Awti Advisory council for science, technology and innovation

Ready for the Future?

Towards a broad ICT strategy

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Summary

The central question addressed in this report is: *What is the impact of current technological development on the structure and functioning of the Dutch economy, and what policy should the Dutch government be pursuing in the light of this?* The report describes how current technological developments influence the economy. The analysis of technological developments, their impact on the economy, on research and innovation and on the way in which the Netherlands responds in policy, lead to the following conclusions.

ICT is a 'general purpose technology', which plays a role in virtually all activities associated with economic production and interaction. It is also a technology that is changing research and innovation and therefore having a major impact on economic change processes. In addition to ICT, all manner of new technologies have an impact on the structure and functioning of our economy. However, where that impact is genuinely substantial, it can today almost always be traced back to the development and exploitation of ICT. This makes ICT the key enabler for virtually all other key enabling technologies.

The great importance of ICT for our economic development still receives too little attention from policymakers. The significance of ICT is underestimated, as is the speed with which it is developing. The exponential increase in computing power, data availability and data transmission speeds is affecting our economy in a way that challenges the imagination. There is no comprehensive ICT policy vision for research, innovation, production and allocation. There is also no cohesive approach to issues surrounding ICT knowledge, development, infrastructure, capacities, skills and usage.

The use of ICT is changing the structure and functioning of the economy in all kinds of ways. New types of businesses and new occupations are emerging. The distinction between industrial companies and service companies is blurring. Smaller businesses, independent business units and networks of sole traders are becoming increasingly dominant in terms of production and employment. It is becoming easier to serve international markets, and this is also driving up competition on the Dutch market from foreign businesses. More and more markets are developing for ICT-related products and services, and tend to have a 'winner takes all' character. This can lead to an undesired concentration of economic power. The widespread use of ICT, including robotisation,is changing the employment landscape. Routine cognitive labour is disappearing as computers take over this work. Occupational groups in the middle of the income spectrum are particularly exposed to the impact of this. There is a chance that the overall extent of employment will fall and that income inequality will increase. This may be a

temporary effect, but could also be more permanent. The use of ICT in research and innovation is not only leading to an acceleration of the research and innovation dynamic, but also to more data-driven research and innovation, in more or less open and cross-border networks.

It is imperative that the Netherlands takes measures early enough to be able to accommodate these developments. Measures in the fields of education and training aimed at equipping citizens with skills that are complementary to ICT are key. Also important are measures which help businesses and research institutes to take advantage of the opportunities offered by new ICT-driven technological developments. The pace of technological development is rapid, and our economic future is uncertain. But whatever the future holds, if it is to be a good one for the Dutch economy it is essential that everything is in order as regards ICT.

These conclusions lead to the following recommendations for the Dutch Minister of Economic Affairs and the Minister of Education, Culture and Science. They are summarised briefly below and explained in more detail in the body of the report:

Recommendation 1:
Place the development of Dutch ICT capacity much more at the heart of policy, based on a comprehensive vision

a) Develop a comprehensive vision for ICT.
b) Improve the cohesion between ICT policy on the one hand and research, innovation and education policy on the other.
c) Ensure that public responsibility for ICT in relation to research, innovation and education is prioritised and properly coordinated within government policy.

Recommendation 2:
Give the development and exploitation of ICT a higher priority within innovation policy

a) Ensure that the designated ‘top sectors’ address the development and exploitation of ICT in a common approach. Encourage them to develop an action plan for this and to pool resources.
b) At the same time, devote systematic attention within innovation policy to needs that receive too little attention in the top sectors policy, in particular those of service producers, small innovative businesses and start-ups, and tailor policy instruments more closely to those needs.

Recommendation 3:

Facilitate and support the further development of data-driven research

a) Ensure that Dutch knowledge institutes continue to have access to top-quality ICT infrastructure and provide SURF, the Dutch national e-infrastructure administrator, with the necessary resources for this.
b) Take a proactive approach to the growing need for ICT investments in the context of the funding for the National Science Agenda.
c) Improve the conditions for transdisciplinary research and development.

Recommendation 4:

Configure the education system to meet the needs of an economy in which ICT is a dominant technology

a) Promote a strong emphasis on ICT knowledge and skills in higher education curricula.
b) Include ICT knowledge and skills in the attainment targets for primary and secondary education.
c) Strengthen the focus on entrepreneurial skills in the education system.
d) Create an institutional framework that makes it easier to combine or interchange working and learning during people's working lives (lifelong learning).

1

Introduction and request for advice

Technological developments today move at an impressive pace. An iPhone 5 costing less than 350 euros has as much computing power as the fastest supercomputer in 1975, which at that time cost 5 million dollars. The Human Genome Project, which took 13 years and was completed in 2003, cost 2.7 billion dollars. By the year 2020, sequencing a person's genome is likely to take no more than an hour and cost less than 100 euros. The costs per kilowatt-hour of solar energy obtained from photovoltaic cells have halved every three years in the first decade of this century.[1]

Technological development has a decisive influence on the dynamics of the economy. When new technological possibilities open up rapidly, as they are doing at present, this immediately raises questions about the economic consequences.[2] The impact of growing robotisation is for example currently the subject of political debate in the Netherlands.[3] The enormous pace at which this new technology is developing is raising fears that it could have a detrimental effect on employment.[4] But technological developments not only have consequences for employment; they also make new products and services available; new markets and new methods of working emerge; new production methods increase the productivity of capital and labour; international economic relations shift. The way we organise our working and personal lives is changing in response to technological developments.

The consequences of rapid technological changes for the structure and functioning of our economy are quite simply enormous. Technological capacity is increasing at an exponential rate. It is this that makes it so difficult to look ahead and oversee the consequences. However, the speed with which these changes take place depends not just on the speed with which new technologies become available, but also on how fast

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1 Examples taken from McKinsey Global Institute (2013) Disruptive technologies: Advances that will transform life, business, and the global economy.

2 The Dutch Council for the Environment and Infrastructure (Rli) (2015) also observes in its exploration of technological innovations in the living environment ('Verkenning technologische innovaties in de leefomgeving') that the speed of technological developments is accelerating, among other things because of the global increase in the number of people focusing on innovation and the intensification of human interaction. Combining (converging) technologies is moreover creating more and more opportunities for innovation.

