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TNO report: The state of the High-tech Industry

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1 Introduction

Building on the TNO Strategy 2022-2025 ‘Connecting, Changing, Accelerating’ the unit Industry aims to develop a system vision on realizing the ‘Twin Transitions’ (sustainability and digital transformation) in the Netherland’s high-tech industry while improving earning power of the Dutch economy. This report is a key input for building that system vision.

The objective of our study is to provide a description of the Dutch High-Tech industry and offer key insights for building a system vision that will address competitiveness and earning power towards 2040. For this study we:

- Performed an analysis of the economic size, structure and characteristics of Dutch high-tech industry.
- Provided the relevant global and European context to put the Dutch high-tech industry in perspective.
- Identified trends impacting the high-tech industry.
- Provided a SWOT of the high-tech industry.

Our study will form a first building block for an innovation agenda and the overall project of the unit Industry to develop a system vision on the Dutch High-tech Industry.

1.1 Reading guide

This report is composed as follows: We start in Chapter 2 with an overview of the high-tech industry. Followed by the trends impacting the high-tech industry in Chapter 3. In Chapter 4 we cover the strengths, opportunities, weaknesses and treats of the high-tech industry. In Chapter 5 we discuss some first suggestions for the innovation agenda to ensure competitiveness and earning power of the changing high-tech industry.

2 Overview of the High-tech Industry

This chapter provides an overview of the High-tech industry of the Netherlands. We start with the definition of the sector in section 2.1, followed in section 2.2 by the characterization of the sector in terms of its economic size and dynamics, labour productivity, types and dynamics of enterprises and R&D and innovation (measured based on R&D expenditure and patents). We end the chapter in section 2.3 with the international position of the sector.

2.1 Definition of the High-tech Industry

The High-Tech industry refers to the sector with the highest form of technology available, also known as the sector providing advanced technology.[1]This definition is broader than the definition adopted by Statistics Netherlands for the top sector High Tech Systems and Materials (High Tech Systemen en Materialen)[2]. However, for our quantitative analysis in this report we follow the 2-digit NACE/SBI classification corresponding with the Statistics Netherlands' monitor of the Topsector Hightech. It includes the following sectors of economic activity (see the Figure below):

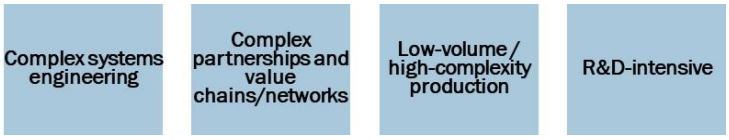
SBI Code of the sector of economic activity	Short English description used in this report
Maakindustrie	**Manufacturing**
22 Rubber- en kunststofproductindustrie	Rubber and plastics
24 Basismetaalindustrie	Basic metals
25 Metaalproductenindustrie	Fabricated metal products
26 Elektrotechnische industrie	Computer, electronic and optical products
27 Elektrische apparatenindustrie	Electrical equipment
28 Machine-industrie	Machinery
29 Auto- en aanhangwagenindustrie	Motor vehicles, trailers and semi-trailers
30 Overige transportmiddelenindustrie	Other transport equipment
33 Reparatie en installatie van machines	Repair and installation of machinery and equipment
Diensten	**Services**
62 IT-dienstverlening	Computer programming, IT-consultancy
71 Architecten-, ingenieursbureaus e.d.	Architectural and engineering activities; technical testing and analysis
72 Research	Scientific research and development

Source: Statistics Netherlands[3].
Figure 1 NACE/SBI codes used to describe the High-Tech Industry

[1] Cortright, Joseph; Mayer, Heike (January 2001). High Tech Specialization: A Comparison of High Technology Centers (PDF). Brookings Institution, Center on Urban & Metropolitan Policy
[2] Topsector *hightech systemen en materialen*: "*bedrijven met technologische activiteiten op het gebied van de metaalindustrie en vervaardiging van machines, apparaten en transportmiddelen. Naast productie worden ook andere activiteiten tot de topsector gerekend. Het gaat dan om het ontwikkelen, produceren en uitgeven van software, de keuring en controle van machines en apparaten en onderzoek en ontwikkeling op het gebied van hightech systemen en materialen".* Hightech systemen en materialen (cbs.nl)
[3] Economische indicatoren topsector HTSM, 2010 - 2020 (cbs.nl)

2.2 Characteristics of the High-tech Industry

The High-tech industry can be characterized by: the application of complex systems engineering, it consists of complex partnerships (based on close cooperation between enterprises, the government and knowledge institutions), value chains and value networks, it produces low-volumes with high-complexity, and it is R&D intensive (see *Source: TNO analysis.*
Figure 2). It is an important sector since a growing number of industries rely on the production of the High-tech industry.



Source: TNO analysis.

Figure 2 – Main characteristics of the players within the High-tech industry

Most of the largest R&D players in the Netherlands are form the high-tech industry (see Table 1); these are 18 enterprises out of 30 largest enterprises.

Table 1 – Top 30 enterprises by R&D Expenditure in the Netherlands in 2020 where blue enterprises fall under the definition of High-tech industry

Ranking	Company name	2020	2019	2018	2017
1	ASML	1.540	1.359	1.078	850
2	Royal Philips	778	733	702	716
3	Janssen pharmaceutical companies of Johnson & Johnson	499	413	360	371
4	Koninklijke KPN NV	413	447	365	430
5	Royal DSM	217	205	199	221
6	NXP Semiconductors	201	204	213	235
7	VDL Groep	159	157	122	101
8	DAF Trucks NV	125	165	163	146
9	Thales Nederland	118	127	136	124
10	Canon Production Printing Netherlands B.V.	112	129	109	114
11	Rijk Zwaan	105	98	101	85
12	Vanderlande Industries	75	57	55	
13	Friesland Campina	75	80	90	88
14	Byondis (previously Synthon[a])	68	60	49	64
15	Prodrive Technologies BV	61	52	45	36
16	Tata Steel	61	72	78	80
17	Enza Zaden	45	46	46	62
18	Lely	40	34	25	28
19	Nedap NV	35	30	26	24
20	DEMCON	30	38	27	12
21	ASM International NV	23	17	13	11
22	Batenburg Techniek	22	22	22	14
23	SKF	20	24	24	30
24	Keygene	19	20	19	21
25	Neways	17	14	14	13
26	Priva BV	17	15	14	15
27	Teijin Aramid BN	16	16	16	16
28	Royal HaskoningDHV[1]	15	16	11	12
29	Royal IHC	14	14	13	
30	Technolution BV	13	15	17	17

[a] – Synthon is partly sold, the Dutch R&D organization will proceed under a new name.
[1] – Royal HaskoningDHV is a consultancy active in the area of the high-tech industry.
Source: TW.nl[4].

Commented [KP(v1]: Check deze nog even – kogellagers etc – niet heel hightech

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Commented [YA(3R2]: SKF (kogellagerfabrikant) - Wikipedia
In NL research and development division

The company manufactures and supplies bearings, seals, lubrication and lubrication systems, maintenance products, mechatronics products, power transmission products, condition monitoring systems and related services globally.

The High-tech ecosystem contains a large network of suppliers and public-private partnerships. Within this ecosystem there are four regions that play an important role;1. in Amsterdam the Science Park, 2. in Delft Yes!Delft, 3. in Twente the Knowledge park of Twente and 4. the Brainport region of Eindhoven see Figure 3.

[4] https://www.technischweekblad.nl/files/44db51a175eb46cf0fccc76b16976346.pdf

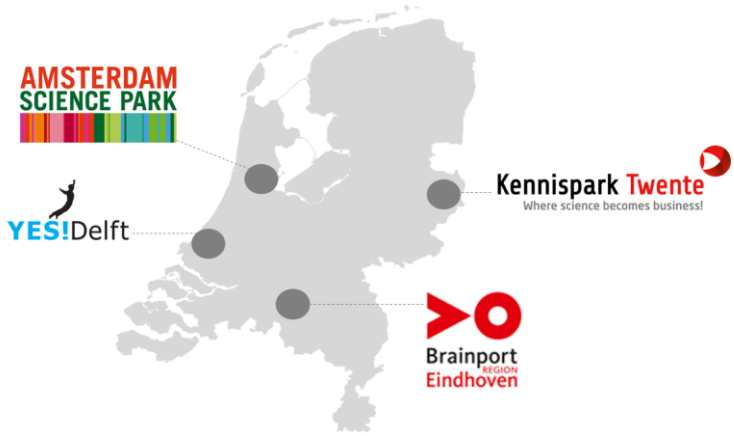


Figure 3 – The high-tech companies are concentrated in four clusters or ecosystems

The High-tech Industry is one of the country's nine "top sectors" and will receive significant support from the National Growth Fund to develop the next generation High-tech equipment.

Other important characteristics of the sector are the *economic size and dynamics*, *labour productivity*, *type and dynamics of enterprises* and *R&D and innovation*. Each of these characteristics will be discussed in the sections 2.2.1-2.2.5.

2.2.1 *Economic size and dynamics*

The High-tech Industry is an important and growing contributor to the Dutch economy, employing 784.000 FTE in 2021 or 10% of total employment in the Netherlands. Its gross value added was estimated at the level of 80.172 mln euro in 2021, and it grew by 35% since 2015. It has continued to grow strongly in the past years, also during the COVID-19 pandemic. The products and services produced by the High-tech industry are used as input for the manufacturing of semiconductors, medical instruments, and data communication.

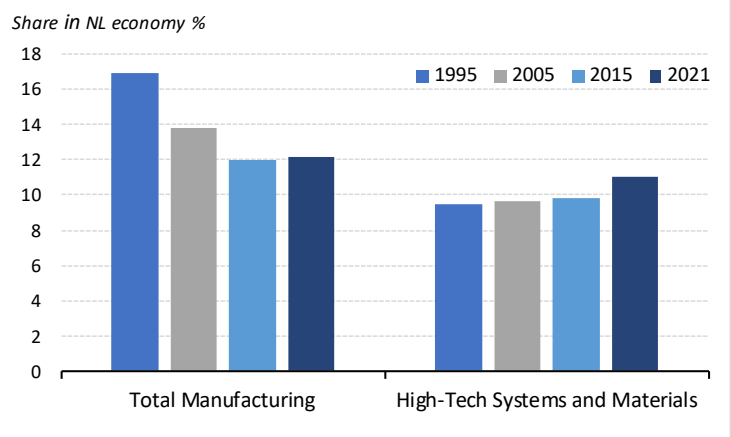
Figure 4 and *Source: Statistics Netherlands, National Accounts 2021V (calculations TNO)* Figure 5 show that the share of Manufacturing in the Dutch economy has been decreasing, while at the same time HTSM gains importance for the Dutch economy. The High-tech industry or the sector of High-Tech Systems and Materials comprised 10,6% in terms of gross value added in 2021. The High-tech sector represents a somewhat smaller share in the Dutch economy compared to manufacturing industry (12,2%). Moreover, the share of manufacturing has been decreasing in the past 15 years. At the same time, HTSM sector has been growing faster in the past years, above the average growth rate of the Dutch economy.

	GVA 2021	Share in NL economy (2021)	GVA growth* 2013-2019	2020	2021
	million euro	*in %*	*in %*	*in %*	*in %*
Total Economy	762.564	100	1,8	-4,1	5,2
Manufacturing	92.723	12,2	2,0	-2,3	7,1
High-Tech Systems and Materials	**84.165**	**10,6**	**3,4**	**1,8**	**8,8**

* price level of 2015.

