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EXPERT REPORT ON INNOVATIONS IN HEALTH CARE IN THE CZECH REPUBLIC

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Expert report on innovations in health care in the Czech Republic

Name of the university: Moravian Business College Olomouc

Department: Business and Economics, Innovations in Healthcare

Address of the university: tř. Kosmonautů 1288/1, 779 00 Olomouc

Autors team:

1. Jindra Peterková, Business and Economics, jindra.peterkova@mvso.cz
2. Tomáš Jelínek, Healthcare Innovations Instituteemail, tomas.jelinek@mvso.cz
3. Michaela Koutná, Vice-rector's office for Strategic Partnership,
michaela.koutna@mvso.cz
4. Ekaterina Chytilová, Business and Economics, sutomina@gmail.com

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Introduction

The health system is the set of measures, procedures and facilities that make up the system of organisation of health care and provision of public health. Health care means the prevention, treatment and management of disease and the protection of mental and physical health, using the services of medical, nursing and auxiliary personnel. According to the World Health Organisation, health care can affect the health of 20% of the population. Other influences such as lifestyle, environment and harmful habits affect 80 % of the population's health.

In recent years, the Czech healthcare system has had to cope with increasing demands for the provision of quality healthcare with limited resources, problems associated with an ageing population and a shortage of qualified staff. The solution lies in innovations in healthcare that positively influence the provision of affordable and quality healthcare. A prerequisite for the implementation of healthcare innovations is the setting up of an effective system for the introduction of healthcare technologies that will lead to the provision of smart healthcare to the citizens of the Czech Republic. The current state and implementation of selected health technologies is described in the expert report.

The expert report on healthcare innovations in the Czech Republic identifies the current state and problems in healthcare related to digitalization, the use of selected modern technologies and mechanisms for establishing start-ups. The most important project areas for joint solutions with V4 partners are identified.

The expert report consists of an introduction, conclusion, and the five following chapters: Research goals, methodology and data sources, Current state and challenges in health care in given country, Use of modern digital technologies in healthcare, Mechanisms supporting creation of start-ups in health care, and Proposed areas in health care including problems in order to solve joint projects.

The first chapter defines the objective and methodology applied in the preparation of the expert report, including the data sources used.

The second chapter focuses on the definition of the functioning of the health care system in the Czech Republic, including the subjects and describes the health insurance system. The focus of the chapter is on the analysis of the demographic situation for the period 2017-2021 and the assessment of the Czech healthcare system based on economic indicators at the international and national level for the period 2017-2021.

The third chapter focuses on the use of modern digital technologies in healthcare. It includes a definition of the state of electrification of healthcare and an evaluation of the use of selected modern technologies in healthcare. This is followed by a description of the state of use of Telemedicine and smart devices, robots, Innovative tools for disease diagnosis and Big Data Processing by healthcare institutions.

Chapter 4 presents the mechanisms that support the creation of start-ups in the health sector. First of all, the existing system of state and private support in setting up start-ups is described, the way in which universities, research institutes and private companies are involved

in setting up start-ups in healthcare including access to health data by universities and private companies.

Chapter 5 identifies the problem areas that emerged from the analyses carried out in the areas of eHealth, the use of selected modern technologies and mechanisms supporting the creation of start-ups.

1. Research goals, methodology and data sources

The aim of the expert report for the Czech Republic is to identify economic and managerial problems in health care, particularly in eHealth, in the use of modern technologies and in the functioning of mechanisms supporting the creation of start-ups. Subsequently, based on the results obtained from the analyses carried out, to define project areas for joint solutions with the partners of the V4 countries. The expert report is prepared based on the established structure, which was approved in the project "The Establishment of a Platform for Healthcare Innovations in V4 countries and Israel", no. 22210051.

The expert report is based on the monitoring of information on the state of health care in the Czech Republic and on data for the period 2017-2021, describing economic indicators at the international and the national level. A comparison of the achieved economic indicators of the Czech health care system compared to OECD countries and, for selected economic indicators, also compared to V4 countries is carried out. This is followed by a synthesis of the results obtained from the analyses carried out in selected areas. The expert report was inspired by the presentations of Israeli experts at the 2nd, 3rd and 4th on-line workshop, which were implemented within the project no. 22210051. At the same time, the results from the analysed data are clearly presented in tables, graphs, and figures, which enables quick orientation in the text.

The main sources of data include mainly healthcare data processed by the Organisation for Economic Co-operation and Development (OECD), data processed by the Czech Statistical Office (CSO), data processed by the Institute of Health Information and Statistics of the Czech Republic (IHIS) and data processed by the consulting companies Deloitte and KPMG. The websites of the Ministry of Health of the Czech Republic, health insurance companies and Czech Invest were also used, as well as information from the website of the Institute of Health Economics and Technology Assessment (iHETA) and others. When collecting data, especially on the use of new technologies and mechanisms supporting the creation of start-ups, they either do not exist at all, or are unrepresentative and often of a partial nature not aggregated for the whole Czech Republic.

2. Current state and challenges in health care in the Czech Republic

The healthcare system is influenced by demographic changes in the population, the nature of the health needs of the population, unexpected epidemiological situations, but also by economic, political, and social pressures. The state plays an important role in the healthcare system, influencing health care to different degrees and in different ways. Health systems are the result of long-term societal development, with specificities in the organisation and financing of health care. [1] In the Czech Republic, the Bismarck model is applied which is based on the principle of universal solidarity and financing of health care by health insurance companies which have a contractual relationship with healthcare providers. This means that health care is provided on the basis of compulsory health insurance.

Currently, there is increasing pressure to monitor the economic efficiency and quality of health care, not only in the Czech Republic, including measuring indicators against other countries. The types and forms of health care, the rights and obligations of patients, healthcare providers, healthcare workers, other professionals, and other persons in connection with the provision of health services, including the conditions for assessing the quality and safety of health services, etc., are regulated in the Czech Republic by the Act No. 372/2011 Coll. on Health Services and Conditions for Their Provision (Health Services Act).

The Ministry of Health of the Czech Republic (MoH) is the central authority of the state administration in the field of health care and public health protection and is responsible for the Health 2030 Strategic Framework. It is a conceptual document that sets the direction for the development of health care for the citizens of the Czech Republic in the next decade. It contains specific objectives that are focused on three strategic goals - the protection and improvement of the health of the population, the optimisation of the health system, and the promotion of research and development. These strategic objectives are then subdivided into seven specific objectives, which replicate the investment and non-investment priorities of the MoH for the programme period of the EU's economic, social, and territorial Cohesion Policy 2021+, and which will be implemented through the seven downstream implementation plans as in Figure 2.1.

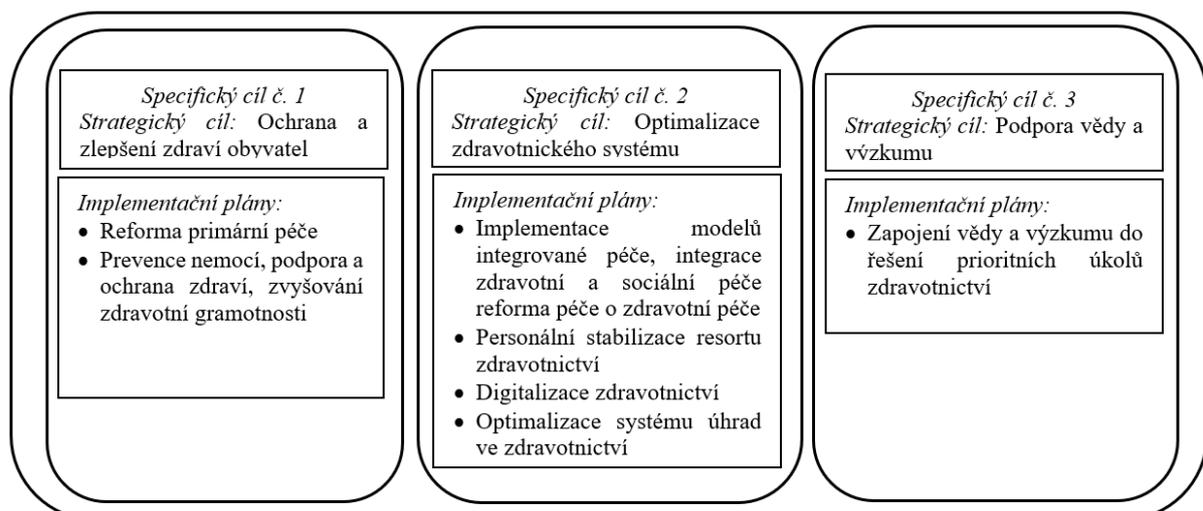


Figure 2.1. Health 2030 Strategic Framework

Source: [2]