3 This debate was sparked off in the Netherlands by the Minister for Social Affairs and Employment (SZW), Lodewijk Asscher, in a speech delivered at the annual SZW conference on 29 September 2014 under the title 'Robotisation: opportunities for tomorrow' ('Robotisering: kansen voor morgen'). The theme was further fleshed out by Ministers Asscher, Kamp (Economic Affairs) and Bussemaker (Education, Culture and Science) in a letter to the Dutch Parliament dated 19 December 2014 on the impact of technological developments on the labour market (Ministry of Social Affairs and Employment, 2014). But also see on this topic e.g. the essay collection published last year by Nesta (2014) Our work here is done – Visions of a robot economy.

4 In its report on 'working towards a robot society' ('Werken aan de robotsamenleving'), the Rathenau Instituut (2015) brings together several scientific insights concerning the relationship between current technological developments and employment. In their joint report on the lower end of the labour market in 2015 ('De onderkant van de arbeidsmarkt in 2015') (2015) the Netherlands Bureau for Economic Policy Analysis (CPB) and the Netherlands Institute for Social Research (SCP) describe the impact of technological development on intermediate and low-skilled workers.

those new technologies can be embedded in economic and societal structures. Marx and Schumpeter were already aware that technological capabilities largely determine social relationships, economic processes and organisational structures. But they also saw in their time that adapting economic processes and social structures to new technologies takes time, often a lot of time. Exploiting new technology is not just a question of investing in means of production, but generally also requires investment in new knowledge and skills, modification of infrastructure and complementary technology, development of appropriate organisations, procedures and rules, accepting new work routines and labour relations, developing new earnings models, accepting new risks, and so on. The actual pace of technological change in an economy is determined above all by economic and social processes.

In this context, the social embedding of new technologies not only determines how much they contribute to competitiveness and increased productivity, but also where the benefits of these processes accrue. And it is the organisation of the economic process which determines how the earnings are shared out. These social processes are in turn also influenced by the government.

1.1 Request for advice

Today's rapid technological developments raise questions for policy. The central issue is what the Netherlands needs to do to make optimum use of the possibilities offered by these new technologies. This report addresses the following question:

> *What is the impact of current technological development on the structure and functioning of the Dutch economy, and what policy should the Dutch government be pursuing in the light of this?*

The report outlines the way in which the current technological developments influence the economy, and sets out what the Dutch government needs to do in order to make the best possible use of the opportunities offered by these developments.

1.2 Focus

In this report we concentrate on the technological developments that have the biggest impact on the economy. The focus is on processes which shape the nature and magnitude of the economic impact of technological developments.[5] There are swathes of new technologies being developed which enables us to do or make things in radically

[5] Our approach is therefore complementary to that taken by the Dutch Council for the Environment and Infrastructure (Rli) (2015) in its exploratory study of technological innovations in the living environment ('Verkenning technologische innovaties in de leefomgeving'), in which attention focuses much more on technologies than on the economic mechanisms and effects.

different ways from in the past, and many authoritative studies have been published on them.[6] But if we consider which new technologies are likely to have the greatest economic impact, we see that developments in information and communication technology (ICT) play a dominant and often decisive role today.

Technological development takes place in successive waves of exploration, discovery and investigation of new technologies, followed by their exploitation: the development of new and ever better applications for those technologies.[7] We are currently in a period of accelerating and improving exploitation of technology which is based on or makes use of advanced ICT.[8] More and more ICT applications are becoming available which build on the growing availability of rapid Internet connections and big data. Devices and other artefacts are generating a burgeoning flood of data which is flowing through the Internet: the Internet of Things. ICT applications are also increasingly being combined with other technologies (converging technologies). The combination of ICT with mechanics, for example, is leading to the production of robots, driverless cars and 3D printing technology, while ICT combined with photonics is found in cameras, binoculars and medical apparatus. Combining ICT with energy technology results in 'smart grids', while the combination with nanotechnology gives us nanosensors, for example, which can be used among other things in the medical world to determine blood counts, and in the food industry to provide warnings when mould is developing or food is about to go off. The basis for all this has been laid in the last half century, when the technology was developed to make computers ever more powerful and communication ever faster – a trend which continues today. The exploitation of ICT has been going on for several decades already, but has accelerated in the recent period.

The fact that by far the greatest economic impact of ICT-related technology is yet to come is illustrated by the list of 12 disruptive technologies which, according to McKinsey (2013), are set to transform life, business and the global economy in the years ahead.[9] This list, ranked by the extent of the estimated global economic impact, is as follows: i) mobile Internet; ii) automation of knowledge work; iii) Internet of Things; iv) cloud computing; v) advanced robotics; vi) autonomous and near-autonomous vehicles; vii)

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[6] In addition to the reports mentioned, the Dutch Council for the Environment and Infrastructure (Rli) (2015) and McKinsey (2013) see e.g. the report by the three Dutch Universities of Technology et al. (2015) Agenda voor Nederland – Inspired by technology, the report of the European Parliamentary Research Service (2015) Ten technologies which could change our lives: Potential impacts and policy implications, the European Commission Communication (2009) 'Preparing for our future: Developing a common strategy for key enabling technologies in the EU', and the policy documents from the various public authorities which cite all manner of promising technologies, such as Bundesministerium für Bildung und Forschung (2014) The new High-Tech Strategy, Commission sous la présidence d'Anne Lauvergeon (2013) Un principe et sept ambitions pour l'innovation, Policy Exchange (2013) Eight Great Technologies, VRWI (2014) Vlaanderen in transitie, prioriteiten voor wetenschap, technologie en innovatie voor 2025 ('Flanders in transition; priorities for science, technology and innovation for 2025').

[7] See e.g. WRR (2008) Innovatie vernieuwd – Opening in viervoud ('Innovation renewed – Opening in fourfold').

[8] See e.g. Perez (2009) Technological revolutions and techno-economic paradigms. According to Perez, we are currently in the second half of a Kondratiev wave which is characterised by the exploration and exploitation of ICT as a technological paradigm.

[9] See McKinsey Global Institute (2013) Disruptive technologies: Advances that will transform life, business, and the global economy.

next-generation genomics; viii) energy storage; ix) 3D printing; x) advanced materials; xi) advanced oil and gas exploration and recovery; and xii) renewable energy. It is striking that the first six items on this list, which together will have by far the greatest economic impact, are all based directly on ICT. That said, the development of the other six technologies would also be unthinkable without ICT. The central role of ICT that emerges from the McKinsey study is confirmed by other reports.[10] It was also stated time and time again in the interviews we conducted in preparing this report that ICT forms the basis for the technological developments that are currently exerting the biggest influence on our economy.

