included and a value of -31 if only extra-EU trade is taken into account. This means that a large number of materials is traded within the EU and that the position of the EU-28 countries is much worse at the worldwide market excluding the EU, while the position at home is rather competitive.

Looking at the export specialisation profile in SGCs a very interesting effect occurs. All values are (slightly) positive, which means in consequence of the construction of this indicator, that the category of other fields (outside SGCs) must be negative. This was not the case with the data including the intra-EU trade. One has to keep in mind that in Europe all SGCs taken together cover almost 80% of the trade of finished goods so that the missing category is rather small. The result indicates – next to generally more positive values in all SGCs – that Europe has an outstanding position in these areas also on the markets outside the EU. To put it differently: the SGCs were very well defined to reflect the areas of European strengths.

Figure A3.2: The output perspective – Revealed Comparative Advantage (export-import) in 2010-2014



The export-import ratios (RCA) excluding intra-EU trade are depicted in Figure A3.2. The patterns are very similar to the ones calculated based on the total EU trade (including intra EU trade). Space and AMT are at the top with clearly positive values, but with higher specialisation indices. This means that supplying the world market with these technologies is mainly grounded on internal (in this case then intra-EU inputs) than on extra-EU inputs. On the other hand, for example, advanced materials that are exported to the world, even stronger rely on input from outside the EU. The SGCs Transport and

Health show a better relation for inputs and outputs (imports and exports) when the intra-EU trade is neglected, and also in the case of food a positive value occurs that is not visible when the total trade of EU countries are taken into account. In security there are hardly any changes in the relative value and the positioning in climate is slightly more beneficial for Europe, but still negative.

Annex 4 – Quantitative data on Competitive positions of KETs and SGCs

1. PUBLICATIONS

Figure A4.1: Absolute number of scientific publications in KETs in EU-28, USA, East-Asia and China

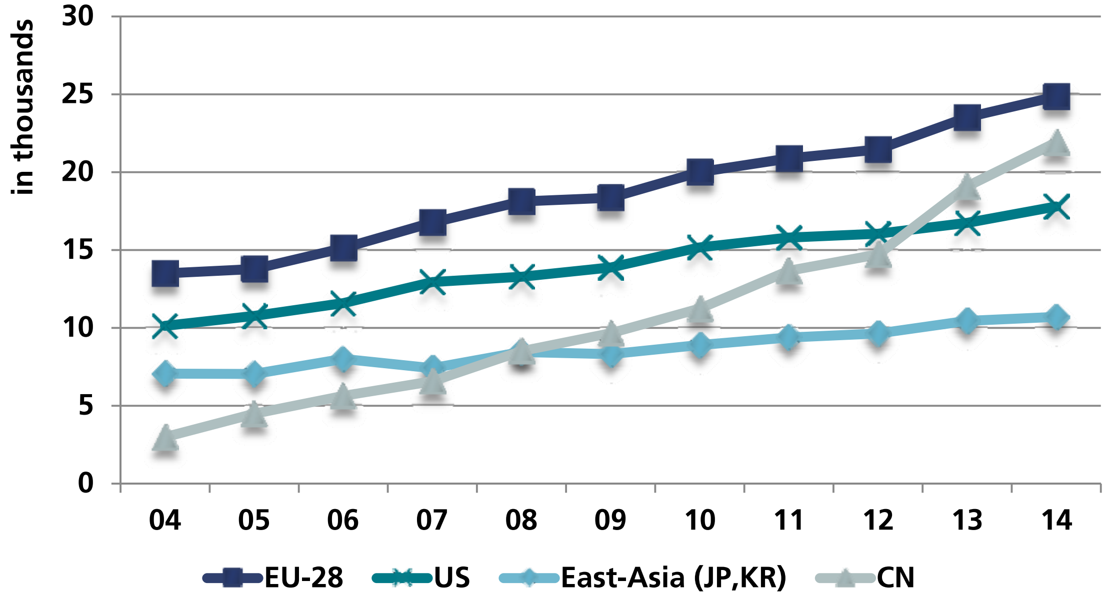


Figure A4.2: Absolute number of scientific publications in KETs in EU-28, USA, East-Asia and China (Part 2)

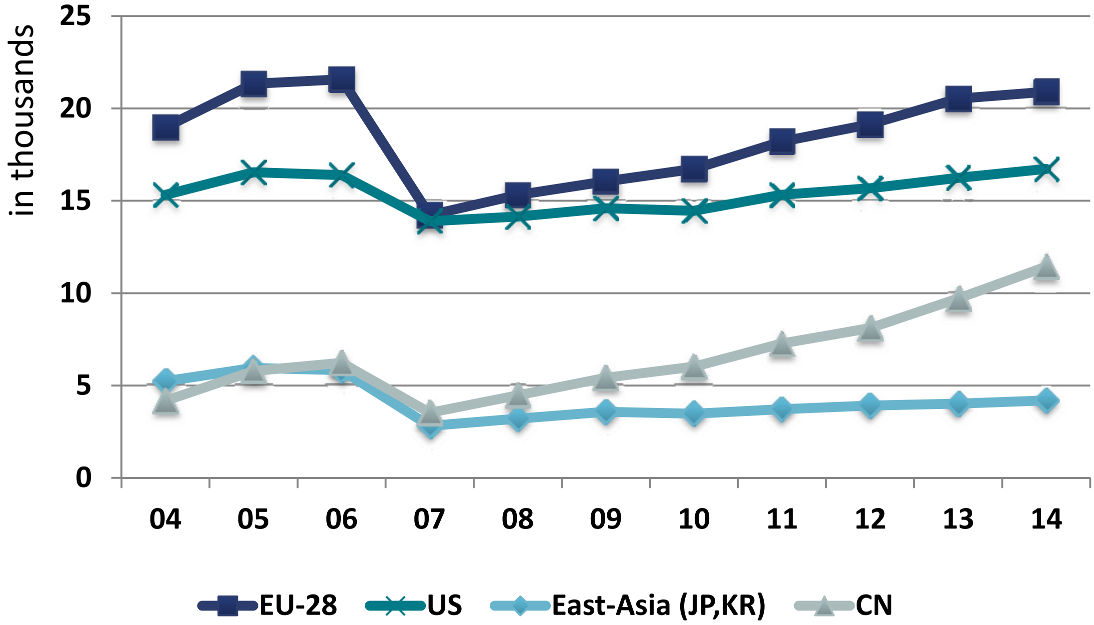


Figure A4.3: Shares of scientific publications in KETs in EU-28, USA, East-Asia and China

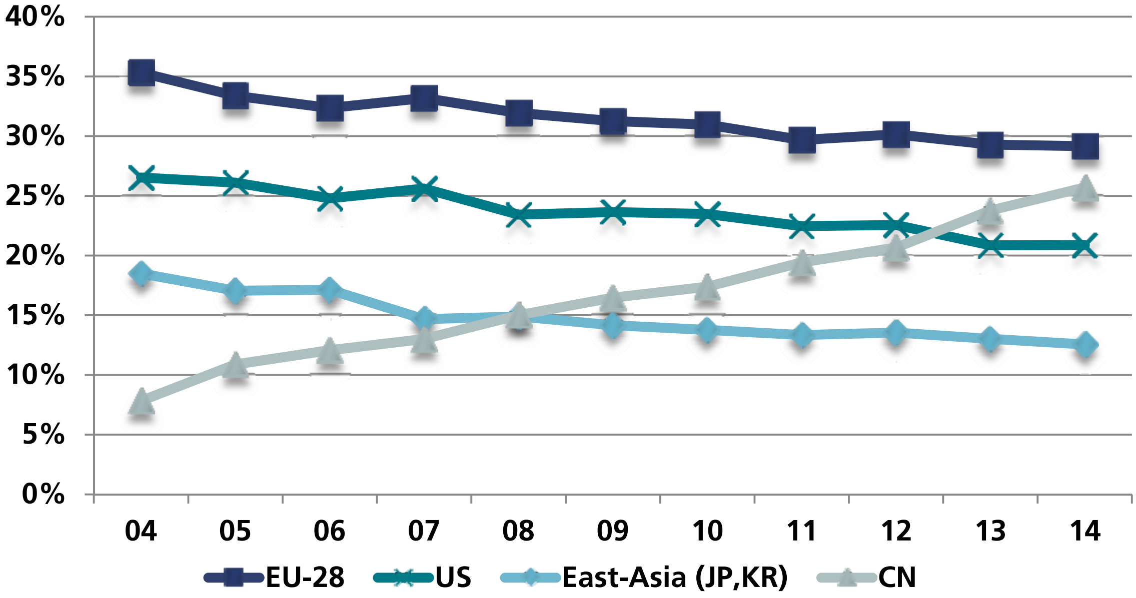


Figure A4.4: Shares of scientific publications in KETs in EU-28, USA, East-Asia and China (Part 2)

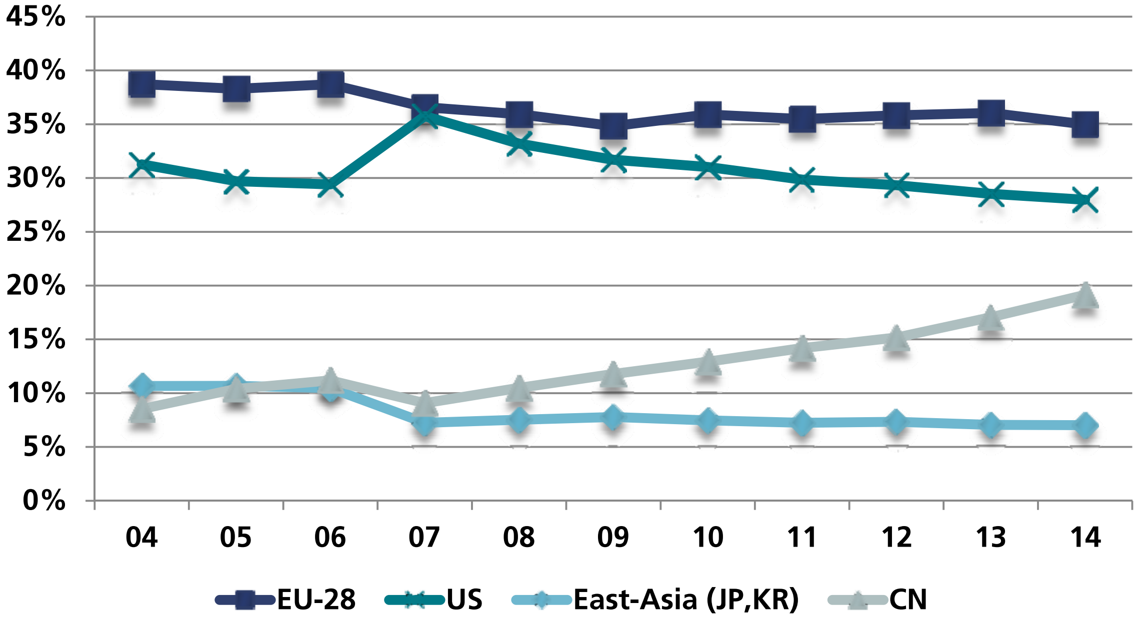


Figure A4.5: Shares of scientific publications in SGCs in EU-28, USA, East-Asia and China

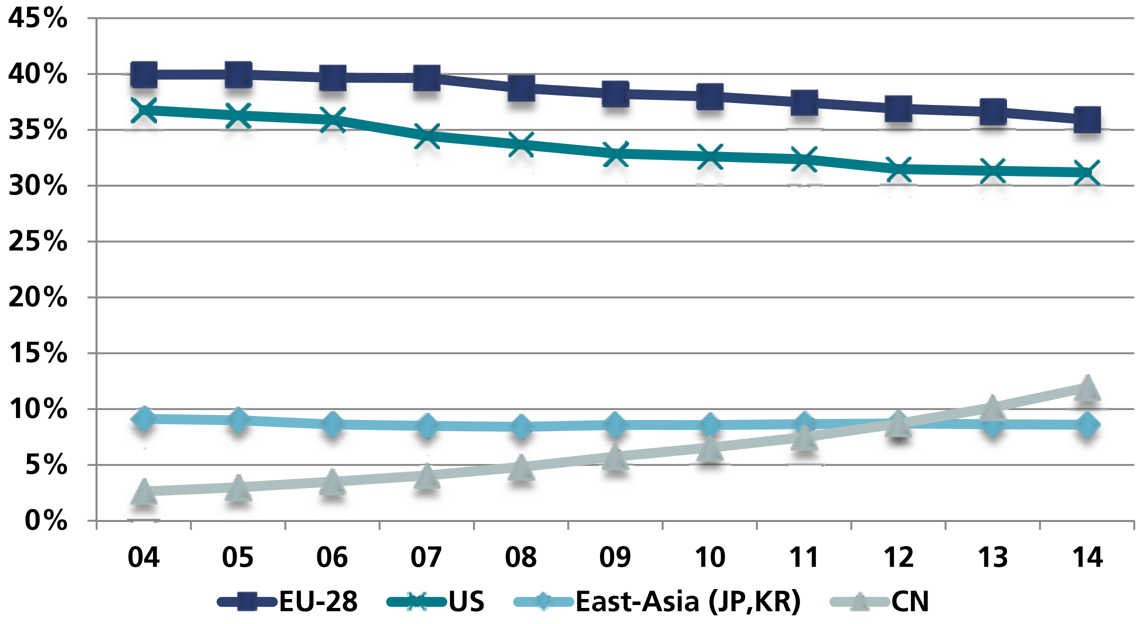


Figure A4.6: Specialisation profile 2010-2014: KETs

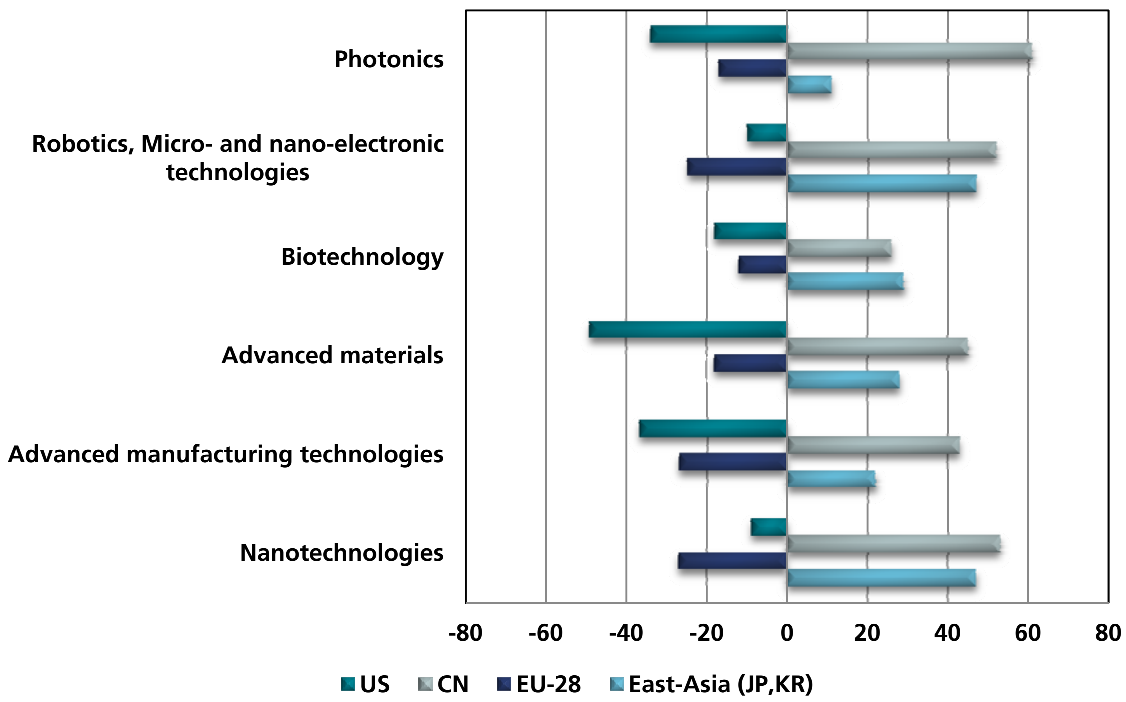


Figure A4.7: Specialisation profile 2010-2014: KETs (Part 2)

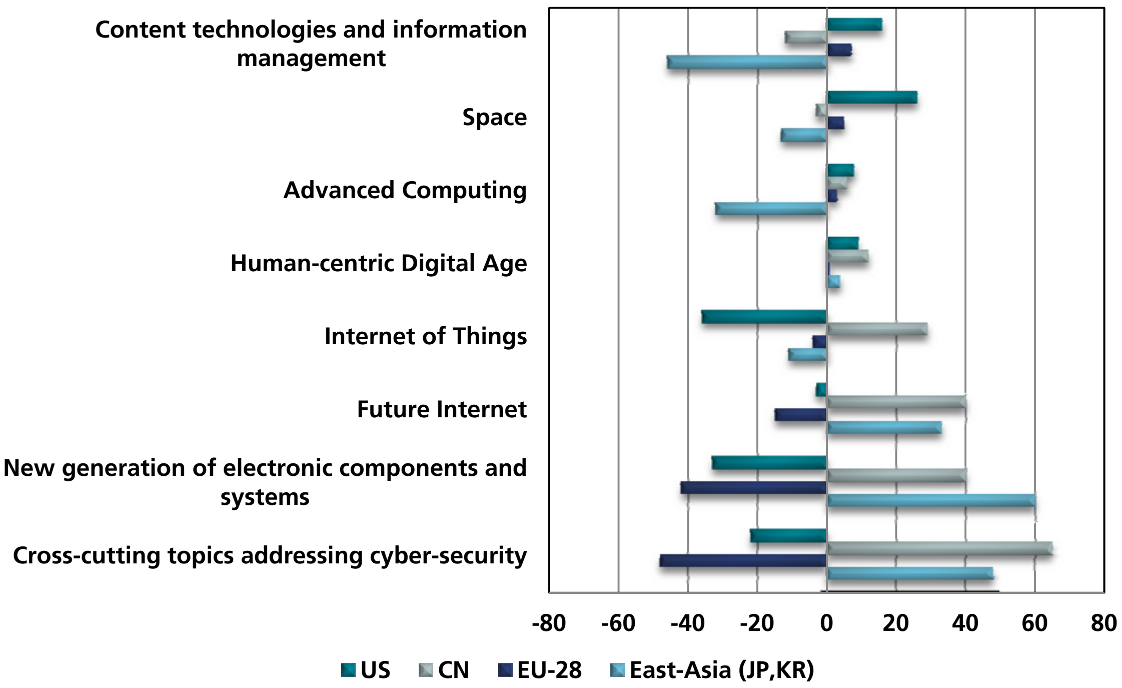


Figure A4.8: Specialisation profile 2010-2014: SGCs

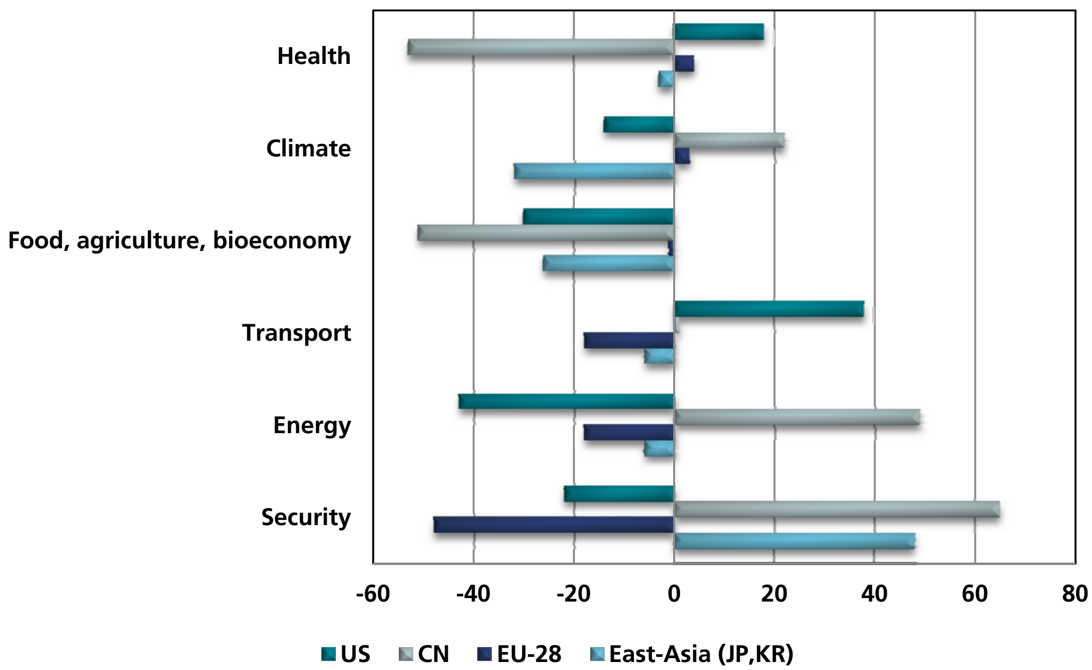


Figure A4.9: EU-28 Shares of Web of Science Publications: KETs

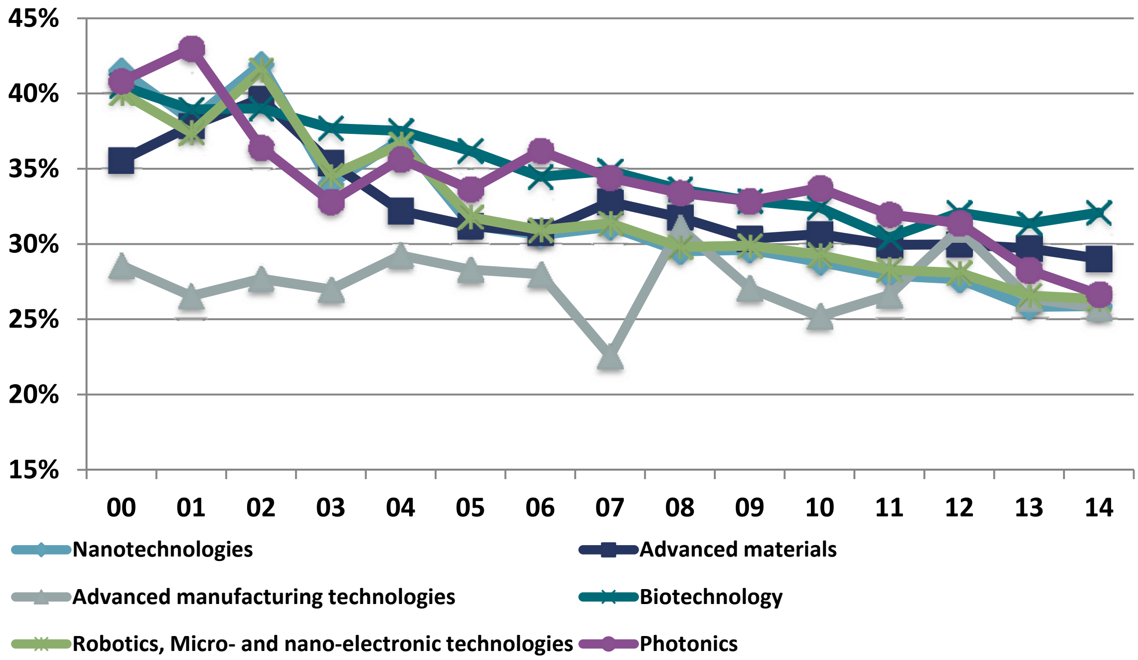


Figure A4.10: EU-28 Shares of Web of Science Publications: KETs (Part 2)