The main healthcare entities are the insured (health care recipients), health care providers (health care intermediaries), and health insurers (health care payers) in Figure 2.2. [3]

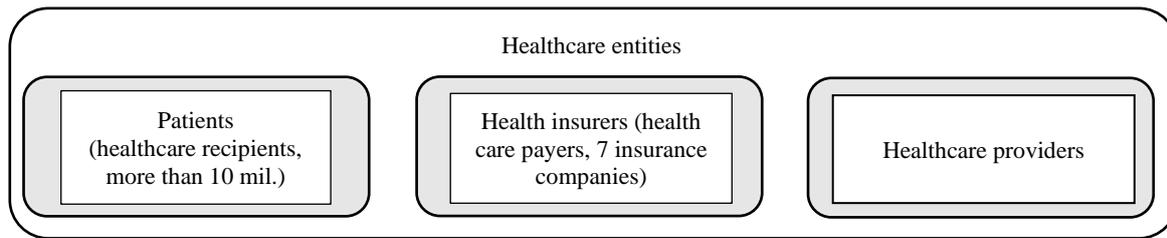


Figure 2.2. Healthcare system entities
Source: [3]

A patient is a natural person to whom health services are provided (Health Services Act, Part One, Section 3, Par. 1).

A health insurance company is an independent legal entity that is responsible for providing public health insurance. The activities of a health insurance company include, on the one hand, the collection of insurance premiums from insurance premium payers and, on the other hand, the payment of health services to health service providers. At the same time, the health insurance company keeps records of insured persons (VZP ČR keeps a central register of all insured persons), records of health service providers and carries out control activities (both of premium payers and health service providers), etc. The main duties of health insurance companies include ensuring the provision of covered services to their insured, which must be locally and temporally available. They fulfil this obligation through the providers with whom they conclude contracts for the provision and reimbursement of covered services. These providers form what is known as the contracted health insurance provider network. The activities and management of health insurance companies are subject to audits carried out by the Ministry of Health in cooperation with the Ministry of Finance. Independently of the supervision carried out by the Ministry of Health and the Ministry of Finance, the management of health insurance companies is also subject to control by the Supreme Audit Office. In the Czech Republic, there is the General Health Insurance Corporation of the Czech Republic and 6 employee insurance companies in Table 2.1. All six employee insurance companies are associated in the Union of Health Insurance Companies, which defends the common interests of health insurance companies and their clients with the main objective of improving the quality of services for their clients.

Table 2.1. Health insurance companies in the Czech Republic

Insurance company name	Number of clients (2019)	Number of contracted institutions (2019)	Average cost per insured person (2018)
Všeobecná zdravotní pojišťovna České republiky	5 950 000	24 021	28 000
Zdravotní pojišťovna ministerstva vnitra České republiky	1 314 389	25 730	25 000
Česká průmyslová zdravotní pojišťovna	1 263 043	25 000	26 638
Oborová zdravotní pojišťovna zaměstnanců bank, pojišťoven a stavebnictví	733 000	23 000	24 000
Vojenská zdravotní pojišťovna České republiky	697 604	24 745	27 987
Revírní bratrská pokladna, zdravotní pojišťovna	428 500	9 600	
Zaměstnanecká pojišťovna Škoda	144 401	6 615	26 500

Source: [4]

Health service provider means a natural or legal person authorised to provide health services under the Health Services Act No. 372/2011 Coll, Part One, Sec. 2.

The legal regulation of health care and health insurance is based on the Charter of Fundamental Rights and Freedoms (*Listina základních práv a svobod*), according to which

everyone has the right to health protection. Under public insurance, citizens have the right to free health care and medical aids under conditions laid down by law. Another important Act that regulates the conditions for the provision of health care and its financing in the Czech Republic is Act No. 48/1997 Coll., on Public Health Insurance.

All citizens are obliged to pay for health insurance to health insurance funds. All insured persons pay 13.5% of the assessment base. This applies to employees (1/3 paid by the employee and 2/3 by the employer), self-employed persons, and persons without taxable income. The state is the payer of the insurance premiums for legally defined groups of citizens (e.g. senior citizens, students, dependent children, etc.). Health insurance contributions are redistributed to individual non-state health insurance companies which collect these financial resources in insurance funds. Health care (health services) is covered by public health insurance and any direct financial participation of citizens does not exceed 15 %. The most common financial participation is in the form of supplements for medicines, dental services and medical devices. Medical devices and pharmaceuticals are divided into groups with at least one in each group that is fully covered by the health insurance company (MoH CR website, Veřejné zdravotní pojištění, 2022). The basic relationships between the entities that arise in health insurance are shown in Figure 2.3.

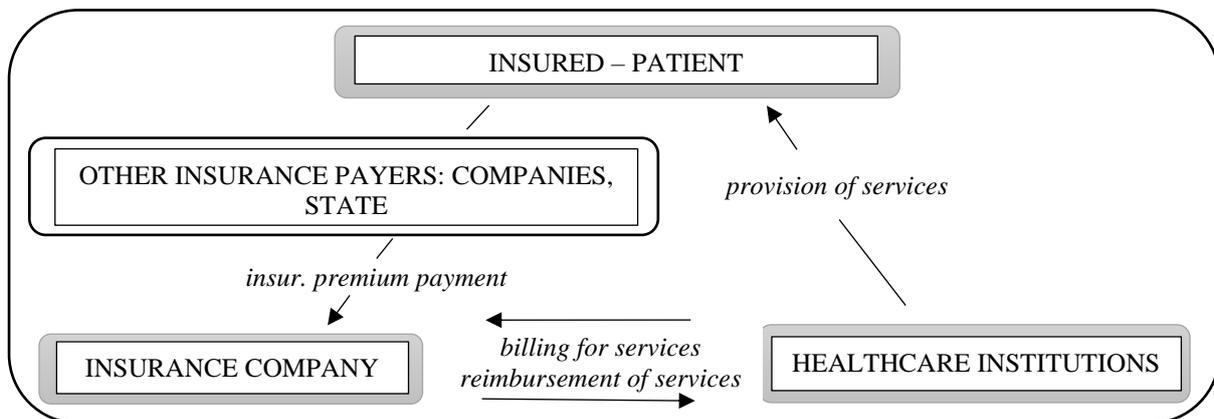


Figure 2.3. Basic relationships between health insurance entities
Source: [5]

The Czech healthcare system managed CZK 400 billion in 2019. Most of the system's revenue comes from public health insurance (65%) and other public sources (18%), and only 14% as direct payments from citizens and households. [6]

The Czech health care system is very solidarity-based because it is dominated by public funds, which come predominantly from labour taxation, i.e. fixed and mandated levies. Thus, the part of the population that is active, capable of work, and mostly healthy pays for health care for the elderly, the sick and the no longer active. The share of private funding in the Czech Republic is well below the average of OECD countries and the European Union average. Direct payments by patients are very limited and leading to the areas of medicines, aids, medical supplies, and dental care only. The Czech Republic does not allow for a commercial supplementary insurance form for routine healthcare, which leaves us among the last in Europe. On the other hand, commercial supplementary insurance in the context of the Czech Republic does not make much sense in the current set-up, as it is not possible to pay appropriately for better health care (formerly known as above-standard) and it is only possible to pay for the entirety of better treatment, which is often very expensive. [6]