Source: Statistics Netherlands, National Accounts 2021V

Figure 4 – Gross value added (GVA) of the manufacturing industry and High-tech Systems and Materials sector

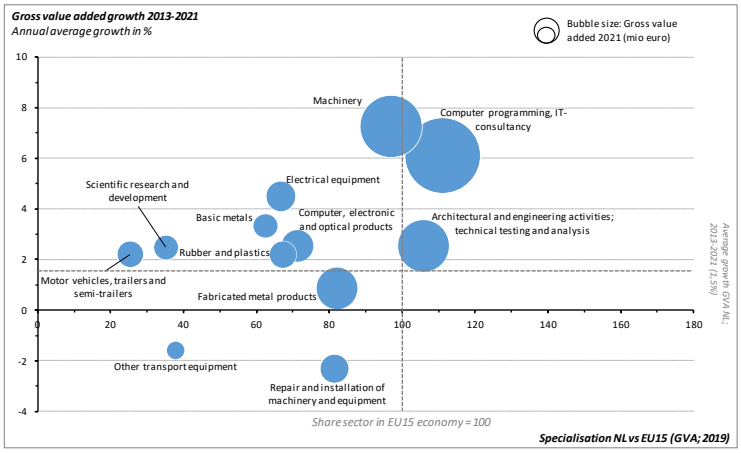


Source: Statistics Netherlands, National Accounts 2021V (calculations TNO)

Figure 5 – Share of Total manufacturing and High-tech sector within the Dutch economy in terms of Gross Value Added

Source: *Statistics Netherlands, National Accounts 2021V (calculations TNO)*

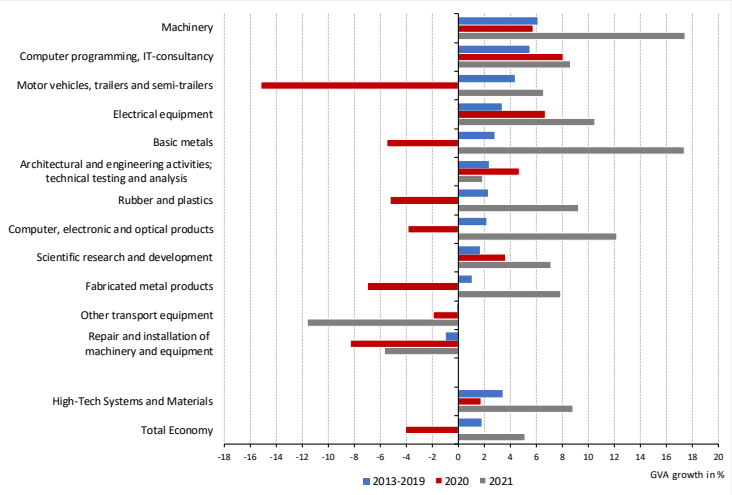
Figure 6 presents an overview of the average growth rate of gross value added per sub-sector within HTSM in combination with the specialization of the Dutch economy compared to the EU15. Machinery and computer programming and IT-consultancy are the largest sub-sectors within the High-tech industry. In addition, these are the fastest growing sub-sectors until 2021.



Source: Statistics Netherlands, National Accounts 2021V (calculations TNO)

Figure 6 – Specialization of the Netherlands vs the EU15 and gross value added growth in the sub-sectors of the High-tech industry between 2013 and 2021

While the share of High-tech sector has been growing in the past years, the growth rate of the sector has slowed down in 2020 because of the Covid-19 pandemic. The growth rate of gross value added (GVA, in prices of 2015) decreased from an average of 3,4% to 1,8% in 2020. In 2021, however, the growth recovered to 8,8% in HTSM well above the 5,2% growth of the Dutch economy as a whole. Figure 7 shows the growth in HTSM sub-sectors in the period 2013-2019; 2020 and 2021. The pandemic had the biggest effect on the sub-sectors motor vehicles, fabricated metal products, basic metals, rubber and plastics and repair and installation of machinery and equipment. Not all HTSM sub-sectors faced a decline of production in the first covid year (2020). Machinery, Computer programming & IT-consultancy, Electrical equipment, Architectural & engineering activities and Scientific research and development continued to grow in 2020. In 2020 the growth recovery was widespread among HTSM sectors. Only other transport equipment and Repair and installation of machinery and equipment were still facing a decline of their gross value added.



Source: Statistics Netherlands, National Accounts 2021V (calculations TNO)

Figure 7 – The growth rates of Gross Value Added of the sub-sectors of High-Tech sector (in price level of 2015)

The High Tech sector employed 784.000 full time equivalents (FTEs) in 2021 as shown in Figure 8. These figures however also include Information service activities (SBI 63) jointly with the computer programming, consultancy and related activities. The employment in the High-tech sector has been increasing on average by 2,6% yearly since 2012, as opposed to the employment within the manufacturing sector where the total labour volume (FTE's) only grew at an average rate of 0,4% per year. Among the sub-sectors, scientific research and development has seen the largest growth in the number of employed persons in the past two years. Motor vehicles, trailers and semi-trailers, on the other hand, has shown the largest drop in the number of employees over the past years by -4,0% in 2020 and -8,3% in 2021.

	2015	2016	2017	2018	2019	2020[5]	2021[5]
Absolute value							
Total Economy	7.015	7.159	7.340	7.561	7.751	7.774	7.951
Manufacturing	699	700	708	722	738	738	737
Total HTSM	**650**	**666**	**688**	**720**	**750**	**767**	**784**
Growth rate							
Total Economy	1,3%	2,1%	2,5%	3,0%	2,5%	0,3%	2,3%
Manufacturing	0,6%	0,1%	1,1%	2,0%	2,2%	0,0%	-0,1%
Total HTSM	**3,0%**	**2,5%**	**3,3%**	**4,7%**	**4,2%**	**2,3%**	**2,2%**
22 Rubber and plastics	29	29	30	30	30	31	31
24 Basic metals	19	19	20	21	21	21	20
25 Fabricated metal products	83	84	84	86	88	88	89
26 Computer, electronic and optical products	24	23	23	25	26	26	26
27 Electrical equipment	20	21	20	21	21	21	21
28 Machinery	75	76	79	80	85	87	89
29 Motor vehicles, trailers and semi-trailers	19	20	21	24	25	24	22
30 Other transport equipment	17	16	16	17	18	17	17
33 Repair and installation of machinery and equipment	39	40	42	44	46	45	44
62-63* IT- and information services	179	188	198	210	223	234	247
71 Architectural and engineering activities; technical testing and analysis	114	116	120	126	130	133	135
72 Scientific research and development	32	34	35	36	37	40	43

* data is only available for the combination of two subsectors.

Source: Statistics Netherlands, National Accounts 2021V (calculations TNO)

Figure 8 – Employment (in thousands FTE)

Zooming in: activities within characteristic HTSM sub-sectors

Some characteristic sub-sectors within HTSM (based on their economic size, growth, R&D-intensity or patent specialization) are heterogeneous by nature. These sub-sectors are home to a broad variety of different activities. This variety of activities is not immediately clear from the name of the 2-digit main sector. To show which specific high-tech activities are predominantly present within the Dutch HTSM sub-sectors we zoom in the Dutch Machinery industry, Electrical equipment industry and Computer, electronics and optics industry.

Dutch Machinery industry

With a company as ASML The Netherlands is World leading in the production of machines that are used to produce chips and semiconductors. However, if we take a closer look at the activities within Dutch machinery industry it is clear that a large share of machinery production activities are related to heavy equipment for weighing, lifting and handling as well as machinery for food processing and agricultural activities (see Figure 9).

Commented [KP(v4]: Weten we zeker dat ASML in deze bucket zit bij het CBS?

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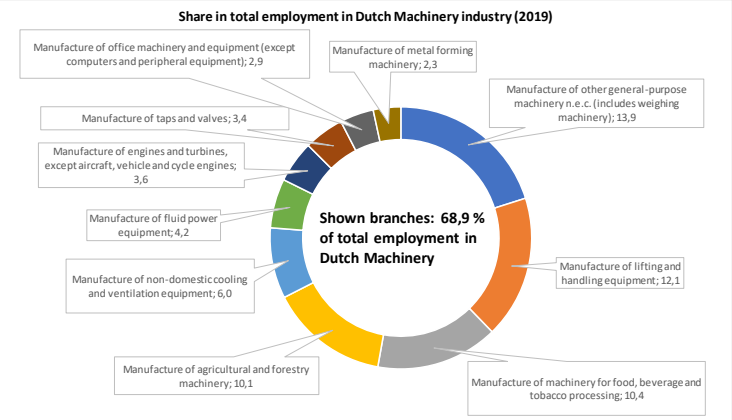
[5] These are tentative figures.

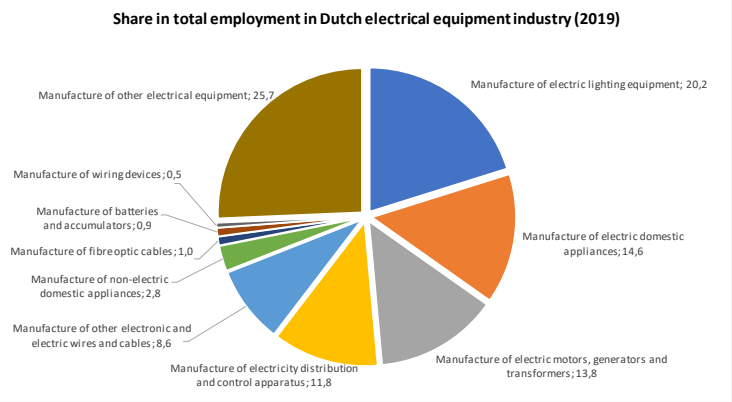


Source: LISA (calculations TNO).

Figure 9 – Distribution of the number of employed persons within the machinery sub-sector, 2019 (% of total employment within the sub-sector)

Dutch Electrical equipment industry

The electrical equipment industry produces a wide variety of equipment and appliances. In the Netherlands the largest activities within this HTSM sub-sector are: production of lighting equipment, production of electric domestic appliances, production of electric motors, generators & transformers, production of electricity distribution & control apparatus and manufacturing of electronic & electric wires and cables. Together these economic activities made up 69% of total employment in Dutch Electrical equipment industry in 2019 (see Figure 10).

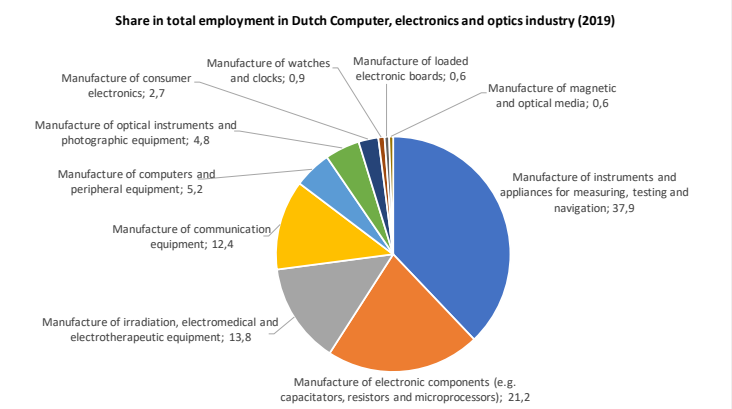


Source: LISA (calculations TNO).

Figure 10 – Distribution of the number of employed persons within the electrical equipment sub-sector, 2019 (% of total employment within the sub-sector)

Dutch Computer, electronic and optics industry

Within Dutch Computer, electronic and optics industry manufacturing of instruments and appliances for measuring, testing and navigation made up the largest share of total employment in 2019: 37,9% (Figure 11). Manufacturing of electronic components, capacitators, resistors and microprocessors counted for 21,2% of total employment in this HTSM sub-sector. Two other relatively large fields of activity within Dutch Computer, electronic and optics industry are (electro)medical equipment and communication equipment.