Since ICT is such a dominant factor in the technological development that is relevant to the structure and functioning of the Dutch economy, it forms the focus of this report. We describe how ICT impacts on the economy and use this as a basis for our recommendations on the best approach for the government to take. This report thus focuses on a particular aspect of ICT; it does not address issues such as safety, security and privacy in relation to digital information flows, nor does it deal with the governance of the Internet.[11]

1.3 Approach and structure of this report

The first part of this report presents our main findings. These are followed by our recommendations for policy. In Part 2 (only available in Dutch) we describe how we arrived at our findings and recommendations, stating why this report focuses mainly on ICT, how ICT impacts on the economy in different ways and how ICT is changing research and innovation processes.

This report was prepared by a project group consisting of Emmo Meijer (chair), Dave Blank, Thecla Bodewes, Valerie Frissen, Arno Peels, Paul Diederen (secretary), Marcel Kleijn and Roel Niessen. Interviews were held during the preparation of this report with more than 50 experts and stakeholders.

[10] See e.g. Accenture (2013) Accenture Technology Vision 2014 – Every business is a digital business, of European Parliamentary Research Service (2015) Ten technologies which could change our lives – Potential impacts and policy applications. This latter report identifies ten promising technologies, but makes no assessment of the extent of their potential economic impact. Most of these technologies are applications of ICT (autonomous vehicles, 3D printing, Massive Open Online Courses (MOOCs), virtual currencies, wearable technologies, drones, intelligent domotics), while others are related to or make use of ICT (graphene, closed-loop aquaculture (aquaponic systems), electricity storage systems).

[11] See e.g. WRR (2015) De publieke kern van het internet ('The public core of the Internet'), AIV (2014) Het internet: een wereldwijde vrije ruimte met begrensde staatsmacht ('The Internet: a global free space with limited state power'), and AIV (2012) Digitale oorlogvoering ('Digital warfare').

2

Findings

Information and communication technology (ICT) is the dominant technology of our age. ICT is a 'disruptive' technology, which greatly increases the dynamic of the economy. It is a technology that not only has innumerable applications itself, but is also the key enabler for virtually all other key enabling technologies. ICT plays a major instrumental role in the further development of most other technologies that are important for our economy.[12] It is the foundation underpinning current technological development.

We take ICT to include digital hardware, software, connections and (big) data. ICT falls into the category of 'general purpose technologies': technologies with an enormously wide range of possible applications, comparable to electrical engineering and plastics chemistry in earlier times. A characteristic of a general-purpose technology is that the constant stream of innovations and applications in turn drives forward the further development of this technology.[13] One ICT application which has brought radical changes to the economy and society over the last two decades is the Internet. ICT applications which are expected to have major consequences in the future are based on big data (the availability and rapid accessibility of gigantic quantities of data from a great many sources), combined with data analytics and machine learning.[14]

ICT-driven technological development is transforming the structure and functioning of the economy. An important question here is how this transformation works, and more specifically whether this general-purpose technology is transforming the economy in a different way from technological developments in earlier periods. ICT influences the economy in two ways: directly and indirectly. ICT has a direct impact on the economy because it changes production and allocation processes.[15] It also exerts an indirect influence through its impact on research and innovation, and thus on the main driver behind the economic dynamic. The direct and indirect channels are discussed briefly in the next two sections.

[12] Biotechnology, nanotechnology, cognitive science, new materials, chemistry, pharmacy: progress in virtually all disciplines depends on data processing, computing power and simulation techniques .

[13] See e.g. Dialogic (2014) De impact van ICT op de Nederlandse economie ('The impact of ICT on the Dutch economy').

[14] See Cukier & Mayer-Schoenberger (2013) The rise of big data – How it's changing the way we think about the world,and Osseyran & Vermeend (2014) De revolutie van Big data – Een verkenning van de ingrijpende gevolgen ('The Big Data revolution – an exploration of the far-reaching consequences').

[15] We interpret the term 'allocation' broadly here, to include the distribution of goods and services, labour and time, income and power, allocation via the market and via bureaucratic, democratic or other mechanisms.

2.1 The impact of ICT on production and allocation

In brief: the use of ICT in production and allocation processes has at least the following six consequences

1. Automation of routine cognitive labour and robotisation: pressure on middle incomes and therefore the middle class; changes in the income distribution; possible emergence of 'technological unemployment'.
2. Reduction in transaction costs: breakdown of production into tasks that are distributed across companies throughout the world; global (niche) markets; increase in capital mobility.
3. Saving in capital: increase in capital productivity and therefore return on capital.
4. Lowering of the minimum efficient scale of production: emergence of more niche markets; opportunities for small businesses and sole traders.
5. Relatively low costs of production and distribution compared to costs of development: trend towards winner-takes-all markets.
6. Emergence of a layered platform structure: ICT applications build on each other (for example, apps build on the underlying infrastructure protocols); some platforms – including the Internet – have the character of a public infrastructure which is provided mainly by the private sector.[16]

ICT-driven technological development has set in motion a number of changes in the structure and functioning of the economy. ICT has opened the way for the development of all kinds of new products and services that are based on information. These product innovations often come from new market operators from different sectors. For example, camera manufacturers are facing competition from mobile telephone manufacturers, newspapers and television stations are challenged by digital media; car manufacturers face challenges from newcomers such as Tesla, and travel organisations from sites such as booking.com. ICT has greatly increased the dynamic in the media and publishing industries, the music and film industries, and the gaming and entertainment industry, but also in the telecommunications sector, financial services and advertising in all kinds of areas. A characteristic of information products in the digital era is that the costs are incurred in their development, but not in their reproduction, which costs virtually nothing. That is creating a need for new earnings models in all kinds of industries, including the music industry, the media and the publishing industry.[17]

[16] See WRR (2015) De publieke kern van het internet – Naar een buitenlands internetbeleid ('The public core of the Internet. Towards a foreign Internet policy').Several other platforms operate on the internet platform, such as Apple Store and Google Play Store.

[17] And also in the scientific publishing market, where a trend can be observed towards 'open access'. An AWTI report was published on this topic in January 2016.