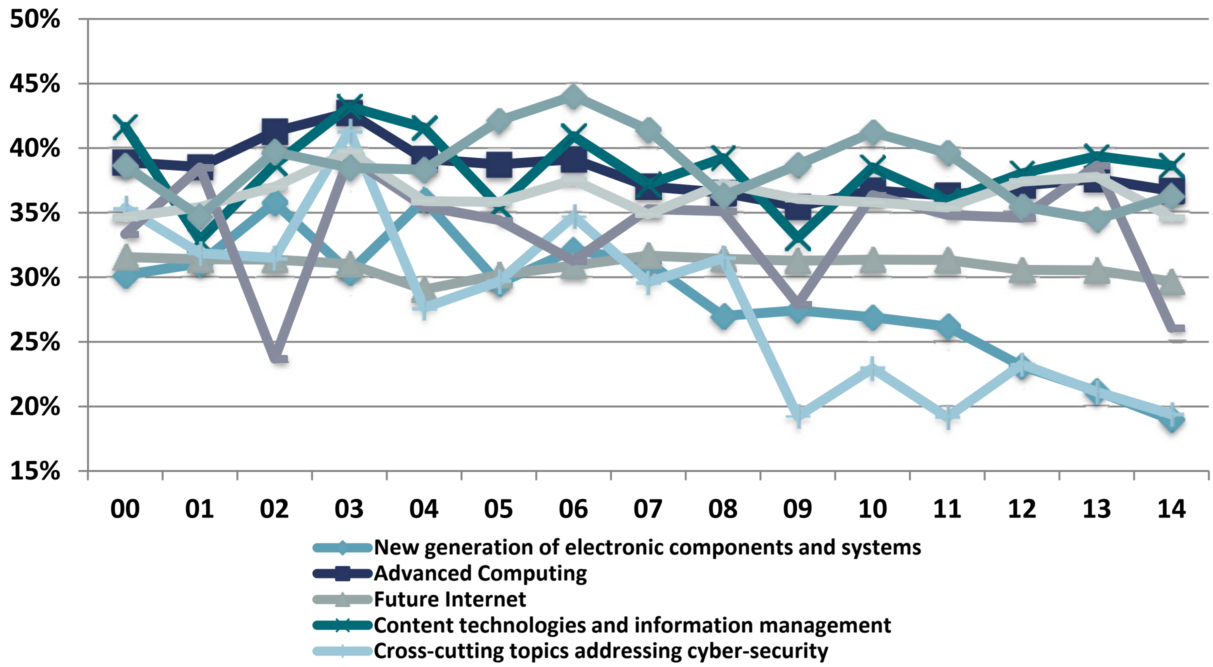


Figure A4.11: Absolute number of scientific publications in SGCs in EU-28, USA, East-Asia and China

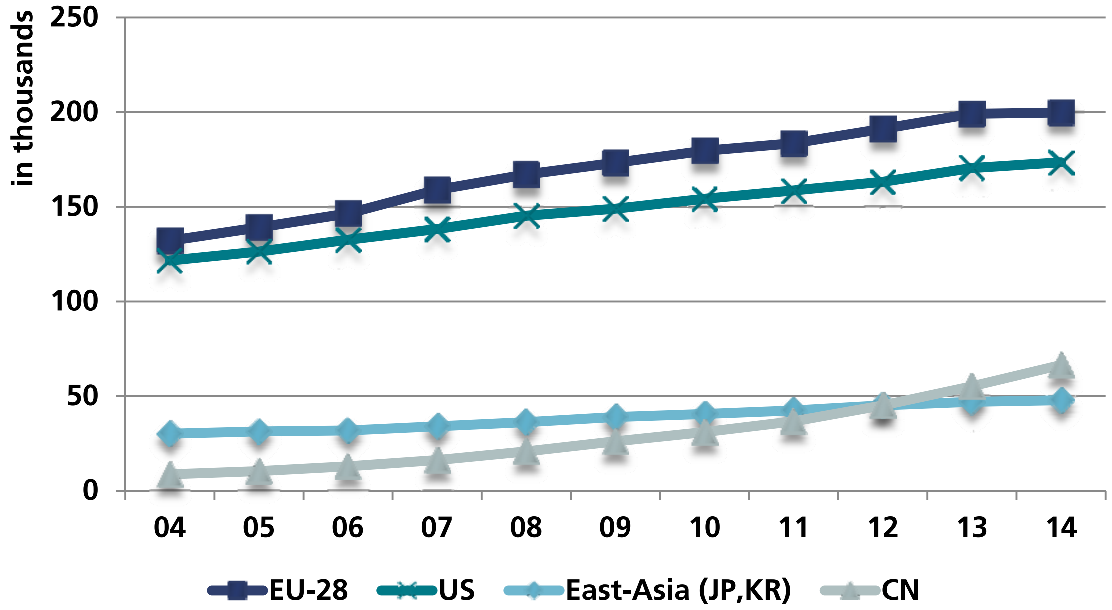


Figure A4.12: EU-28 shares of Web of Science Publications: SGCs

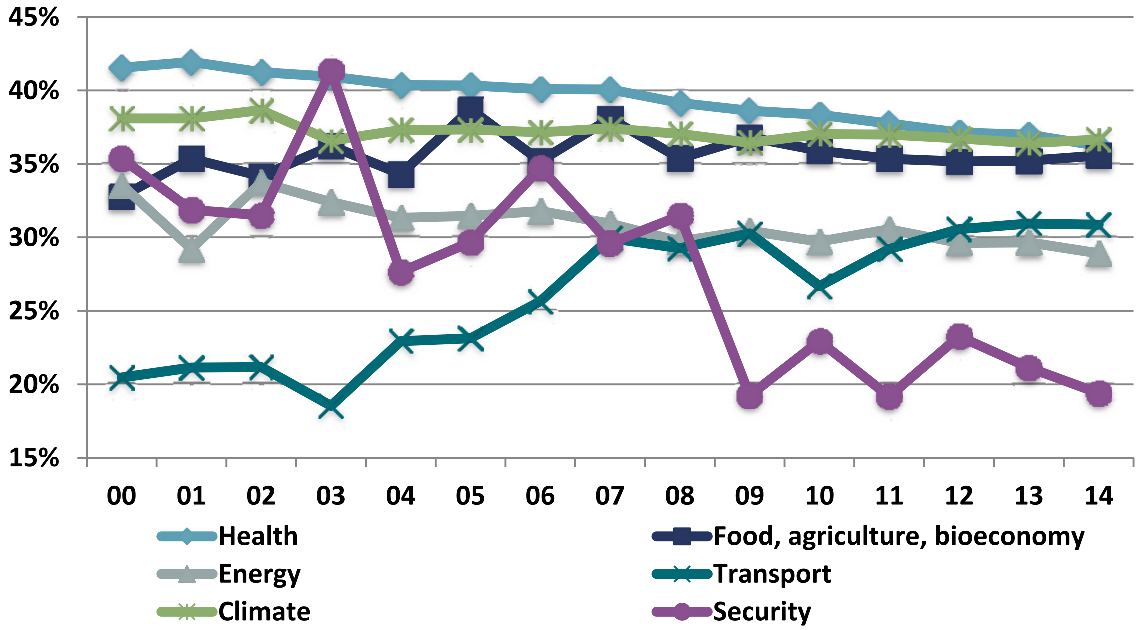


Figure A4.13: Shares of Web of Science Publications: nanotechnology

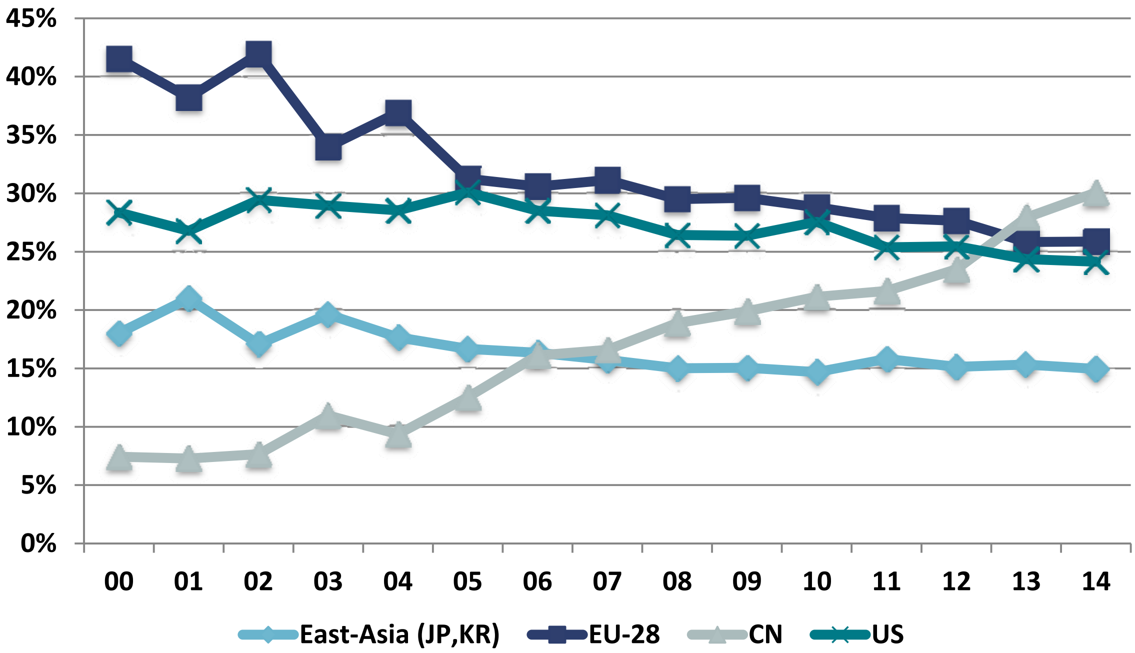


Figure A4.14: Shares of Web of Science Publications: advanced materials

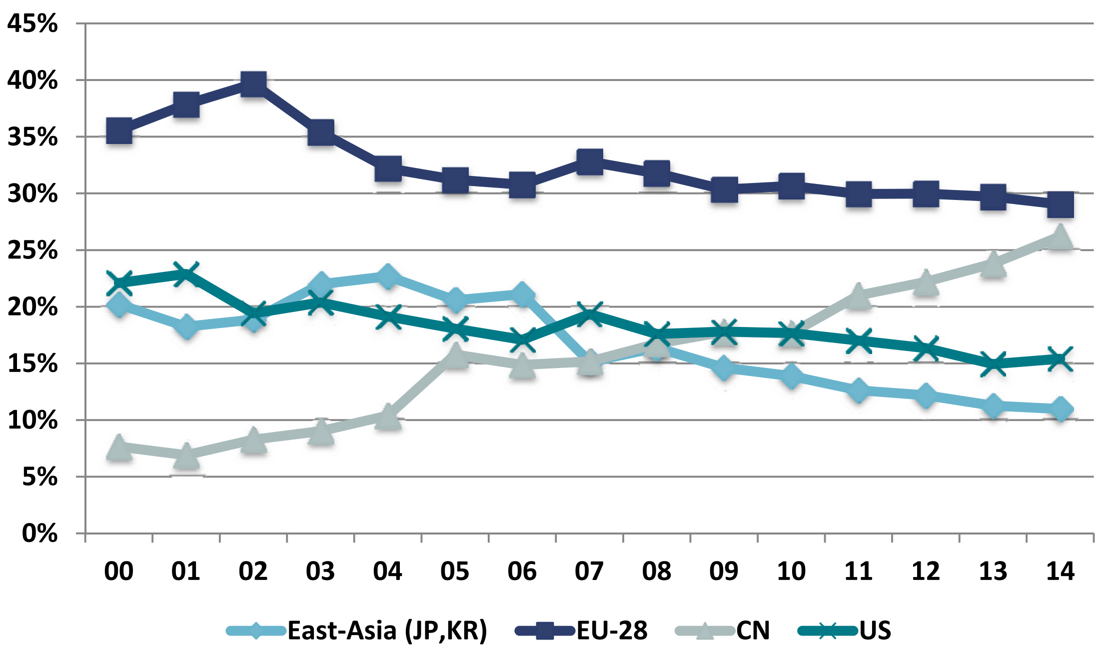


Figure A4.15: Shares of Web of Science Publications: advanced manufacturing

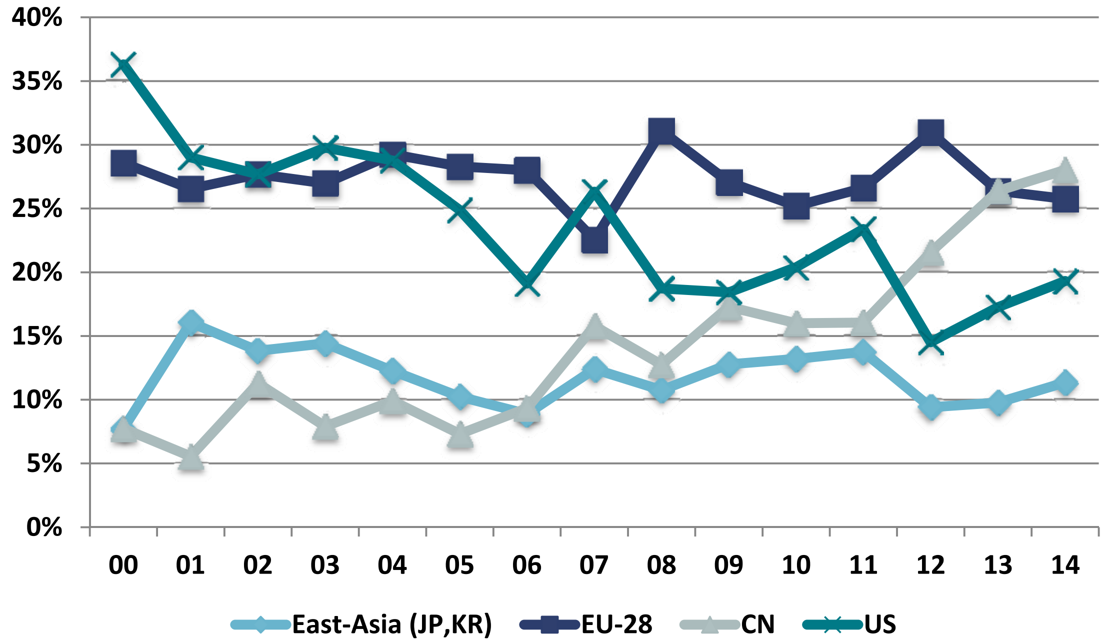


Figure A4.16: Shares of Web of Science Publications: biotechnology

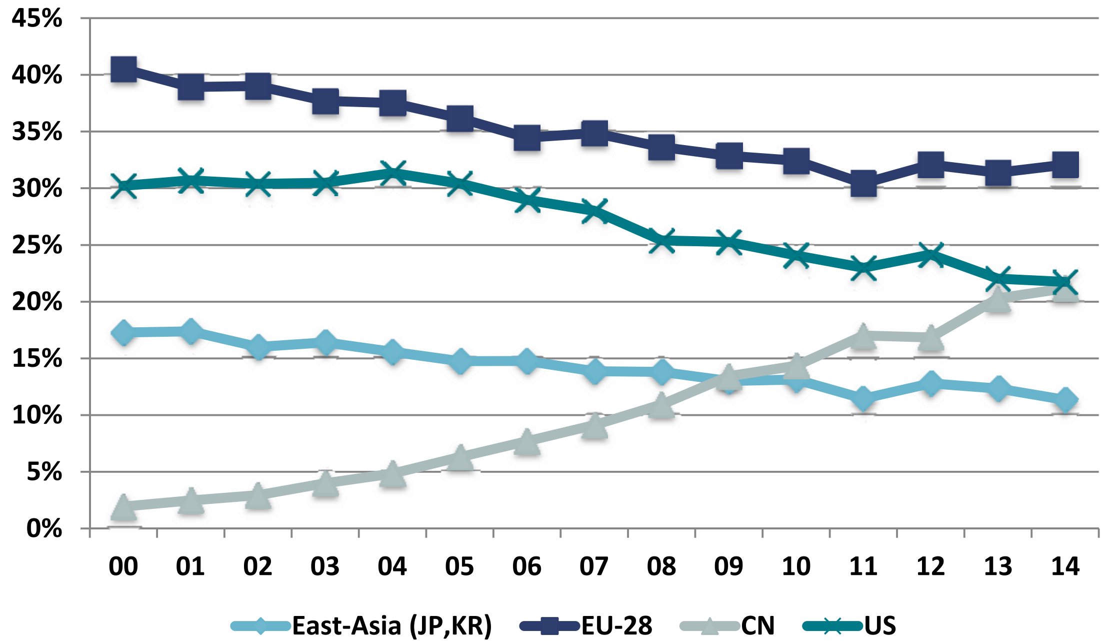


Figure A4.17: Shares of Web of Science Publications: robotics, micro- and nano-electronics

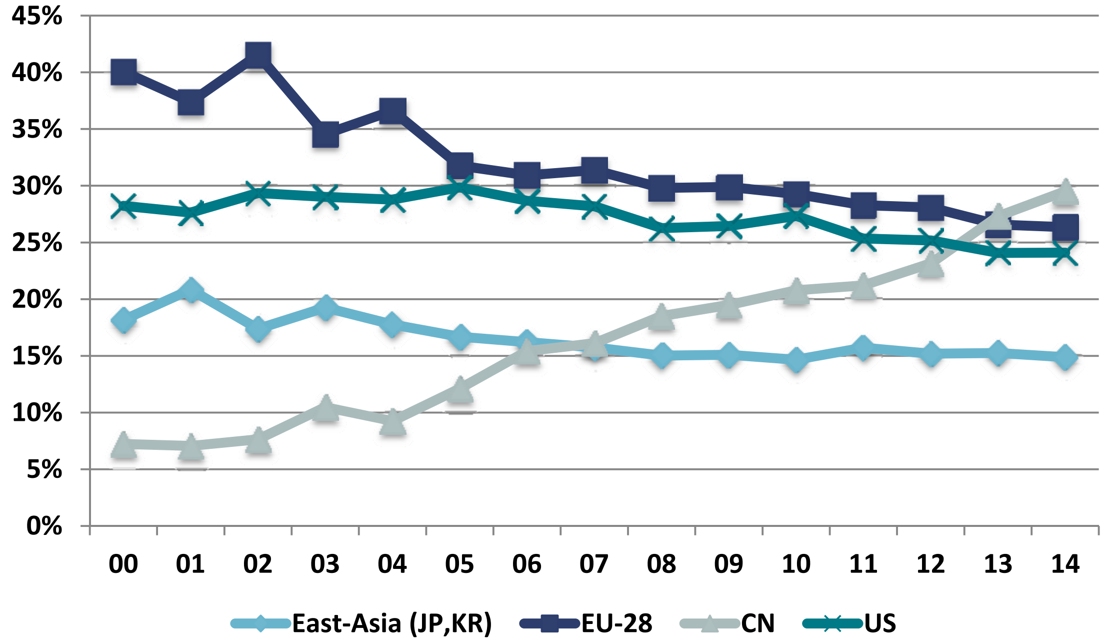


Figure A4.18: Shares of Web of Science Publications: photonics

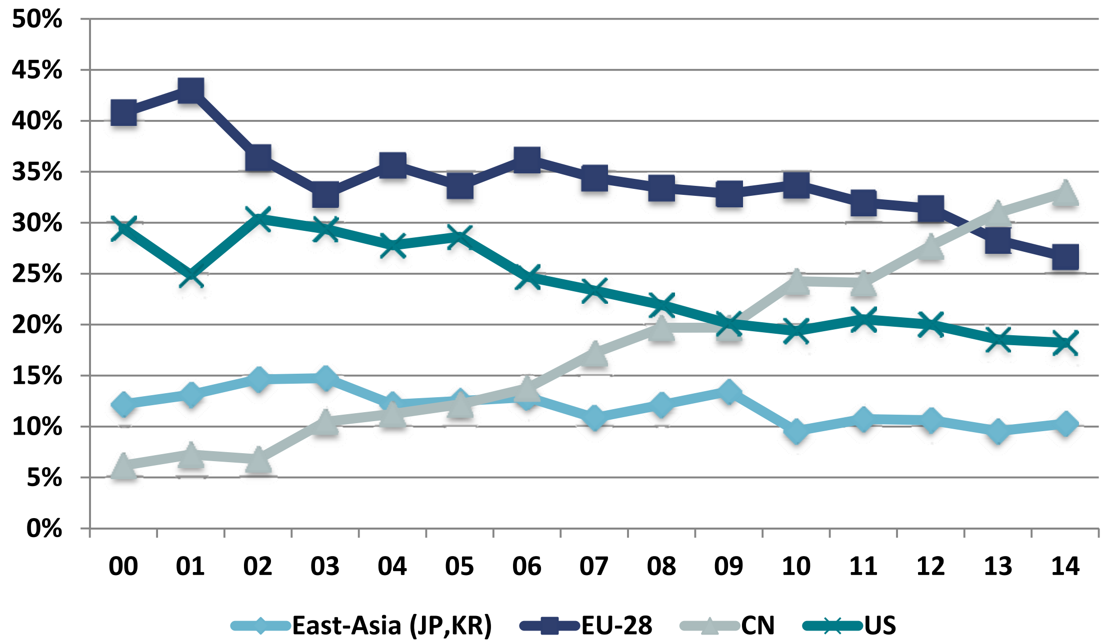


Figure A4.19: Shares of Web of Science Publications: electrical components and systems