Source: LISA 2019 (calculations TNO)

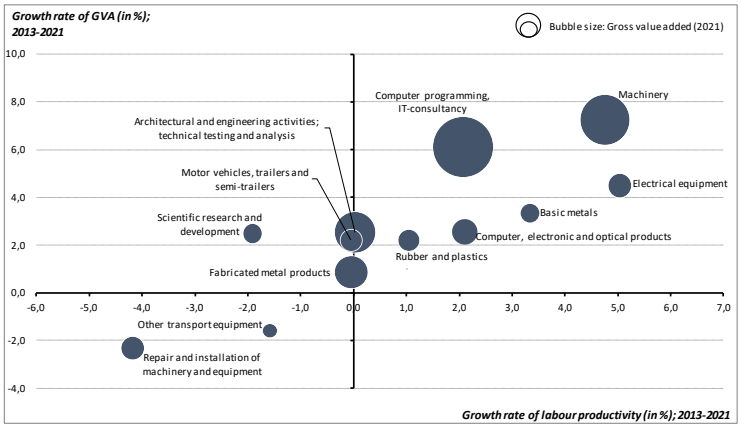
Figure 11 - Distribution of the number of employed persons within the Computer, electronics and optics sub-sector, 2019 (% of total employment within the sub-sector)

2.2.2 *Labour productivity*

Prior to the Covid-19 pandemic, labour productivity within the High-tech sector has shown a moderate growth rate of 1% between 2013 and 2019, which is higher than the growth rate of the labour productivity[6] for the whole economy. In 2020 the majority of High-tech sub-sectors experienced a drop in productivity, and recovered largely in 2021. On average, the labour productivity grew by 6,4% in 2021, which was lower than that of the manufacturing industry (7.3%).

When zooming into the individual sub-sectors of the high-tech industry, not all HTSM industries had a strong productivity growth supporting their economic development between 2013-2021 (Figure 12). The labour productivity has on average decreased for three sub-sectors in the period 2013-2021: 1. Repair and installation of machinery and equipment, 2. Scientific research and development and 3. other transport equipment. Repair and installation of machinery equipment experienced the largest decrease in both labour productivity and added value between 2013 and 2021 among the sub-sectors of high-tech industry. Machinery, on the other hand, grew the fastest in gross value added: on average 7,3% per year. At the same time it showed one of the largest growth rates in the labour productivity (4,8%) being the second after electrical equipment (5%).

[6] Labour productivity is measured as gross added value divided by the number of full time employees.



Source: Statistics Netherlands, National Accounts 2021V, Eurostat (calculations TNO)

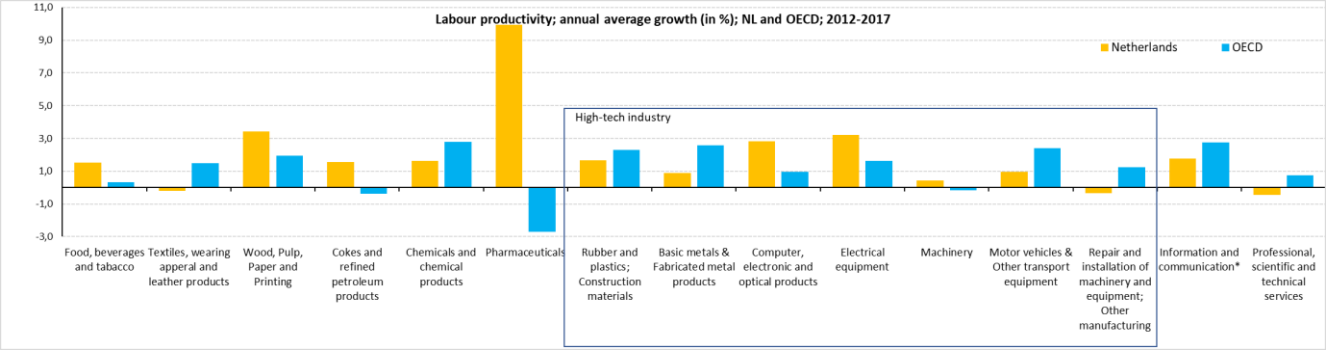
Figure 12 – Comparison between the growth of gross value added (GVA) and labour productivity for the sub-sectors of High-tech industry (in price level of 2015)

International perspective

When comparing the evolution of the labour productivity between 2012 and 2017 from an international perspective, there are large variations between the sectors in the Netherlands and the OECD countries (see *Source: CBS, Eurostat, OESO, ECB, DNB and IMF (calculations TNO)*

*Note: * 1 NACE/SBI code at the level of 2 digits (out of 6) is included in the high-tech sector within Information and Communication, and therefore it is not marked as being part of the high-tech industry*..

Figure 13). Electrical equipment, computer, electronic and optical products show the labour productivity growth rates that are approximately twice as large as the level of it for the OECD countries. Within manufacturing industry, the pharmaceuticals sub-sector showed also a larger productivity growth: 10% as opposed to -2,8% for the OECD countries. While the growth rate of GVA for information and communication technologies is much lower in the Netherlands than that of the OECD countries (3,9% and 6,2% respectively) as shown on Figure 32, the labour productivity in this sub-sector is much higher in the Netherlands (10%).



Source: CBS, Eurostat, OESO, ECB, DNB and IMF (calculations TNO)

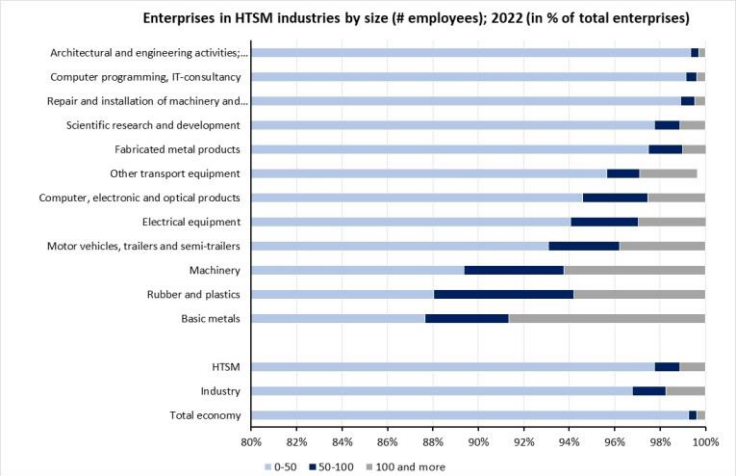
*Note: * 1 NACE/SBI code at the level of 2 digits (out of 6) is included in the high-tech sector within Information and Communication, and therefore it is not marked as being part of the high-tech industry..*

Figure 13 – Labour productivity annual average growth rate of labour productivity between 20212 and 2017 (in %) in the Netherlands and OECD countries

2.2.3 *Type and dynamics of enterprises*

The majority of enterprises active in the high-tech industry are small and medium sized enterprises, as shown in Figure 14. There were 161 thousand enterprises active in the high-tech industry in 2022[7], out of which 147 thousand or 96,5% enterprises employ up to 50 persons. The share of the smaller enterprises, that employ up to 50 persons, is slightly higher than it is within the manufacturing industry (96,8%) and slightly lower than it is within the total economy (99,3%). It is similar when looking at the individual sub-sectors of the high-tech industry.

Machinery, rubber & plastics and basic metals employ the lowest number of SME's in relative terms.



Source: Statistics Netherlands (calculations TNO)

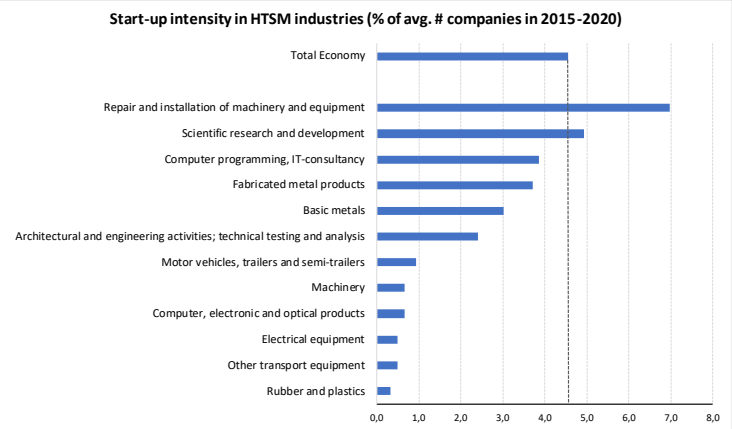
Figure 14 – Relative importance of enterprise size classes for the high-tech industry and its sub-sectors, total economy and manufacturing industry in 2022 (as a share of total number of enterprises)

Start-ups could be considered as sources of radical and disruptive innovation[8]. Figure 15 shows the average start-up intensity measured as an average share of the number of net start-up enterprises[9] of the total number of enterprises across 2015 and 2020.

On average there have been 4,5% of net start-ups in the Netherlands as a share of the total number of enterprises. Within the High-tech industry, the share of net start-ups is lower, averaging to 2,4% between 2015 and 2020. Among the sub-sectors of

[7] The data is for the second quarter of 2022, which is the latest data available at the moment of performing analysis.
[8] https://www.oecd.org/cfe/smes/ministerial/documents/2018-SME-Ministerial-Conference-Plenary-Session-1.pdf
[9] The number of start-ups is measured as the positive difference between newly established and closed organizations.

the high-tech industry, repair and installation of machinery and equipment has the largest start-up intensity, amounting on average to 7%.



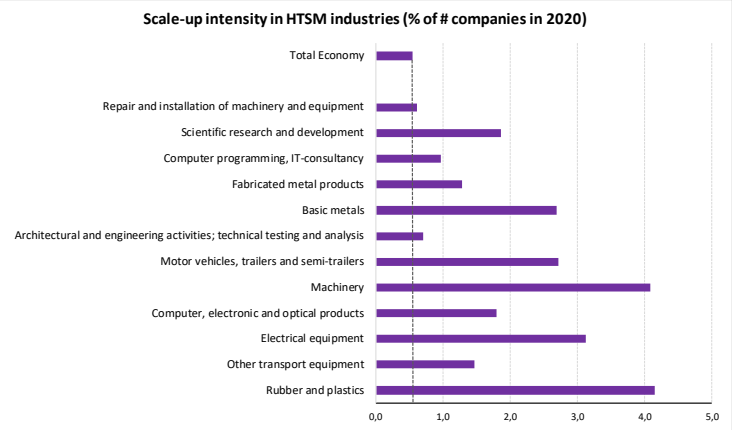
Source: Statistics Netherlands (calculations TNO)

Figure 15 – Start-up intensity in High-tech Industries (as a share of the average number of companies) between 2015 and 2020

Figure 16 presents the scale-up intensity. It is measured as the number of fast growing enterprises as a share of the total number of enterprises, where fast growing enterprises are determined according to the definition of Statistics Netherlands[10]: "*enterprises with an annual growth rate of 10% of more over a period of three consecutive years based on the number of employees. In addition, companies must have at least 10 employees at the start of the growth period and companies established in the start year of the growth period are not counted".*

The scale-up intensity was 0,5% in the Netherlands in 2020. While it has been significantly higher for the high-tech industry: 2.1% in 2020. Rubber & plastics and Machinery show the highest scale-up intensity: 4,2% and 4.1% in 2020 respectively. The third highest scale-up intensity is within the sub-sector of Electrical equipment (3% in 2020).