As well as product innovation, ICT also leads to process innovation, with labour-saving process innovation being an especially striking example. ICT systems are becoming increasingly good at taking over routine and procedural tasks which until recently could not be automated.[18] This has prompted the current debate about the consequences of robotisation. The labour market is changing and the sectoral structure of our economy is shifting, with old jobs disappearing and new ones emerging.[19] Whether the creation of new jobs will be able to keep pace with the speed at which the old ones disappear is a matter of speculation at this point.

ICT-driven technological development has led to enormous changes in production processes, and not just in relation to the demand for labour. The minimum efficient scale of production has reduced greatly, and the ability to tailor all kinds of services to individual needs and therefore to exploit niche markets has grown steadily.[20] These markets are increasingly taking on a 'winner-takes-all' character because, once they have been developed, services can be reproduced and distributed via the Internet at relatively low cost.

ICT has drastically reduced the transaction costs that allow markets to function, for example the costs of gathering and disseminating information, establishing contacts and negotiating contracts, and generally doing business. Lower transaction costs have led to new earnings models, often based on payment for use (a service) rather than payment for ownership (a product).[21]

These lower transaction costs, combined with the lower minimum efficient scale, are making it increasingly easy for smaller businesses to hold their own in the marketplace. It is also much easier and cheaper to start a business today than in the past, and increasingly easy for smaller businesses to organise themselves and collaborate in networks. This is leading to a change in the structure of the economy, with smaller businesses accounting for a much larger share of total output.

The impact of ICT is not limited to industrial sectors, but also extends to – and perhaps more so – what we are accustomed to calling the service sectors. However, the distinction between industrial and service sectors is becoming increasingly blurred, and

[18] This is work which consists largely in following (sometimes complex, but nonetheless fixed) procedures, such as the activities of sales staff and accountants, but also of credit assessors and claims adjusters, train drivers and referees. See Levy & Murnane (2013) *Dancing with robots – Human skills for computerized work*, for a further analysis of the type of activities that computers can and cannot take over from humans.

[19] See Frey & Osborne (2013) *The future of unemployment: how susceptible are jobs to computerisation?,* who estimate that 47% of employment in the United States is at risk of disappearing due to computerisation (i.e. automation using computer-controlled equipment).

[20] This is not only done by Amazon, which is able to sell books printed in very small runs to very specific reader groups, but also the travel agent Riksja Travel, for example, which gives travellers the building blocks to put together their own tailor-made trip.

[21] See also AWT (2012) *Diensten waarderen* ('Valuing services').

production processes are increasingly converging, for two reasons. First, industrial manufacturers are increasingly providing services alongside their products, and an increasing share of the value added lies in those services. Second, the production of services increasingly resembles an industrial process: standardised and capital-intensive.

The geographical size of many markets is growing enormously thanks to digital distribution channels. One stumbling block here is that the European single market for services is not yet functioning optimally; in 2013, for example, cross-border trade via web shops in Europe accounted for only around 12% of total sales. In the Netherlands, 25-30% of purchases are made from foreign online retailers.[22]

The fact that European businesses operate within a much smaller integrated home market than their US counterparts puts them at a disadvantage. Further market integration at European level, a priority of the new European Commission, will give innovative companies access to a much larger home market.[23] This will be of particular help to businesses that sell knowledge-intensive (information) products, which are relatively expensive to develop but cheap to roll out across an integrated market.

[22] See Ayden and Edgar, Dunn & Company (2014) Cross-Border Payments – Opportunities and Best Practices For Going Global.

[23] The digital market in Europe today is made up of 42% domestic online service providers, 54% service providers based in the United States, and no more than 4% service providers from other European countries. The European Commission estimates that a digital single market could deliver extra growth to the tune of 415 billion euros and a hundred thousand additional jobs. See also Juncker (2014) *A New Start for Europe: My Agenda for Jobs, Growth, Fairness and Democratic Change – Political Guidelines for the next European Commission*; see European Commission (2015) *A digital single market strategy for Europe* for a detailed strategy for moving Europe closer to a digital single market.

2.2 The impact of ICT on research and innovation

In brief: the use of ICT in research and innovation will produce the following effects:

1. Acceleration of all kinds of processes in research and innovation: faster processing of much larger quantities of data.
2. Changes in the knowledge development process: i) from more deductive to more inductive and data-driven; ii) from more analytical (development of understanding through analysis of subsystems, followed by aggregation) to more synthetic and integrated (development of understanding through integrated systems analysis); iii) from predominantly monodisciplinary to more transdisciplinary; iv) from narrow to broad issues.
3. Changes in the organisation of knowledge development: intensification and upscaling of collaboration and network-building; more real-time collaboration across geographical and disciplinary boundaries.

Scientific research in most disciplines will be increasingly data-driven in the future and based more on methodologies involving induction, statistics and pattern recognition. The pace at which knowledge development advances is therefore determined not only by the size of the available data flows, but also by the availability of computing power and the speed with which methods and algorithms are developed that can recognise patterns in this vast flood of data.

The increasingly inductive and data-driven nature of science offers opportunities for more transdisciplinarity based on the intelligent combining of data flows from different disciplines. There is a great need for more transdisciplinary research in view of the impending societal and economic challenges. Research funders such as the Netherlands Organisation for Scientific Research (NWO) and knowledge institutes can tailor their organisational development and their activities to this. By encouraging transdisciplinary research, they will be able to facilitate a systemic approach and a more integrated research perspective. Focusing on broad research topics and ‘grand societal challenges’ such as climate change, social safety and food security will also be helpful here.

Knowledge development takes place largely in international networks. However, where in the past the results of scientific activity were shared internationally mainly through journals and conferences, today the actual research itself is increasingly carried out in collaboration. Researchers in the Netherlands, for example, increasingly work in virtual communities on joint projects with researchers elsewhere in the world. Interestingly, contrary to what might be expected given the present-day communication technologies,

this network-based integration of global research has not led to an equal distribution of research across the world. On the contrary, it has reinforced the trend towards the growth of a limited number of scientific 'hotspots'; the best researchers seek each other out and the rest cluster around them.

2.3 The policy challenge

Technological development is transforming our economy. However, the current economic policy discourse in the Netherlands is not focused on technology, but on top sectors and the top sector policy. Recurrent themes in this discourse are whether this policy offers challengers to the established order sufficient scope and incentive; whether it contributes to the tackling of societal challenges; and whether it fosters cross-sectoral and transdisciplinary innovation. The technological foundation on which the whole structure of the top sectors is based and within which ICT is the dominant element is usually ignored. The consequence is that ICT is regarded as a given and characterised as a shared responsibility. It is everyone's responsibility, and therefore no one's responsibility.

