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THE TECHNOLOGICAL ASPECTS OF CYBERSPACE: THE U.S.–CHINA RIVALRY AS SEEN FROM BUDAPEST

INTRODUCTION

The hardware is Chinese, the software is American. If you had to sum up in one short sentence what is one of the most worrying trends of the 21st century for the digital sovereignty of Europe and Hungary, this is probably what most technology experts would say. But of course, as we will see, if we start to expand this sentence and dig deeper into the real context, the situation is not so black and white. Except that Europe, and Hungary in particular, actually has a small and shrinking space in which to develop the technologies that will underpin the fourth industrial revolution.

It is no coincidence that the political agenda of the new leaders of the European Commission elected in 2020 put a strong emphasis on regaining Europe's digital independence. The two industry agreements announced in July 2021, the Alliance for Processors and Semiconductor Technologies and the European Alliance for Industrial Data, Edge and Cloud, were important steps in this direction. As Margrethe Vestager, Executive Vice-President of the European Commission responsible for a Europe fit for the Digital Age, said:

> "Cloud and edge technologies present a tremendous economic potential for citizens, businesses and public administrations, for example in terms of increased competitiveness and meeting industry-specific needs. Microchips are at the heart of every device we use nowadays. From our mobile phones to our passports, these small components bring a wealth of opportunities for technological advancements. Supporting innovation in these critical

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> sectors is therefore crucial and can help Europe leap ahead together with like-minded partners."[1]

There are real, well-recognised geostrategic interests behind the announcement; however, its implementation is not straightforward due to decades of lag, the outsourcing of manufacturing to Asia for economic reasons, and primarily the successful brain drain to the USA. An example of the latter is Andy Grove, one of the founders and later Deputy Director of Development at Intel, one of the architects of the microchip manufacturing revolution, born in Budapest as András István Gróf, who left Hungary in 1956 to start a new life in the United States. Or, as an example, many of the author's university classmates from the 2003 graduating class of electrical engineers and computer scientists have also found the fulfilment of their professional careers in the USA. So the challenge for Europe's leaders is how to reverse the trends – where are the points of intervention? Especially in a situation in which both the United States and China are seeking to move the European Union and its individual countries according to their own interests, thereby reducing the possibility of creating an autonomous space for manoeuvre. The U.S. wants to achieve this by restoring and strengthening multilateral relations, and China by seemingly favourable investment agreements.[2]

THE GEOPOLITICS OF RAW MATERIALS

Let us perhaps start with the question of raw materials for hardware, in an extremely simplified form! The fourth industrial revolution, the foundation of modern digital society, is based on ubiquitous information technology, the Internet of Things (IoT). In the early 2020s, we are already surrounded by nearly 20 billion networked IT devices, from the clearly visible computers and smartphones to the smart robot vacuum cleaners and internet-enabled washing machines that dot our homes, to the invisible sensors that help manufacturing and utilities run invisibly to the average

1 European Commission 2021a.
2 Mártonffy–Nystrom 2021: 43–59.

person. The production of these devices requires the availability of raw materials from which the products can be created, the knowledge to design the hardware components, and finally, manufacturing capacity to not only produce the individual hardware components but also assemble them into the final products.

Two important raw materials are needed to make microchips: silicon and pure water. Seemingly both of these materials are available in infinite quantities on Earth, but in reality there are obstacles to obtaining them due to the high purity requirements. Of the two, silicon is perhaps the easier to produce, being the second most abundant chemical element on Earth after oxygen. The U.S. Geological Survey's annual flash reports show that 8,000 tons of silicon used to make microchips are processed each year. Of this, China alone accounted for 5,400 tons in 2020, highlighting the enormous appetite for raw materials that characterises the Eastern superpower.[3] The United States accounted for 290 tons, ranking fifth after Russia, Brazil and Norway. But access to clean water is not so easy in China. It is no coincidence that some experts believe that the Himalayan water resources are behind the border tensions with India, as the resources from there could perfectly serve the manufacturing needs. The provinces of Kashmir, Aksai Chin and Ladakh are rich sources of water, and the Taklamakan desert is ideal for building a major manufacturing infrastructure because of its sand.[4]