[10] Snelle groeiers, Europese norm; SBI2008 (cbs.nl).

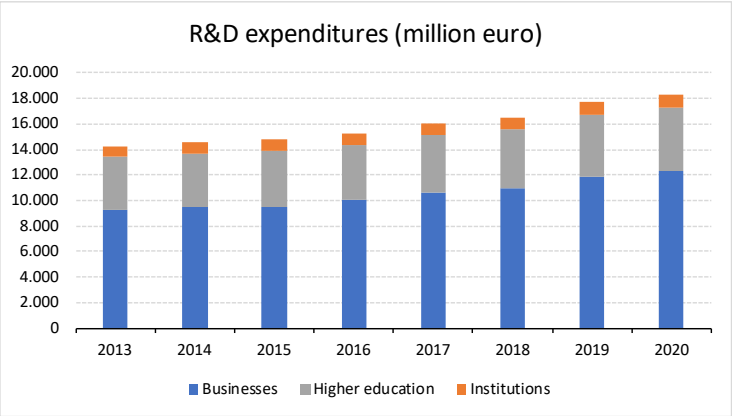


Source: Statistics Netherlands (calculations TNO)

Figure 16 – Scale-up intensity in High-tech industry (as a share of the total number of companies) in 2020

2.2.4 *R&D and Innovation – R&D expenditures*

In 2020 the Netherlands spent around 18.356 million euro on research and development. This is an increase of 0.5 million euro compared with 2019 (17.760 mln euro). Figure 17 shows the evolution and division of the research and development expenditures split per type of organization: the businesses, institutions and higher education.

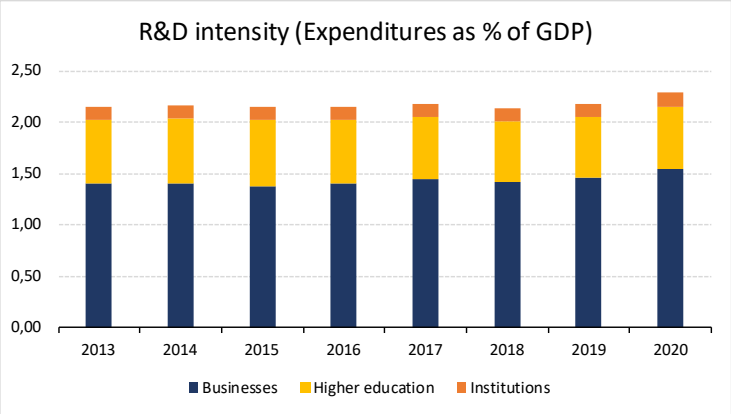


Source: Statistics Netherlands

Figure 17 – Research and development expenditures in the Netherlands between 2013 and 2020 (in million euro)

R&D expenditure as a percentage of GDP was at 2.3% in 2020 (see Figure 18), which was approximately equal to the average of the EU Member States. Over the last ten years, R&D intensity increased in the Netherlands with slight fluctuations

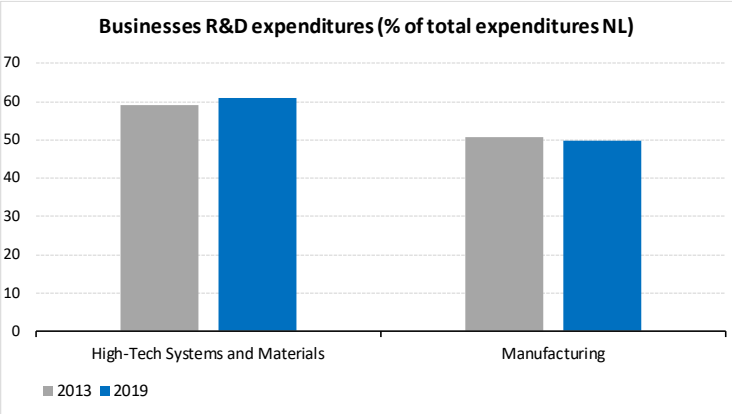
and remained approximately at the average intensity level of the EU Member States.



Source: Statistics Netherlands

Figure 18 – Research and development intensity in the Netherlands between 2013 and 2020 (in %)

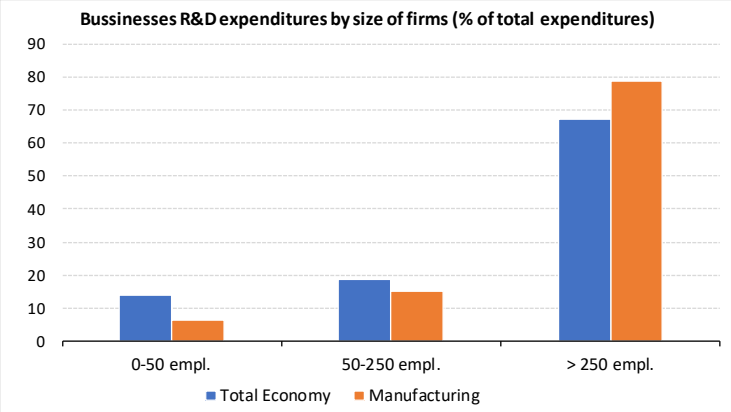
In 2019 the businesses spent 11.846 million euros on research and development. Within manufacturing sector, they spent 5.9 million euro, which is lower than the businesses within the high tech industry (that spent 7.207 million euro). In other words, the high tech industry constituted 60,8% of the total R&D expenditures in 2019, while manufacturing had a share of 49,9% in total R&D expenditures in the Netherlands (Figure 19). On average, the growth rate of the R&D expenditures was 4,6% between 2013 and 2019, that is higher than the average growth rate within the manufacturing industry and for the Dutch economy as a whole.



Source: Statistics Netherlands (calculations TNO)

Figure 19 – Share of the R&D expenditures spent by businesses in total R&D expenditures across the whole economy in the Netherlands, 2013 and 2019

Looking at the R&D expenditures by businesses, the majority of research and development expenditures are invested by the large enterprises (Figure 20). At the level of sub-sectors there is only fragmented data available (SBI 2 digits), we can assume that this is comparable between the manufacturing and the High-tech industry.

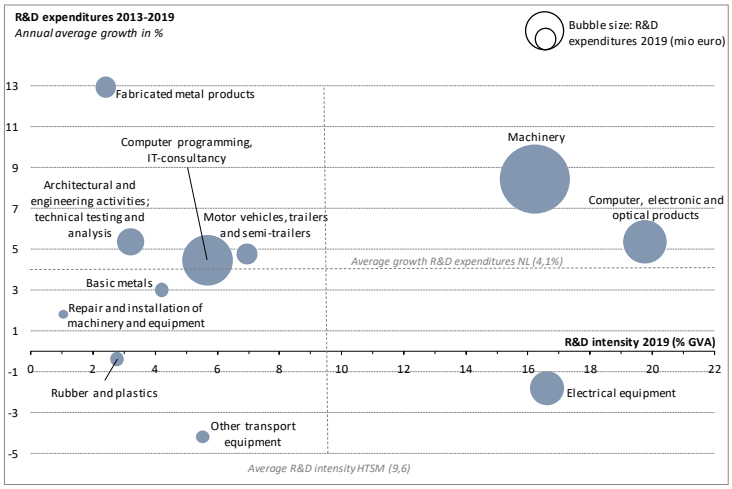


Source: Statistics Netherlands (calculations TNO)

Figure 20 – R&D expenditures by businesses by size of the enterprises as a share of the total expenditures (%) in 2019

Among the different sub-sectors in the high-tech industry, machinery and computer programming invested most in R&D in 2019: 2.186 million euro and 1.152 million euro respectively. The businesses within the sector of computer, electronic and optical products spent almost 867 million euro in 2019, while R&D expenditures by the businesses within the rest of the sub-sectors ranged between 39 and 528 million euro.

Computer, electronic and optical products, electrical equipment, and machinery have the highest R&D intensity, where R&D expenditures amounted to 19,8%, 16,6%, and 16,2% of the gross value added respectively in 2019 (Figure 21). For the rest of the sub-sectors, the R&D intensity ranged between 1% and 7% in 2019.

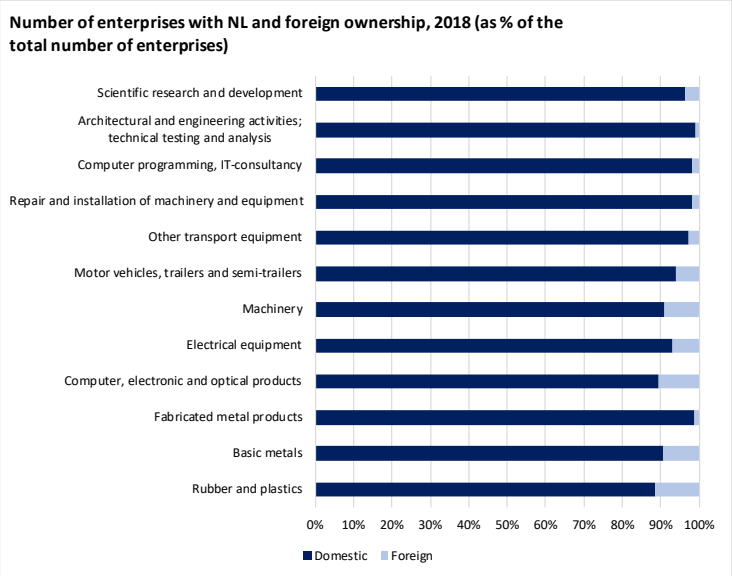


Source: Statistics Netherlands (calculations TNO)

Figure 21 – R&D expenditures by business per sub-sector of the high-tech industry in the Netherlands between 2013 and 2019

2% of the enterprises had foreign ownership in 2018[11]. Within the individual sub-sectors the foreign ownership varied between 1 and 11% (Figure 22). The two sub-sectors: rubber and plastics and computer, electronic and optical products, have the highest share of the foreign owned enterprises (11%), followed by machinery and basic metals (9%) and electrical equipment (7%). The majority of these companies are owned by EU or US enterprises.

[11] At the moment the report was written, the latest data was available for 2018.



Source: Statistics Netherlands (calculations TNO)

Figure 22 – The share of the number of enterprises with domestic and foreign ownership in 2018 (in %)

In 2018, expenditures on R&D in foreign owned enterprises constituted a large share within the total R&D expenditures for a number of sub-sectors of the high-tech industry (Figure 23). Particularly, this share was the highest in the rubber and plastics industry (66% in 2018). The other sub-sectors with a relative large share of R&D in foreign owned enterprises were: other transport equipment (50%) and computer, electronic and optical products (40%).

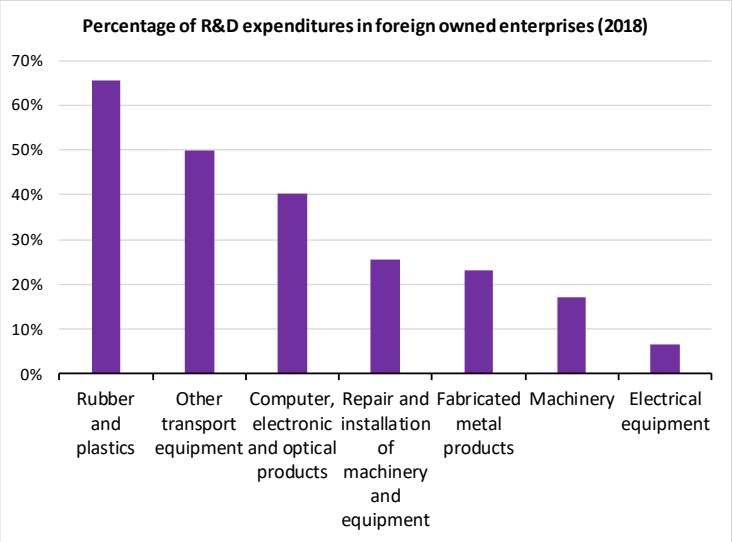


Figure 23 – The share of the R&D expenditures in foreign owned enterprises in 2018

Note: data is not available for the sub-sectors: basic metals, Motor vehicles, trailers and semi-trailers, Computer programming, IT-consultancy, Architectural and engineering activities; and Scientific research and development.
Source: Statistics Netherlands (calculations TNO)

2.2.5 R&D and innovation – Patents

Another indicator of R&D and innovation next to R&D expenditure are the number of patents. They capture some of the technological trends and innovation, though not all innovations are patented. Based on the information of the location of the legal owner of the patent, one can trace where the patents have originated.