Computers, digital hardware and embedded devices are everywhere today, in our homes, our vehicles, our offices and our businesses. The rollout and exploitation of ICT is mainly driven by the private sector; private companies have furnished society with a whole infrastructure of cables, antennas and satellites. The public sector, by contrast, has built up a dubious reputation as regards its own ICT projects.[24] What should the public sector's responsibility be with regard to ICT? That responsibility is limited to specific aspects of ICT-driven developments; we highlight six areas of public responsibility below.

Public responsibilities with regard to ICT:

1. Ensuring the safety, reliability and privacy of data transmission by regulating and supervising the ICT sector.
2. Responding from the basis of the public interest to changes in employment, income distribution and economic structure, including positions of economic power, resulting from ICT-driven developments.
3. Investing public resources effectively and efficiently in public ICT projects.
4. Promoting optimum use by the business community of the opportunities offered by ICT to strengthen competitiveness.

[24] Notorious examples include the ICT problems at the Dutch tax authorities, the ICT drama at the Employee Insurance Agency UWV, the botched modernisation of the Municipal Personal Records Database (GBA), the failed introduction of electronic medical records, the slowness of the introduction of basic ICT facilities in the police force and the new (ERP) software system at the Ministry of Defence. See Tweede Kamer (2014) Parlementair onderzoek naar ICT-projecten bij de overheid (report by the Elias Committee on the Parliamentary inquiry on ICT projects in the public sector).

5. Seeking to ensure that public knowledge development delivers an optimum response to changes in research and development resulting from ICT.
6. Helping ensure that the labour force develops the capacities needed by the labour market in the future as a result of ICT-driven developments.

In the first place, the government has a role to play because the ICT infrastructure – in particular the Internet and, increasingly, big data – has acquired the character of a public good.[25] It is a vital infrastructure with a public character, which is provided mainly by private sector operators. The ICT infrastructure is vital because the functioning of our society has become dependent upon it. It is a utility which is provided by private corporations – many of which are foreign. In that sense, the ICT industry is similar to the banking sector: banks are also private companies, which provide a universal payment and lending system as well as a vital infrastructure. Experiences in the banking sector make clear that when private sector players are responsible for a public infrastructure, a crucial responsibility rests on the government's shoulders. For the banking sector, an extensive system of regulation and supervision has been developed in order to safeguard vital public interests.[26] The history of the last few years has demonstrated the fallibility of this system, and the ensuing discussions have shown that optimum regulation and supervision are far from simple. The same applies in the ICT sector. The discussions about regulation and supervision in this sector are of more recent date than those in the banking industry, and are currently focused on issues such as safety and security on the Internet. The system of governance intended to safeguard those public interests is not yet fully crystallised.

It goes without saying that this requires a properly thought out strategy on the part of the Dutch government. Among the current focus areas are guaranteeing access to the Internet, the issue of 'net neutrality' (i.e. no discrepancy in the speed with which Internet service providers pass on information from different providers), the safety of Internet traffic, the reliability and stability of the Internet, and privacy. A number of issues are becoming ever more pressing as big data grows and huge datasets are increasingly becoming a source of economic value creation, including the ownership of data and the monopolising of data sources.[27] These are complex issues which are of great importance

[25] A public good is a product or service that is characterised by *non-excludability* (no one can be excluded from its use) and *non-rivalry* (users do not compete with each other). The Internet comes close to this. The number of databases having the character of a public good is growing – see e.g. the trend report on open data by the Netherlands Court of Audit: Algemene Rekenkamer (2015) Trendrapport open data 2015.

[26] Parallels can also be drawn with the electricity industry and telecommunications industry (which is becoming increasingly integrated with the rest of the ICT sector).

[27] The value of companies such as Google and Facebook is already largely based on the value of the information they collect via their own websites. See Cukier & Mayer-Schoenberger (2013) The rise of big data – How it's changing the way we think about the world.

to society and which go beyond the limited scope of this report. We therefore do not discuss them any further here.

Secondly, the government has a role to play in relation to competition, employment and income distribution.[28] Competitive relationships change when ICT promotes the emergence of dominant market operators, for example because of the development of 'winner takes all' markets. In certain cases, this may require a competition policy intervention.[29] ICT also changes the nature and possibly the extent of employment. In the current landscape, ICT-driven technological development is observed to be skill-based (complementary to skills acquired through more training), labour-saving (particularly as regards routine cognitive labour) and capital-saving. This combination of factors means that this technological development could potentially lead to reinforcement of the divisions on the labour market, a further widening of income and wealth gaps, and in the worst case to technological unemployment. If these scenarios manifest themselves, a response will be needed through fiscal policy, income policy and social policy combined with education policy. Given the important interests that are at stake here, timely and open-minded reflection on these matters is called for.[30]

In the third place, the government has a responsibility to run its own ICT projects as well as possible. When spending public money, it is important to strike a good balance between short-term efficiency and efficiency in the long term through the encouragement of innovation. In earlier reports, AWTI has advocated an innovation-based government procurement policy.[31]

Fourthly, the government has a responsibility to stimulate the competitiveness of the private sector, among other things through its innovation policy. ICT is a key driver of innovation, and it is important that the innovation policy supports both the further development and the exploitation of ICT.

The Dutch 'top sectors' policy mainly supports established players, whereas it is often the challengers of the established order that are strongly ICT-based. The top sectors approach and the Smart Industry initiative are moreover heavily focused on (existing) industrial activities and pay scant attention to innovation in services,[32] which is precisely

[28] Full employment and a fair income distribution have for more than five decades been among the explicit goals of Dutch socio-economic policy. Since 1992, the Social and Economic Council of the Netherlands (SER) has formulated the following socio-economic objectives: i) balanced economic growth that is in keeping with the commitment to sustainable development; ii) the highest possible labour participation rate; iii) a reasonable income distribution.

[29] The European Commission has for example taken Microsoft to court in the past, and is currently preparing a case against Google.

[30] The government has asked the Netherlands Scientific Council for Government Policy (WRR) to carry out a study on 'the future of work'.

[31] See e.g. AWT (2012) *Diensten waarderen* ('Valuing services') and AWT (2013) *Waarde creëren uit maatschappelijke uitdagingen* ('Creating value from social challenges').