Other important raw materials are the rare earth elements scandium, yttrium, lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium and lutetium. Contrary to their name, these metals are available in significant quantities on Earth and are widely used in the manufacture of electronic products, including smartphones and wearable smart devices. However, in the most commonly cited application, which is the production of long-life batteries, the primary metals needed are not rare earth elements but rather lithium, manganese and cobalt. These metals are used in the production of lithium-ion batteries.[5]

3 Schnebele 2021.

4 Tewari 2021.

5 Gorrill 2019.

Indeed, the mining of genuine rare earths has been a virtual Chinese monopoly since the early 2000s, with 90–95% of world production in China at the start of the millennium. However, in 2010, after a Japan–China incident in which the Japanese authorities arrested the crew of a Chinese fishing boat sailing in a disputed stretch of sea, China cut back its exports, causing noticeable disruption worldwide. After lengthy negotiations within the World Trade Organization, the WTO, the original Chinese export volumes were restored by 2016. This has encouraged the exposed countries to diversify extraction of these materials. In 2020, with unchanged production, China accounts for only 58% of global production, with the United States second with 16%, followed by Myanmar, Australia and Madagascar.[6] In the long term, Brazil and Vietnam could even take China's place, reducing its hegemony, which is indeed significant in the short term.[7]

By contrast, the extraction of cobalt and lithium is indeed cumbersome and geographically concentrated. For lithium, the largest reserves are in South America, in the Argentina–Bolivia–Chile triangle. It is followed by Australia, which is currently the largest producer, and then China, whose companies are becoming increasingly large shareholders in mining companies in the South American region. Australia currently mines 40,000 tons, Chile 18,000 tons and China 14,000 tons, while the total world mining volume is 82,000 tons.[8] The largest cobalt mines are in the Democratic Republic of Congo – also mainly Chinese-owned. China controls 86.5% of Congo's cobalt exports, supplying the metal mainly to its own industry, preventing access to this raw material for companies in other countries.[9] This figure, in the light of the fact that world production in 2020 totalled 140,000 tons, of which the DRC alone produced 95,000 tons, clearly illustrates how crucial ownership of raw material sources remains in the 21st century. It also highlights how consciously China has taken control of this, partly

6 Daigle–DeCarlo 2021.
7 Erdey et al. 2019: 281–295.
8 Jaskula 2021.
9 Rapoza 2021.

by leveraging its own mines and partly through the acquisition of large corporations, even in distant parts of the world.[10]

We can see, therefore, that the strategic threat is not so much the lack of rare earths and rare metals, but rather access to them, which may become more difficult due to the decreasing but still very strong Chinese control. From a European perspective, one of the cornerstones of digital sovereignty would therefore be that if we have manufacturing capabilities, we should also have access to the necessary raw materials. In the case of rare earths, Greenland, which belongs to Denmark, could be mentioned as an example of a country with huge reserves, but it is perhaps more appropriate to study continental Europe, where research suggests that there may be significant deposits, for example in Hungary. For instance, at the Nagyharsány bauxite deposit, substantial concentrations were identified as early as the 1970s.[11] Lithium production has also started in several countries, with 900 tons of metal already coming from Portugal, and further investments are planned in Finland, Germany, Austria and the United Kingdom.[12] There is also potential for cobalt mining, as there are currently 509 known sources across 25 European countries. However, mining operations are currently active in only three mines in Finland. Other significant opportunities exist in Sweden, Norway, Poland, Germany, the Balkans and Turkey.[13] In silicon production, France, Iceland, Norway, Spain and Ukraine have world-class mining capacities.[14]

But mining is traditionally a very polluting industry, so even if increased extraction were to start in Europe, it would likely face significant public opposition due to environmental concerns. It is therefore worth considering recycling instead. According to a 2018 article by Jowitt and his co-authors, for example, only 1% of rare earths are recycled, for a variety of reasons including lack of appropriate technology and the issue of economical extraction.[15]