The mechanisms for the distribution of funds are in the hands of health insurance companies under the supervision of the MoH and with the participation of providers and

professional organisations. The annual process is the preparation of the Reimbursement Decree, which sets the financial framework in the different segments of care providers and financial chapters for the following calendar year. The reimbursement decree, which determines the volume and unit reimbursement in the inpatient and outpatient segments, is negotiated annually in a so-called conciliation procedure between insurers and providers with the participation of professional associations. The Ministry then confirms this process legislatively by issuing the reimbursement decree. Medicines and medical devices are included in the system through entirely different processes and categorised in lists of covered medicines, medical devices and materials. A different mechanism is used to decide on the purchase of large equipment such as MRIs. And completely different mechanisms and processes are found in the redistribution of funds in the areas of prevention, home and health and social care. [6]

2.1 Demographic situation in the period 2017-2021

In 2021, the Czech Republic had a population of 10.517 million, 5.184 mil. of which were men and 5.333 mil. women. With regard to the age structure, the most represented is the 15-64 age group (63%), followed by the 65+ age group (20%), and the last one is the 0-14 age group (16%). According to the CSO data, the population will exceed 10.7 million in 2020 and will be the largest since the end of World War II. However, the total annual increase in 2020 was lower than in previous years due to lower migration and an increase in the number of deaths. The Czech Republic has long been a migration-profitable country, with the exception of 2013, the population has been increasing continuously since 2003. [7]

Significant changes occur due to population ageing in the age structure. There is an increasing proportion of seniors and simultaneously the proportion of working age people declines as shown in Table 2.2. and this has been occurring since 2017.

Table 2.2. Selected demographic data in the Czech Republic 2017-2021

Demographic data	2017	2018	2019	2020	2021
Population as of 31 December (in thousands of persons)	10 610	10 650	10 694	10 702	10 517
Men	5 220	5 244	5 272	5 275	5 184
Women	5 390	5 406	5 422	5 427	5 333
In age:					
0–14	1 671	1 693	1 710	1 720	1 693
15–64	6 899	6 870	6 852	6 824	6 654
65 and above	2 040	2 087	2 132	2 158	2 169
In age (%):					
0–14	15,7	15,9	16,0	16,1	16,1
15–64	65,0	64,5	64,1	63,8	63,3
65 and above	19,2	19,6	19,9	20,2	20,6

Source: [7]

The average life expectancy at birth over the period 2017-2021 is around 76 years for men and 82 years for women in the Czech Republic, that is 6 years longer for women than for men, see Table 2.3.

Table 2.3. Life expectancy at birth

Demographic data (in years)	2017	2018	2019	2020	2021
Men	76,0	76,1	76,3	75,3	74,1
Women	81,8	81,9	82,1	81,4	80,5

Source: [7]

In 2020, 129.3 thousand people died, the highest number since 1987. In comparison to 2019, 15% more people died. For 8.2% of deaths in 2020, covid-19 was the main cause of death. At the same time, there are more deaths than live births in 2019-2021 see. Table 2.4.

Table 2.4. Births and deaths in CR 2017-2021

Demographic data	2017	2018	2019	2020	2021
Live births	114 405	114 036	112 231	110 200	111 793
Live births per 1 000 inhabitants	10,8	10,7	10,5	10,3	10,6
Deaths	111 443	112 920	112 362	129 289	139 891
Deaths per 1 000 inhabitants	10,5	10,6	10,5	12,1	13,3

Source: [7]

According to the CSO data, the main cause of death among the deceased in the period 2017-2019 are diseases of the circulatory system in the first place, followed by neoplasms in the second place and diseases of the respiratory system in the third place, see Table 2.5.

Table 2.5. Causes of death in the deceased in CR 2017-2019

Deaths by cause of death	2017	2018	2019	2020	2021
Circulatory system diseases	49 346	48 792	47 393	51 299	47 873
Neoplasms	27 852	28 266	28 869	28 716	27 717
Respiratory system diseases	8 067	8 315	8 192	8 290	7 735
External causes of morbidity and mortality	5 608	5 845	5 685	5 633	5 300
Endocrine, nutritional and metabolic diseases	4 497	5 137	5 160	5 897	6 091
Acute myocardial infarction	4 707	3 989	3 793	3 642	3 392

Source: [7]

2.2 Evaluation of selected economic indicators in the period 2017-2021

In the Czech Republic, the evaluation of health care is carried out through selected economic indicators both at international and national levels. The evaluation at the international level is based on OECD data for the period 2017-2021 and 12 indicators are evaluated, as well as the World Index of Healthcare Innovations. At the national level, the economic indicators assess public expenditure on health care and its structure, the costs of health insurance companies and the level of average wages in the health care sector.

2.2.1. Evaluation of the Czech health care based on economic indicators at the international level

The data OECD [HEALTH AT A GLANCE, 2021] show that during the 1990s and early 2000s, OECD countries experienced a steady increase in the ratio of health spending to gross domestic product (GDP). During the economic crisis of 2008, the ratio remained relatively stable, i.e., growth in health spending roughly matched overall economic performance across OECD countries. Subsequently, COVID-19 pandemic significantly reduced economic activity and health spending increased again. In 2019, prior to the COVID-19 pandemic, OECD countries spent on average around 8.8% of their GDP on health care (the figure remained more or less unchanged since 2013). The annual real growth in healthcare spending per capita and GDP for 23 OECD countries, including the Czech Republic, from 2006 to 2020 is shown in Figure 2.4.

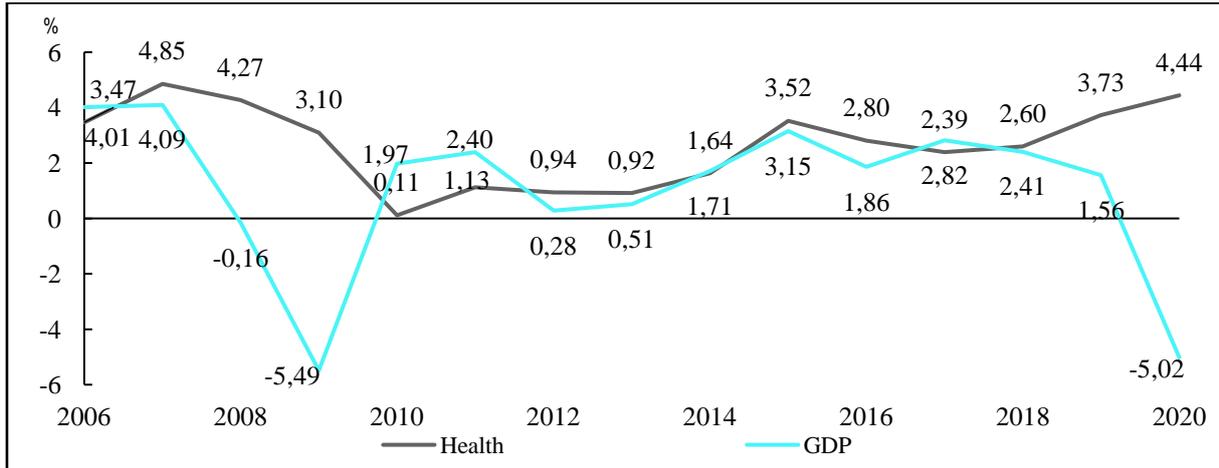


Figure 2.4. Annual health expenditure per capita and GDP in 23 OECD countries including the Czech Republic from 2006-2020
Source: [8]

The ratio of health spending to GDP was below the level of the OECD countries at 7.8% in the Czech Republic in 2019, see Figure 2.5. Preliminary estimates for 2020 for many OECD countries indicate a significant increase in the ratio of health spending to GDP. This is due to the increase in health spending to tackle COVID-19 and the reduction in GDP due to the reduction in economic activity. Based on initial data, the average health expenditure to GDP ratio of OECD countries is estimated to increase from 8.8% in 2019 to 9.7% in 2020. In the Czech Republic, the health expenditure to GDP ratio is projected to increase by 1.27% to 9.07%.