[32] See e.g. AWT (2012) *Diensten waarderen* ('Valuing services') and AWT (2014) *Briljante bedrijven* ('Business jewels')..

where a great deal of ICT-driven innovation is taking place. And finally, although ICT is making it increasingly easy to start up a new business, it is still difficult for smaller and start-up businesses to tap into the specific innovation policy.[33]

The government's fifth responsibility concerns public knowledge development. This is where research and science policy comes in. On the one hand, this policy can support research in making optimum use *of* ICT, and at the same time promote research *in* ICT. Research is becoming increasingly ICT-intensive, and the burgeoning flows of research data in particular present researchers with opportunities to explore new avenues. If they are to do so successfully, they must have the right computer and communication facilities. Science must also be organised and funded in a way that provides ample scope for data-driven, transdisciplinary research.

In sixth place, the government shares responsibility for the development of the expertise and capacities that are needed to meet the demand for labour in an economy whose dynamic is largely driven by ICT. Education policy has a part to play here. An economy in which ICT innovation is the driver that is transforming the structure and functioning of that economy, faces specific demands in terms of knowledge and skills. In the first place, this means ICT knowledge and skills: economic activities, innovation and research can only make intensive use of ICT if sufficient digital skills and ICT expertise are available. But it also means the knowledge and skills needed for an economy where a much larger share of employment is provided by small enterprises, in which organisations are much flatter and in which far more self-employed workers earn their living through networks. Such an economy needs far more in the way of entrepreneurial skills. In such an economy, ICT dictates the speed of change processes. This requires workers who are able to keep pace with the speed of this change and who keep up their own knowledge and skill levels. Under these circumstances, a school education will no longer be enough to carry someone through an entire career, and in-service training and retraining will become increasingly necessary.

The first and second themes, which are concerned with regulation and supervision of the ICT sector and socio-economic policy, fall outside the scope of the AWTI's advisory activities. We would stress the importance of these themes and advocate an open debate on them, but refrain from making specific recommendations. The third theme, an innovation-based ICT procurement policy, is a specific theme which demands separate attention, and is therefore not discussed further here. The fourth, fifth and sixth theme do fall within AWTI's remit, and we will set out our recommendations in the next section on the basis of our observations.

[33] The generic innovation policy is mainly focused on the SME sector. However, it is through the specific business policy, the top sectors policy, that network-building is facilitated and a bond is forged between public knowledge development and the needs of industry.

Before doing that, however, we will briefly reflect on how responsibility for ICT is formalised within government. The public responsibility for ICT is not only diverse, as the six points mentioned above illustrate, but is also enormously fragmented across different policy directorates and ministerial departments, public bodies and organisations. ICT is omnipresent and taken for granted – and therefore elusive. ICT belongs to everyone – and therefore to no one. Responsibility for the further development and exploitation of ICT rests with all top sectors and all knowledge institutes. This carries a risk. ICT is not properly embedded within the top sectors policy. Much of the activity of the HTSM (High Tech Systems and Materials) top sector is for example ICT-related and focused largely, though not exclusively, on hardware. However, the links between HTSM and the other top sectors (and non-top sectors) are too weak to provide a broad stimulus to the use of ICT. The initiative to create an ICT top team is a first step in achieving more broadly coordinated innovation within ICT, but is not enough on its own to adequately anchor the public responsibility for ICT. The top team currently lacks the position, the authority and the tools needed to move the further development and exploitation of ICT further up the political agenda and to make it more of a practical reality.

2.4 Conclusions

Our findings, summarised above, lead us to the following conclusions:

1. ICT is a general purpose technology, which plays a role in virtually all activities concerned with economic production and interaction. It is also a technology that is changing research and innovation and therefore has a major impact on economic change processes.
2. ICT is the key enabler for virtually all other key enabling technologies. All kinds of new technologies are having an impact on the structure and functioning of our economy. However, where that impact is genuinely substantial, this can almost always be traced back to the development and exploitation of ICT.
3. The great importance of ICT for our economic development still receives too little attention from policymakers. The significance of ICT is underestimated, as is the speed with which it is developing. The exponential increase in computing power, data availability and data transmission speeds is affecting our economy in a way that challenges the imagination. There is no comprehensive ICT policy vision for research, innovation, production and allocation. There is also no cohesive approach to issues surrounding ICT knowledge, development, infrastructure, capacities, skills and usage.
4. The use of ICT is changing the structure and functioning of the economy. New types of businesses and new occupations are emerging. The distinction between industrial companies and service companies is blurring. Smaller businesses, independent

business units and networks of sole traders are becoming increasingly dominant in terms of production and employment. It is becoming easier to serve international markets, and this is also driving up competition on the Dutch market from foreign businesses. More and more markets are developing for ICT-related products and services, and tend to have a 'winner takes all' character. This can lead to an undesirable concentration of economic power.

5. The widespread use of ICT, including robotisation, is changing the employment landscape. Routine cognitive labour is disappearing as computers take over this work. Occupational groups in the middle of the income spectrum are particularly exposed to the impact of this. There is a chance that the overall extent of employment will fall and that income inequality will increase. This may be a temporary effect, but could also be more permanent.
6. The use of ICT in research and innovation is not only leading to an acceleration of the research and innovation dynamic, but also to more data-driven research and innovation, in more or less open and cross-border networks.

It is imperative that the Netherlands takes measures early enough to be able to accommodate these developments. Measures in the fields of education and training aimed at equipping citizens with skills that are complementary to ICT are key. Also important are measures which help businesses and research institutes to take advantage of the opportunities offered by new ICT-driven technological developments.

The pace of technological development is rapid, and our economic future is uncertain. But whatever the future holds, if it is to be a good one for the Dutch economy it is essential that everything is in order as regards ICT.

3

Recommendations

Our analysis as briefly summarised above, offers a broad overview of arguments which illustrate that ICT is omnipresent and that its influence on the structure and functioning of the economy is very far-reaching. All manner of issues have been covered which need to be better regulated if the Netherlands is to derive full benefit from the advantages that ICT can offer and reap the scientific and other rewards that ICT can generate.

Based on this analysis, AWTI proposes four recommendations to the Dutch Minister of Economic Affairs and the Minister of Education, Culture and Science. The first concerns the shaping of and responsibility for ICT in relation to innovation, research and education. The remaining recommendations are about incorporating ICT into innovation policy, research policy and education policy, respectively.