10 Shedd 2021; Kalantzakos 2020: 1–16; Bihari 2020: 26–35.

11 Goodenough et al. 2016: 838–856.

12 Scott 2021.

13 Horn 2021.

14 Schnebele 2021.

15 Jowitt et al. 2018: 1–7.

However, if we look at the issue from a digital sovereignty perspective, in the long run it may be worth investing in the necessary recycling innovation. Even in Hungary, which is among the leading countries in Europe, only 51.1% of e-waste is currently recycled, whereas the European average is only 40%. And with the advent of the Internet of Things, e-waste is becoming more and more abundant, so it makes sense to focus on recovering the materials that have already been mined, rather than on primary, polluting mining. The European Union's regulatory system is moving in this direction, as for example the European Parliament resolution of 10 February 2021 on a new Circular Economy Action Plan or the European ban on the import of minerals from conflict zones – wrapped in the core values of human rights and environmental protection – gradually limits the possibility of importing primary raw materials controlled by China.[16] It remains questionable, however, whether alongside restricting imports, it will be feasible to ensure the sufficient domestic production of resources necessary for the European industry. With the right supply chain, even successes like the one reported in Apple's U.S. Product Coverage Report can be achieved. This report shows that 98% of the rare earth metals in the iPhone 12 are recycled.[17] This, of course, requires the creation of global companies like Apple that can control the entire supply chain. In the end-user market, only U.S. and Chinese companies are currently able to do this, although sustainability is not yet a priority for the latter.

THE GEOGRAPHY OF HARDWARE MANUFACTURING

The next step towards digital independence is to transform raw materials into components and then into finished products. Continuing the previous line of thought, silicon should be used to make chips, lithium and cobalt to make batteries, and rare earths to make sensors, speakers and displays, among other things. However, designing and manufacturing these requires highly specialised knowledge and technology. It is not surprising, therefore,

16 European Parliament 2020.

17 Apple 2020.

that significant manufacturing concentration can be observed regardless of which component is considered. However, as we will see, in each of the areas examined, the U.S. and Asian countries other than China dominate, so component design and production are currently much less dependent on China than the news reports might suggest.

Among the 15 highest revenue semiconductor (microchip) companies, there is not a single Chinese company included. The largest company is Intel, followed by Samsung of South Korea and TSMC of Taiwan. The list of the 15 largest companies includes eight from the U.S., two from South Korea, two from Taiwan, one from Europe, and one from Japan.[18] Since this list reflects revenue, it primarily showcases design and sales capabilities. But if we focus on manufacturing, we see that the world's microchip supply depends on one small island, Taiwan. It is home to 63% of the world's manufacturing capacity, with a single company, TSMC accounting for 54%. In second place is South Korea with 18%, almost all of which is Samsung. China is at 6%, including the largest semiconductor manufacturer SMIC at 5%. GlobalFoundries, the largest U.S. producer, that also has significant European capacities, accounts for 7% of global production.[19]

It is not surprising, therefore, that one of the most important economic policy implications of the Covid-19 epidemic, after facing the global semiconductor shortage, was the need to diversify supply chains and protect current sources of supply, specifically Taiwan. The analysis of Tamás Csiki Varga and Péter Tálas on the Biden Administration's foreign policy strategy clearly highlights the importance of Taiwan: "The most tangible example of the strategic rivalry between Washington and Beijing, and the most acute point of escalation, is Taiwan, where the Biden Administration has moved from diplomatic offensive to provocation and humiliation of Beijing to a show of military force, using various means with greater intensity than previously seen, in a new phase aimed at containment."[20]

The authors do not go into the reasons for this in detail, but note that, in addition to security, international trade, financial and development

18 Flaherty 2021.

19 Lee 2021.

20 Csiki Varga – Tálas 2021: 10.

considerations, supply chain protection and technological competition are also important. A possible conflict between China and Taiwan would be an immediate problem for the world economy, as more than half of semiconductor production would be lost. The impact of this can be imagined, if we recall that during the pandemic, due to logistics becoming more challenging and demand for consumer electronics increasing, Hungarian automotive factories had to shut down multiple times because they could not procure essential electronic components needed for modern cars on time.[21]