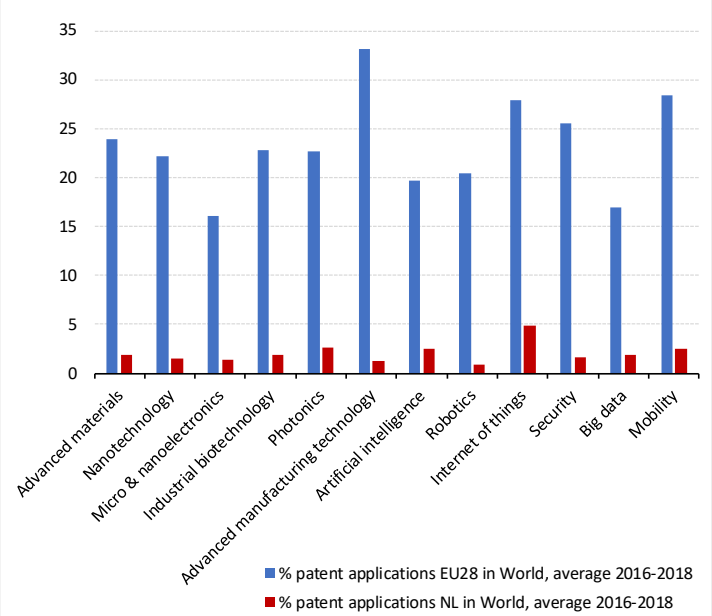
Within this section, we use the advanced technologies for industry as a proxy for the technologies used within the high-tech industry. The distinction is made between advanced manufacturing technology, advanced materials, artificial intelligence, augmented/virtual reality, big data, blockchain, connectivity, cloud industrial biotechnology, internet of things, micro- and nanoelectronics, mobility, nanotechnology, photonics, robotics, IT for security/cybersecurity[12].

The EU28's share in global patenting in advanced technologies varied between 16% in micro- and nanoelectronics and 33% in advanced manufacturing technologies on average between 2016 and 2018 (see Figure 24). The highest shares in global patenting are attributed to the advanced manufacturing technologies, mobility and internet of thing, and security. In terms of absolute numbers, the EU is lagging behind players like China. China filed 3.2 times more

[12] Specific definitions used for each of the technologies are presented here: European Commission (2021). *Advanced Technologies for Industry – Methodological report. Indicator framework and data calculations*. Brussels, EISMEA and DG GROW, September 2021.

patents than Europe in 2014.[13] Since then, the gap has only increased. In 2019 Europe filled 12.2 times fewer patents than China. Within the high-tech industry, China submitted one to seven times as many patent filings in 2019 as in 2014, led by batteries, cloud, and AI. [13]

The contribution of the Netherlands to global patenting in advanced technologies varied between 1% and 5% on average between 2016 and 2018. Internet of Things technologies had the highest share of all advanced technologies for industry, followed by photonics and artificial intelligence.

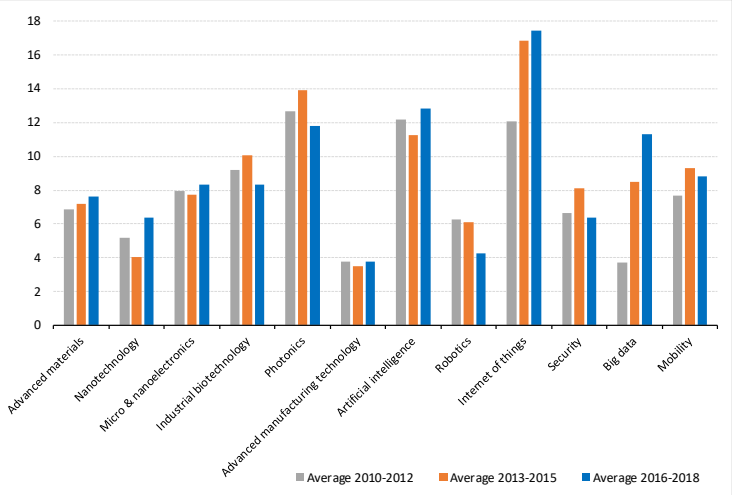


Source: European Commission/Patstat, calculations TNO

Figure 24 – The share of the patent applications from the Netherlands in the number of patent applications worldwide, on average between 2016-2018

Zooming into the Dutch patent applications originating within EU28, three technologies have shown the largest contributions over the past ten years: 1. internet of things (17%), 2. artificial intelligence (13%), and 3. photonics (12%) (Figure 25). While the share of patent applications for internet of things and artificial intelligence have been growing, that of photonics has shown some decline between 2016-2018. Industrial biotechnology, robotics, mobility and IT security/cybersecurity have also decreased in terms of the patent contributions between 2016-2018.

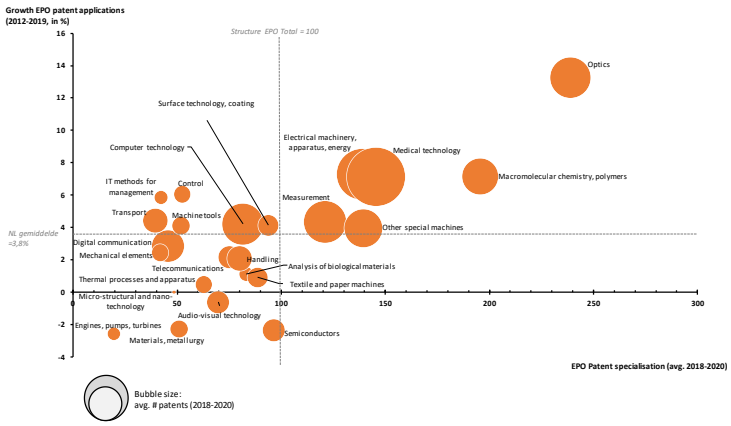
[13] https://www.kearney.com/communications-media-technology/article/-/insights/the-tipping-point-for-european-high-tech-catch-up-or-lose-out



Source: European Commission/Patstat, calculations TNO

Figure 25 – The share of the Dutch patent applications originating from EU28, on average between 2010 and 2018

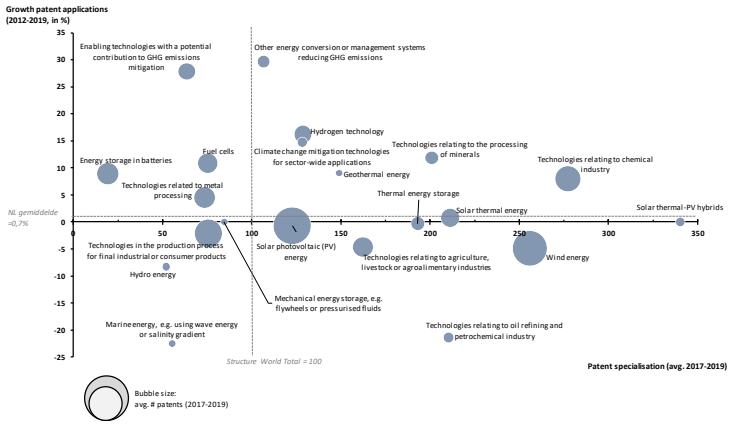
Overall, the data suggests that the Netherlands has a strong technology position in optics and photonics. Looking at the European patent applications by field of technology, the Netherlands also has a strong technology position in Optics, Polymers, Medical technology, Electrical machinery and measurement (see Figure 26). Figure 26 shows the growth of patent applications in the Netherlands compared to the patent specialization of the Netherlands. The patent specialization index compares the share of patents in specific technologies over the total innovative activity for the Netherlands against the respective share for the World regarding patents that are filed at the European Patent Office. Optics has a patent specialization index of 239 on average between 2018 and 2020, while the growth rate of patent applications was on average 13,3% between 2012 and 2019. Electrical machinery, apparatus, energy is another example of a technology with a high patent specialization and relatively high growth rate in patent applications (138,7 and 7,3% respectively).



Source: European Patent Office (calculations TNO)

Figure 26 – Growth in patent applications and patent specialization between 2012 and 2020

Besides optics, polymers, medical technology and electrical machinery, the Netherlands builds-up position in some upcoming Environmental and Climate technologies (Figure 27). This is particularly the case for solar thermal-PV hybrids, technologies relating to chemical industry and to oil refining and petrochemical industry, and to the processing of minerals with patent specialization scores above 200.



Source: OECD (calculations TNO)

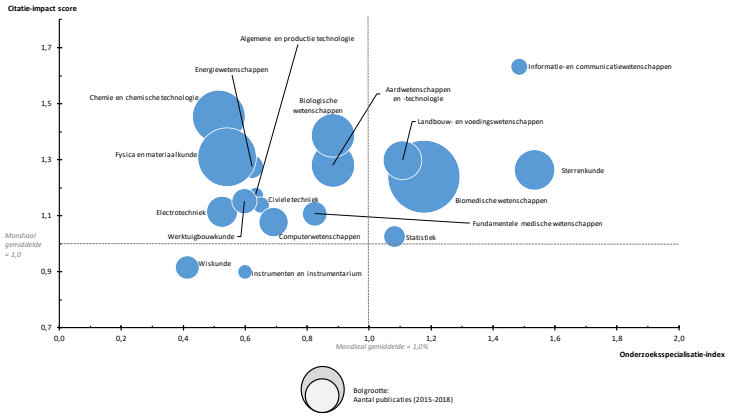
Figure 27 – Growth in patent applications and patent specialization between 2012 and 2020

The analysis of the research system of the Netherlands based on the comparison of the international research specialization index[14] and citation impact scores[15], shows that the volume of research output (number of publications) of the Netherlands in for high-tech industry relevant fields of science is relatively low compared to other countries.. However, with high citation impact scores it is clear that although scientific research groups and resulting number of publications might be somewhat smaller than elsewhere in the World, the impact or quality of Dutch research output in these fields of science *is* internationally recognized.

Figure 28 presents the research specialization index and citation-impact scores in the Netherlands between 2015 and 2019. In particular, chemistry and chemical engineering, mathematics, computer sciences, civil engineering and construction, electrical engineering and telecommunication, energy science and technology, physics and materials science, general and industrial engineering, mechanical engineering and aerospace are the fields with a relative low share in scientific output, where the research specialization index is lower than 0,8. This specialization index represents the relative share of the number publications in each field of science as a percentage of the total number of publications. The World average share of each field of science in total publications is set as benchmark (index = 1,0).