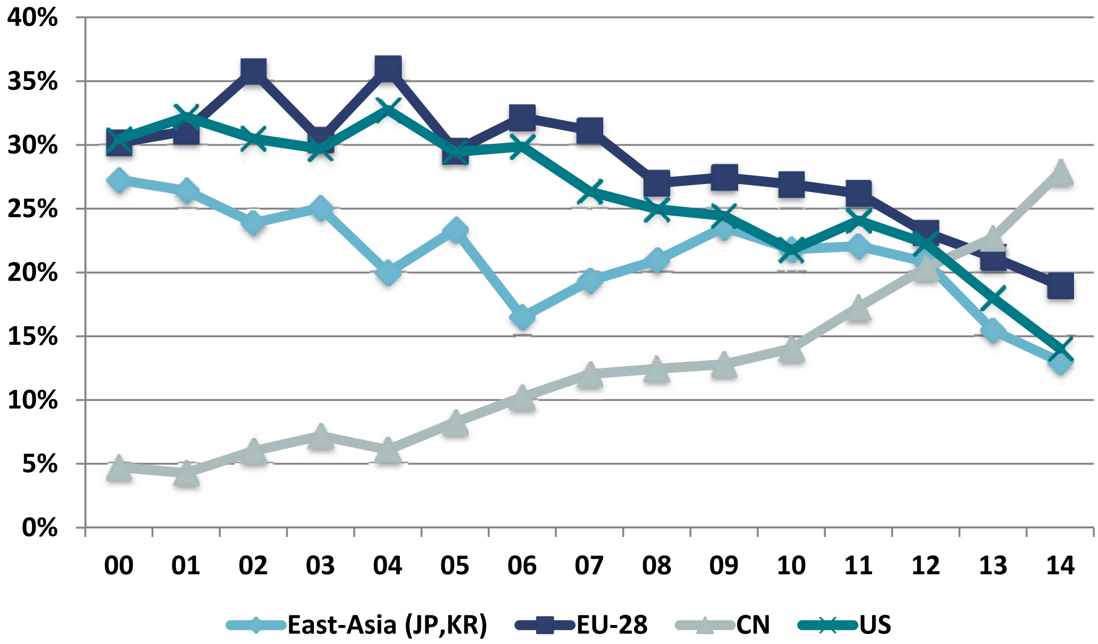


Figure A4.20: Shares of Web of Science Publications: advanced computing

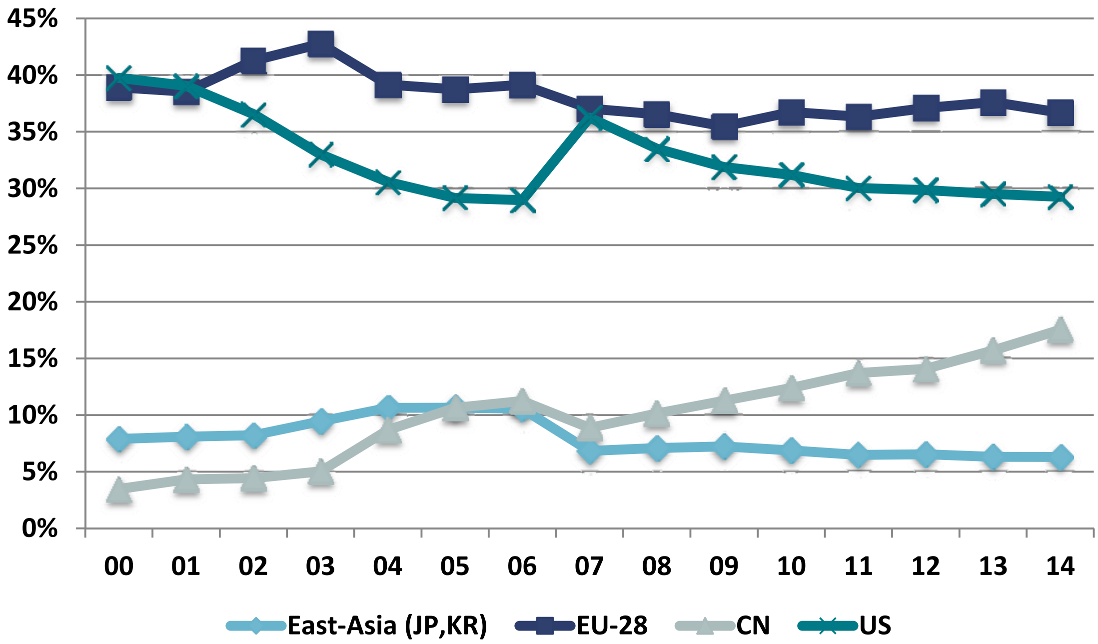


Figure A4.21: Shares of Web of Science Publications: future Internet

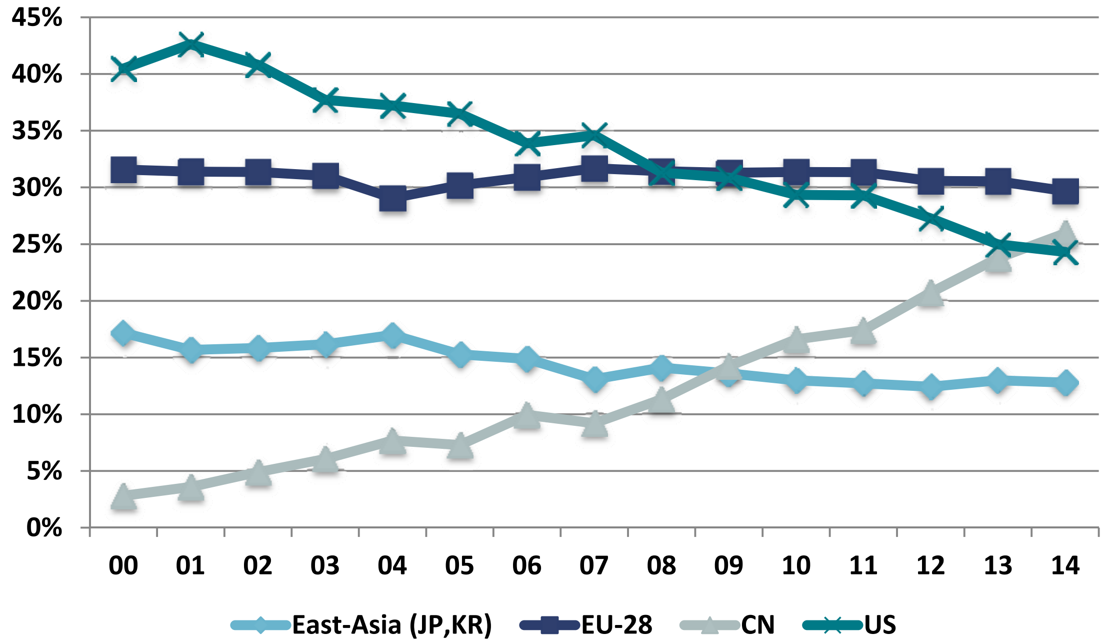


Figure A4.22: Shares of Web of Science Publications: content technologies and information management