Therefore, diversification is inevitable. But it is neither easy, nor cheap. Taiwan's TSMC alone has innovated more than $100 billion in its own factories, making it the only two companies with Samsung capable of producing the most advanced microchips. The manufacturing metric for microchips is the feature size, measured in nanometres. Since 2018, TSMC has been capable of manufacturing chips with a 7-nanometre feature size, and from 2020, they have extended this capability to 5 nanometres. They are currently in the development phase of 3-nanometre chips. Samsung also started manufacturing 5-nanometre microchips in 2020. At the same time, Intel has been able to achieve 10 nanometres since 2018, with the 7-nanometre feature size not expected to be reached until 2023.[22] Meanwhile, China's SMIC aims to invest around $9 billion to set up a factory capable of producing 12-nanometre chips.[23] This company is also on the latest U.S. ban list, so the investment will have to be made without using U.S. technology.[24] European capabilities currently allow for production at 16 nanometres, but the Alliance for Processors and Semiconductor Technologies aims to get below 10 nanometres as soon as possible, with a long-term target of 2–5 nanometres.[25] It should be added that most devices do not require such small feature sizes, so there is a benefit to investing in cheaper but less advanced technology.

21 HVG 2021.
22 Sun 2021.
23 Hong 2021.
24 The White House 2021.
25 European Commission 2021a.

The market for lithium-ion batteries is also dominated by Asia, but again production is not concentrated in China. In fact, this is an area where Europe is ahead of the curve and can successfully compete with its Asian rivals, thanks mainly to its advanced automotive industry. At least in terms of production capacity, because none of the largest manufacturers are European, only factories are being relocated to Europe at a huge pace, as is the case with SK Innovation, a South Korean company that is building a manufacturing base in Iváncsa, near Dunaújváros, in the largest greenfield investment in Hungary's history, which will be approximately the same size as the world's largest facility, the Tesla Gigafactory in the U.S.[26] Thanks in part to this latter factory, one of the largest manufacturers currently is the American company Tesla, along with its technology supplier, the Japanese company Panasonic. Other major players include South Korea's LG Chem and Samsung SDI, as well as China's CATL and BYD.[27]

Thanks mainly to the automotive industry and the green revolution, lithium-ion battery production is therefore growing dynamically, with a projected total capacity of 3,000 GWh in 2030, compared to 500 GWh today. Currently, China accounts for 72.5%, Europe for 5.4% and North America for 9.2%, but by 2030 China's share is projected to fall to 66.9%, while Europe will account for 16.7% and the U.S. for 11.9%. To this end, significant economic policy measures are also being taken. For instance, just as the Hungarian Government supported SK Innovation's investment, the Swedish company NorthVolt is planning major developments in Germany, and the French company SAFT is planning significant advancements in France, both with the encouragement of their respective governments.[28] In the United States, the development of manufacturing capacity has become a strategic area of intervention in the wake of a survey carried out based on a presidential executive order.[29]

[26] HIPA 2021.
[27] Ulrich 2021.
[28] Moores 2021.
[29] U.S. Department of Energy 2021.

Electronic products ultimately take their final form in assembly plants. The market for contract manufacturing companies is collectively known as electronic manufacturing services (EMS), and 90% of the revenues of the top 50 companies are generated in Asia. The largest of these is Taiwan-based Foxconn, which has its largest factories in China. They assemble products of some of the best-known brands, such as Apple's iPhone. Other important players include Taiwanese companies like Pegatron, Wistron and New Kinpo Group, American companies such as Jabil and Sanmina, the American–Singaporean company Flex, as well as Chinese companies like BYD Electronics and USI, and the Canadian company Celestica.[30] Several of these companies have interests in Hungary, and Videoton has one of the largest assembly plants in Europe. There is less need for intellectual capital in this area, with factories typically being set up where production is cheapest, so as Chinese wages have risen, factories have started to spill over into other Asian countries such as Vietnam, Indonesia and Thailand. As we have seen in Hungary on several occasions, such factories are relatively easy to relocate to other countries and are therefore less important in terms of strategic dependence.[31] Though, it is true that logistical problems can cause significant disruption even when the goods are coming not from China, but from another Asian country, as was the case when the Ever Given cargo ship blocked the Suez Canal in May 2021. This is why China's activities in the South China Sea and the security of the Straits of Malacca are a cause for concern, as if this shipping lane is closed, the finished assembled products will not reach Europe, or will take longer to reach Europe.

SOFTWARE, DATA, CLOUD

The foundation of the Internet of Things is provided by hardware components. Whether we examine the origin of components or finished products, they primarily come from Asian manufacturers, especially Taiwanese-based

30 Clarke 2021.

31 Mordor Intelligence 2021.

ones. But they are worthless if there is no software ecosystem that enables them to work, and no network connection that connects the Internet of Things into the real Internet. Without them, the key foundations of the fourth industrial revolution will not be possible and the digital data created by machines will not be properly processed in the cloud. Following this chain, we come to the conclusion that American dominance is nearly complete in the key areas.