An index score for the Netherlands of 0,8 than means that e.g. that the number of publications in a certain field of science adds up to a share of 10% in the World total while the share of this field in the Netherlands' total number of publications is 8%. The index score is than calculated as share NL/Share World, meaning 8/10=0,8. A specialization score >1,0 indicates that the Netherlands publishes more scientific research in that particular field compared to the World average, hence the Netherlands has a specialization in that field of science.
To get a feeling for the order of magnitude of the number of Dutch scientific publications: The largest field of science included in Figure 28 is Biomedical sciences. The average number of Dutch publications in the period 2015-2018 was 15.537. Other large fields, yet with a specialization score <1, are Physics & Materials Science & Engineering ("Fysica en materiaalkunde") with an average of 10.128 publications and Chemistry & Chemical technologies with an average of 8.149 publications. The Netherlands had an average of 580 publications in Instruments and instrumentations – the smallest field of science included in Figure 28.

[14] The research specialization index is calculated as the share of a given field in the publications of a given country with the share of the same field in the world total of publication.
[15] The citation impact score is calculated as a ratio of the number of citations within scientific journals received between 2015 and 2018 to the number of publications of the journals in 2015 and 2019.



Source: Thomson Reuters/CWTS Web of Science (calculations TNO)

Figure 28 – Citation-impact score and research specialization index in the Netherlands between 2015 and 2019

2.3 International position of the High-Tech industry

To give a view on the international position of the High-Tech industry of the Netherlands the export rates are used and will be discussed in this section. The export of goods and services amounted to 710.604 million euros in 2021. This was higher than the level of it in 2020 (623 billion) and it exceeded the pre corona value in 2019 (671 billion). The exports comprises of two categories: domestically produced export or domestic export and re-export[16]. Re-exports is the exports of goods previously imported to the Netherlands and then exported in a completely or nearly unprocessed condition, from which there are little or no earnings to the Dutch economy. The level of re-exports accounted for 35,4% of the total exports (251 billion) in 2021 as shown on Figure 29. Domestically produced export accounted for 56,2% of the total exports or 399.524 million euro in 2021. It was higher than the level of it in 2020 (362 billion euro).

Figure 29 also shows the composition of the origin of the domestically produced exports. High-tech industry is responsible for 25,4% of all domestically produced exports and amounted to 101.301 million euros in 2021. The share remained stable over the past 7 years with slight variations. Manufacturing industry exported more than twice the value of domestically produced goods and services of the high-tech industry (214.003 million euro).

[16] There could be other positions within the total export. These however constitute usually less than 10% and therefore are not named here.

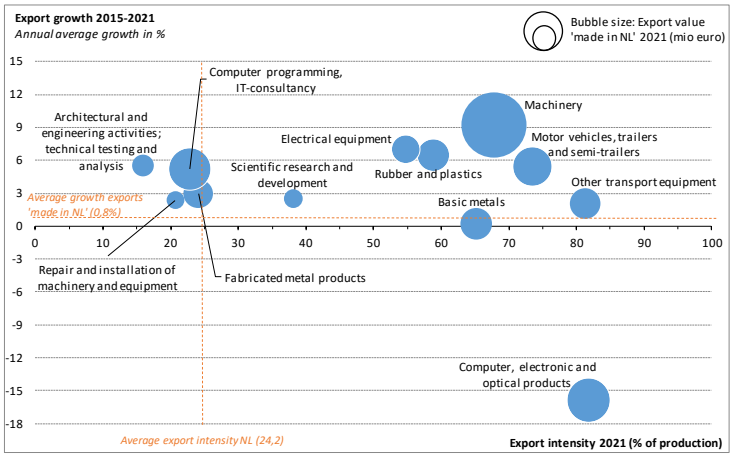
	Export value 2021	Share of total exports 2021	Growth 2015-2019	Growth 2020	Growth 2021
	million euro	*in %*	*in %*	*in %*	*in %*
Total domestic produced exports ('made in the Netherlands')	**399.524**	**56,2**	**2,4**	**-6,0**	**1,6**
Exports by NL Manufacturing industries	214.003	30,1	1,7	-2,7	4,2
Exports by NL High-Tech Systems and Materials industries	101.301	14,3	2,5	-3,2	-0,4
Re-exports	251.433	35,4	5,6	-1,6	10,5
Product-related taxes less subsidies, trade and transport margins, Cif/fob-corrections	59.647	8,4			
Total Exports	**710.604**	**100**	**3,6**	**-4,3**	**5,2**

Source: Statistics Netherlands, National Accounts 2021V (calculations TNO)

Figure 29 – Export of goods and services by sector of origin

A relative large share of domestic production in HTSM industries are exported (see Figure 30). 45,7% of the produced goods and services were exported in 2021. Goods and services produced within computer, electronic and optical products and other transport equipment are the top exporters with export intensity[17] of 81,8% and 81,3% in 2021. The following sectors are exporting the least as a share of the production of the individual sub-sectors: architectural and engineering activities; technical testing and analysis (15,9%), and Computer programming, IT-consultancy (22,8%) and Fabricated metal products (24,1%). At the same time computer, electronic and optical products experienced a decrease in export by 15,9% annually (between 2015 and 2021). Because of it, the average growth rate of the export of high-tech industry is low: 1,1% between 2015 and 2021. For all the other sub-sectors, the average export growth rate was 4,4%.

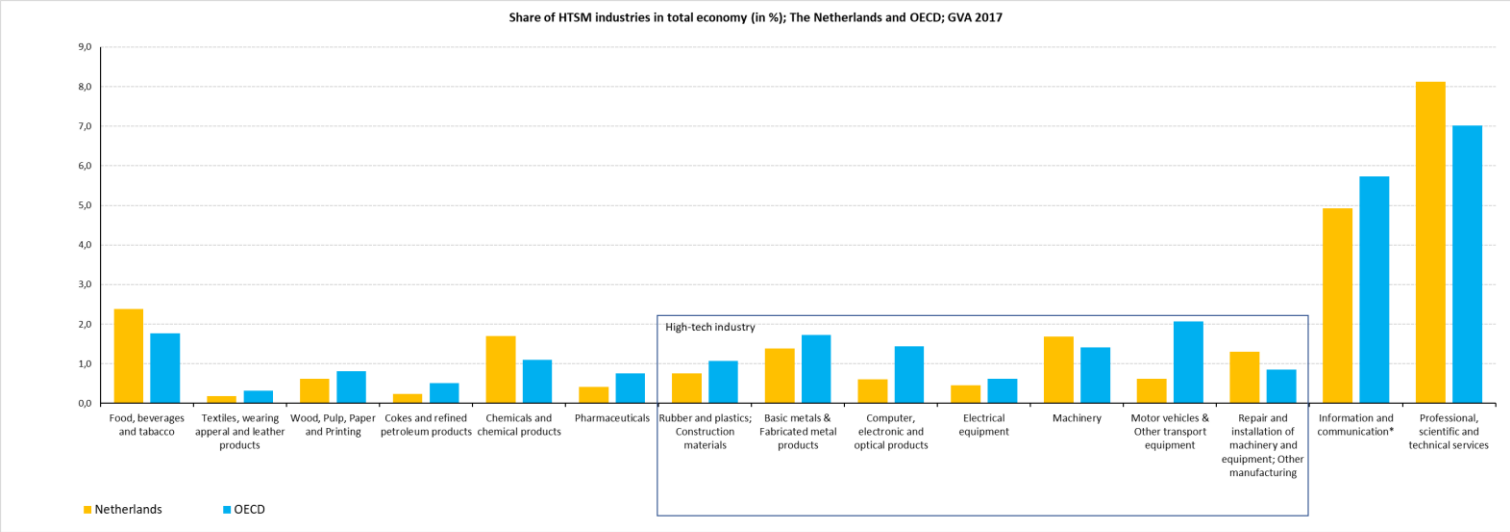
[17] The export intensity is measured as a share of the export in the production value.



Source: Statistics Netherlands, National Accounts 2021V (calculations TNO).

Figure 30 – Export growth, export intensity and export value of the sub-sectors of the high-tech industry

Compared to other EU15 countries, the Netherlands specializes in Computer programming & IT-consultancy, Architectural & engineering activities (see). Compared to OECD countries, the Netherlands also specializes in Machinery and Repair & installation of machinery and equipment (see Figure 31). Machinery as a sub-sector of the high-tech industry constituted 1,6% of the total economy in terms of the gross value added in 2017, which is slightly higher than that of on average across OECD countries. On average, motor vehicles and other transport equipment constituted the largest share in total economy for the OECD countries (2,1% in 2017). While it was significantly lower in the Netherlands, comprising 0,6% in 2017.

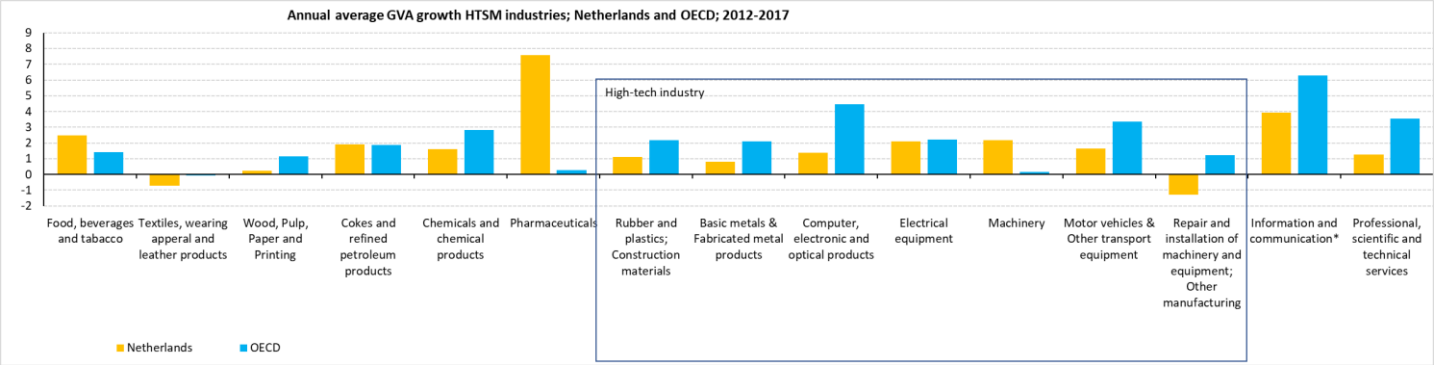


Source: CBS, Eurostat, OESO, ECB, DNB and IMF (calculations TNO)

Note: * 1 NACE/SBI code at the level of 2 digits (out of 6) is included in the high-tech sector within Information and Communication, and therefore it is not marked here as being part of the high-tech industry.

Figure 31 – Share of the sub-sectors of the high-tech industry and other manufacturing in total economy (%, GVA) in 2017 in the Netherlands and OECD

The Machinery sub-sector is also one of the fastest growing sub-sectors across the OECD countries (Figure 32). The rest of the sub-sectors of the high-tech industry in the Netherlands experienced a smaller growth compared to that of the OECD countries. Repair and installation of machinery and equipment is the only sub-sector that experienced a decrease in the Netherlands between 2012 and 2017.



Source: CBS, Eurostat, OESO, ECB, DNB and IMF (calculations TNO)

Note: * 1 NACE/SBI code at the level of 2 digits (out of 6) is included in the high-tech sector within Information and Communication, and therefore it is not marked as being part of the high-tech industry.

Figure 32 – Annual average growth of gross value added per sub-sector of the high-tech industry and other manufacturing in the Netherlands and OECD (in % between 2012-2017)

3 Trends impacting the High-tech Industry

Trends that have an impact on the current high-tech Industry are both internal (originating within the sector) and external (coming from outside the sector). The internal trends are discussed in section 3.1 and the external trends are described in section 3.2. This is not an exhaustive list of trends, but these are the trends often mention by experts and in the literature.