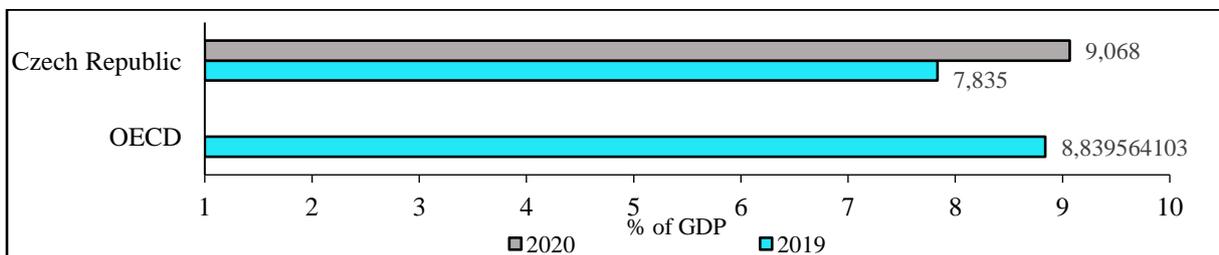


Figure 2.5. Health expenditure as a share of GDP in the Czech Republic and in the OECD 2019 and 2020
Source: [8]

According to OECD data, the level of per capita health spending varies over time depending on demographic, social and economic factors, as well as the financing and organisation of a country's health system. In 2019, the OECD¹ per capita health expenditure was USD 4 084. In the Czech Republic, health expenditure per capita was USD 3 417, which is below the OECD average per capita health expenditure, see Figure 2.6.

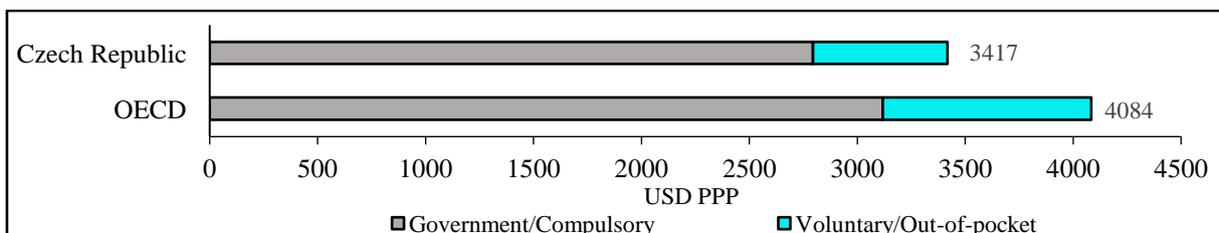


Figure 2.6. Health expenditure per capita in the Czech Republic and in the OECD in 2019
Source: [8]

¹ When comparing the expenditure level between countries, the healthcare per capita expenditure was converted to common currency, i.e. USD and adjusted with respect to national exchange purchasing power of national currencies.

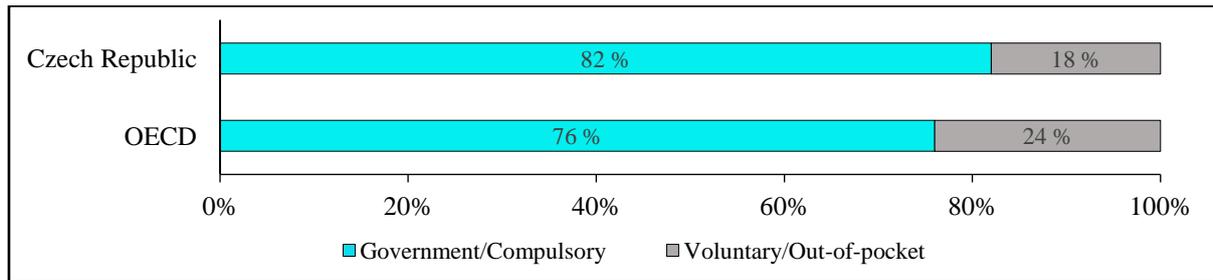


Figure 2.7. Financing of Health expenditure in the Czech Republic and in the OECD in 2019
Source: [8]

The distribution of health expenditure is made according to the type of financing, either through government or compulsory insurance (public or private), or through voluntary health insurance or direct payment by households. In OECD countries, more than 76% of all health expenditure is financed through government or compulsory insurance. In the Czech Republic, as well, the financing of health expenditure through state or compulsory insurance prevails, at 82%. The distribution of health expenditure by type of financing is shown in Figure 2.7.

In order to analyse health expenditure in more detail, both the price level of health care expenditure reflecting the prices of health care goods and services and the quantity of health care goods and services consumed, or the amount of care used by individuals, are tracked. Conversion factors are used to compare price levels of health care expenditure, specifically PPP² of actual individual consumption (AIC). The level of prices for health care using a representative basket of health care goods and services for the V4 countries is shown in Figure 2.8. In contrast, the highest healthcare prices among the V4 countries are in Slovakia, which is 7% higher than the Czech Republic. On the one hand, healthcare utilisation volumes are almost comparable in Poland and Hungary and with a larger difference in Slovakia see Fig. 2.8. On the other hand, the Czech Republic has a significantly higher level of healthcare volumes as opposed to the V4 countries and 29.8% more than in the OECD countries see Figure 2.9.

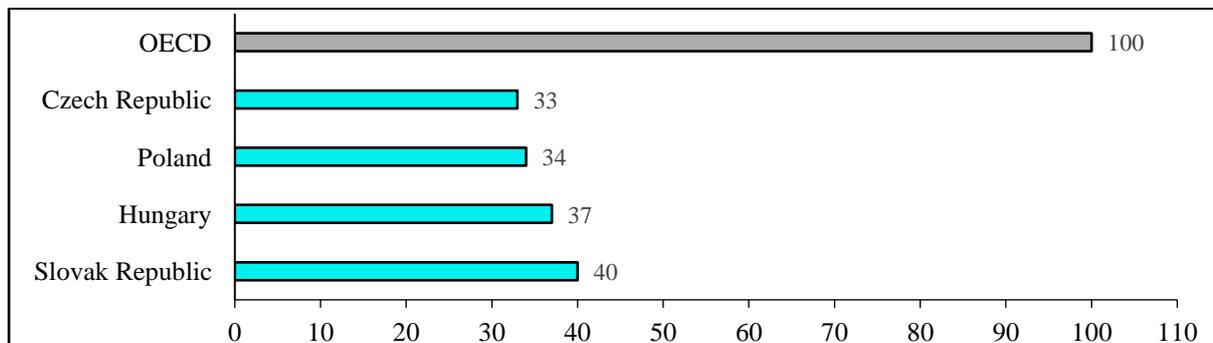


Figure 2.8. Price levels in the health care sector in V4 in 2017
Source: [8]

² Purchasing power parities (PPPs) are indicators of price differences between countries. They represent the ratio of prices in national currencies for the same goods and services in different countries. PPPs are used to calculate a price level health index to compare price levels and volumes across countries. These indices are calculated as ratios of health PPPs to exchange rates and indicate the number of units of a common currency needed to purchase the same volume.