3.1 Public responsibility

It is key that the government organises the public responsibility for ICT better. In this context, 'better' means bringing responsibility for ICT more on to the government's radar, placing it higher on the policy agenda, introducing more cohesion and reducing fragmentation.

Recommendation 1:
Place the development of Dutch ICT capacity much more at the heart of policy, based on a comprehensive vision

a) Develop a comprehensive vision for ICT.
b) Improve the cohesion between ICT policy on the one hand and research, innovation and education policy on the other.
c) Ensure that public responsibility for ICT in relation to research, innovation and education is prioritised and properly coordinated within government policy.

As a minimum, this public responsibility includes responsibility for the public ICT infrastructure for education and research, for the development of ICT capacity through education and training, for the development of ICT knowledge through research, and for coordinating all of this with the private sector, particularly as regards the top sectors. It is vital to bring more focus and cohesion to a policy which supports ICT developments and ensures a good dovetailing of public and private initiatives. This is crucial in ensuring adequate preparedness for the imminent changes in the structure and functioning of the economy, the organisation of economic activities and the extent and structure of employment. A first step in putting this recommendation into practice would be the

development of a comprehensive vision for ICT policy in relation to research, innovation and education. The Vision for Science 2025 (*Wetenschapsvisie 2025*), the new NWO strategy, the multi-annual plan developed by the national e-infrastructure administrator SURF, the forthcoming National Science Agenda and the plans for an ICT top team, are key building blocks for creating such a vision. Tying together the different elements, anchoring the responsibilities and giving long-term undertakings are necessary subsequent steps which have yet to be taken.

3.2 Innovation policy

The development of new ICT applications is leading to changes in the structure of the economy, not just in industry but also in all kinds of service sectors, giving rise to a highly dynamic product development and innovation environment. Boundaries between sectors are blurring, traditional manufacturers and suppliers are facing competition from unexpected, often ICT-driven quarters. More services are being linked to industrial products. The trade in services is increasingly replacing the trade in products (paying for usage rather than for ownership). ICT development is also bringing more small businesses to the market, more networks of small businesses and more start-ups.

Dutch innovation policy is inadequately geared to these changes in its present form. Options include not only developing the current business policy further, but also broadening the policy to take in the needs of start-ups, smaller enterprises and non-manufacturing businesses.

Recommendation 2:
Give the development and exploitation of ICT a higher priority within innovation policy

a) Ensure that the designated ‘top sectors’ address the development and exploitation of ICT in a common approach. Encourage them to develop an action plan for this and to pool resources.
b) At the same time, devote systematic attention within innovation policy to needs that receive too little attention in the top sectors policy, in particular those of service producers, small innovative businesses and start-ups, and tailor policy instruments more closely to those needs.

ICT is a shared interest that must be approached by top sectors acting together. Innovative ICT applications within traditional sectors often come from outside, from new players or new partnerships[34]– yet another reason why a joint approach is important. This not only requires consultation and coordination, but above all joint initiatives and funding, among other things within the context of the present round of innovation contracts. The ICT top team can serve as a catalyst here, provided it is adequately facilitated and supported in this.

ICT-driven technological change dictates the speed at which production processes and markets change. In order to be able to continue generating wealth under these circumstances, it is important to be flexible and responsive. Being responsive means among other things that structures such as top sectors and Top consortia for Knowledge and Innovation (TKIs) must not adopt a restrictive and conservative approach. The organisation and collaboration in the area of knowledge development and innovation must be sufficiently dynamic to respond to new developments taking place outside existing structures.

As regards the needs of start-ups, small businesses and service providers, specific attention needs to be given to accommodating innovations based on ICT. It is important that regulations anticipate these innovations and that legislation creates scope for the use of new technology where this is socially desirable in areas such as ownership, liability and privacy.[35]

Since ICT lowers the minimum efficient scale for businesses and increases the potential growth rate of businesses, small, innovative enterprises with growth ambitions are becoming increasingly important players in our economy. These 'growth drivers' will have to make a major contribution in the future to Dutch earnings capacity, international competitiveness and employment. Innovation policy must take greater account of this.[36]

The European Commission has given further integration of the European markets for innovation services a prominent place on the agenda.[37] An integrated European services sector would give innovative companies a larger home market; the lack of this is one of the reasons that Europe lags behind the United States as a home for ICT companies

[34] The classic example is the industry that produced mechanical watches, and which was swept away by electronics companies. The application of digital technology in the Life Sciences & Health sector comes from HTSM companies such as Philips and Siemens, but also start-ups which build apps to measure the user's physical condition.

[35] See e.g. the discussions currently taking place on the admissibility of services provided by companies such as UberPop and Airbnb, but also about the use of drones to provide urgent medical assistance. These are areas where innovation clashes with regulations designed to deal with the technological possibilities of the past.

[36] See also AWT (2014) *Briljante bedrijven* ('Business jewels'). The recently launched StartupDelta is an excellent initiative intended to encourage ICT-related innovation, but is currently still strongly linked to the established order.

[37] The European Commission is already taking the lead in the development of a Digital Single Market. See also Recommendation 5 in AWT (2012) *Diensten waarderen* ('Valuing services').

such as Microsoft and Apple and dominant ICT applications such as Facebook and Twitter. It is in the interests of the Netherlands to actively support the European Commission on this point.

3.3 Research policy

Several aspects are important in facilitating an optimum response to the possibilities offered by ICT in the field of research and development, including a first-rate public ICT infrastructure for public sector knowledge institutes and incentives for transdisciplinary collaboration on complex themes. A solid position in international networks of top researchers will be an essential condition here.[38]

Recommendation 3:
Facilitate and support the further development of data-driven research

a) Ensure that Dutch knowledge institutes continue to have access to top-quality ICT infrastructure and provide SURF, the Dutch national e-infrastructure administrator, with the necessary resources for this.
b) Take a proactive approach to the growing need for ICT investments in the context of the funding for the National Science Agenda.
c) Improve the conditions for transdisciplinary research and development.

The Netherlands has an excellent public ICT infrastructure for research, and is one of the top countries in the world in this respect. That infrastructure includes both the digital hardware and software (digital networks, computing power and storage capacity), largely developed and implemented by SURF, and the data infrastructure (databases, collections). Maintaining the Dutch lead in this area will require substantial investments in the short term.[39] However, given the developments in the field of big data, in particular, it is likely that the necessary investments will rise further in the near future. It is therefore advisable to set aside substantial amounts for this as part of the funding of the National Science Agenda. Better coordination of the investments by SURF in the basic ICT

[38] See AWT (2014) *Boven het maaiveld* ('Above ground level').