As every end user probably knows, it is the operating systems that make the hardware work. In the world of computers, these are typically Microsoft Windows, Linux, which is open source and therefore comes in many forms, and Apple macOS, which is little used in its market segment but still highly regarded. For smartphones and tablets, Google Android and Apple iOS are the most popular. Other smart devices are typically based on some version of Linux, and industrial process control systems are typically based on Windows or Linux. Of course there are other solutions, but they are marginal. Of the software vendors listed, Microsoft, Apple and Google are all American. Linux is community-developed, but the underlying kernel can still only be modified with the final permission of its first programmer, Finnish–American Linus Torvalds. As a good illustration of how this situation benefits the U.S. Government, after Google was banned from licensing Android to China's Huawei in 2019, Huawei was forced to come up with its own operating system, Harmony OS. However, its market share remains negligible, and users widely rejected its adoption. This was such a blow to Huawei that it was forced to sell its Honor smartphone brand to a government-backed company independent of the parent company in order to survive in the market. Once this happened, they regained their Android license, which clearly demonstrates the indispensability of American software.[32]

At the end of the 20th century, at the dawn of the internet, operating systems were designed to run user software. Several seemingly indispensable, massive software developer conglomerates emerged, which during the Internet boom of the turn of the millennium often became completely insignificant, replaced by new, dynamic enterprises primarily built on

32 Porter 2021.

data-driven digital services. Twenty years after the revolution, it is interesting to compare the difference between traditional software and data-driven companies! Based on 2020 revenue data, Microsoft is the largest traditional software company with $118.2 billion in revenue and a market capitalisation of $946 billion. The next runner-up, Oracle, also from the U.S., has "only" 39.6 billion dollars in revenue and a capitalisation of 186 billion dollars. The top 10 list includes eight American, one French and one German company, most of them developing financial and business management software.[33] Meanwhile, Apple tops the list of the world's most valuable companies, with a market capitalisation of $2,550 billion at the time of writing, followed by Microsoft with $2,263 billion (more than double the value in 2020), and then Alphabet, the parent company of Google, ranks third with $1,924 billion. The first non-technology company on the list is Saudi Aramco oil company, worth $1,870 billion. Of the 20 most valuable companies, 11 are linked to the digital world, two of them Chinese.[34]

It is a good indication of the world's semiconductor appetite that four of these companies come from the world of microelectronics manufacturing. However, this is likely to be a seasonal blip, with data and cloud infrastructure companies holding their place in the most valuable companies list for years. Apple, Microsoft, Google and Amazon own a significant part of the world's cloud computing capacity, and Google, Amazon and Facebook have the largest repositories of digital data. Chinese companies Tencent and Alibaba also build their services primarily on data and the cloud. In its justification for the creation of the European Alliance for Industrial Data, Edge and Cloud, the European Commission pointed out that currently less than 1% of cloud service revenues are being delivered to European providers, indicating their negligible presence in the market.[35]

Moving data to the cloud and generating new knowledge there requires the mention of two more technologies. These are 5G, i.e. fifth generation mobile communications, and artificial intelligence, the priority role of which is also mentioned in Hungary's National Security Strategy 2020:

[33] BizVibe 2020.

[34] Marketcap 2021 (status on that day).

[35] European Commission 2021b.

"Power competition is increasingly extending to global commons: there is escalating rivalry over international waters and resources therein, control over the Arctic region and outer space, and dominance in cyberspace. With the rapid advancement of humanity's technological capabilities (digitalization, fifth-generation wireless networks (5G), space technology, etc.), new opportunities and challenges constantly emerge, impacting the security of our country. The development brought about by 5G technology could potentially enable revolutionary advancements that may generate significant changes in our society and economy. [...] The development of revolutionary technologies is a matter of strategic importance. The security of our country requires that we pay particular attention to research and development, as well as its defensive components, in key areas such as cybersecurity, artificial intelligence, autonomous systems, and biotechnology."[36]