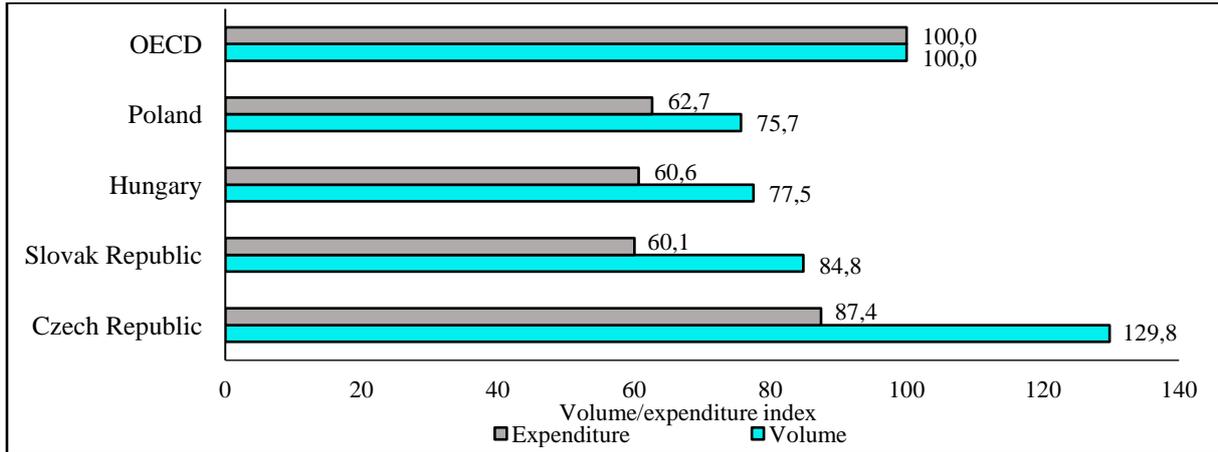
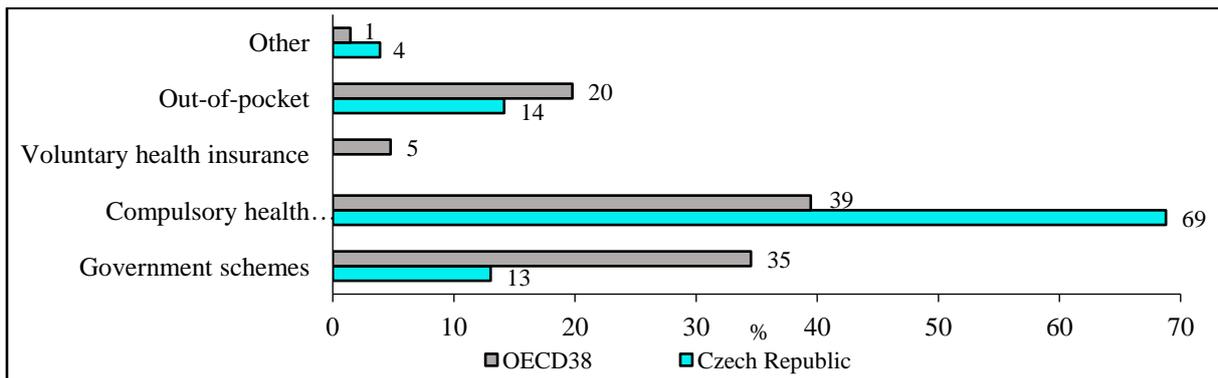


Figure 2.9. Health care volumes per capita compared to health expenditure per capita in V4 in 2017
Source: [8]

Citizens' health care in OECD countries is financed in different ways, with financing in terms of the financing schemes defined in the System of Health Accounts (OECD/Eurostat, 2017). The types of financing are funding through government schemes (coverage through government programmes), compulsory health insurance, voluntary health insurance, and private funds such as household expenditure (out-of-pocket) and funding from non-governmental organisations (NGOs) and private corporation schemes. In OECD countries in 2019, the majority of health care is financed through government programmes or government schemes (35%) and compulsory health insurance (39%), i. e. 74% in total, see Figure 2.10. In the Czech Republic, health care is mostly financed through compulsory health insurance (69%), followed by out-of-pocket financing (14%) and government programmes (13%), see Figure 2.10. In the other V4 countries (Slovakia, Poland, Hungary), health care is also mostly financed through compulsory health insurance and household out-of-pocket, with out-of-pocket financing being the highest in Hungary (28%). At the same time, health care is not financed through voluntary health insurance in Slovakia and the Czech Republic, whereas it is financed this way by 2% in Hungary and by 7% in Poland. For the methods of health care financing, see Figure 2.11.



Note: All spending by private health insurance companies reported under compulsory health insurance. Category “Other” refers to financing by NGOs, employers, non-resident schemes and unknown schemes.

Figure 2.10. Health expenditure by type of financing in 2019
Source: [8]

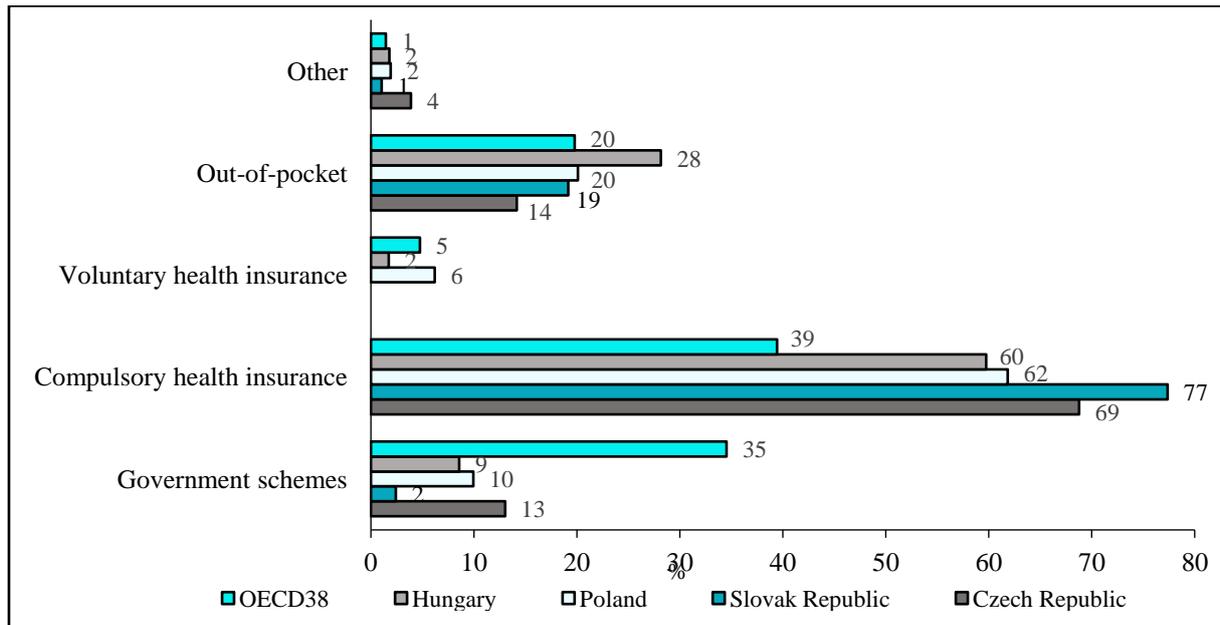
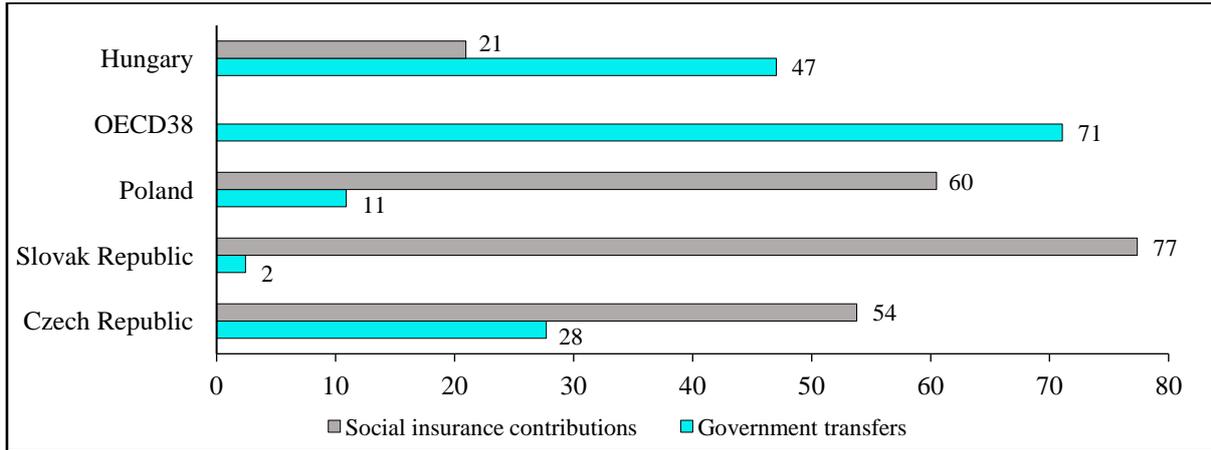