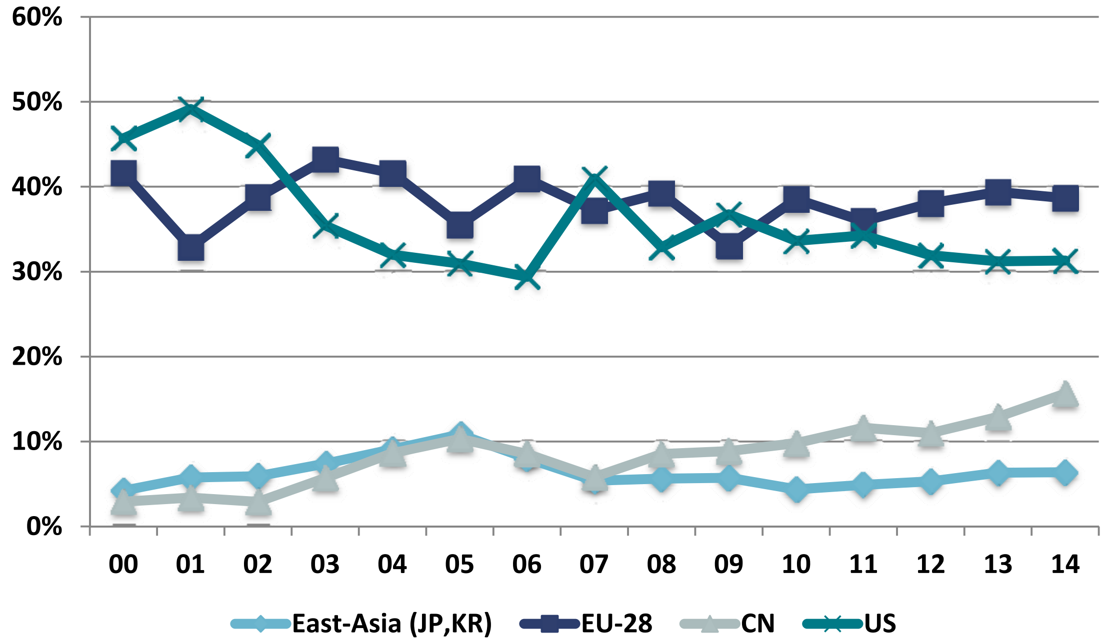


Figure A4.23: Shares of Web of Science Publications: cyber security

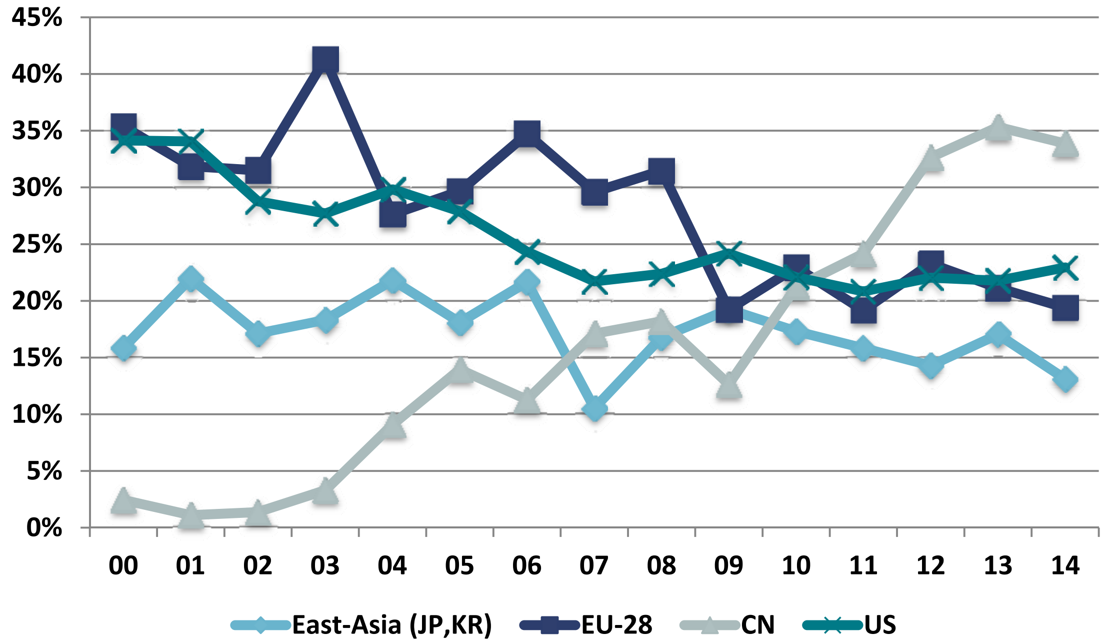


Figure A4.24: Shares of Web of Science Publications: Internet of Things

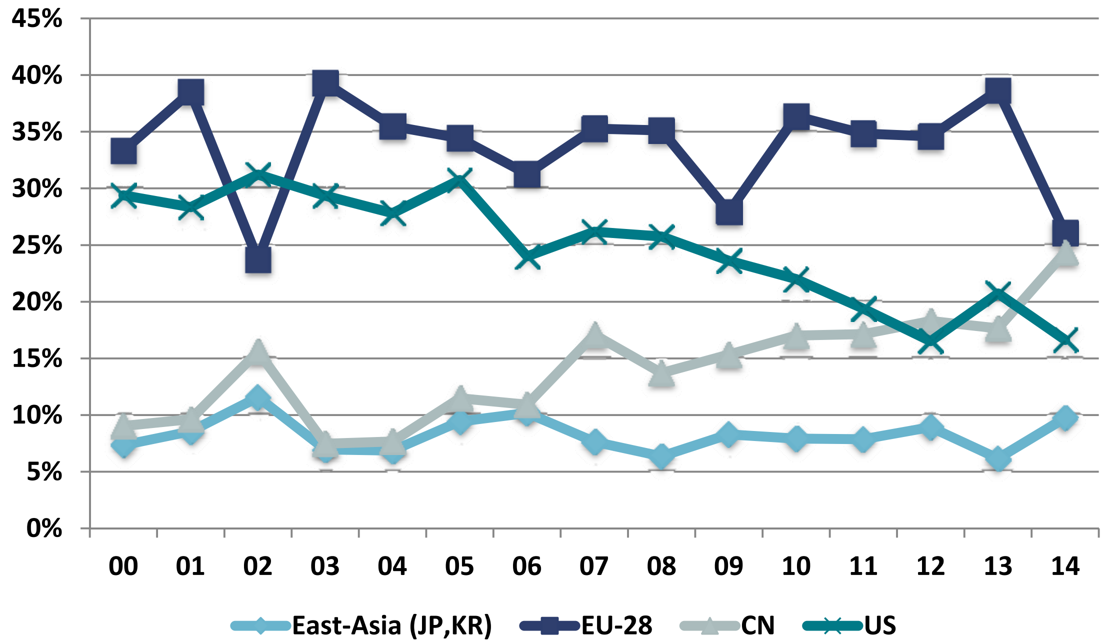


Figure A4.25: Shares of Web of Science Publications: digital age

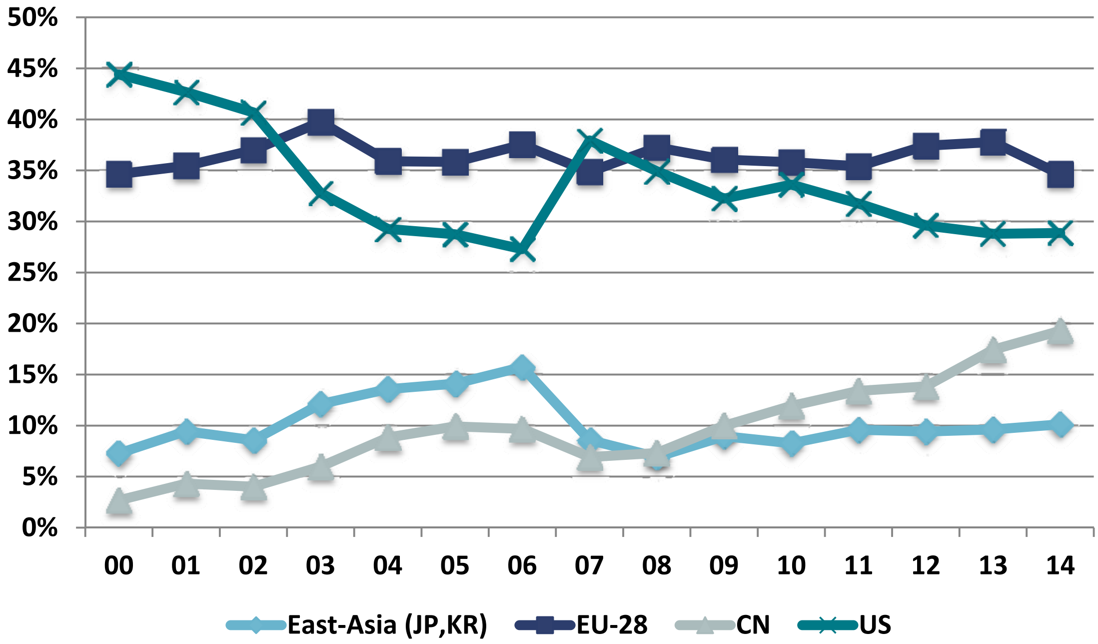


Figure A4.26: Shares of Web of Science Publications: space

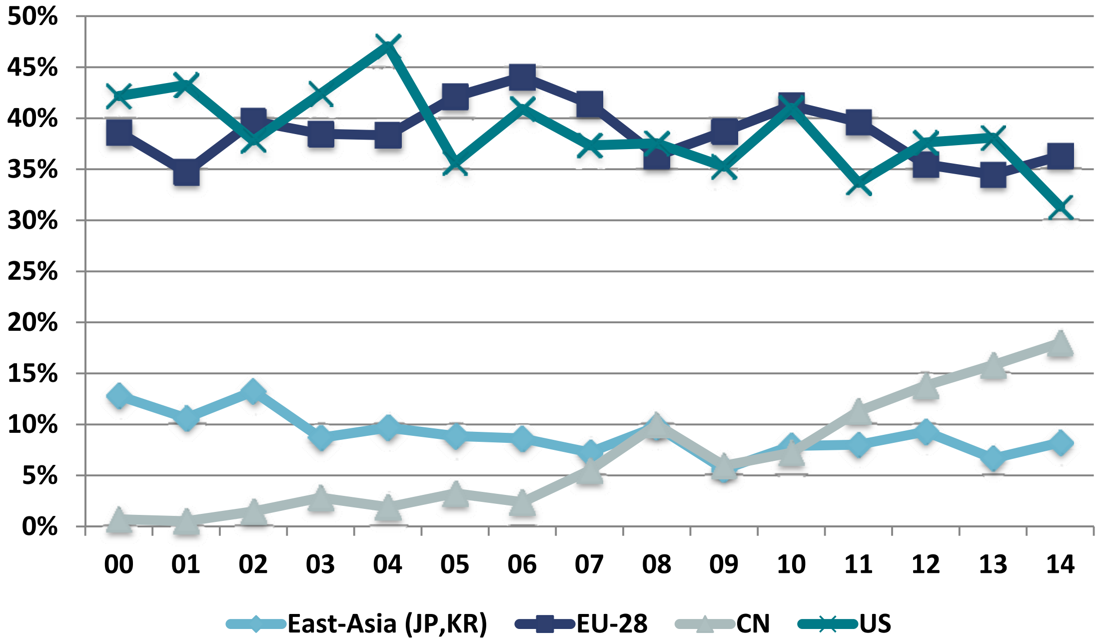


Figure A4.27: Shares of Web of Science Publications: health

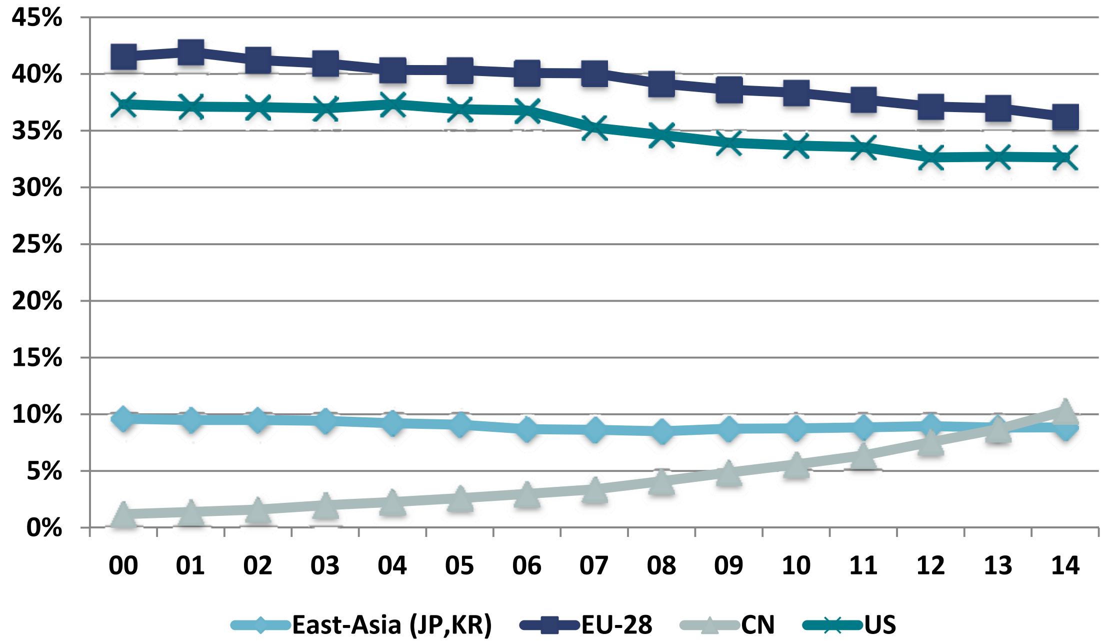


Figure A4.28: Shares of Web of Science Publications: food

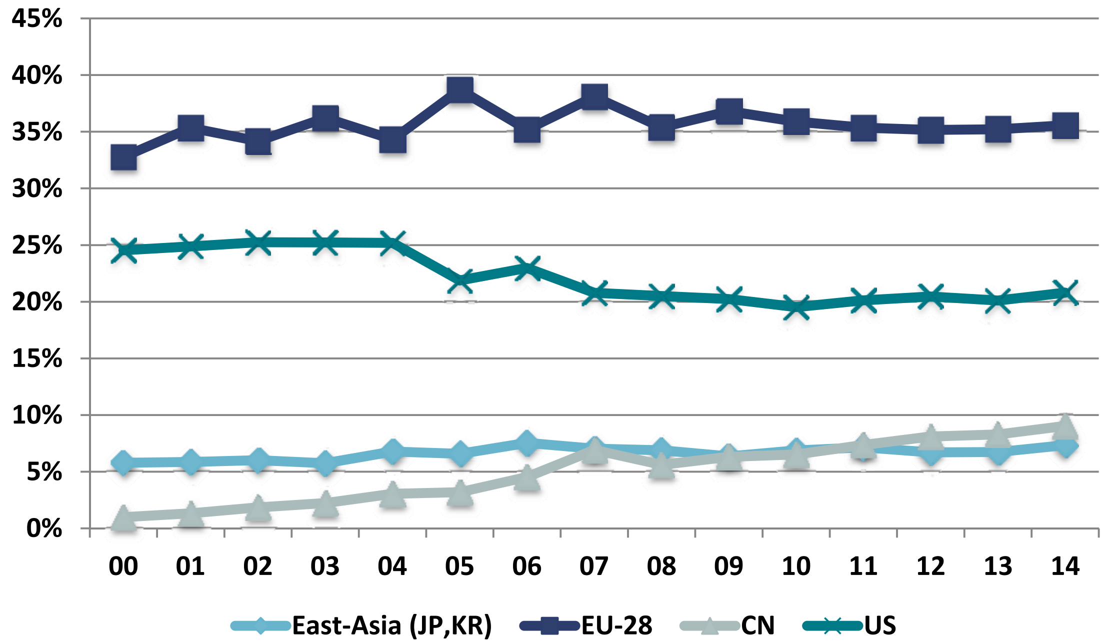


Figure A4.29: Shares of Web of Science Publications: energy

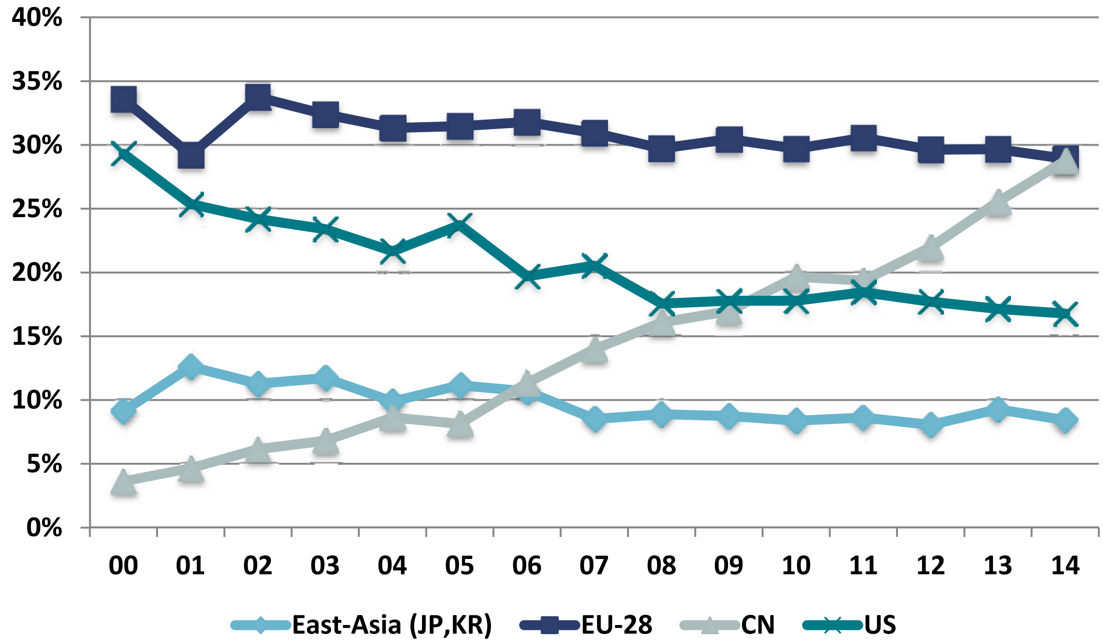


Figure A4.30: Shares of Web of Science Publications: transport

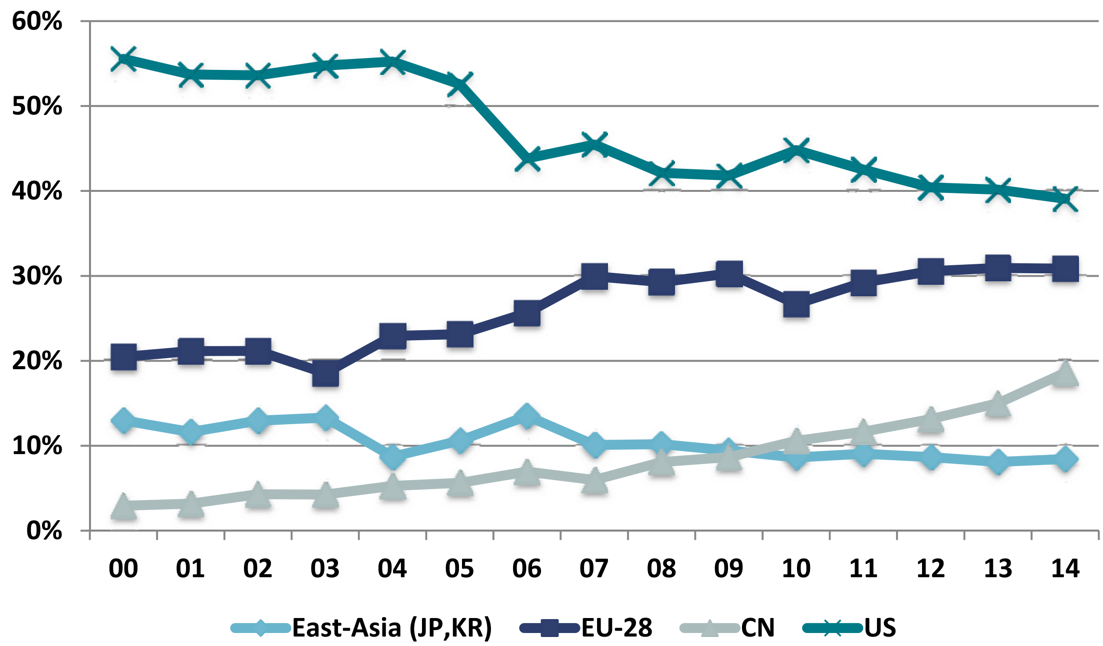


Figure A4.31: Shares of Web of Science Publications: climate

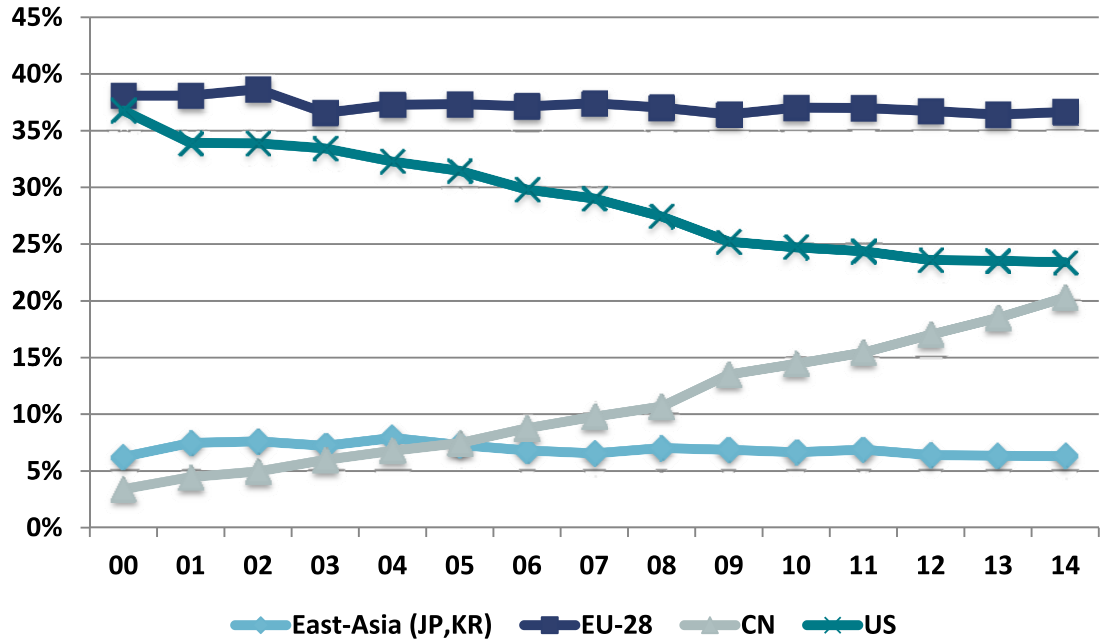
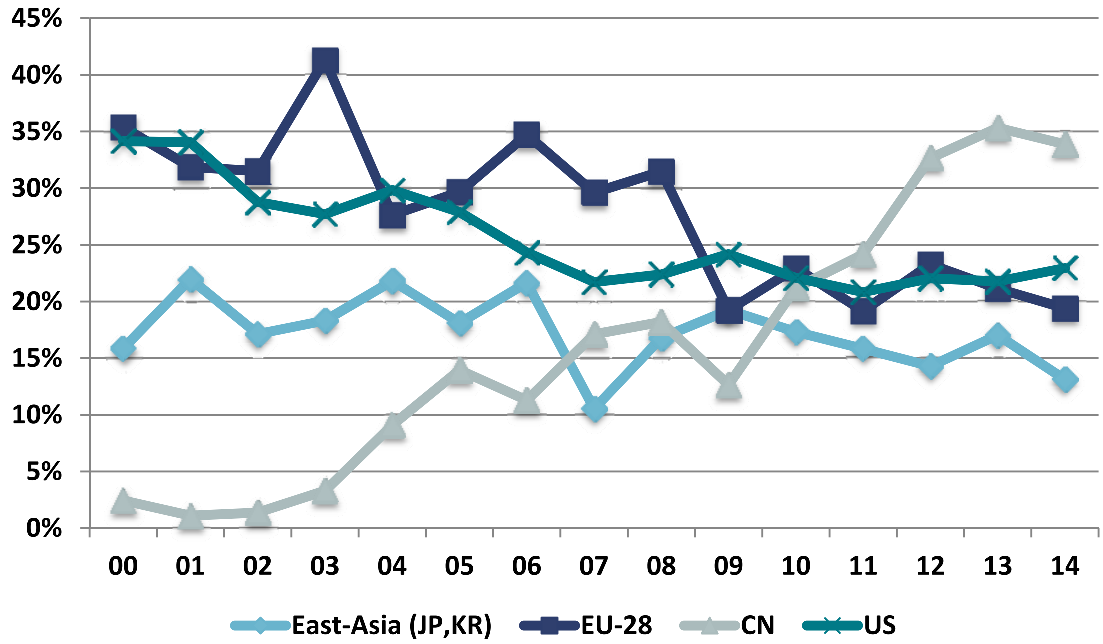


Figure A4.32: Shares of Web of Science Publications: security



2. PATENTS

Figure A4.33: Number of transnational patent applications in KETs in EU-28, USA, East-Asia and China

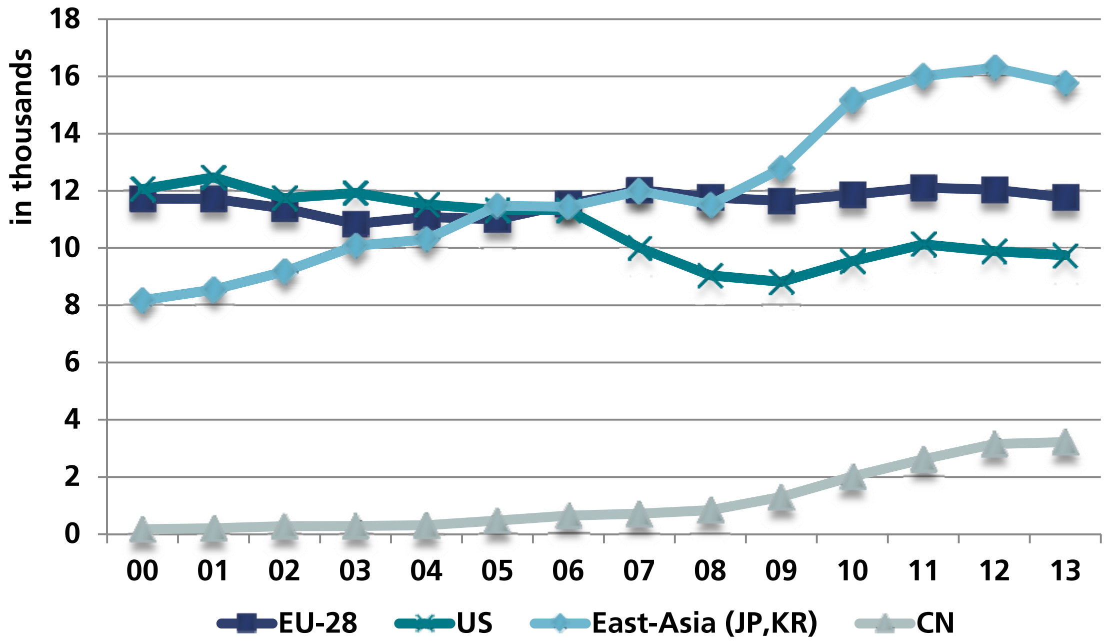


Figure A4.34: Number of transnational patent applications in KETs in EU-28, USA, East-Asia and China (part 2)

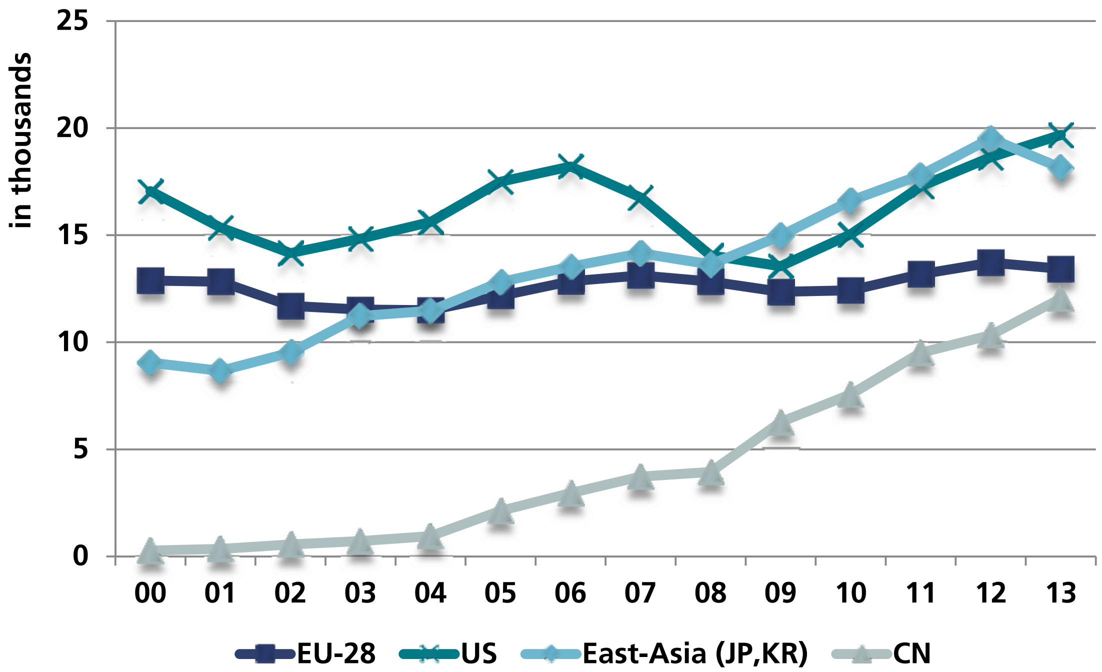


Figure A4.35: Shares of transnational patent applications in KETs in EU-28, USA, East-Asia and China

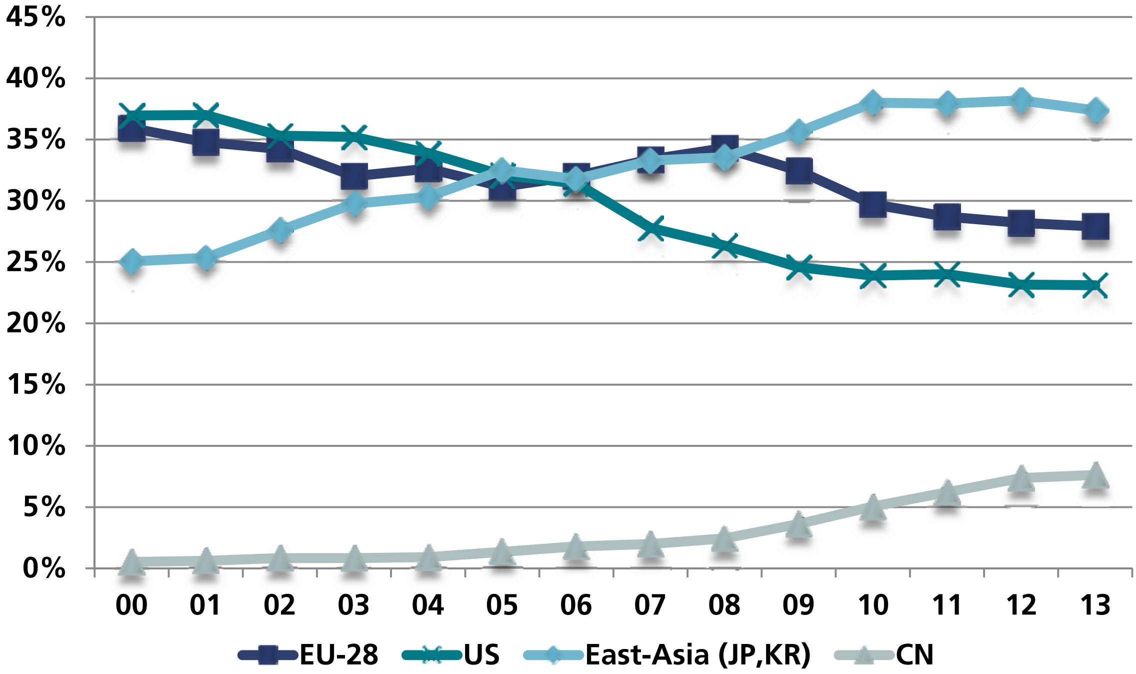


Figure A4.36: Shares of transnational patent applications in KETs in EU-28, USA, East-Asia and China (part 2)

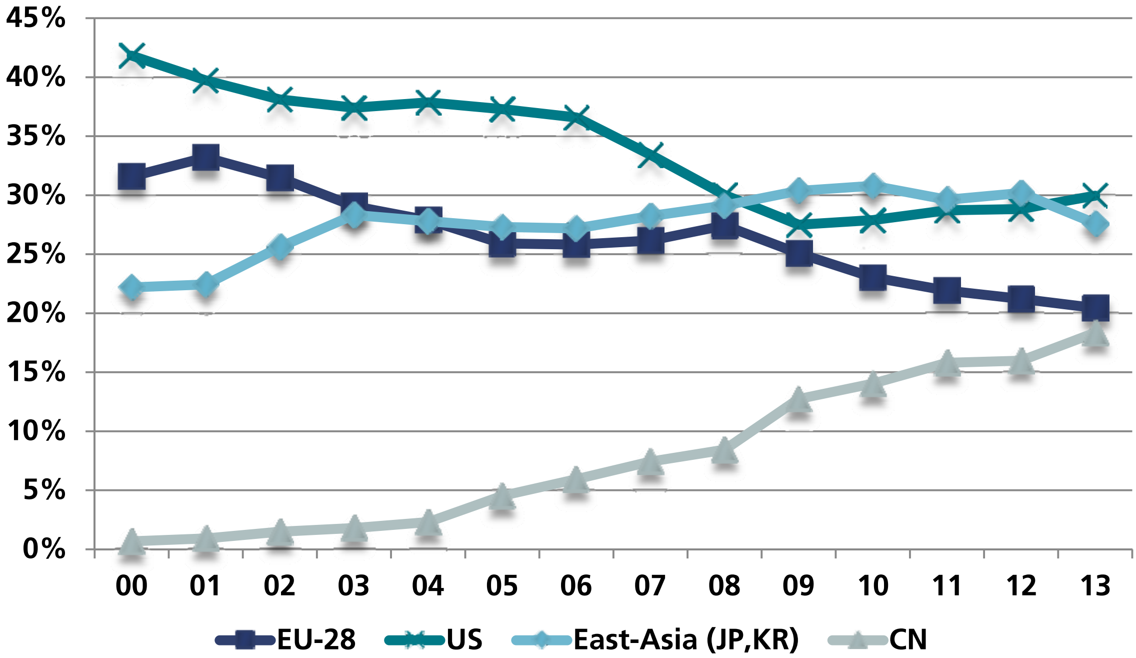


Figure A4.37: EU-28 shares of transnational patents: KETs

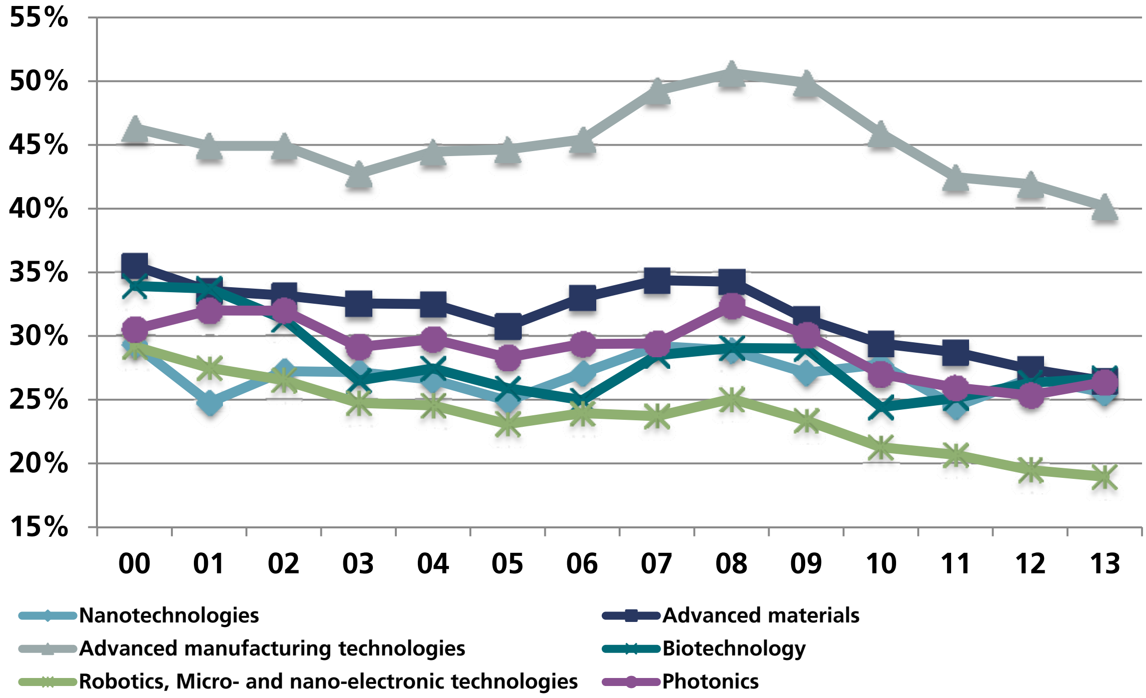


Figure A4.38: EU-28 shares of transnational patents: KETs (part 2)

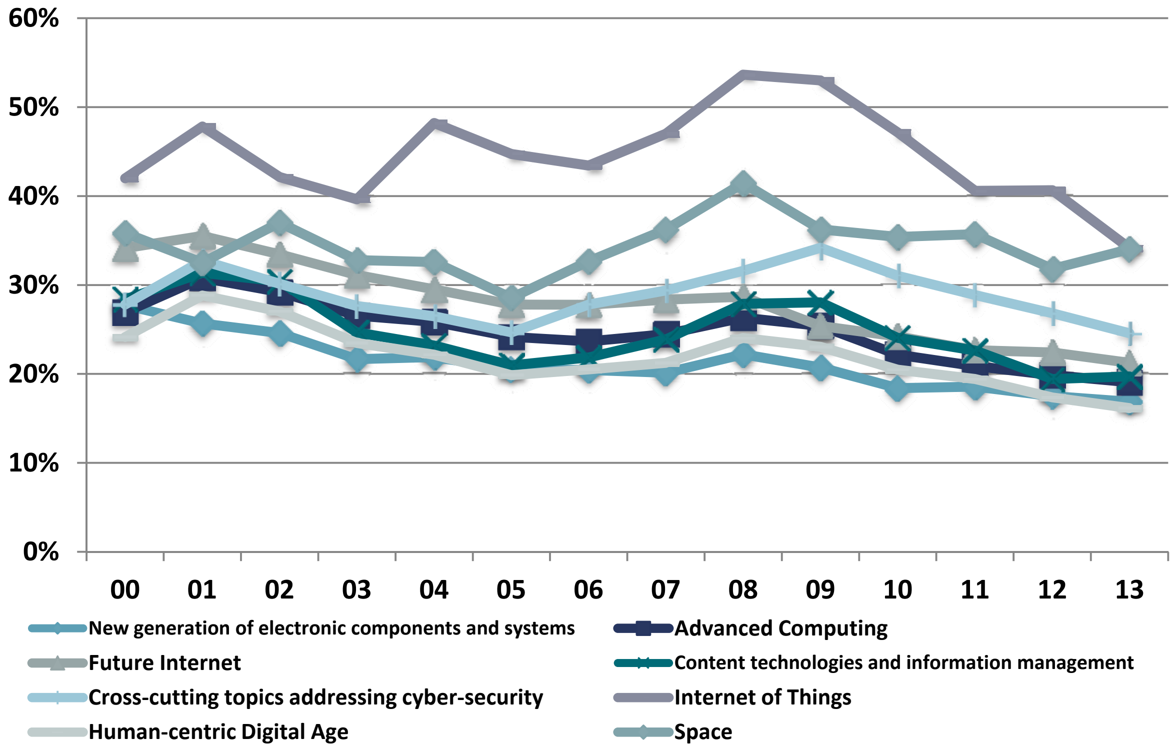


Figure A4.39: Number of transnational patent applications in SGCs in EU-28, USA, East-Asia and China