[39] SURF reports a shortfall of 8 million euros per year in the funding needed to maintain the public ICT infrastructure for research and education. On 31 October 2014 the Association of Universities in the Netherlands (VSNU), the Netherlands Federation of University Medical Centres (NFU), the Netherlands Association of Universities of Applied Sciences (NFU) and the Dutch National Students' Union (LSVb) sent an urgent letter on this subject to the Ministers of Education, Culture & Science and Economic Affairs (accessible at http://www.scienceguide.nl/media/1744188/urgentie_innovatie_einfrastructuur_hoger_onderwijs_en_onderzoek_ez_en_ocw.pdf). In mid-April 2015, the Dutch Parliament passed a motion tabled by the MPs Paul van Meenen and Mei Li Vos calling on the government to top up the SURF budget with the required funds: Tweede Kamer (2015) Gewijzigde motie van de leden Van Meenen en Mei Li Vos […]. The ministerial response came in June 2015: Ministerie van Onderwijs, Cultuur en Wetenschap (2015) Uitvoering motie Van Meenen / Vos over SURF.

infrastructure and the investments being made by NWO in large-scale research facilities is also desirable.[40]

In order to exploit the new research possibilities presented by ICT – including research based on big data, more research at system level, greater use of pattern recognition – it is important that both knowledge institutes and research funders offer scope for this. This requires a stronger focus on an integrated approach, data-driven research and a transdisciplinary perspective, alongside – not instead of – monodisciplinary and hypothesis-driven research. Complex issues such as those relating to the 'grand challenges' offer an obvious starting point for a systemic approach. The strategy of NWO for the period 2015-2018 devotes ample attention to cross-border collaboration and rightly cites complexity as a task that demands transdisciplinary research.[41] It is important that the National Science Agenda should also take into account the issues that these developments bring within the scope of scientific research.

Dutch research is in a good position to take advantage of these new possibilities. Our research is rooted in a tradition of collaboration that crosses borders, whether they be between disciplines (transdisciplinarity), between institutes or between countries. The Netherlands is well represented in the international networks of top researchers. We also have extensive and long-standing experience with forms of public-private partnership. Finally, we have a relatively non-hierarchical and informal tradition of labour relations. All of this offers the Netherlands opportunities to lead the field in knowledge absorption and to stand out for its integration of knowledge from different disciplines. In order to grasp these opportunities, the ICT facilities and funding mechanisms must be matched to the developments in scientific research outlined above. If the government does this successfully, this will create attractive opportunities for research and development and contribute to the creation of innovative hotspots in the Netherlands.

3.4 Education policy

The digital revolution is changing the structure and functioning of the economy. This places new demands on knowledge and skills. To ensure that the Netherlands possesses the required knowledge and skills to an adequate degree, the education system will have to adapt at all levels.

[40] The Royal Netherlands Academy of Arts and Sciences (KNAW) has also expressed concerns about the lack of adequate structural funding for digital and other infrastructure, and about the deficient national coordination. See Koninklijke Nederlandse Akademie van Wetenschappen (2015) Ruimte voor ongebonden onderzoek – Signalen uit de Nederlandse wetenschap ('Scope for unfettered research – Signals from Dutch science'), p. 12 and pp. 43-44.

[41] NWO (2015) NWO Strategie 2015 – 2018.

Recommendation 4:
Configure the education system to meet the needs of an economy in which ICT is a dominant technology

a) Promote a strong emphasis on ICT knowledge and skills in higher education curricula.
b) Include ICT knowledge and skills in the attainment targets for primary and secondary education.
c) Strengthen the focus on entrepreneurial skills in the education system.
d) Create an institutional framework that makes it easier to combine or interchange working and learning during people's working lives (lifelong learning).

In order to benefit from the development of the key technologies of our age, it is important to invest in training to give people expertise that is complementary to digital technology. That means investing in the knowledge and skills needed to take the development of digital technology further, including data sciences and data analytics, machine learning and artificial intelligence. Investments will also be needed in all those disciplines that make use of ICT to deliver new knowledge and provide scope for innovation. These are not just the natural and medical sciences, but also social sciences and humanities. There are suggestions that the shortages of ICT capacity in the Netherlands are more pressing than the shortages of science graduates in general.[42]

Ensuring that people have sufficient ICT-related knowledge and skills begins at school. All pupils and students must as a minimum have an understanding of basic computer technology and be able to work with computers and be aware of what they can do.[43] To achieve this, all primary schools need to ensure that children become acquainted with computers and the Internet, and all secondary schools must devote attention to digital skills. Developing better digital skills is a first step in countering the technological unemployment that may accompany the rapid digitalisation of our economy. In higher education, ICT warrants a prominent place within most disciplines. All students must learn to use digital research tools. It is moreover important to train more students in ICT-related subjects.

Use of ICT is changing the structure of the economy, causing businesses to become smaller, organisations flatter and self-employed workers more numerous. This creates a concomitant need for entrepreneurial skills, a need which must be met by education. This means not just knowledge of business organisation, company law, accountancy,

[42] One recent initiative to do something about this is the founding of a Master's degree programme in Data Science in Den Bosch through a partnership between Eindhoven University of Technology (TU/e) and Tilburg University, in which data science is combined with economic and legal perspectives. See: http://www.emerce.nl/nieuws/plannen-graduate-school-data-science-volgende-fase. A Data Science Center was also opened in Eindhoven at the end of 2013.

[43] See also Koninklijke Nederlandse Akademie van Wetenschappen (2013) Digitale geletterdheid In het voortgezet onderwijs – Vaardigheden en attitudes voor de 21ste eeuw ('Digital literacy.in secondary schools – Skills and attitudes for the 21st century').

marketing and finance, but also social skills, networking skills, assertiveness and creativity. Training in these aspects should be given a prominent place in curricula.

Finally, in an economy which is changing at an enormous pace due to rapid technological advances and real-time communication, it is important that knowledge capital is permanently maintained. Such an economy requires a framework which makes it easier for people to combine or alternate learning and working after completing their main educational career, and to engage in lifelong learning – something for which the prevailing economic arrangements such as employment contracts, pension schemes and the income tax system offer only limited scope.

The Hague, September 2015

Professor Uri Rosenthal (Chairman)
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