Figure 2.11. Health expenditure by type of financing in 2019
Source: [8]

Based on the analysis of the flow of resources or revenues to finance health expenditure, see Figure 2.12. a more comprehensive view of the financing of health services can be obtained, including the impact on different sectors of the economy. The revenue needed to finance health spending comes from a variety of sources. These are either from government revenues in the form of taxes and levies, from social health insurance contributions on behalf of certain population groups, from payments of current insurance premiums, or from direct payments by households. The health sector may also be financed by donations, investment other commercial operations' income, or from bilateral agreements between foreign governments or development partners. Total public financing can be defined as the sum of government transfers and all social contributions. Private resources consist of voluntary and compulsory insurance premiums, as well as any other resources from households or enterprises. In 2019, on average, public sources financed around 71% of healthcare expenditure in OECD countries, see Figure 2.12. In contrast, in the V4 countries, public funding for health expenditure was highest in Hungary (47%), the Czech Republic (28%), Poland (11%), and the lowest in Slovakia (2%). In the V4 countries, including the Czech Republic, public funding dominates the financing of healthcare expenditure. It is reported that the amount of public funding of health care is determined by the type of existing health care system, the demographic composition of the population and government policy, including budget priorities.

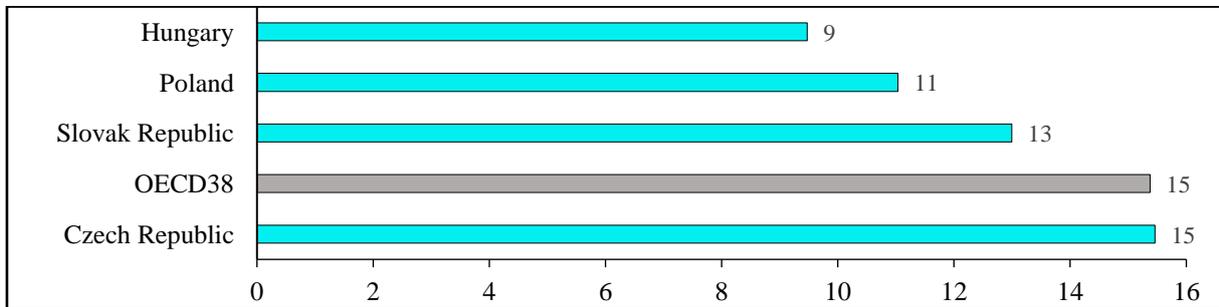
Public funding of health spending (through government transfers and social insurance contributions) accounted for an average of 15% of total government spending in OECD countries in 2019, see Figure 2.13. Public funding of health spending was at the same 15% level of total government spending in the Czech Republic, slightly less at 13% in Slovakia, followed by Poland (11%) and Hungary (9%). It is reported that all OECD countries expanded and revised their budget allocations in 2020 as part of government responses to address the impact of COVID-19. While public resources allocated to health increased, the magnitude of these increases was generally smaller than the subsidies provided to businesses suffering from economic stagnation. [8]



Note: Public funding is calculated using spending by government schemes and social health insurance

Figure 2.12. Health expenditure from public sources as a share of total

Source: [8]

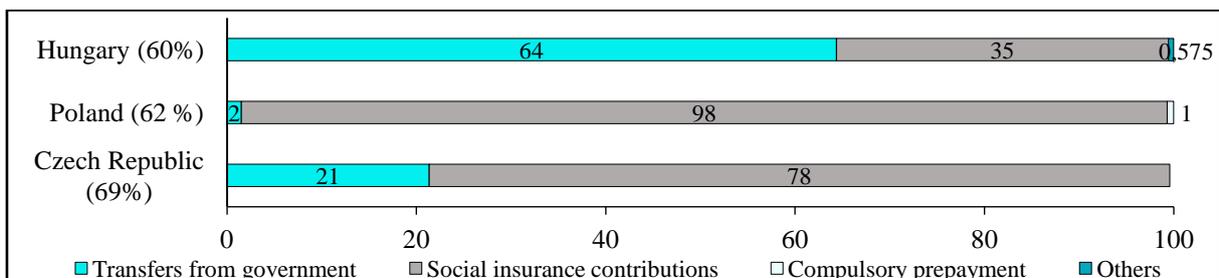


Note: Public funding is calculated using spending by government schemes and social health insurance

Figure 2.13. Health expenditure from public sources as a share of total government expenditure, 2019

Source: [8]

Data analysis [8] shows that the funding of compulsory health insurance includes transfers from the state, social insurance contributions, compulsory advances and others, see Figure 2.13. In 2019, the main funding source of compulsory health insurance in the Czech Republic was social insurance contributions at 78% and, by a greater margin, transfers from the state (21%). The situation is similar in Poland, where the main funding source of compulsory health insurance were also social insurance contributions (98%) and only 2% of funding was contributed by transfers from the state. In Hungary, the situation is reversed, where, on the contrary, government transfers funded 64% of compulsory health insurance expenditure and only 35% was funded by social insurance contributions. At the same time, the contribution of compulsory health insurance accounts for the largest share of total health expenditure in the Czech Republic (69%), followed by Poland (62%) and Hungary (60%). Due to rounding, percentages may not add up to 100%.



Note: Numbers in brackets indicate the contribution of compulsory health insurance to total health expenditure. Category "Others" includes other domestic revenues and direct foreign transfers.

Figure 2.14. Financing sources of compulsory health insurance, 2019

Source: [8]

Primary health care is the foundation for an effective people-centred health system. It is an effective way to improve care coordination and health outcomes and reduce wasteful spending by reducing unnecessary hospital admissions and associated costs in hospitals and other parts of the health system. Primary health care relates to spending on primary care services, including general outpatient, dental and home health care, as well as preventive services provided by outpatient providers. Primary health care represents on average about 13% of health expenditure in OECD countries and approx. 11% in the Czech Republic, see Figure 2.15.