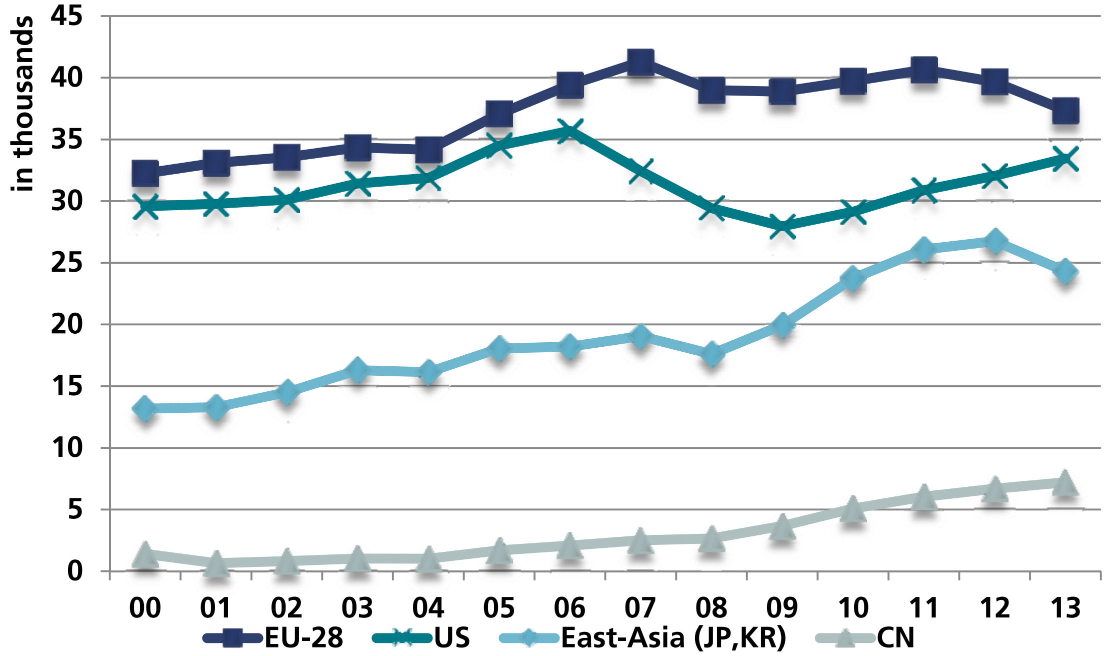


Figure A4.40: Shares of transnational patent applications in SGCs in EU-28, USA, East-Asia and China

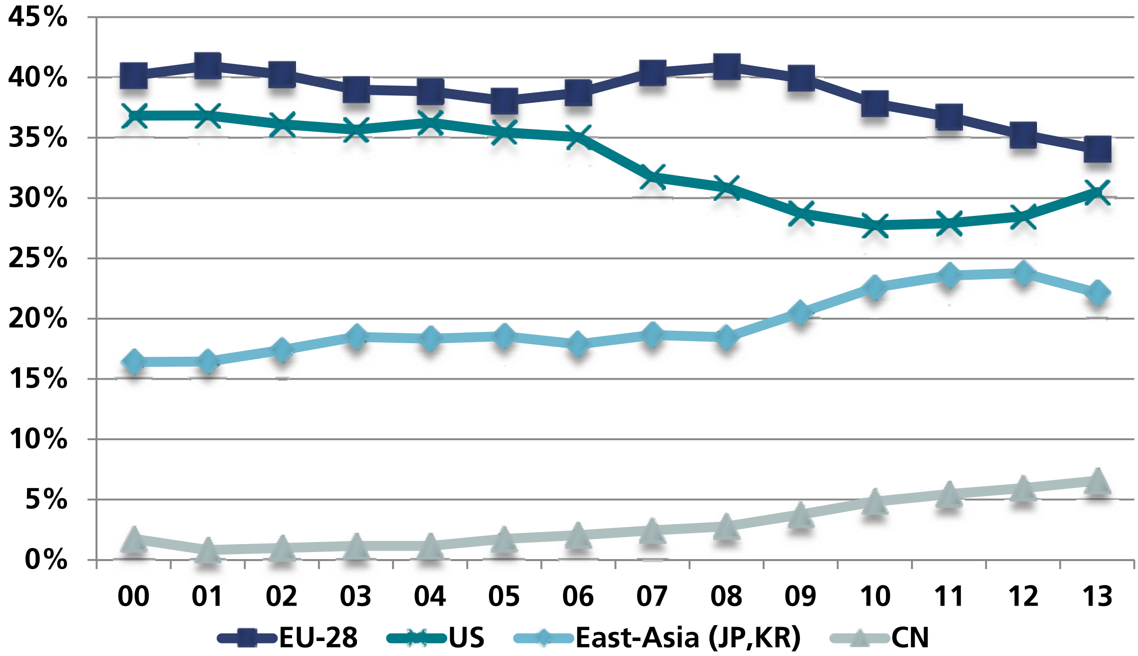


Figure A4.41: EU-28 shares of transnational patents: SGCs

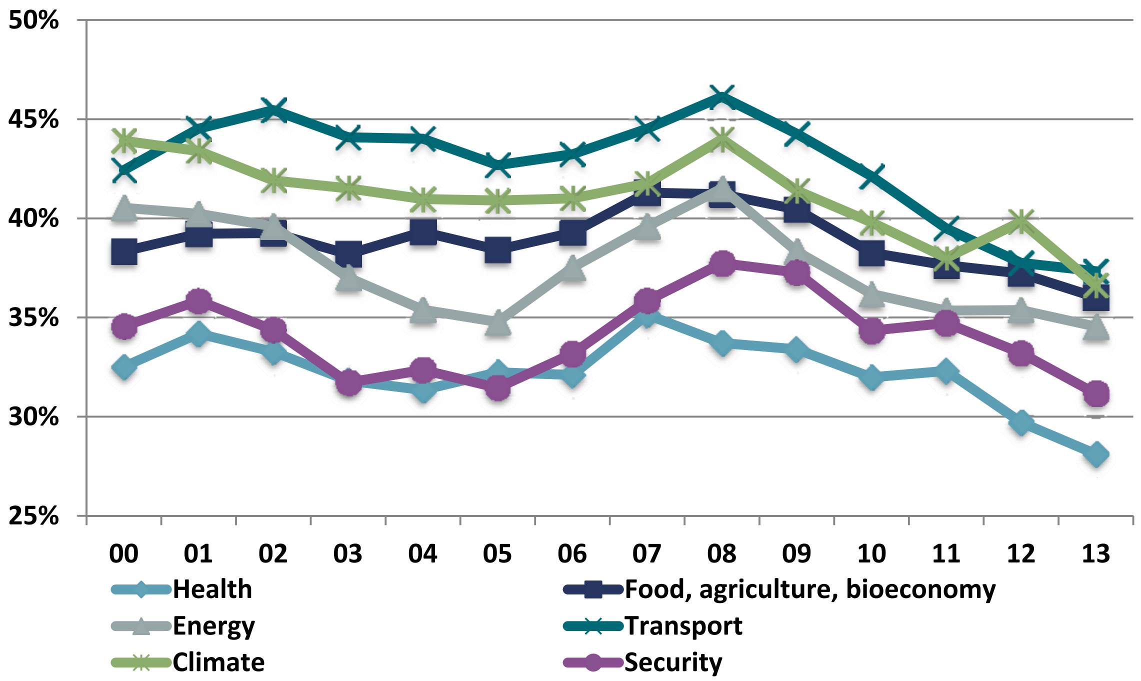


Figure A4.42: Specialisation profile 2009-2013: KETs

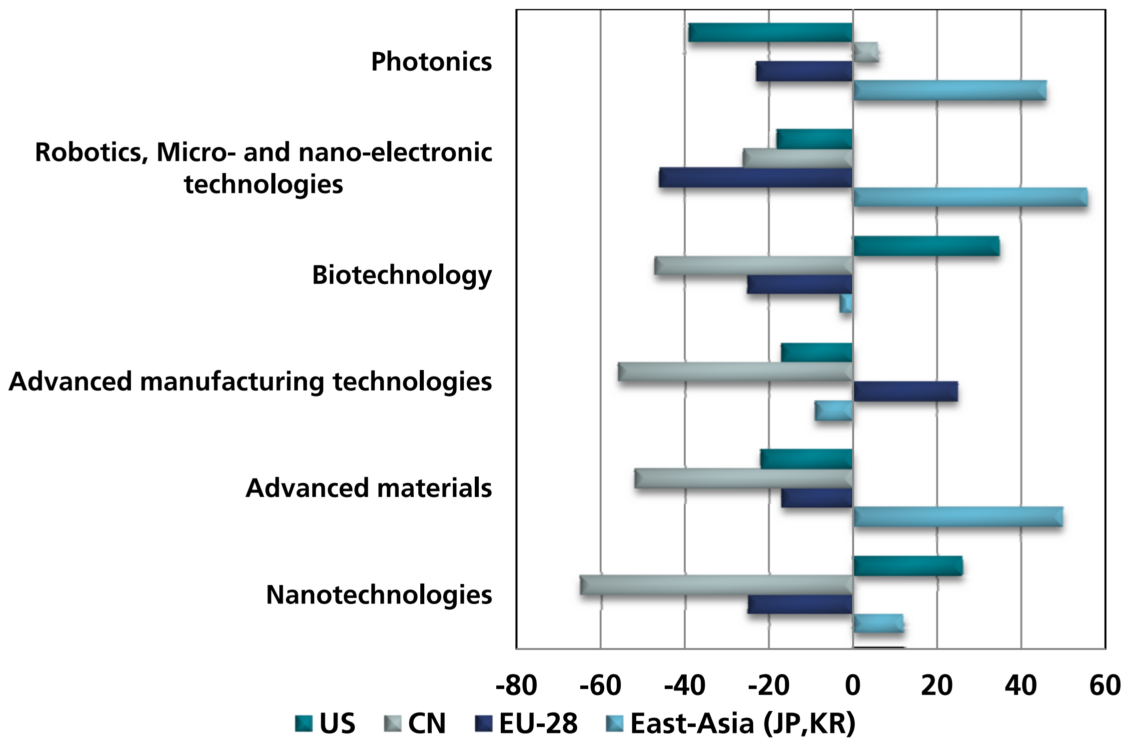


Figure A4.43: Specialisation profile 2009-2013: KETs (part 2)

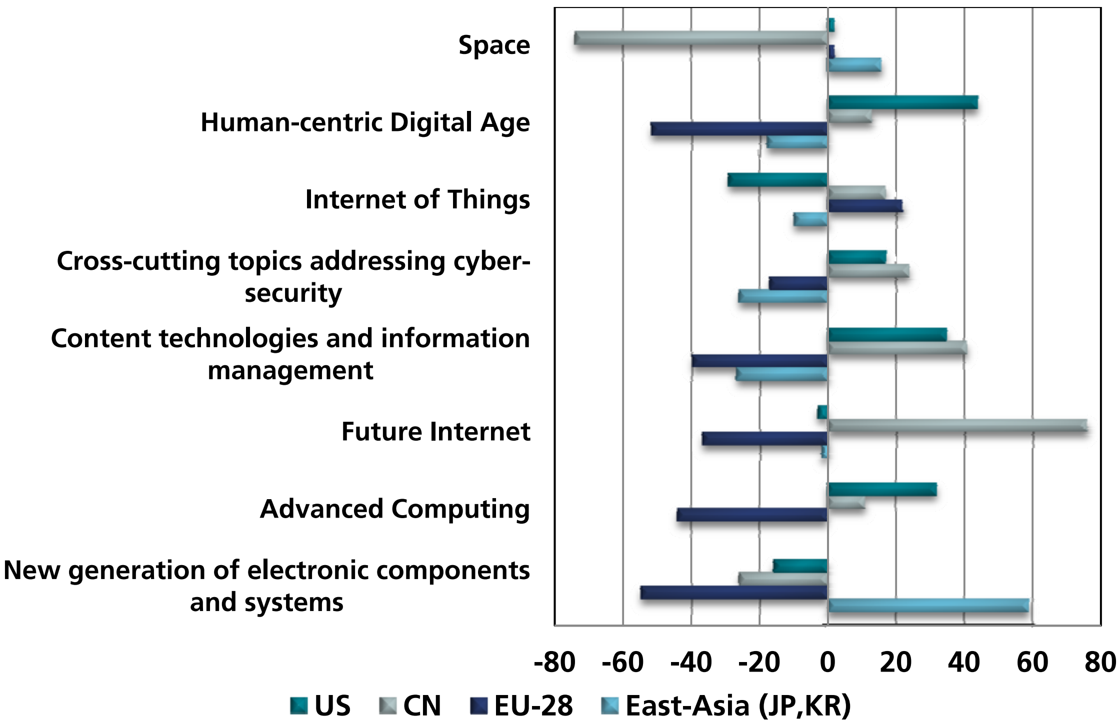


Figure A4.44: Specialisation profile 2009-2013: SGCs

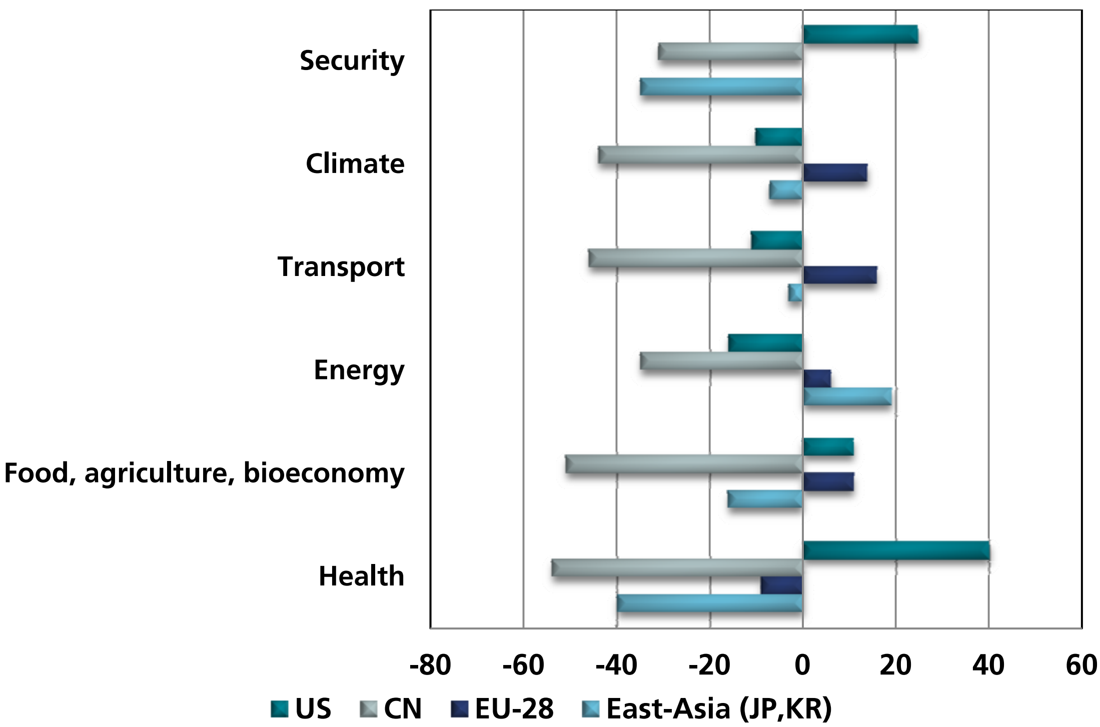


Figure A4.45: Shares of transnational patents: nanotechnology

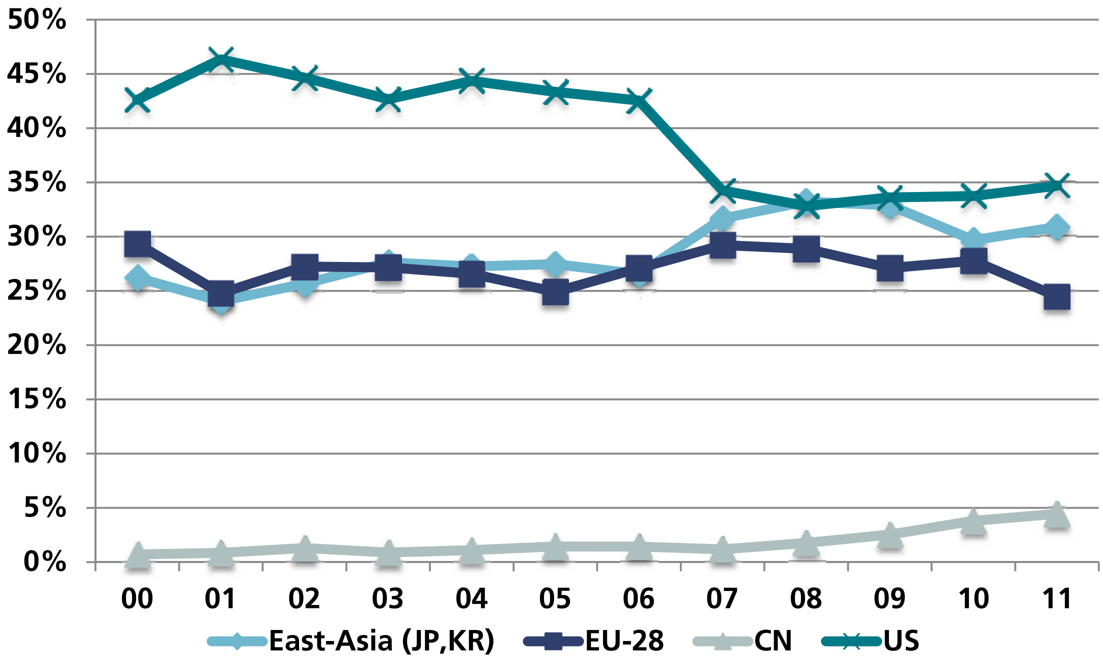


Figure A4.46: Shares of transnational patents: advanced materials

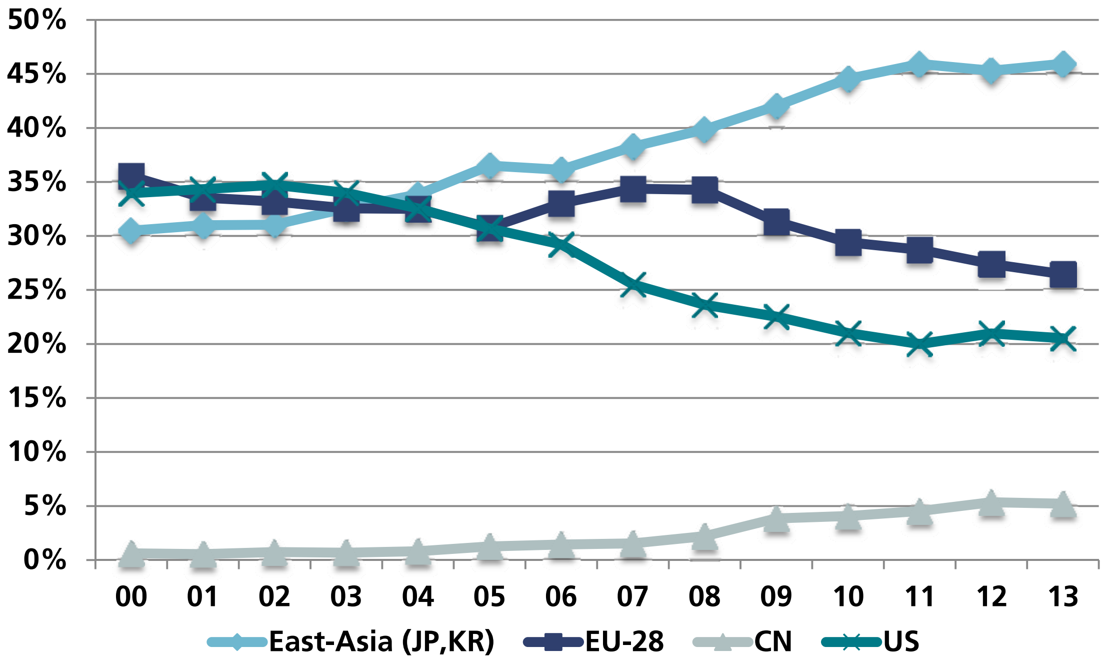


Figure A4.47: Shares of transnational patents: advanced manufacturing

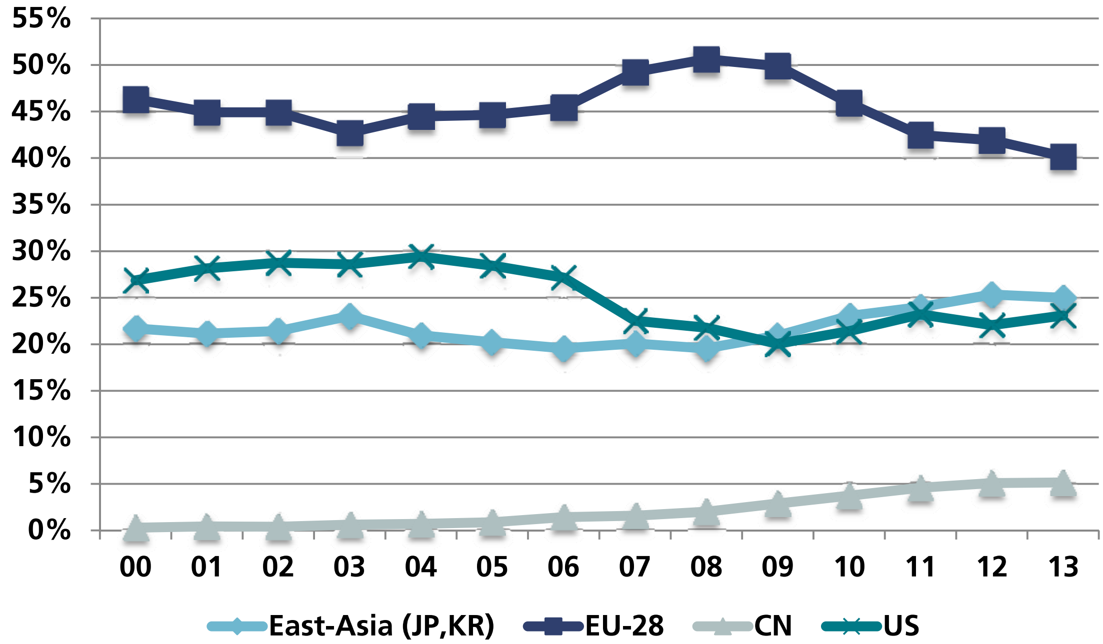


Figure A4.48: Shares of transnational patents: biotechnology

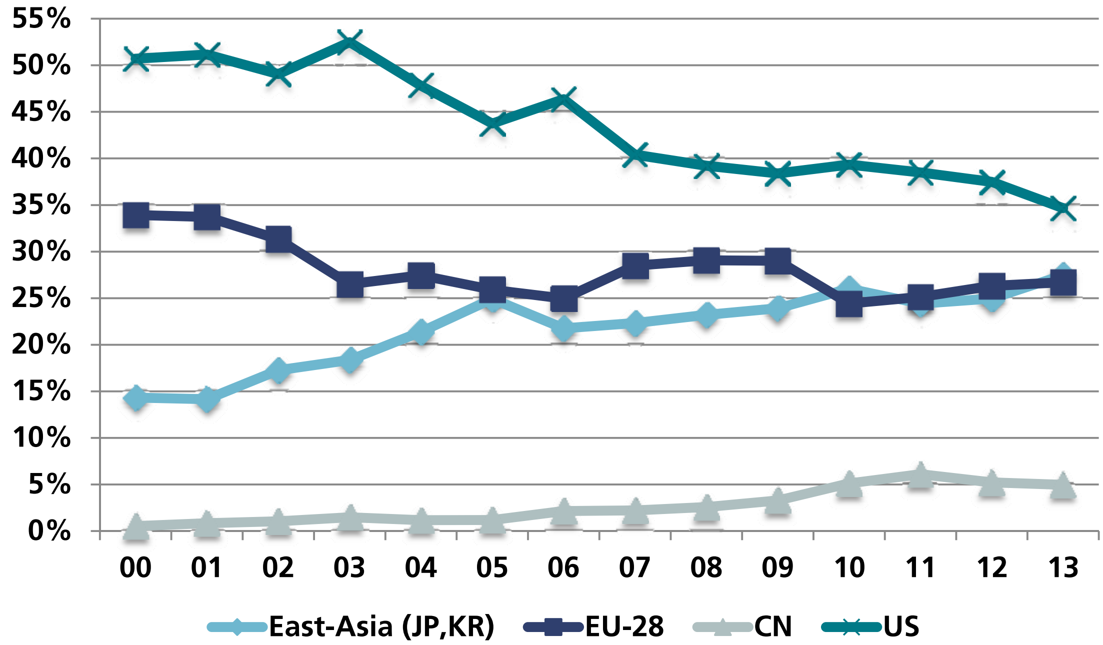


Figure A4.49: Shares of transnational patents: robotics, micro- and nano-electronics