The most visible confrontation in the U.S.–China tech race is also taking place in the data – 5G – artificial intelligence triangle. Indeed, 5G serves as the "highway" for the Internet of Things, the foundational infrastructure upon which the digital economy can thrive. Meanwhile, artificial intelligence relies fundamentally on data for its operation. So whoever owns these three technologies will dominate the fourth industrial revolution. In international diplomacy, therefore, the U.S. Government has exerted significant pressure to sideline Chinese 5G companies. Specifically, the aim is to make Huawei and ZTE impossible to use because of their practices that threaten national security.[37] The exact details of this allegation have not been shared with the public, but several allied countries have joined China's ban on 5G technology in an attempt to prevent the Chinese Government from influencing modern economies in the coming decades. Less visibly, the two countries have introduced reciprocal export restrictions on AI technologies and are actively regulating the use of AI.[38] In the case of data aggregator companies, there is no real dependency between the two countries, as U.S. services such as Google's search engine or Facebook's social networking site have no real presence in China, just as Baidu's search platform or WeChat's social

36 Government Resolution 1163/2020 (IV. 21.) on Hungary's National Security Strategy.

37 Shepardson 2021.

38 Reuters 2020.

networking site are not really used outside China and Chinese nationals. However, the social service TikTok of the Chinese company ByteDance started spreading in the West, and solutions from Tencent and Alibaba are also widely used. This led to serious consideration of placing these companies on a blacklist during President Trump's tenure.[39]

THE TECHNOLOGICAL RIVALRY BETWEEN THE USA AND CHINA – AS SEEN FROM BUDAPEST

Looking at Hungary's foreign economic indicators, China is the second most important import partner after Germany. This is not surprising, considering that China is a primary source of important raw materials for the Hungarian economy. Exports, on the other hand, show a strong deficit (€7,926.6 million in imports and €1,813.5 million in exports), as the export volume to China is surpassed by many other European countries. In terms of the U.S., however, there is a positive balance, with imports of €2,042.7 million and exports of €3,133 million in 2020. Germany, the largest trading partner, shows a trade balance of €24,372.9 million imports and €29,253.7 million exports.[40]

So the sheer numbers show that the United States is a less significant trading partner for Hungary, and therefore it may be more worthwhile to explore Chinese opportunities instead. But if we look at the issue from the perspective of security of supply and national security, the picture is much more complex. From a technological point of view, Hungary is much more exposed to U.S. digital products and services, and our alliance system and western orientation mean that there is much more trust and knowledge towards U.S. solutions. Below, we will review and analyse the areas previously examined from the perspective of Hungary's security, taking into account European strategies.

39 Alper–Pamuk 2021.

40 Hungarian Central Statistical Office 2023.

The question of raw materials

The European Union lists 30 raw materials that are critical for the economy. This list includes all the materials mentioned earlier, such as silicon, rare earths, cobalt and lithium.[41] China is the EU's source of 98% of rare earths, while 70% of China's global cobalt exports are subject to restrictions, for example due to human rights abuses. Meanwhile, the demand from industry is growing exponentially. This is the subject of the Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – *Critical Raw Materials Resilience: Charting a Path towards Greater Security and Sustainability* – which sets out a 10-step action plan.

For Hungary, the procurement of raw materials for production is particularly important in the field of batteries, as significant production capacity is being built in the country. There are a number of steps that can be taken to support European action to reduce our exposure:

- Action 3 is to launch critical raw materials research and innovation in 2021 on waste processing, advanced materials and substitution, using Horizon Europe, the European Regional Development Fund and national R&I programs. As Hungary has a very high e-waste recycling rate, it is worth taking advantage of this opportunity.
- Action 4 aims to map the potential supply of secondary critical raw materials from EU stocks and wastes and identify viable recovery projects by 2022. Here it is worth assessing the potential for rare earth extraction in Hungary.
- Action 6 aims to develop expertise and skills in mining, extraction and processing technologies, as part of a balanced transition strategy in regions in transition from 2022 onwards. Given the centuries-old tradition of higher education in mining in Hungary, it may be worthwhile to launch a targeted degree program or specialisation to transfer knowledge related to the extraction of rare earths, and to develop training courses related to recycling.[42]

41 European Commission 2020b.

42 European Commission 2020a.

Among these options, waste recycling is included in the National Smart Specialisation Strategy (S3) – 2021–2027 plan. According to the chapter of S3 entitled *Resource-efficient Economy,* the objective is to "strengthen the circular economy to reduce environmental burden, strengthen RDI activities to minimise waste and enhance the diffusion of innovations and the adaptation of good practices in this direction".[43] It should be highlighted that, in terms of raw materials, this is important not only to reduce the environmental burden, but also for security of supply. Strengthening mining capabilities is not included among the priorities, so it is worth developing this at institutional level, with the participation of the universities concerned in international innovation projects.