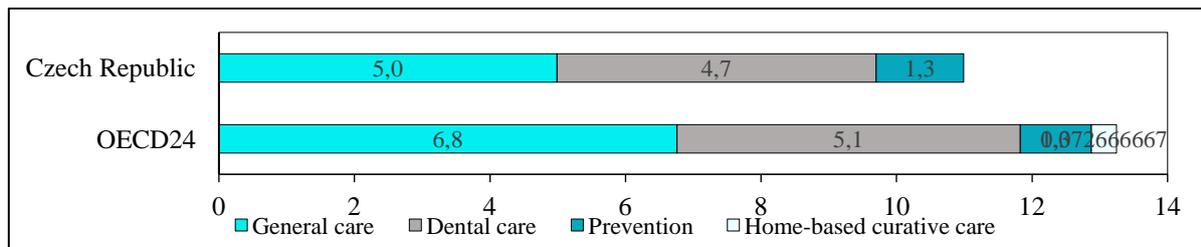
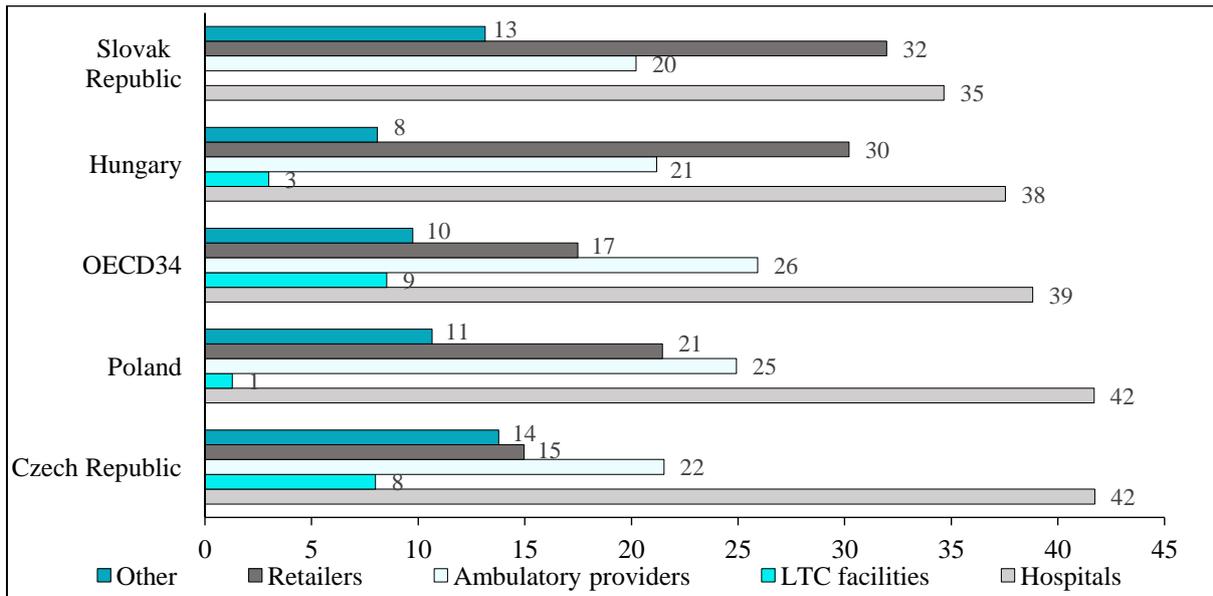


Figure 2.15. Spending on primary health care services as a share of current health expenditure, 2019
Zdroj: [8]

Simultaneously, general outpatient care accounts for the largest share (6.8%), dental care for another 5.0%, home care for 0.4% and preventive care for 1% in the OECD countries, see Fig. 2.15. The situation is similar in the Czech Republic; general care accounts for 5%, dental care for 4.7%, home care is zero and preventive care is slightly higher than in the OECD countries at 1.3%, see Fig. 2.15.

Health expenditure analysis looks at health expenditure by health care provider. [9] Based on the Health Accounts System, providers are divided into primary providers, which are organisations and actors for whom the provision of healthcare goods and services is a primary activity. At the same time, secondary providers, for whom the provision of healthcare is only one of many activities. Primary providers include hospitals, residential long-term care facilities, outpatient providers, ancillary service providers (e.g. outpatient clinics and laboratories), retailers (such as pharmacies), and preventive care providers (e.g. public health institutes). Secondary providers include residential care facilities whose primary activity might be the provision of accommodation but provide nursing supervision and ancillary activities; supermarkets selling over-the-counter medicines, and facilities providing health care services and limited population services such as prison health. Secondary providers include providers of health care system administration and financing (e.g. government agencies and health insurance agencies) and households as home health care providers.

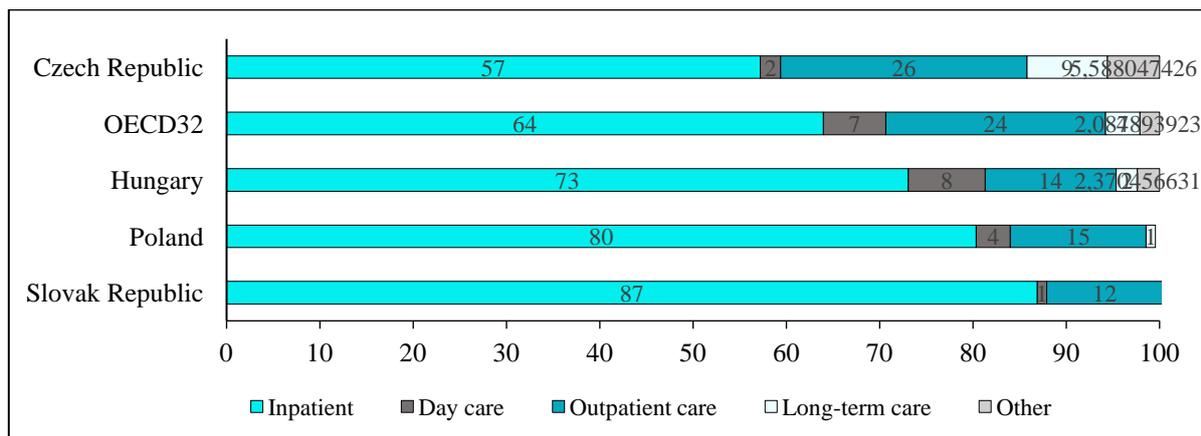
The data analysis [8] indicates that activities provided in hospitals accounted for the largest share of health system funding in OECD countries in 2019, i.e. at 39%, see Figure 2.16. This amount was exceeded by 3% to 42% in the CR and in PL, as in Figure 2.16. It has turned out that after hospitals, outpatient providers are the largest category of providers in the CR, i.e. 22%, see Figure 2.15. In OECD countries, care provided by outpatient providers accounted for 26% in 2019. Also in Poland, the second largest category of providers was outpatient providers at 25%, while in Slovakia (32%) and Hungary (30%), the second largest category of providers was retailers in 2019. In the Czech Republic, retailers (15%) were only the third most important provider group. The lowest spending in the Czech Republic goes to LTC facilities (8%), which is below the OECD level (9%), see Figure 2.17.



Note: “Other” includes ancillary service providers (e.g. patient transport, laboratories); health system administration, public health and prevention agencies; households in cases where they provide paid LTC; and atypical providers where health care is a secondary economic activity.

Figure 2. 16. Health expenditure by provider, 2019

Source: [8]



Note: “Other” includes preventive care activity, pharmaceuticals if dispensed to outpatients and unknown services.

Figure 2.17. Hospital expenditure by type of service in 2019

Zdroj: [8]

In a more detailed analysis of hospital expenditure by type of services provided in OECD countries, inpatient care accounts for the largest share, at 64%, followed by outpatient care (24%) and day care (7%). In the Czech Republic, hospital expenditure on inpatient care is below the OECD average (57%), followed by outpatient care (26%), which is lower than in OECD countries. Expenditure related to long-term care (2%) is lower in the Czech Republic than in OECD countries (4%), see Figure 2.17.

In addition to human resources, physical resources such as new medical facilities, diagnostic and therapeutic equipment and information and communication technology (ICT) play an important role in the provision of health services. Failure to invest in physical resources can have a negative impact on the ability of the health system to meet the health care needs of the population. Decisions on investment spending in physical resources depend on economic and political circumstances and future need and past levels of investment. [8] Investment in

physical resources is tracked through the indicator Annual capital expenditure on health as a share of GDP, this is the average for 2015-19, see Figure 2.18.