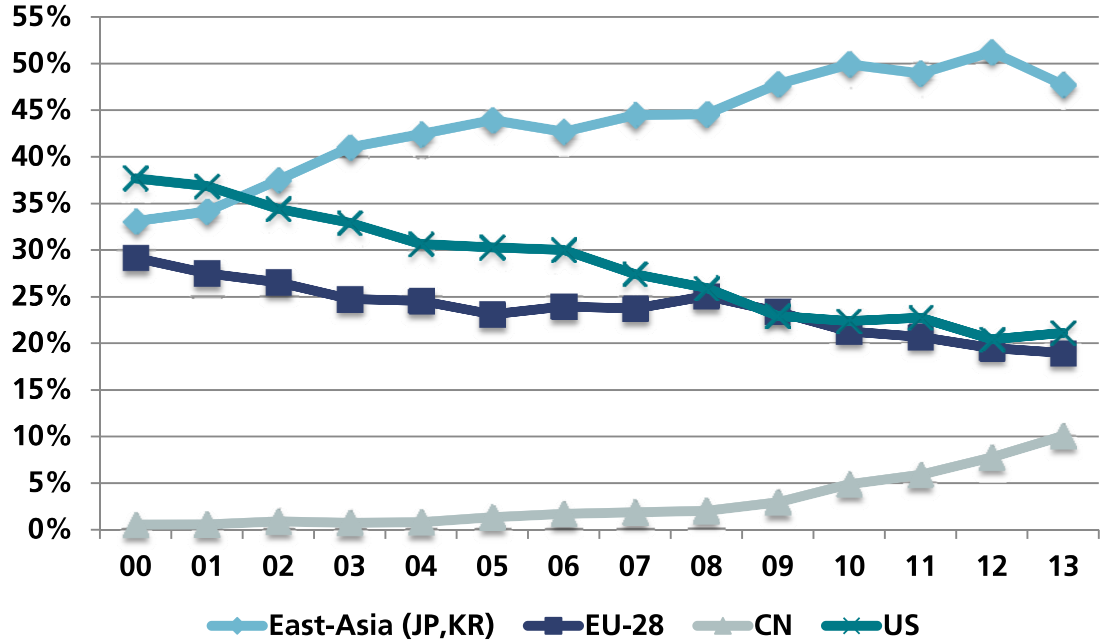


Figure A4.50: Shares of transnational patents: photonics

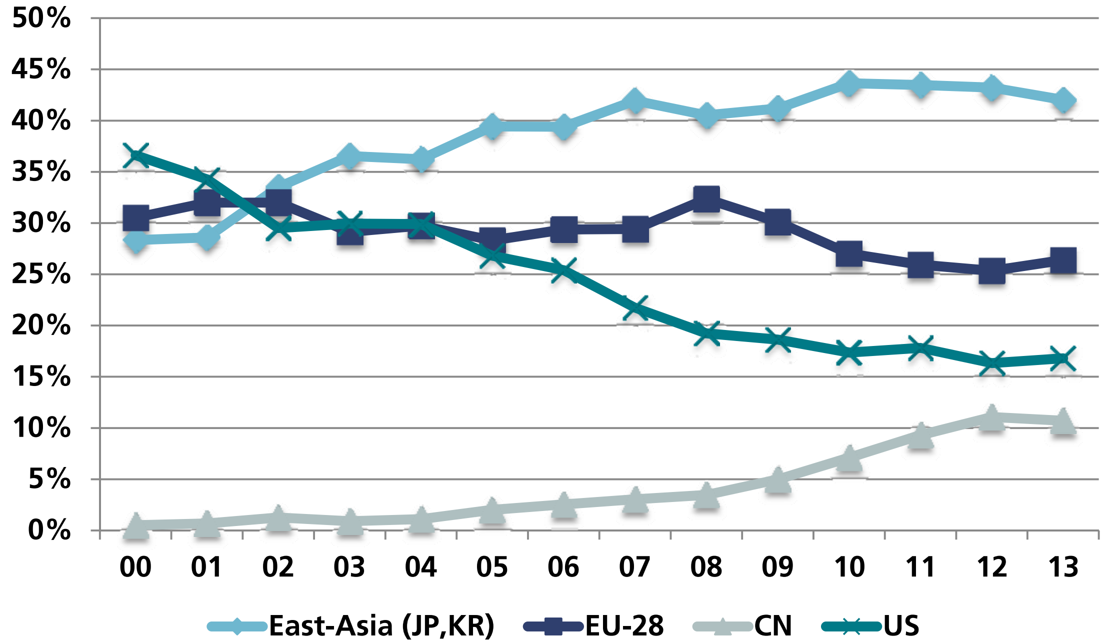


Figure A4.51: Shares of transnational patents: electrical components and systems

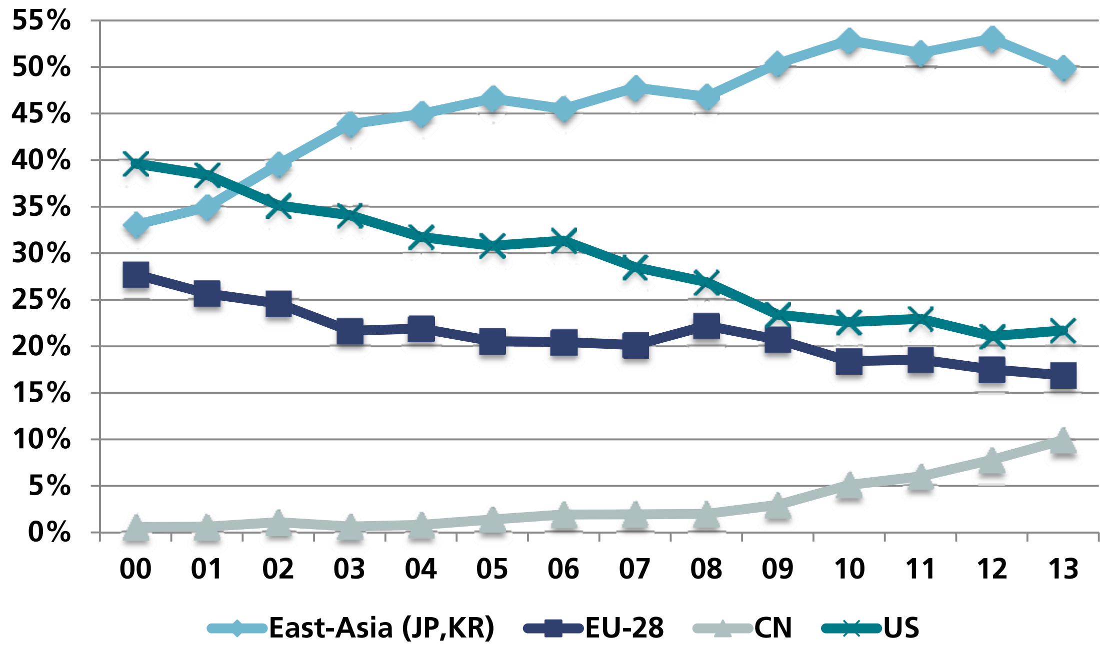


Figure A4.52: Shares of transnational patents: advanced computing

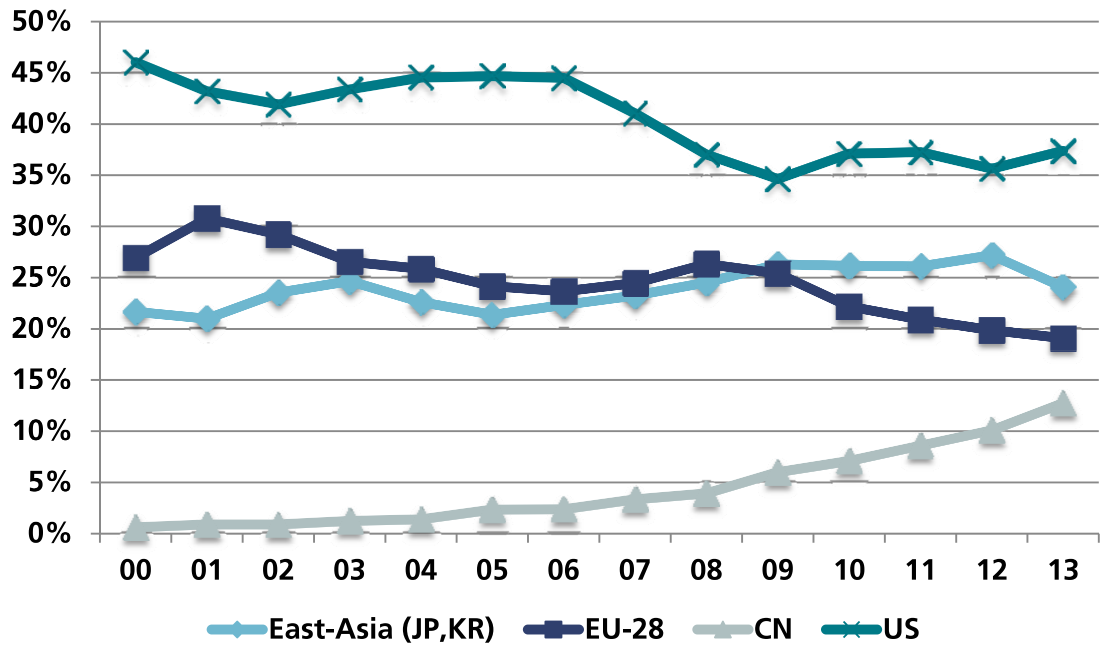


Figure A4.53: Shares of transnational patents: future Internet

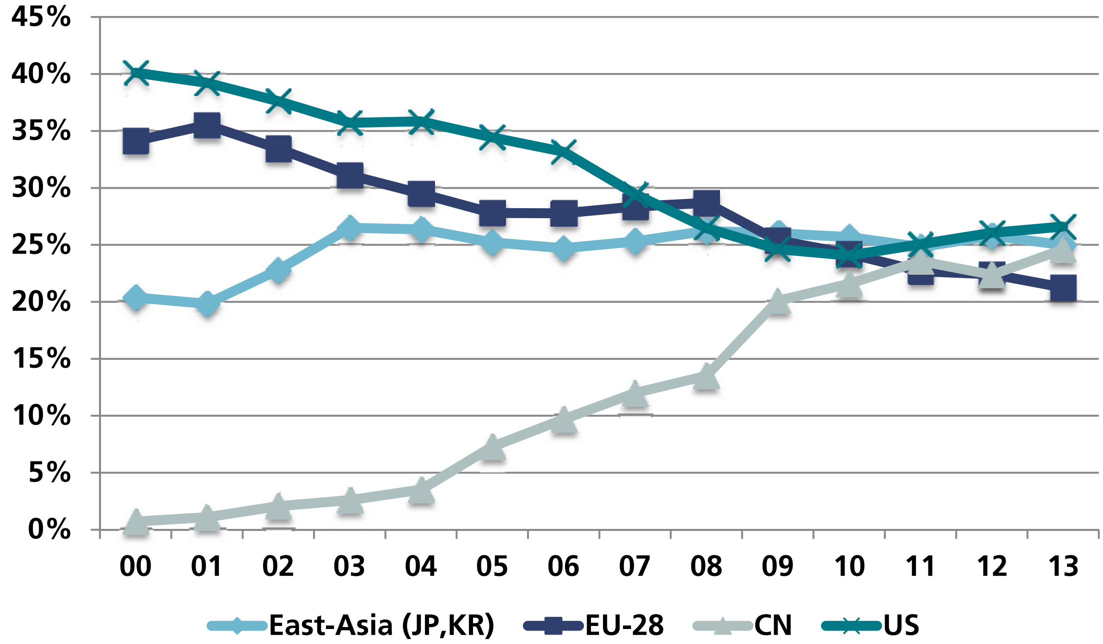


Figure A4.54: Shares of transnational patents: content technologies and information management