Opportunities in hardware manufacturing

The establishment of the Alliance for Processors and Semiconductor Technologies clearly shows that the European intention is to (re)build its own semiconductor manufacturing capability. However, the example of TSMC and SMIC mentioned earlier shows that this represents an investment of billions of euros. In addition, the knowledge to create this capability is not there, because the Europeans who have the knowledge are obviously working for American companies that use the latest technologies. The European Union is therefore moving towards developing skills and capabilities. It seeks to acquire lost knowledge, to buy companies where expertise is available and to secure supply chains.[44]

For lithium-ion batteries, the aim is mainly to improve access to raw materials and manufacturing capabilities. The European Battery Alliance was founded in 2017 and has more than 600 members. Hungarian participation is marginal, with only 3 Hungarian companies participating, while there is no Chinese company among the members. In Europe alone, €60 billion was invested in electromobility in 2019, three times the amount invested in China. The European Horizon program will invest €1 billion

43 National Research, Development and Innovation Office 2020.

44 European Commission 2021b.

in research and development. This is perhaps the area where European knowledge has the best chance of becoming a leader.

The issue of assembly is not mentioned by the European Union as a strategic dependency issue. Europe, including Hungary, has seen the establishment of a number of assembly plants which are unlikely to be in danger of closure after the supply chain disruption caused by the pandemic. However, it should be recognised that acquiring knowledge of modern assembly technology is key for the Hungarian economy. This is why we must strive for training at European level. In addition, research into new types of materials and production technologies should be supported, in line with the National Smart Specialisation Strategy. This knowledge can realistically be acquired through European cooperation, in line with European development aspirations.

One of the most important sources of Hungary's economy is assembly, which is heavily affected by the Sino–U.S. disputes both directly, through the electronics assembly plants established here, and indirectly, for example through the use of microchips by car manufacturers, but primarily by the issue of Taiwan's independence and secondarily by the situation of South Korea. As the security of both countries depends heavily on U.S. support, U.S. actions and alliance requests in the region cannot be ignored. In this area, meanwhile, Hungary's exposure to China is much lower, and in this area there are no large investments on a scale similar to the other two Asian countries. In addition, it should be noted that the much-debated Fudan University has been rumoured to create faculties of science and engineering in Hungary, but from a technological point of view there is currently no base in the country where the knowledge taught there could be put to practical use.

Data economy in Hungary – Between two great powers

From the perspective of the fourth industrial revolution, the most interesting and strategic question is who will own the information and knowledge derived from the data. From the U.S. perspective, the situation is worrying because, while U.S. technology companies clearly dominated the field in the past, in the 2010s Chinese competitors have come up with cheaper and sometimes better-quality products and services, often at the cost of infringing U.S. intellectual property. In simple terms, the question for the two great powers is who controls the transmission networks, who owns the cloud and who can best exploit artificial intelligence. It is no coincidence that the most spectacular political struggle is in the area of ousting Chinese 5G players and regulating American data aggregator companies.[45] The cloud is perhaps less in the spotlight, thanks to the breakthrough of a new technological trend, the so-called edge cloud, which keeps data inside organisations rather than in the big (mainly U.S.) data centres we have known so far.