3.1 Internal trends impacting the sector

Various internal trends impacting the high-tech industry can be distinguished such as:

High-tech firms have to deal with more demanding customers

The high-tech firms are in a race to serve more demanding customers. To remain competitive, firms have to offer more personalized and customized products and services. High quality services, reliable products and fast delivery are only a few things that continue to put pressure on the manufacturing processes.
This leads to a higher complexity of products, as well as the knowledge and the skills needed in their assembly. Manufacturing increasingly relies on the ability to apply technological developments in advanced products and solutions that were not possible before.

Varying and increasing needs are changing the type of required employees

Different and increasing requirements are changing the type of employees needed by the high-tech industry. Therefore the need for multidisciplinary experts is growing within the high-tech Industry. Specifically, the high-tech industry demands more comprehensive skills profiles. These include but are not restricted to: science, technology, engineering, mathematics, literacy, numeracy and digital, data literacy; a mix of cognitive and socio-emotional skills.[18]

3.2 External trends impacting the sector

There are also a number of external trends impacting the high-tech Industry such as:

Rising geopolitical tensions that impact high-tech value chains

The EU high-tech industry is being affected by the rise of China as superpower and the increasing geopolitical tensions across the globe. China has been gaining a prominent position in manufacturing and high-tech industry. In particular, China's share in global manufacturing value chains has risen sharply from 6% to 19% between 2005 and 2019 at the expense of the EU whose share dropped from 27 %

[18] Skills for Smart Industrial Specialisation and Digital Transformation - Brochure.pdf (skills4industry.eu)

to 16%.[19] Furthermore, China launched the 'Made in China 2025 strategy'[20] setting ambitious goals for key industrial sectors. The main goals is to strengthen its domestic innovation capacity and to reduce its reliance on foreign technologies, thereby improving its positions in global value chains. Unlocked by this strategy, Chinese investors have been increasing the investments in the industries with a high innovative and technological content where traditionally the EU has been stronger than China.[21] As a reply European policymakers and the industry put strategic autonomy of the European high-tech industry and the manufacturing sector high on the agenda.[22]

Economic efficiency and economic specialization drove the original global set-up of the value chains within the high-tech industry in the past. However, how the value chains are organized has been contested by the Covid-19 pandemic and geopolitical events such as the most recent issues surrounding Russia and Ukraine. Each stakeholder in the value chain is dependent on one or more or stakeholders in the chain and therefore they are vulnerable to disruptions in in their respective chains, where effects span from the shortages in the availability of raw materials to delays in logistics and supply of products and services. It is not surprising that geopolitical issues have a stronger impact on enterprises that have a larger number of foreign customers***Error! Bookmark not defined.*** and suppliers. Besides that rising geopolitical risks and uncertainties are likely to stifle innovation where companies are more likely to launch fewer innovative product development projects.[23] This negative impact is most likely to last for the years to come.

Emergence of new, disruptive (digital) technologies

Technology development is usually seen as a disruptive force triggering change across different aspects of life, economies and sectors. Questioning the traditionally established ways of doing, value chains evolve due to the technological development. This happens across different sectors and specifically within the high-tech industry, that by definition is a sector with the highest form of technology available. As a result, new business models emerge, allowing customization and personalization of products and/or services (e.g. such as new business models focused on servitization). Different stages of production such as design, engineering and manufacturing could take place on different locations worldwide because of digitalization. Logistics and movements of production components, goods, employees and investments could span through regions, countries or even continents.

Examples of technologies triggering the change of the high-tech industry are according to McKinsey[24]: process automation and virtualization, future connectivity, distributed infrastructure, next-generation computing, applied AI, future of programming, trust architecture, bio revolution, next-generation materials and future

[19] https://publications.jrc.ec.europa.eu/repository/handle/JRC116516.
[20] 国务院关于印发《中国制造2025》的通知（国发〔2015〕28号）_政府信息公开专栏 (www.gov.cn).
[21] China is rapidly increasing its investments towards industries with high innovative and technological content where traditionally the EU has been stronger than China (europa.eu)
[22] Shift in the geopolitical landscape | Knowledge for policy (europa.eu)
[23] Research: When Geopolitical Risk Rises, Innovation Stalls (hbr.org)
[24] Top 10 tech trends for next 10 years (according to McKinsey) | World Economic Forum (weforum.org)

clean technologies. These technologies transform the manufacturing industry and constitute the core of the high-tech industry. Disruptive technologies generate both opportunities and challenges for the businesses and employees across sectors and economies.[25] Some technological developments could help address the climate change and the increasing raw material scarcity, they increase labour productivity and therefore help mitigate the aging population trends.

Climate crisis and sustainability

Climate change is a topic of ongoing discussion. Climate change has caused an increase in global temperatures. This trend is projected to continue. Coupled with the extreme weather conditions, it could result in disruptions in water availability. This could lead to the situation where all resources are diverted towards maintaining the basic needs of the human population. Therefore it has an impact on the manufacturing industry and high-tech industry as well. If the society does not take action and change to curb the greenhouse gas emissions, the economies across the world might suffer substantial losses.[26]

Manufacturing industry together with transportation and construction are top energy consumers accounting for a large share of emissions. Manufacturing alone accounted for 20% of CO2 emissions within the EU in the first quarter of 2022.[27] Emissions from the industrial processes sector[28] increased by 16.8% (0.35 Mt CO_2 eq) in 2021 when compared to 2020[29]. Therefore the manufacturing needs to tackle climate change and sustainability. Since the high-tech industry is partly comprised of the sectors from manufacturing, they have the same issues.

New and emerging disruptive technologies could help mitigate the intensification of the climate change.[30] For example, energy efficiency could be improved through energy monitoring applications enabled by AI. Reuse of resources and tools, waste reduction of manufacturing processes, physical transport, optimization of logistics processes, and reduction of physical transport are only a few examples of how technologies that form the core of the high-tech industry can contribute to the mitigation of the climate change.

Ageing population

The whole world is undergoing a demographic transformation as the society ages. By 2070 it is expected that there will be less than two working-age persons for every person aged 65 and more.[31,32]

[25] Disruption by technology (europa.eu)
[26] Economic losses from climate-related extremes in Europe (europa.eu)
[27] Quarterly greenhouse gas emissions in the EU - Statistics Explained (europa.eu)
[28] The industrial processes sector estimates greenhouse gas emissions occurring from industrial processes, from the use of greenhouse gases in products, and from non-energy uses of fossil fuel carbon.
[29] Manufacturing and industry | Environmental Protection Agency (epa.ie).
[30] Youssef, Adel. (2020). How Can Industry 4.0 Contribute to Combatting Climate Change?, available at (PDF) How Can Industry 4.0 Contribute to Combatting Climate Change? (researchgate.net).

The higher the age of the employees, the less they perform physically and cognitively though it might not be uniform across all abilities. This could be partly compensated by the experience of older employees.
To combat these changes in the labour force, the governments across the globe are taking actions for example in the form of the pension reforms. Nevertheless, the European Commission projects that the labour supply is likely to decline because of the changes in the working-age population.

Traditionally, manufacturing is labour intensive and therefore labour dependent. At the same time, the high-tech industry relies on the use of technologies. Emergence of new, disruptive technologies will transform the use of labour within the manufacturing and the high-tech industry. Implementation and use of these new technologies changes the workforce; new technologies will increase productivity and will require trainings to keep up with the new developments.

Increasing raw material scarcity

Besides being R&D intensive, the high-tech industry is dependent on raw materials. Raw material are scarce, and rising demand for it can have an impact on future innovations. In particular for rare earths, the dominance of China on the market of raw materials and their processing make the EU vulnerable to value chain disruptions of the EU's high-tech industry[33]. Cobalt, gallium, rhodium, and tantalum are examples of raw materials that are commonly used in high-tech products.[34] These metals and minerals make it possible that we have mobile phones, iPads, flat screens or electric cars.

The European Commission has created a list of critical raw materials specifying those of high importance to the EU economy and of high risk associated with their supply.[35] Approximately two thirds of the 30 raw materials on the list are imported, and China is one of the largest exporters of these materials.

Concluding remark

Some of the trends discussed in this Chapter might strengthen the high-tech industry such as a growing customer demand and new disruptive technologies. Other trends such as geopolitical tension and raw material scarcity require mitigation strategies to protect the high-tech industry and make the high-tech industry future proof. Relevant actions to strengthen or mitigate the trends are described in Chapter 5.

[33] CRMs_for_Strategic_Technologies_and_Sectors_in_the_EU_2020.pdf (europa.eu)
[34] Ibid
[35] Critical raw materials (europa.eu)

4 SWOT

To make the high-tech industry future proof it will be important to anticipate the various trends discussed in Chapter 3 and build on the current strengths of the sector. The Dutch high-tech industry is for instance one of the most important growth engines for the Dutch economy.[36] This enables the Netherlands to compete in an international context. In this Chapter we will elaborate on these **s**trengths, but also on the **w**eaknesses, **o**pportunities and **t**reats of the high-tech industry. Also called the SWOT, which is composed based on expert discussions and desk research. For an overview of the SWOT see Table 2.

4.1 Key strengths

The Dutch high-tech industry can be characterized by various strengths. The high-tech industry is first of all leading in the development and manufacturing of high-tech equipment at micro and nano scale components such as[37]:

- Very intelligent embedded systems, software and sensors.
- Very precise nano electronics and high precision manufacturing.
- Highly efficient technology such as mechatronics.

The Dutch high-tech industry also has a strong knowledge base (e.g. for Optics, Polymers, Medical technology, Electrical machinery and measurement).

Besides that the Dutch high-tech industry also has a well-functioning ecosystem with a favorable business climate based on an open economy and stable government.[38] The ecosystem is composed of specialized companies and knowledge institutions. The partners in the ecosystem are especially strong in translating knowledge into industrial solutions that are multidisciplinary and have strong systems engineering skills.[39]

4.2 Key weaknesses

The high-tech industry in the Netherlands also has some weaknesses. First of all in terms of financing:

- There is more limited financing through venture capital compared to foreign countries (e.g. to stimulate innovation by start-ups). [40, 41]
- This leads to mergers and acquisitions of successful Dutch (start-up) companies leading to knowledge, expertise and experts moving to other (often non-European) countries. [42]
- It also leads to start-ups that have difficulties with scaling up.[43] This often also results in the fact that start-ups are searching for international partners to solve this issue.[44]

[36] Propositie formulier NGHT
[37] https://www.dutchglory.com/high-tech-industry-in-the-netherlands/
[38] Based on expert input.
[39] Ibid
[40] Based on expert input.
[41] https://dsa.pr.co/209495-the-dutch-startup-investment-records-reached-in-2021-continue-this-year
[42] Ibid
[43] Based on expert input
[44] Ibid

Firms in the high-tech industry are also vulnerable due to[45]:

- Increasing digital connectivity; Although digitalization and connectivity has a lot of advantages in terms of an increasing efficiency and productivity, it also makes them more vulnerable to cyberattacks.
- A lack of computer hardware, middleware and software companies in Dutch high-tech industry makes the industry dependent on a limited number of non-European suppliers.
- Reliance on SME's in value chains that inherently have a relatively low ability to innovate, are not sufficiently automated and digitally connected.
- Focus on core activities seems to distract companies from developing new opportunities in the complex machine manufacturing domain.[46]

4.3 Opportunities

The high-tech industry also has a lot of opportunities such as:

- For some technologies there is a lot of interest from abroad (e.g. thin film technology and optomechatronics). It is possible to sell these technologies or have it produced abroad. The question is if this is the best option since it is strategic technology.
- The creation of new control points.[47] Control points are products, services or solutions in the value chain that other players cannot ignore.[48] An example of such a control point is the EUV machine from ASML. With this EUV machine ASML dominates the high-end chip market.[49] But it is also possible to acquire a control point position within the high-tech supply chain, for example in the local market for electrolyser stacks.[50] It actually does not matter for a control point what position it has in the value chain: as OEM, OMM, supplier or even as a raw material producer.[51]
- Start-ups and scale-ups that contribute to the development and implementation of new technologies.[52] Stimulating and investing in those companies is important to avoid that they will be acquired by foreign partners and leave the Netherlands.
- Technological innovations for societal challenges such as developments for autonomous driving and power electronics are important for both the high-tech industry and the energy transition.
- The development of new high-tech value chains such as for[53]:
  - Equipment for sustainable processes (e.g. Batteries, Electrolysers)
  - Equipment for an Aging Population (e.g. Remote Monitoring)
  - Equipment for transformational digital technologies (e.g. Quantum, PIC)
  - Equipment for safety & security
- Development of new business models such as servitisation for sustainability, provide new ways of earning money.