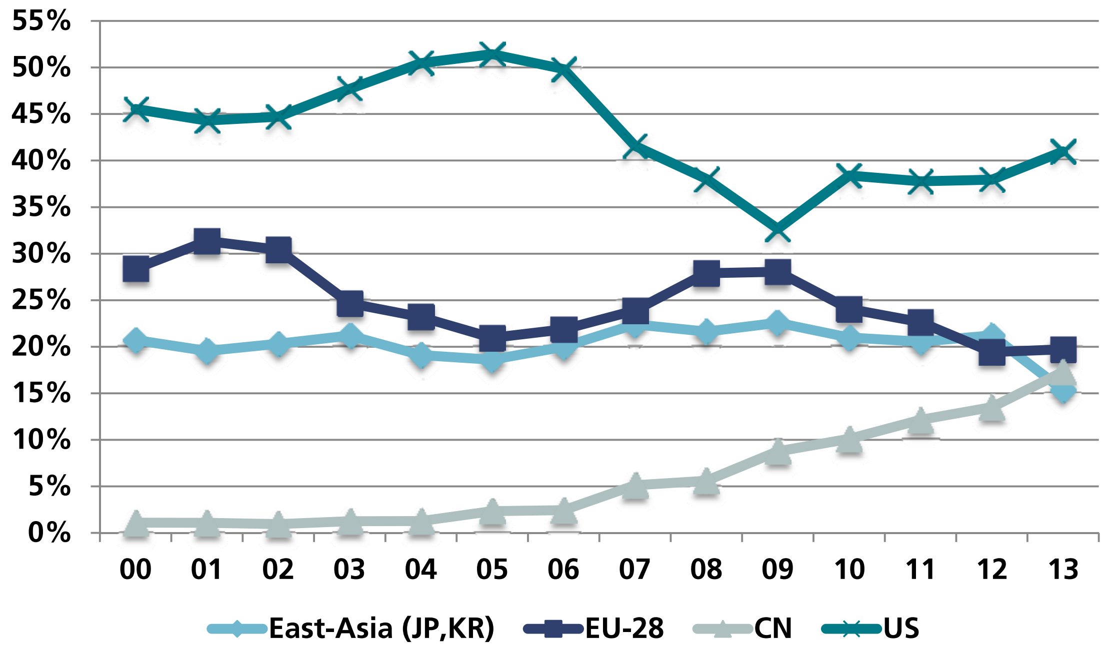


Figure A4.55: Shares of transnational patents: cyber security

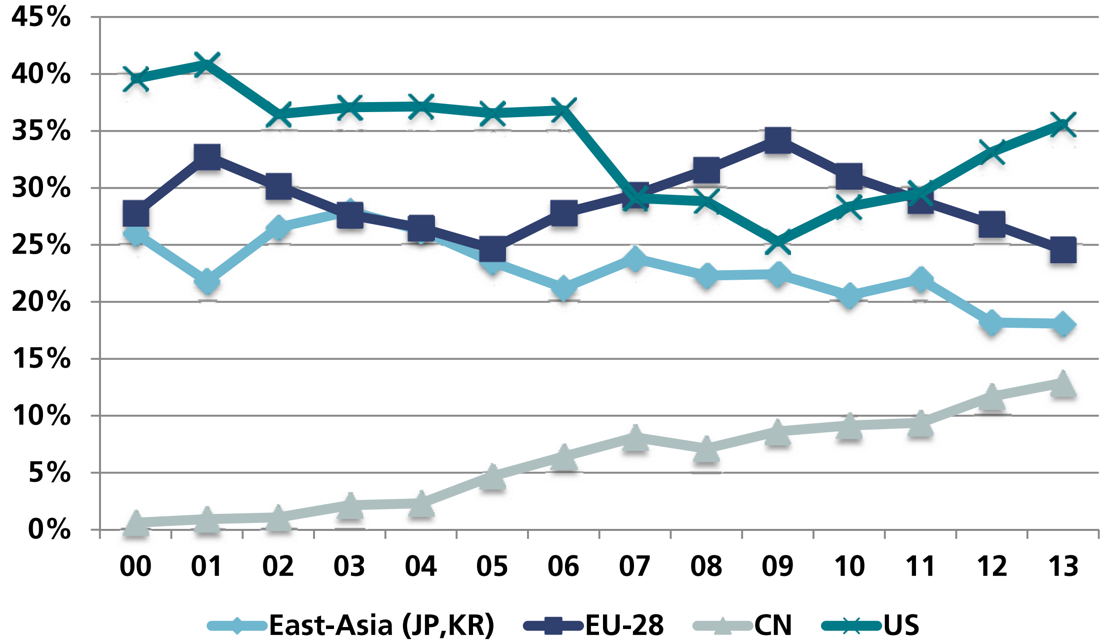


Figure A4.56: Shares of transnational patents: Internet of Things

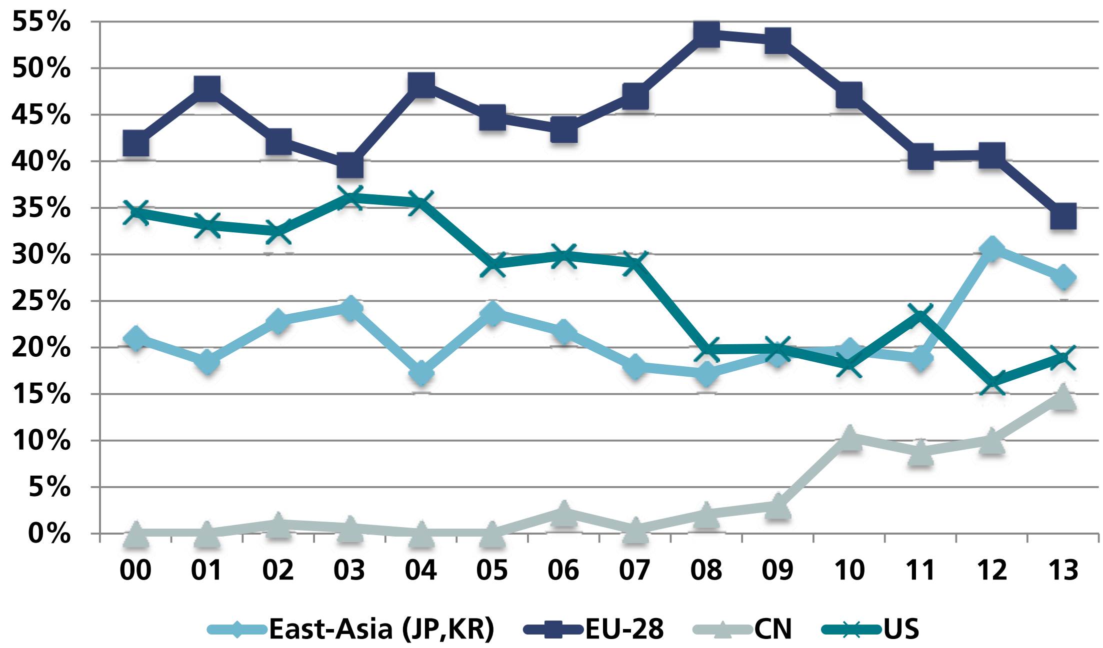


Figure A4.57: Shares of transnational patents: digital age

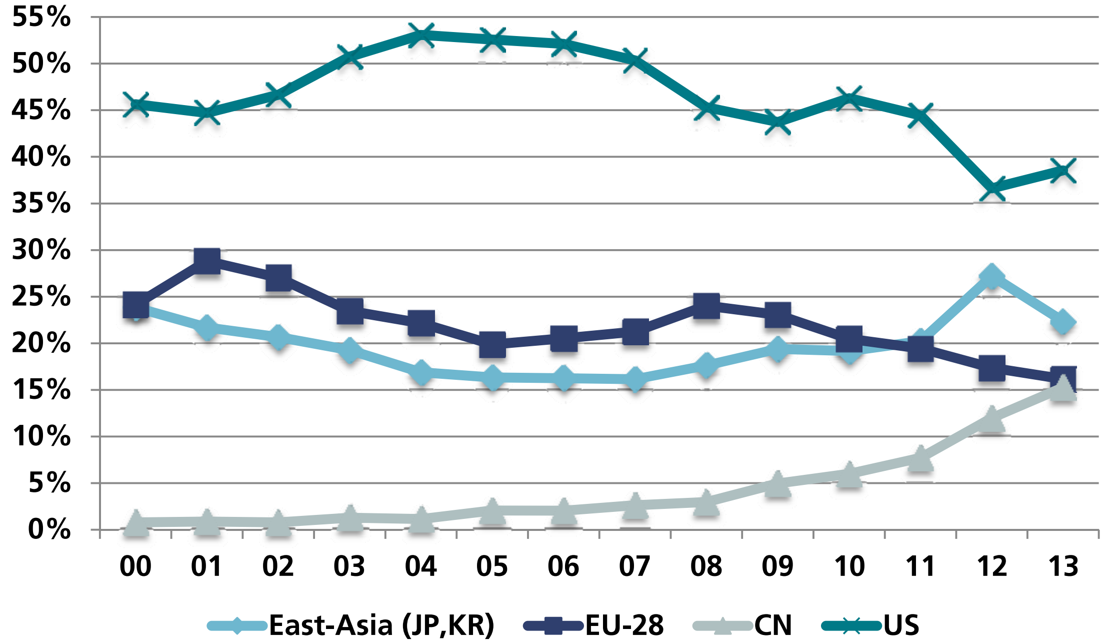


Figure A4.58: Shares of transnational patents: space

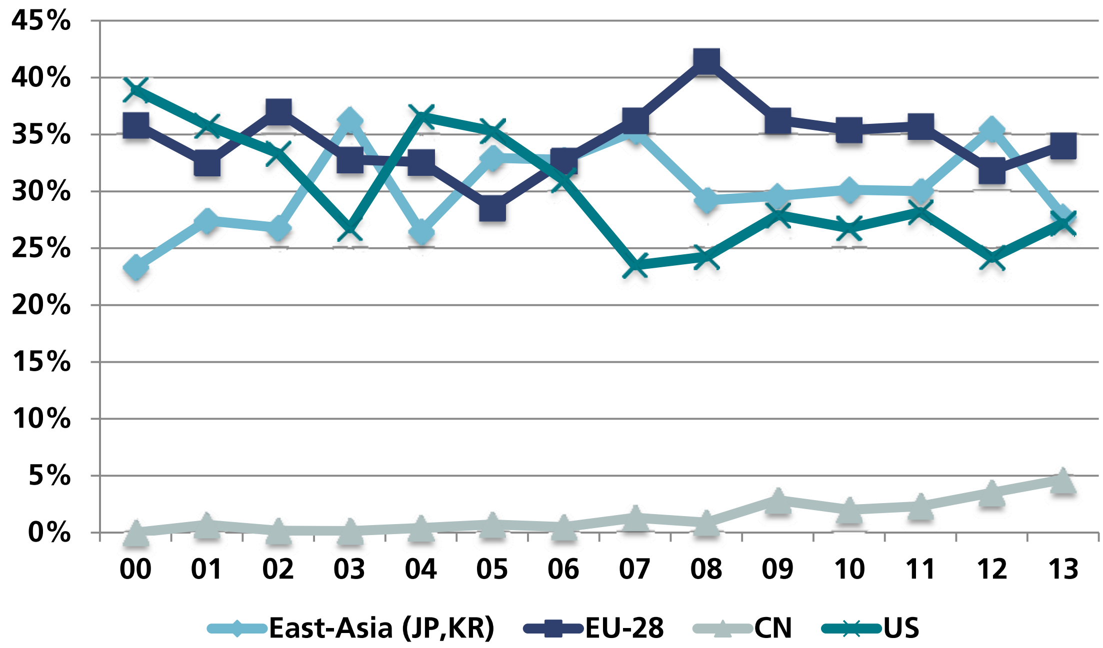


Figure A4.59: Shares of transnational patents: health

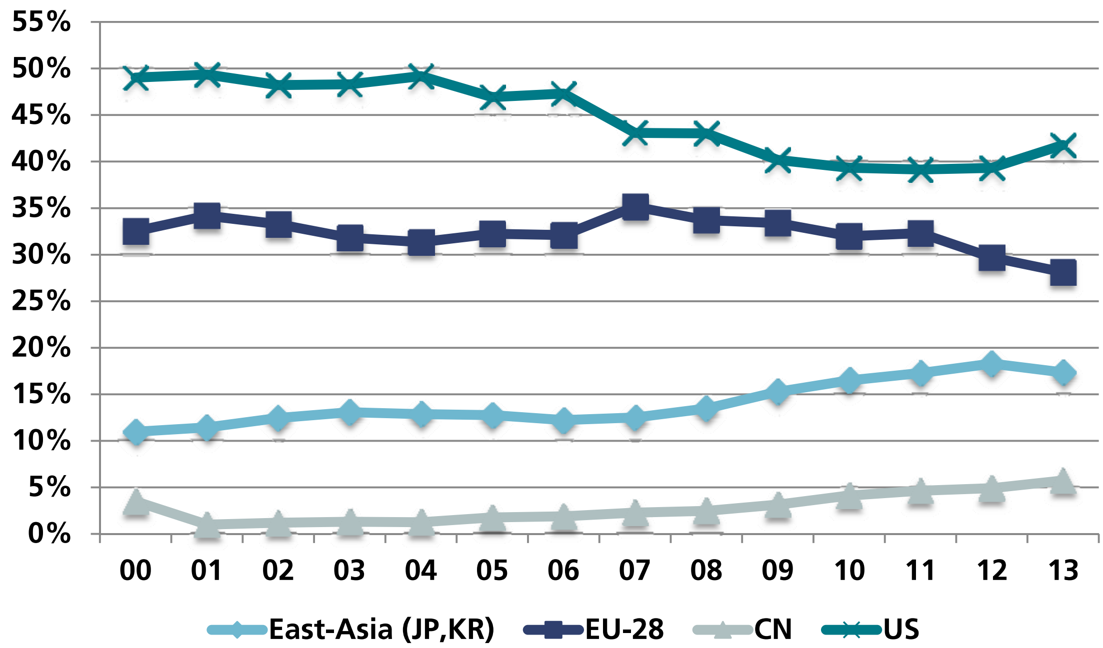


Figure A4.60: Shares of transnational patents: food

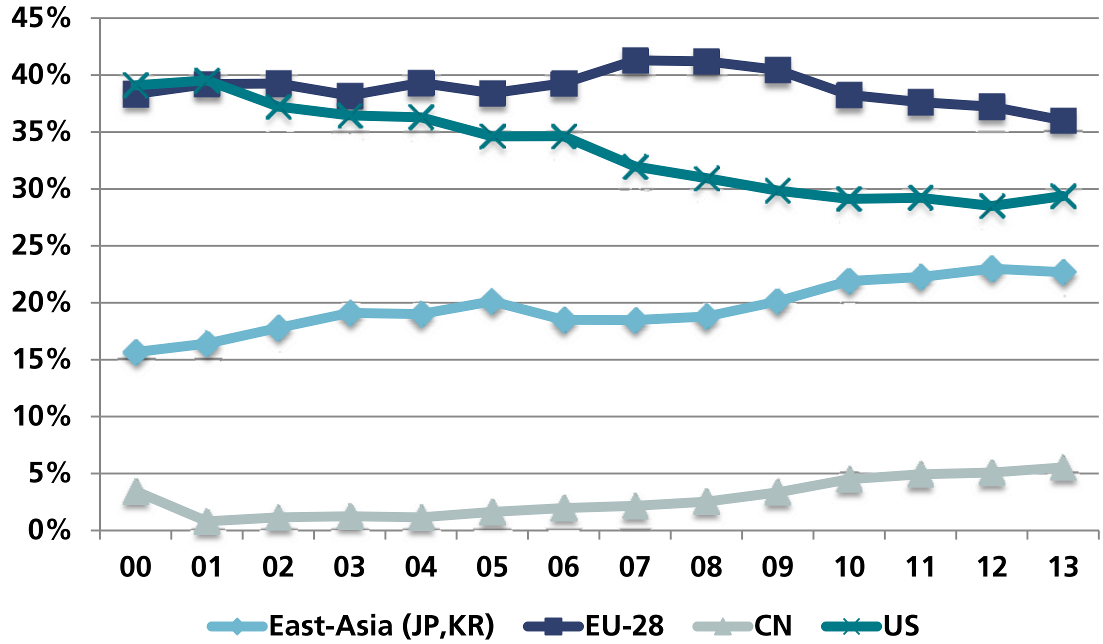


Figure A4.61: Shares of transnational patents: energy

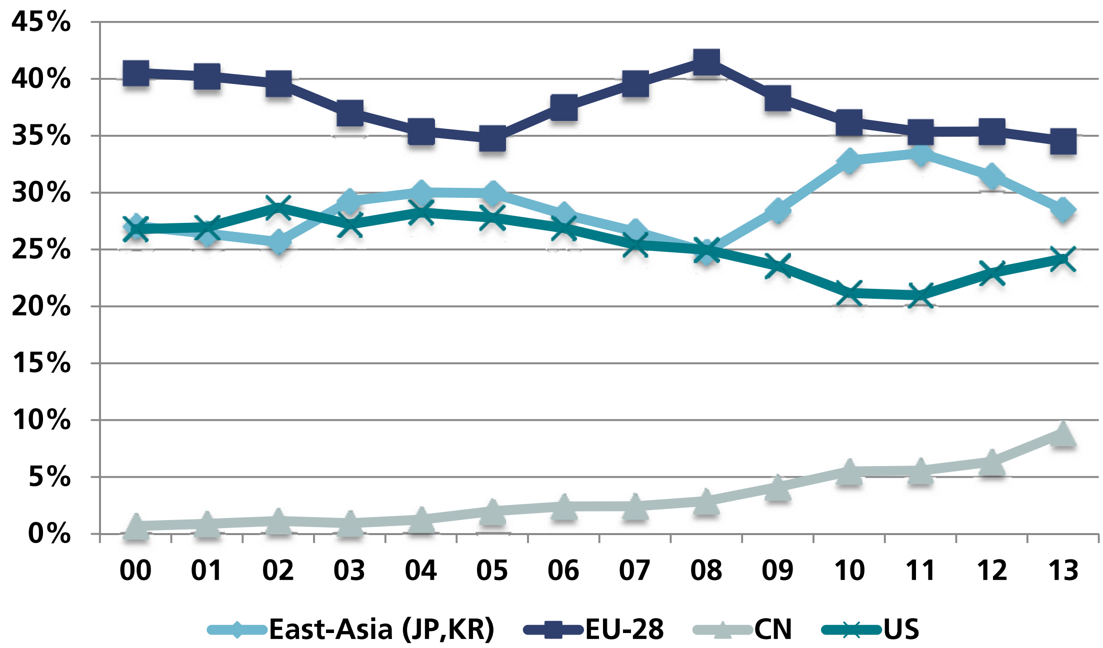


Figure A4.62: Shares of transnational patents: transport

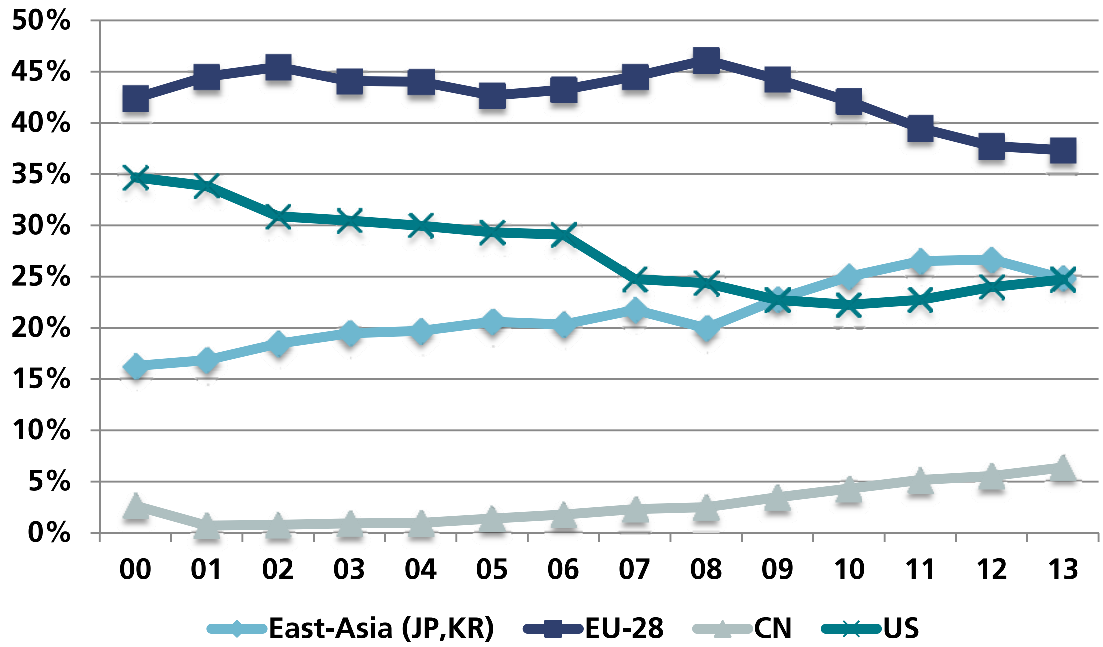


Figure A4.63: Shares of transnational patents: climate

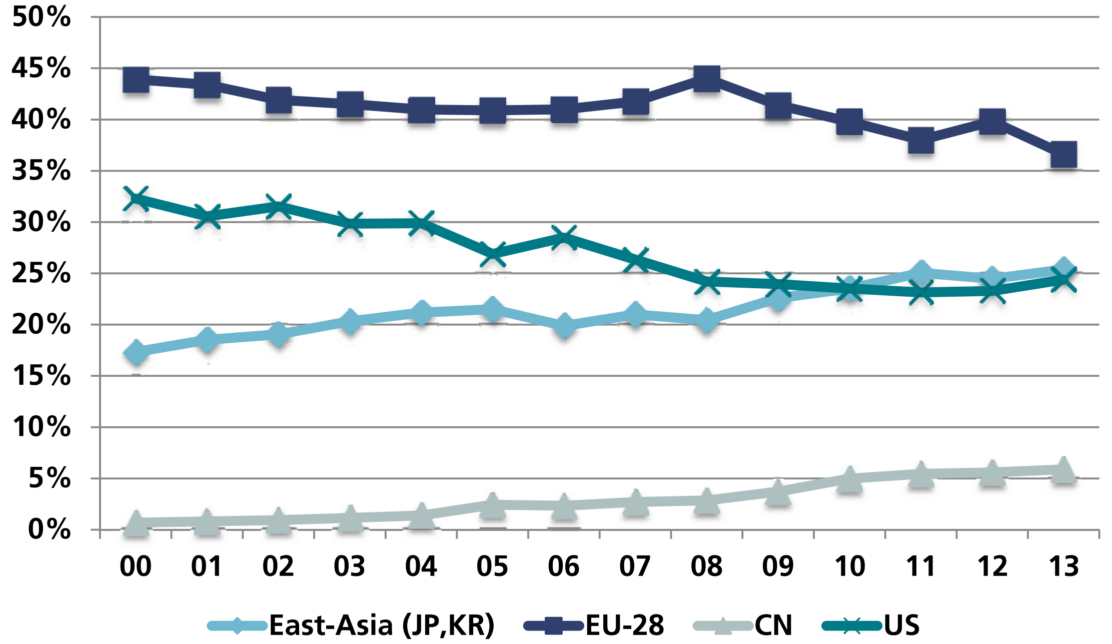
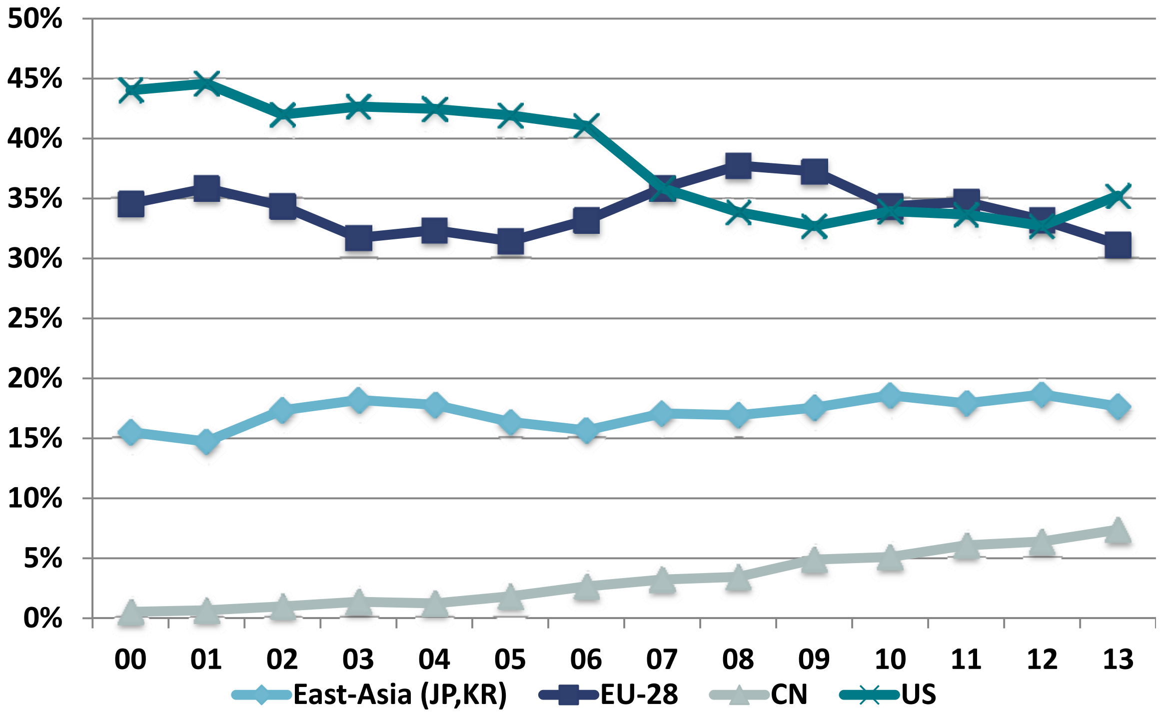
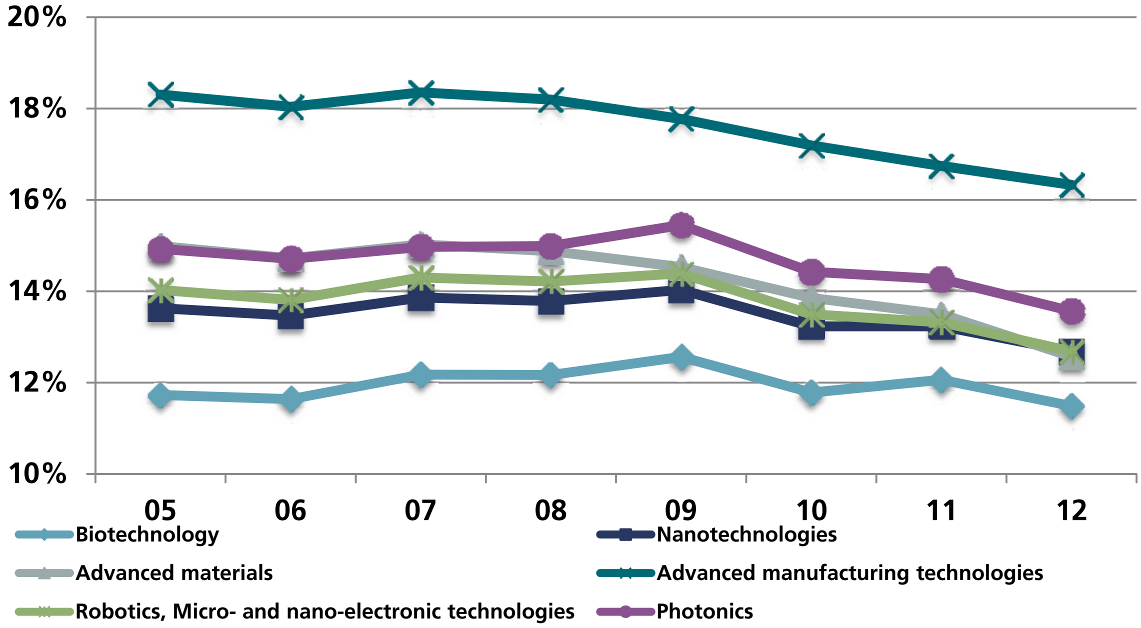


Figure A4.64: Shares of transnational patents: security



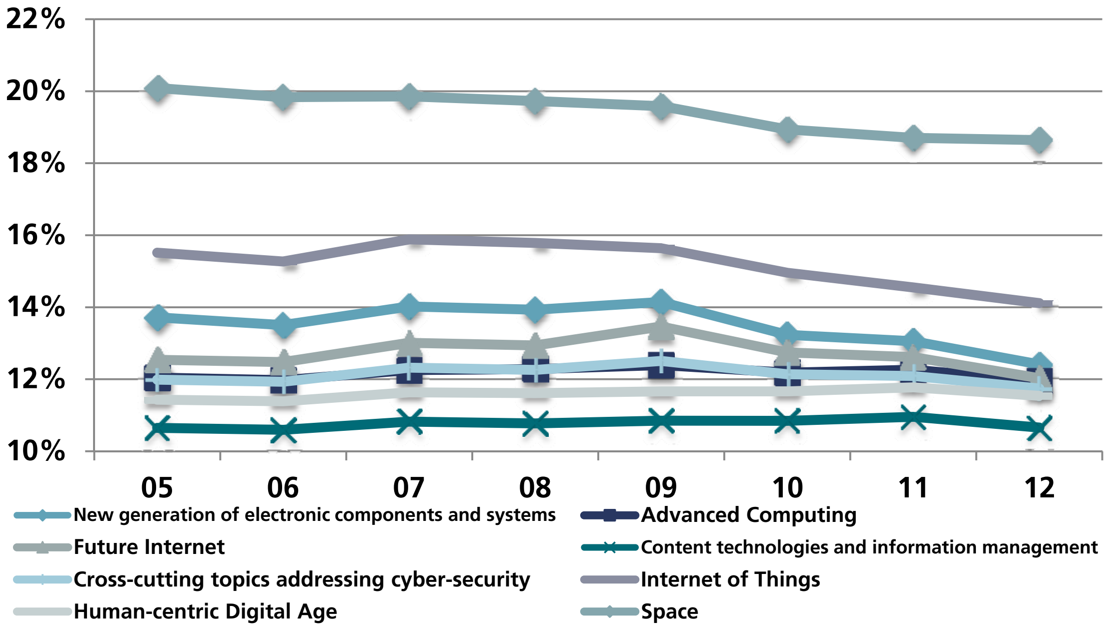
3. RESEARCH AND DEVELOPMENT (R&D)

Figure A4.65: EU-28 shares of R&D: KETs



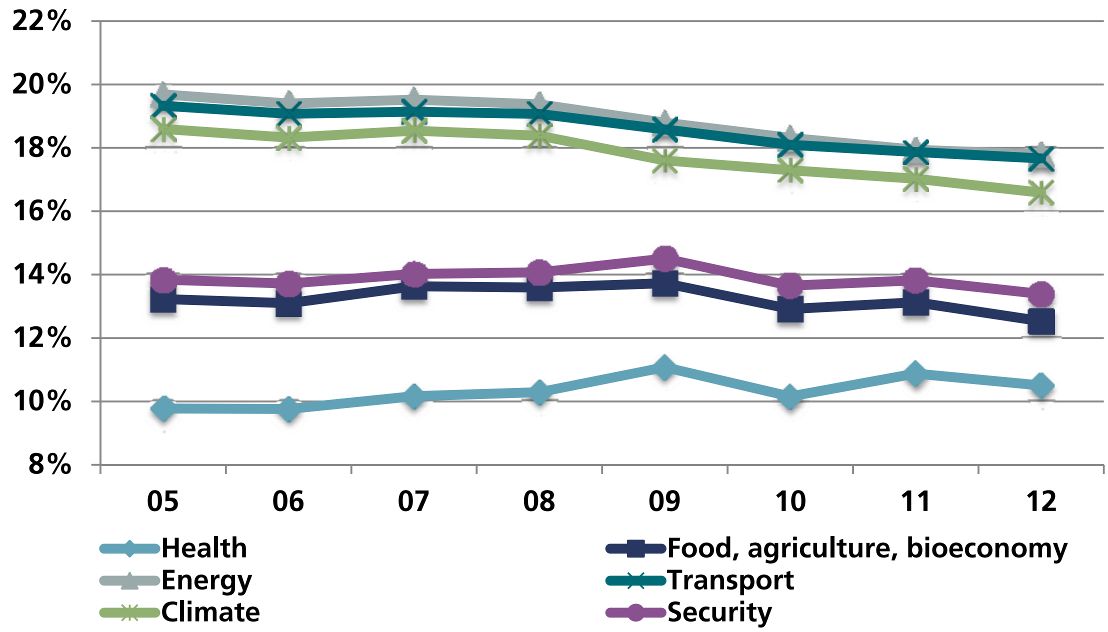
Note: EU-28 without Greece and Luxembourg