The European Commission estimates that by 2025, 80% of the data generated will be processed in the edge cloud, where there are currently no dominant companies. The Commission sees significant opportunities in software services alongside edge clouds, and hybrid 5G networks built and supplied by various manufacturers could also ensure strategic independence. But this will require a significant increase in investment, given that the EU invests €11 billion less a year in cloud technology than the U.S. or China, and that European companies are less likely to use this technology, mainly because of a conservative development mentality and mistrust. With the creation of the European Alliance for Industrial Data, Edge and Cloud, this situation may change. But there is a significant gap to fill, which is perhaps easier than addressing the geographical challenges outlined earlier.[46]

This is an area that is given a prominent place in Hungary's strategies. The three strands of the National Smart Specialisation Strategy (Digitalisation of the Economy priority, Services priority, Creative Industries priority) also address the problems identified by the EU. Hungary's National Security Strategy mentions the challenges posed by 5G and artificial intelligence. Within the Digital Success Program, the Government gives priority to data assets, 5G and artificial intelligence. These efforts typically emphasise the development of own skills, in line with European action. The country is dependent on solutions from the U.S. and China, despite the fact that it actually has excellent potential of its own.

45 Boros–Kolozsi 2019: 258–280.

46 European Commission 2021b.

First, Hungary's digital data assets are significant but mostly untapped. The primary beneficiaries of the digital data produced by citizens are currently U.S. data aggregation companies – just like in other European countries. The development of a domestic data market is therefore of paramount importance both economically and in terms of digital autonomy. 5G networks are developed by foreign companies (German, British, Czech), the basic technologies used are typically Chinese (Huawei and ZTE), but European solutions are also present (Ericsson, Nokia). While Huawei "only" has its primary European manufacturing centre in Hungary, European manufacturers also have R&D centres in Hungary, and thus bring significantly higher added value to the Hungarian economy. In the field of cloud services, Hungarian usage is low even by European standards, and there is no significant cloud capacity in the country. However, a number of Shared Service Centres (SSCs) has been set up in Hungary, which we can further develop to participate in the advancement of edge clouds. The situation is similar for artificial intelligence. The country does not have significant capabilities, but on the ruins of what was once a world-class mathematics education, we still have excellent data science education, and several U.S. data and AI companies operate development centres in Hungary, building on this intellectual capital.

CONCLUSIONS

If we look at Hungary's position in the Sino–American struggle purely in terms of strategic dependence, there can be no question on whom our country's cyberspace depends. With the exception of raw materials, a significant proportion of the hardware and software technology is based on U.S. expertise, whereas their manufacturing technology comes from Asian countries allied with the U.S. There is no denying China's significant advance in the world of digital technologies, but with the exception of 5G – where there are significant European manufacturers also present in Hungary – there is no real Chinese participation in either Hungary or Europe. If we take into account the restrictive measures taken by the United

States and the European Union's own measures, it is unlikely that there will be any significant change in this area in the next decade.

The question may arise whether it is in Hungary's interest to reduce our technological dependence on the U.S. by using Chinese technology instead. If we look at the examples where this has happened, such as HIKVision solutions in public surveillance, Huawei devices in the national emergency call system and national 5G networks, we find virtually without exception companies that have been embargoed by the U.S., so they cannot build on U.S. knowledge capital in their development. In addition, national security concerns are raised regularly, at least the domestic press and U.S. diplomacy strongly articulate these assumptions.

The question naturally arises: why not work with Chinese solutions if they are "cheaper and better"? As digital technology is highly innovation-intensive and requires very large investments, the Chinese model that the product should be both cheap and good is becoming less and less sustainable. For a very long time, the prerequisite for cheapness was that the basic technologies were acquired by large Chinese companies through solutions that were legally highly questionable, not necessarily respecting intellectual property, and often with employees working in the factories under inhumane conditions, for very low wages. Meanwhile, the best Chinese minds were being groomed in American universities, at no cost to the Chinese education system. By the mid-2010s, it became clear that none of the above three conditions could be sustained. The protection of intellectual property has become a priority, Chinese wages are rising and Chinese universities are innovating in their own right. Prices are therefore rising.

But will Chinese products be "better" than American ones? It is always up to the market to decide, and the digital technology market is typically influenced by aspects such as marketing, which is less well used by Chinese companies. The U.S., and in particular the Silicon Valley, will retain for a very long time two capabilities that China and Shenzhen cannot match. These are the multicultural, creative environment, which we can safely call a successful brain drain, and the flexible availability of capital, in other words capitalism itself. The Chinese culture and political system will not be able to reproduce these parameters, which are crucial for innovation, for a long time. It is premature, therefore, to envision the decline of Western technological superiority and to bet on the superiority of Eastern technology – as is true for all other aspects of the U.S.–China competition.[47]

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