[45] Based on expert input
[46] https://www.technishow.nl/nieuws/nieuws/maakindustrie-is-strategische-motor-nederland/
[47] Propositie formulier NGHT
[48] New age, new control points? - STL Partners
[49] Propositie formulier NGHT
[50] Ibid
[51] Ibid
[52] https://www.techleap.nl/blog/the-dutch-economy-in-the-covid19-era/
[53] I Propositie formulier NGHT

4.4 Threats

Within the high-tech industry there are also various threats. The Dutch high-tech industry is for instance smaller compared to the industry in Germany. That means that the high-tech industry has a strong focus on niches. What all niche strategies have in common is that they are unlikely to endure forever.[54] One threat for the niche is the potential to be outflanked, and especially by technological change.[55] That means that it will be important to keep on focusing on various niches to spread the risks and increase the opportunities.

Besides that there is an increasing geopolitical tension[56] (e.g. protectionist approaches in foreign countries, and export limitations). That is an important threat since this can limit the export opportunities of the Dutch high-tech industry, which means a potential loss of market share.

Other threats are:

- A strong one way dependency on underlying digital infrastructure of a limited number of non-European suppliers (e.g. cloud platforms, connectivity etc.), which makes the high-tech industry dependent. [57]
- Limited venture capital to stimulate innovation in the high-tech industry.
- R&D intensive companies leaving the country.
- Lack of technical experts with the appropriate knowledge and skills level.
- High investments needed to catch up with the investments made by foreign and non-European countries.[58]
- License to Operate of various companies is at risk due to[59]:
  - Requirement to decarbonize
  - Requirement to become circular
  - Requirement to control exports
- Competitive position under pressure due to[60]:
  - Scarcity of personnel
  - Scarcity of materials
  - Deteriorating knowledge position
- Long-term Resilience under pressure due to[61]:
  - Risk of losing access to/control over supply chains
  - Risk of losing access to/control over technology
  - Risk of being too slow in renewing the industry

[54] https://meaningring.com/2017/08/24/threats-to-niche-strategies-by-peter-drucker/
[55] Ibid
[56] https://insidetelecom.com/is-technology-a-weapon-in-geopolitical-conflicts/
[57] https://www.tno.nl/nl/digitale-soevereiniteit/
[58] Based on expert input
[59] Based on expert input
[60] Ibid
[61] Ibid

Table 2 SWOT analysis

Strengths

- Leading in the design, development and manufacture of high-tech equipment and micro / nano component:
  - very intelligent (embedded systems, software, sensors)
  - very precise (nano electronics, high precision manufacturing)
  - highly efficient (mechatronics)
- Well-functioning network ('ecosystem') by specialized companies and knowledge institutions
- Strong in translating knowledge into industrial solutions (multidisciplinary, systems engineering skills)
- Favorable business climate (open economy, stable government)
- Strong knowledge base based (e.g. for Optics, Polymers, Medical technology, Electrical machinery and measurement)

Weaknesses

- Focus on core activities seems to distract companies from developing new opportunities in the complex machine manufacturing domain
- Relatively weak in scaling up; requires international collaboration
- Mergers and acquisitions of successful Dutch companies leading to knowledge, expertise and experts moving to other (often non-European) countries
- Reliance on SME's in value chain that inherently have relatively low ability to innovate, are not sufficiently automated and digitally connected and that do not sufficiently scale up
- Limited financing through venture capital compared to foreign countries
- Digitally vulnerable due to openness and connectedness
- Lack of computer hardware, middleware and software companies

Opportunities

- For some in the Netherlands developed technologies is a lot of interest from abroad (e.g. thin film technology and optomechatronics). It is possible the sell technology or have it produced abroad. The question is if this is the best option since it is strategic technology
- Creation of control points
- Start-ups and scale ups
- Technological innovations for societal challenges (e.g. developments for autonomous driving, power electronics for the energy transition)
- Opportunities for new high-tech value chains:
  - Equipment for sustainable processes (e.g. Batteries, Electrolysers)
  - Equipment for an Aging Population (e.g. Remote Monitoring)
  - Equipment for transformational digital technologies (e.g. Quantum, PIC)
  - Equipment for safety & security
- Opportunities for new business models:
  - Servitisation for sustainability

Threats

- Relative small high-tech industry compared to other countries (e.g. Germany)
- Increasing geopolitical tension (e.g. protectionist approaches in foreign countries, export limitations)
- Potential loss of market share
- Strong one way dependency on underlying digital infrastructure of a limited number on non-EU suppliers (e.g. cloud platforms, connectivity etc.)
- Limited venture capital
- R&D intensive companies leaving the country
- Lack of technical experts with the appropriate knowledge and skills level
- High investments needed to catch up with the investments made by foreign and non-European countries
- License to Operate at risk due to:
  - Requirement to decarbonize
  - Requirement to become circular
  - Requirement to control exports
- Competitive position under pressure due to:
  - Scarcity of personnel
  - Scarcity of materials
  - Deteriorating knowledge position
- Long-term Resilience under pressure due to:
  - Risk of losing access to/control over supply chains
  - Risk of losing access to/control over technology
  - Risk of being too slow in renewing the industry

5 Towards and innovation agenda

Given the ‘changing world’ around Dutch High-tech Industry as described in the previous chapters the *key objective is to ensure competitiveness and earning power of the high-tech industry*. In this Chapter we will formulate some first actions for an innovation agenda to achieve this key objective. In section 5.1 we start with a summary of the strengths of the starting position of the high-tech industry on which actions described in section 5.2 can be build.

5.1 Strong starting position

The starting position of Dutch High-Tech industry is relatively strong, with a diversity of manufacturing activities that outperformed average economic growth of the Netherlands, with high R&D intensity and high productivity compared to other EU or OECD member states. This particularly holds for the Machinery and apparatus industry. High-tech machinery is the strongest contributor to R&D expenditures, NL’s most R&D intensive industry and high-tech’s strongest export driver.

In general Dutch high-tech industry can build on complex systems engineering, partnerships and value chains. It is focused on highly complex production, often (but not always) in low volumes. Moreover, the high-tech ecosystem in the Netherlands contains a large network of suppliers and public-private partnerships, combining the strengths of stakeholders in and around e.g. the Brainport region of Eindhoven, Delft, Amsterdam Science Park, Knowledge Park of Twente as well as connections with medical and bio science activities in Leiden or Utrecht and many linkages with the agri-food industry and engineering services in the offshore industry, water management etc.

Overall our patent publication analysis suggests that the Netherlands has a strong technology position in optics and photonics. Looking at the European patent applications by field of technology, the Netherlands also has a strong technology position in Optics, Polymers, Medical technology, Electrical machinery and measurement. Besides optics, polymers, medical technology and electrical machinery, the Netherlands builds-up position in some upcoming Environmental and Climate technologies.

The analysis of the research system of the Netherlands based on a comparison of the international research specialization index and citation impact scores, shows that the research output of the Netherlands is not leading in many high-tech industry related fields of science. This does not mean that the Netherlands has a shortage of relevant knowledge, but it means that other European countries have stronger concentrations of scientific groups working in relevant fields for the high-tech Industry.

In short the High-tech Industry:

- Is gaining importance in the Dutch economy fueled by machinery and computer programming / IT;
- Is a key contributor to Dutch export;
- Is fueled by good knowledge positions on most relevant technologies, with recognized quality and impact of research output as indicated by high citiation-

impact scores, but facing relative strong competition from research groups in other European countries;
- Is building up knowledge positions in key environmental and climate technologies;
- Leverages well-functioning ecosystems of specialized companies and institutions.

5.2 Required actions

Internal and external trends of the high-tech industry mentioned in Chapter 3 will shape future developments. In terms of opportunities for new high-tech value chains, business models and opportunities for new manufacturing activities in the EU contribute to the competitiveness and earning power of the high-tech industry (see Chapter 3). That means that actions are needed to stimulate these opportunities.

Next to these opportunities there are also some weaknesses, threats and challenges (see Chapter 3 and 4 for more details) that require mitigation actions to stimulate the earning power and competitiveness of the high-tech industry. Examples of such weaknesses and challenges are; the license to operate (e.g. due to requirement to decarbonize), scarcity of raw materials and personnel and resilience.

Table 3 provides an overview of some opportunities, strengths and weaknesses and some first required actions (see the row called in short).[62] This is a first starting point. Based on this study and the larger study of the unit Industry additional workshop(s) will be required to develop a joint innovation agenda.

[62] Table 2 is composed based on an expert workshop organized as part of the activities for the system vision of the unit Industry within TNO

Table 3: Actions to stimulate the competitiveness and earning power of the high-tech industry

	1. MAJOR OPPORTUNITIES FOR NEW VALUE CHAINS BASED ON NL STRENGTHS MUST BE CAPTURED	2. NEED TO BUILD DECARBONIZED AND CIRCULAR SUPPLY CHAINS TO SAFEGUARD LICENSE TO OPERATE	3. NEED TO ADDRESS SCARCITY OF KNOWLEDGEABLE PERSONNEL AND MATERIALS TO MAINTAIN COMPETITIVE POSITION	4. NEED TO BUILD LONG-TERM RESILIENCE IN SUPPLY CHAINS AND TECHNOLOGY
IN SHORT	Use strength in translating complex processes into machine concepts to build new value chains for sustain-ability, healthy and digital society. This renewal must take place.	NL HIGHTECH must meet increasingly stringent government regulations, especially with regards to decarbonization and circularity	Increasing shortages in personnel and key materials will force NL HIGHTECH to innovate their operating models, product designs and materials used	Global competition, instability and geo-political tensions require renewal of NL high-tech while safeguarding access to/control over supply chains and technologies
RELEVANT STRENGTHS	Dutch strength in high-tech and high complexity markets, the well-functioning local ecosystem, a favorable business climate and a strong relevant knowledge position	The industry's well-functioning ecosystem and strong and relevant knowledge base will help the supply chain meet this challenge	The industry's well-functioning ecosystem and strong and relevant knowledge base will help the supply chain meet this challenge	The well-functioning ecosystem and strong knowledge base should help increase flexibility and control in supply chain.
RELEVANT WEAKNESSES	Insufficient long-term and decisive government policy, insufficient OEMs with broad innovation scope, limited ability to scale, reliance on SMEs with low ability to innovate	SME's in value chain have relatively low ability to innovate. This will require impulses from the government with a long-term vision which currently is lacking.	SME's in value chain have relatively low ability to innovate. This will require impulses from the government with a long-term vision which currently is lacking.	The high level of connectedness and openness makes the supply chain digitally vulnerable.