Figure A4.66: EU-28 shares of R&D: KETs (part 2)



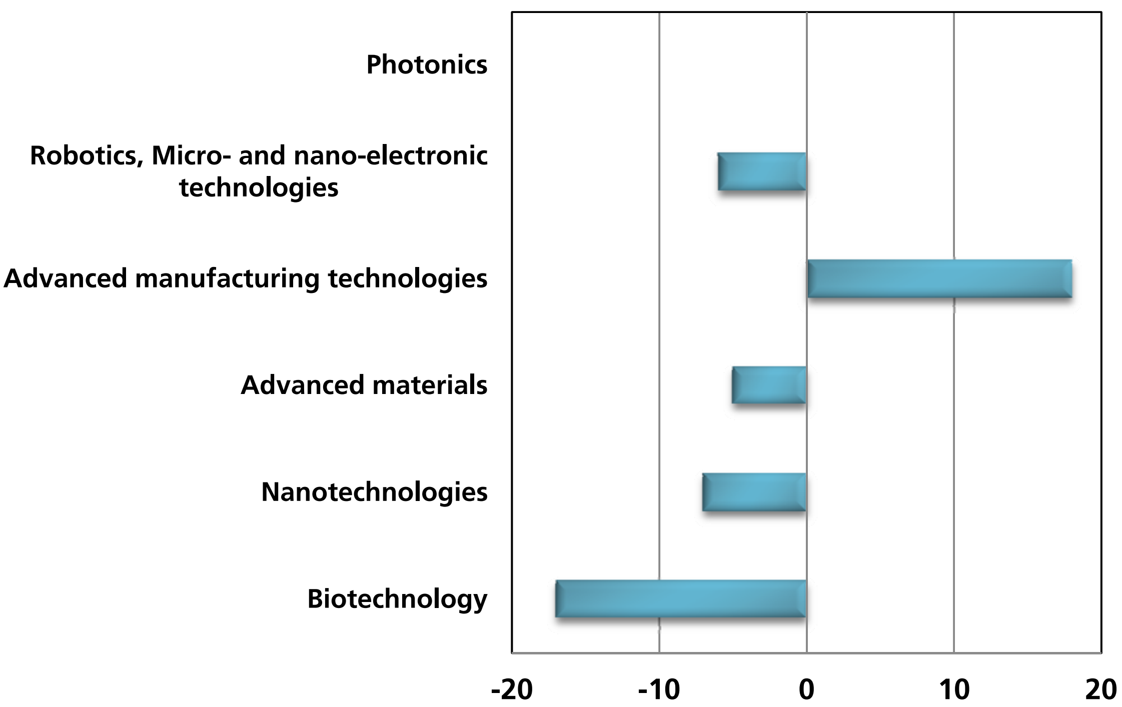
Note: EU-28 without Greece and Luxembourg

Figure A4.67: EU-28 shares of R&D: SGCs



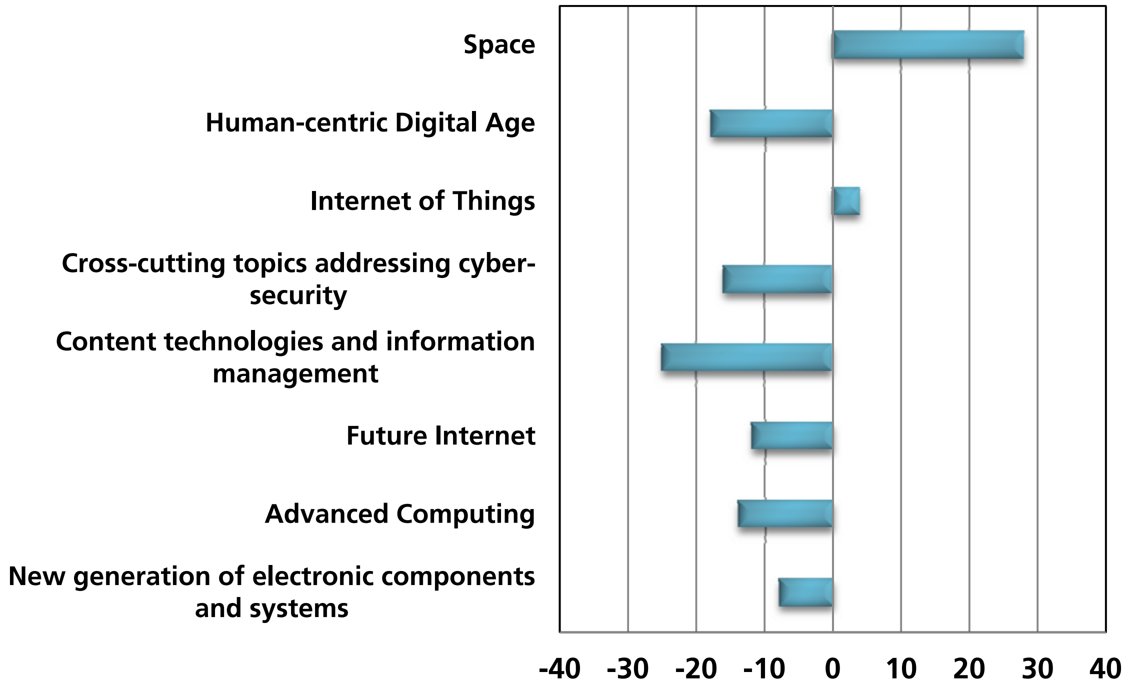
Note: EU-28 without Greece and Luxembourg

Figure A4.68: EU-28 specialisation profile 2010-2012: KETs



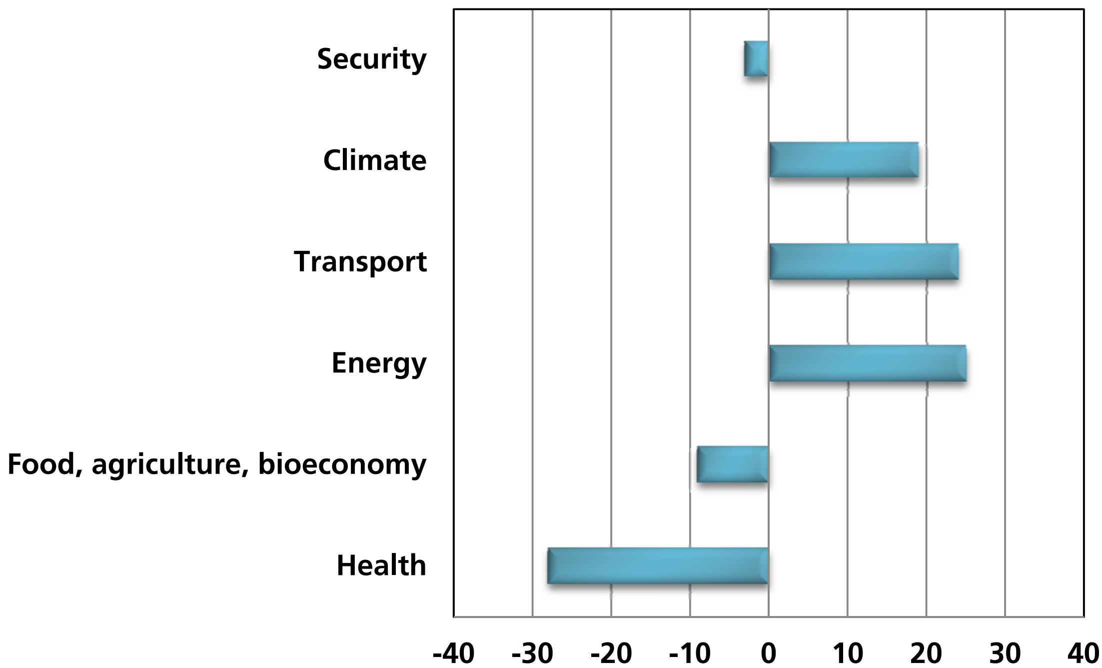
Note: EU-28 without Greece and Luxembourg

Figure A4.69: EU-28 specialisation profile 2010-2012: KETs (part 2)



Note: EU-28 without Greece and Luxembourg

Figure A4.70: EU-28 specialisation profile 2010-2012: SGCs



Note: EU-28 without Greece and Luxembourg

4. EXPORTS

Figure A4.71: EU-28 shares of exports: KETs

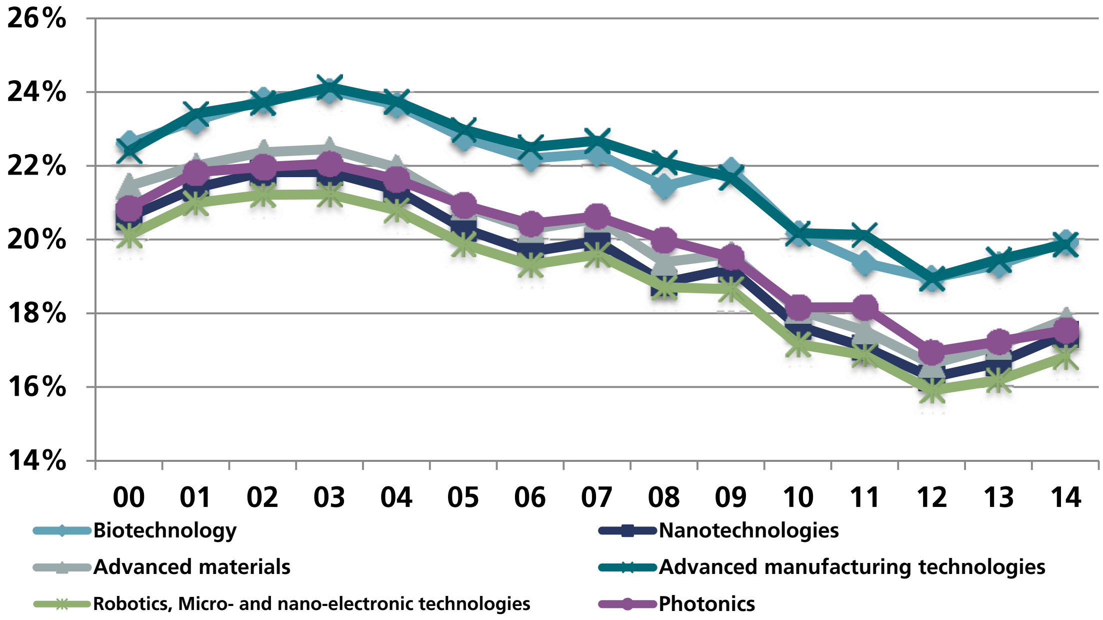


Figure A4.72: EU-28 shares of exports: KETs (part 2)

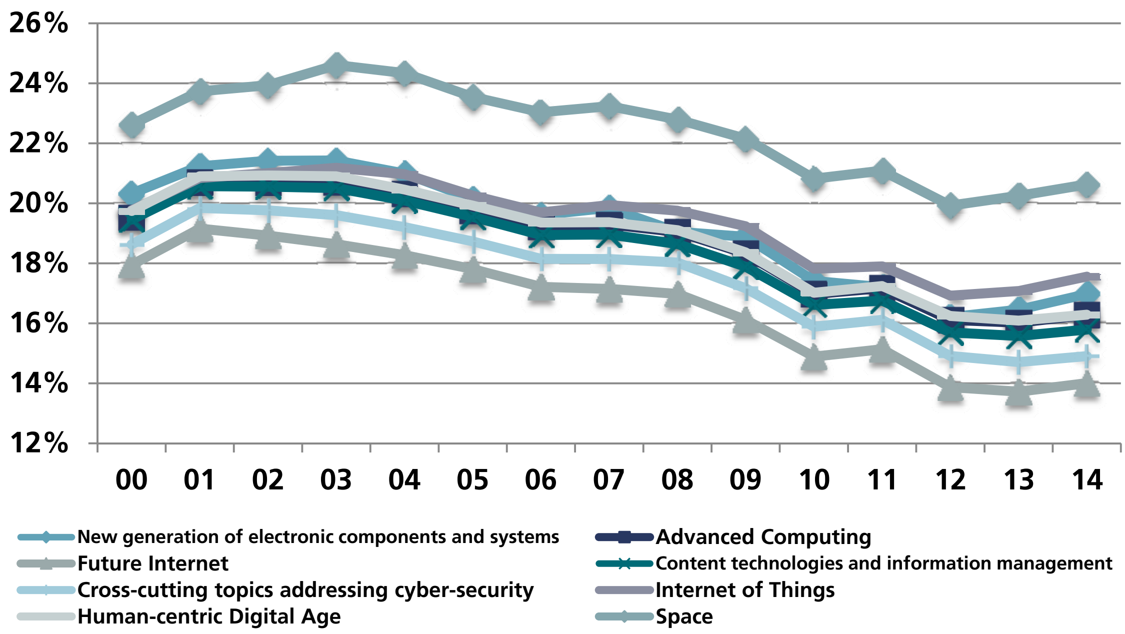


Figure A4.73: EU-28 shares of exports: SGCs

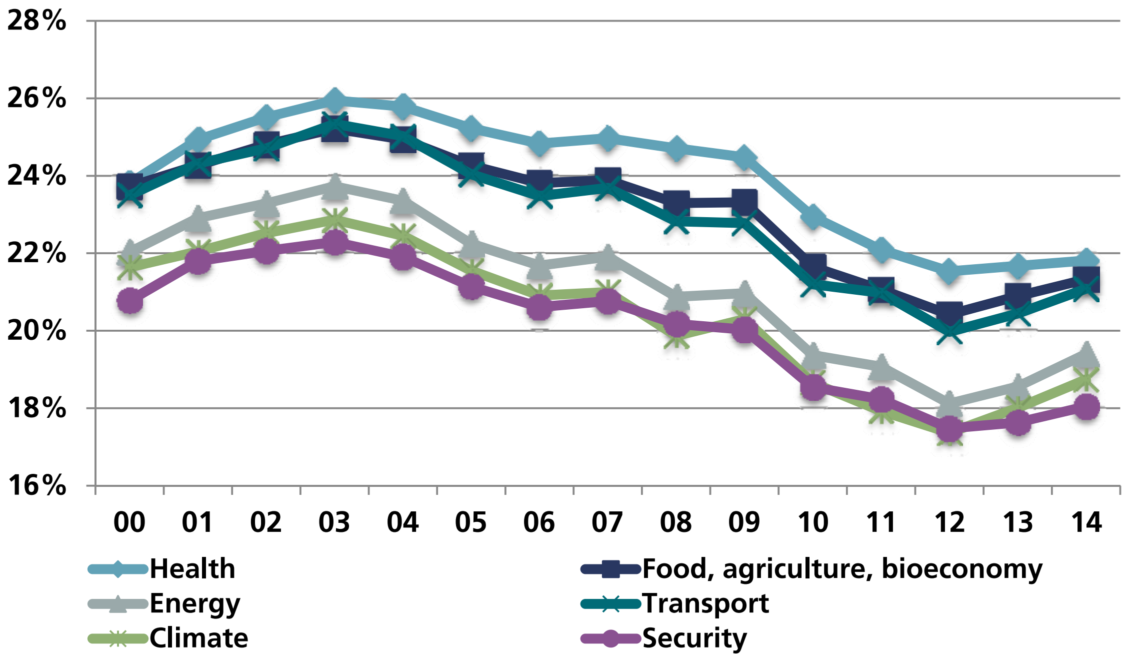


Figure A4.74: EU-28 specialisation profile 2010-2014: KETs

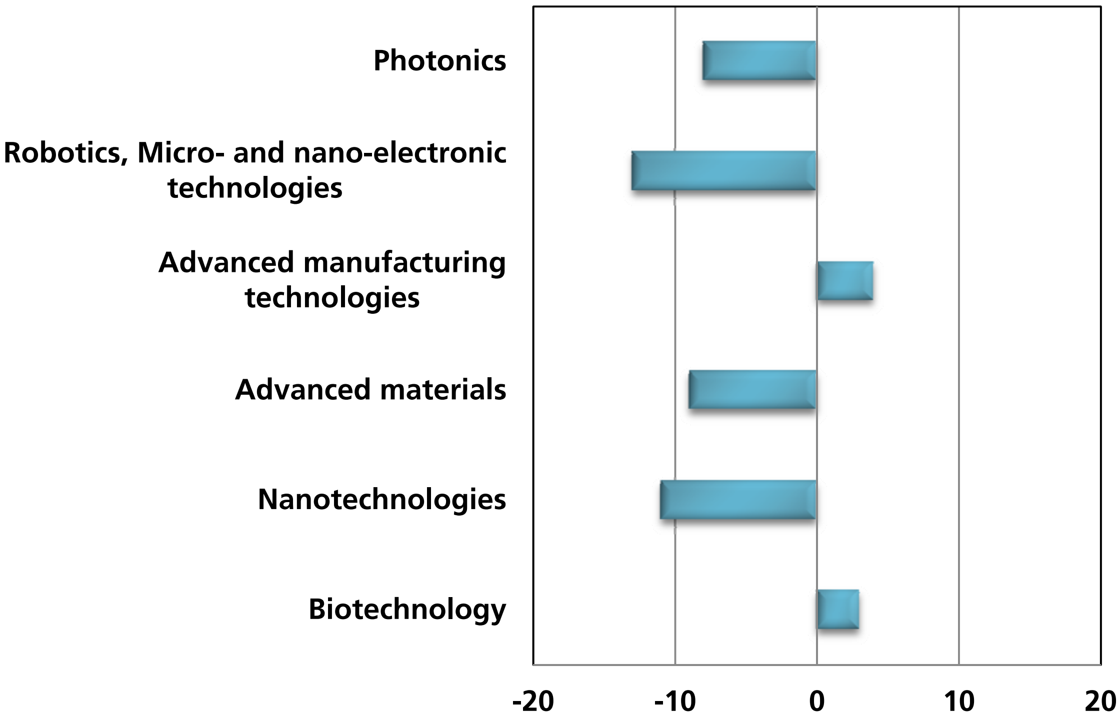


Figure A4.75: EU-28 specialisation profile 2010-2014: KETs (part 2)

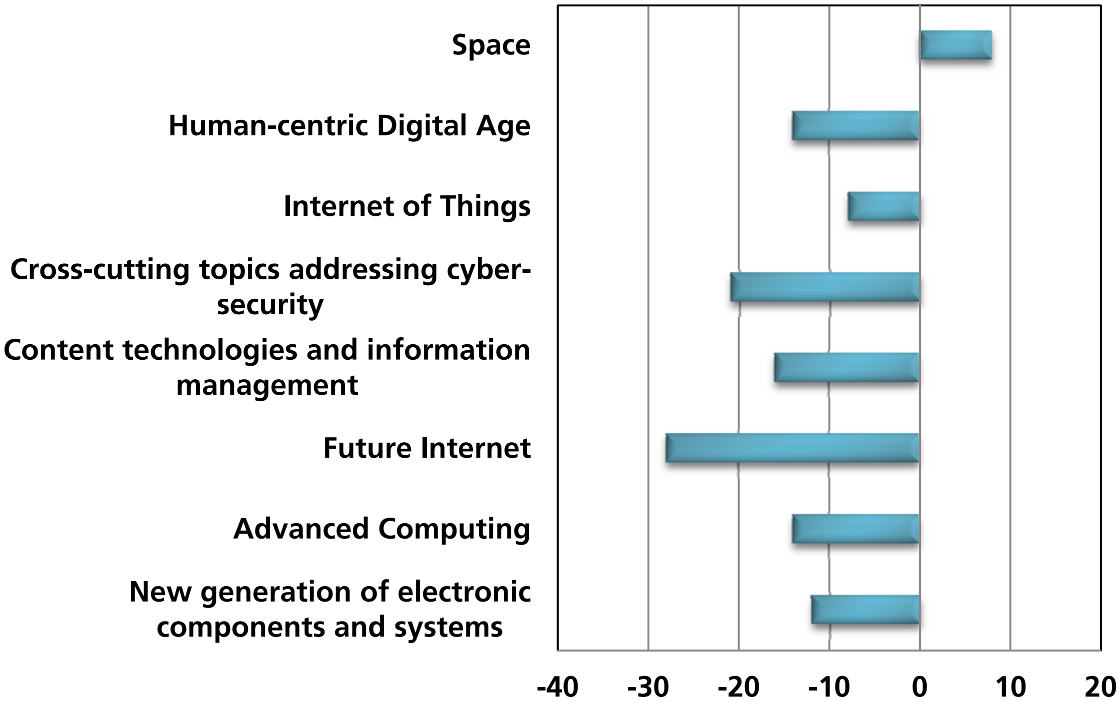
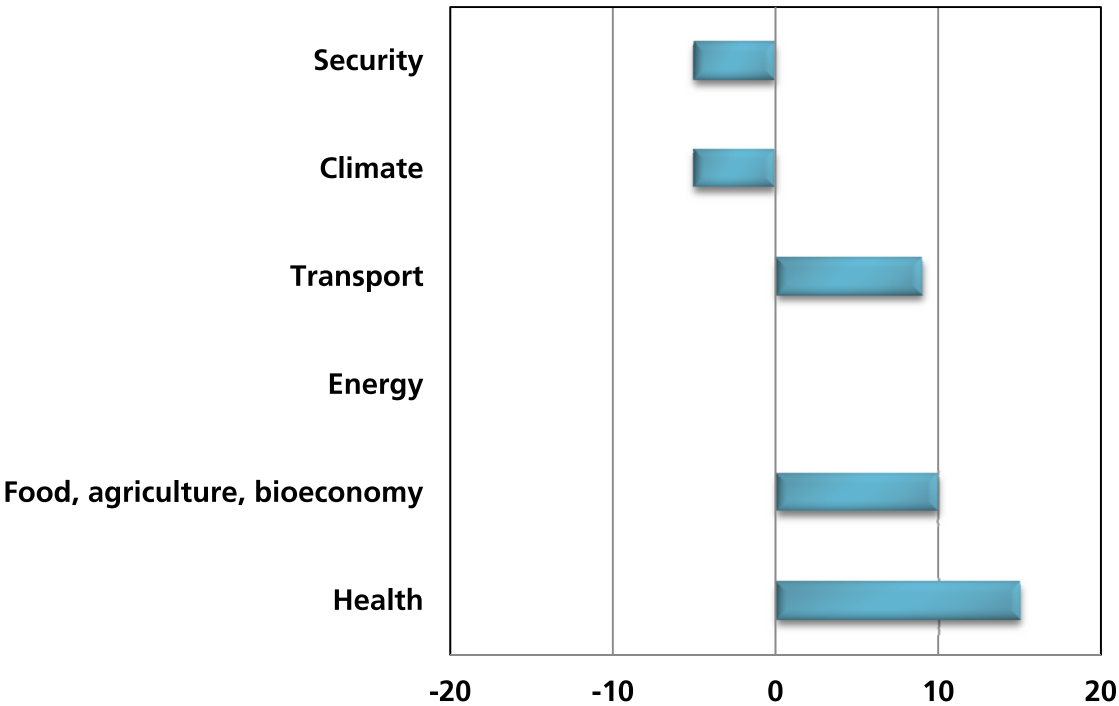


Figure A4.76: EU-28 specialisation profile 2010-2014: SGCs



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