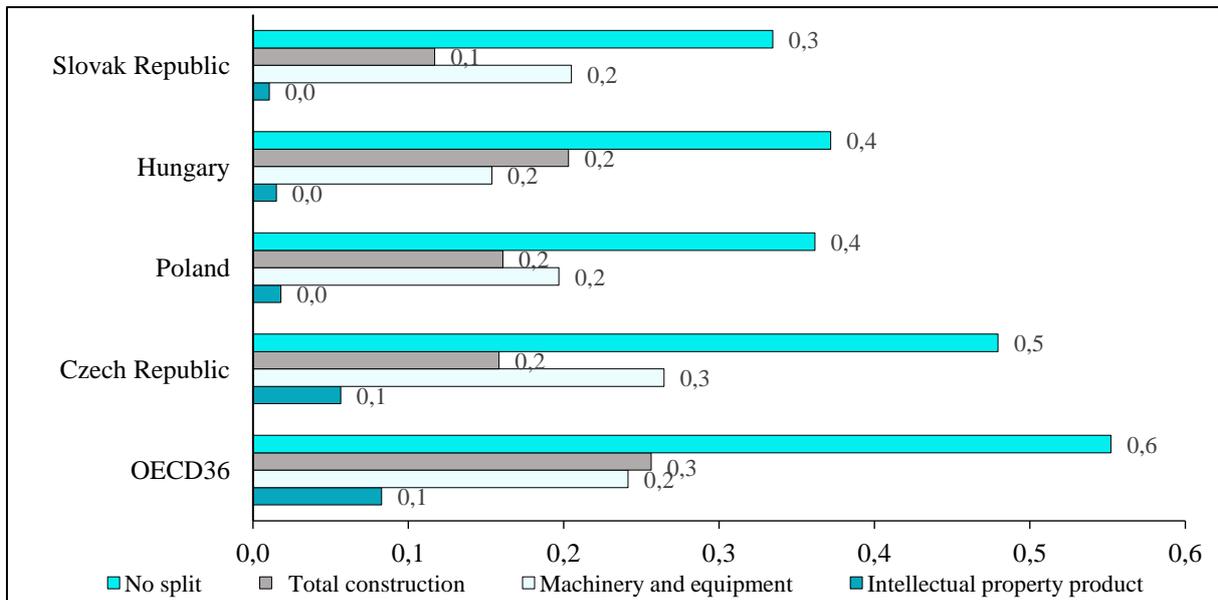


Figure 2.18. Annual capital expenditure on health as a share of GDP in OECD and in V4 for 2015-2019
Source: [8]

Figure 2.18. shows that the average annual capital expenditure on health care in the period 2015-2019 in OECD countries was approximately 0.6% of GDP, while capital expenditure on health care in the Czech Republic was slightly less (0.5%), but the highest compared to the V4 countries. At the same time, Annual capital expenditure on health as a share of GDP for 2015-19 is tracked in detail by asset type. They are tracked in detail Annual capital expenditure on health as a share of GDP to Intellectual property product, Machinery and equipment and Total construction see Figure 2.19.

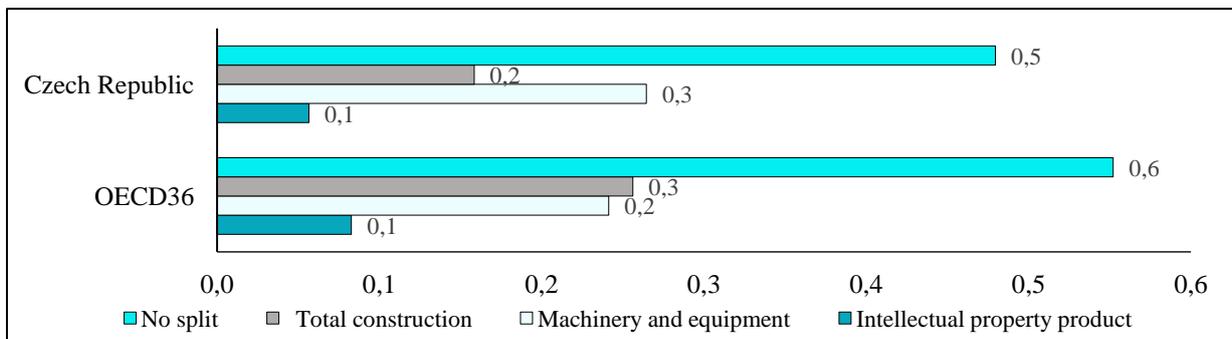


Figure 2.19. Annual capital expenditure on health as a share of GDP in OECD by asset for the period 2015-2019
Source: [8]

Figure 2.19. shows that the Czech Republic invested the most in medical machinery and equipment (0.3%), which was higher than that of OECD countries, while it invested the least in intellectual property products (0.1%), which was on par with OECD countries. Interestingly, Slovakia, Poland and Hungary did not invest in intellectual property products at all.

Another means of healthcare assessment that allows for international comparison is the structured World Index of Healthcare Innovations. This index compares national health systems based on traditional measures such as universal access and health outcomes, but also considers the degree to which patients can choose their doctor and insurer, existing patents related to healthcare, scientific impact and Nobel Prizes in chemistry and physiology or medicine, access

to new treatments, and digitalization of healthcare. The index also measures the fiscal sustainability of countries' health care systems, or how much ability a nation has to sustain its public health spending without punitive taxes or a debt crisis.

The World Index of Healthcare Innovations ranks 31 high-income national healthcare systems on four dimensions: quality, choice, science and technology, and fiscal sustainability. There are 3-5 elements in each dimension, for a total of 13 elements. Each element, composed of measures derived from different data sources, is weighted and aggregated to produce a score for each of the four dimensions and then an overall score and ranking in the index. All measures, elements, and dimensions use a standardized scoring method on a 0-100 scale to rank each country's performance with respect to the others. Refer to Table 2.6 for the dimensions and elements of the index.

Table 2.6. Methodology for evaluating health systems using the World Index of Healthcare Innovations

DIMENSION: QUALITY	DIMENSION: CHOICE
<p>ELEMENT 1: MEASURES OF PREVENTABLE DISEASE (35%)</p> <ul style="list-style-type: none"> Hospital admissions Acute care survival 5-year cancer survival PPP-adjusted GDP growth <p>ELEMENT 2: PANDEMIC PREPAREDNESS AND RESPONSE (25%)</p> <ul style="list-style-type: none"> COVID vaccination rate Lockdown stringency COVID fatality rate Economic isolation <p>ELEMENT 3: PATIENT-CENTRED CARE (25%)</p> <ul style="list-style-type: none"> Medical appointment wait times Patients receiving easy-to-understand explanations Patients being involved in decisions about care <p>ELEMENT 4: INFRASTRUCTURE (15%)</p> <ul style="list-style-type: none"> Primary care doctors per capita Nurses per capita Acute care hospital bed occupancy 	<p>ELEMENT 5: AFFORDABILITY OF HEALTH INSURANCE (35%)</p> <ul style="list-style-type: none"> Gross cost of health insurance Out-of-pocket spending (as percentage of per capita income) Legal residents insured <p>ELEMENT 6: FREEDOM TO CHOOSE HEALTH CARE SERVICES (45%)</p> <ul style="list-style-type: none"> Choice of insurance products Choice of providers Out-of-pocket spending (as percentage of total national health expenditures) <p>ELEMENT 7: ACCESS TO NEW TREATMENTS (20%)</p> <ul style="list-style-type: none"> New drugs available Generic drug market share Access to biosimilars
DIMENSION: SCIENCE & TECHNOLOGY	DIMENSION: FISCAL SUSTAINABILITY
<p>ELEMENT 8: MEDICAL ADVANCES (35%)</p> <ul style="list-style-type: none"> Health care patents New drugs approved R&D Expenditures <p>ELEMENT 9: SCIENTIFIC DISCOVERIES (45%)</p> <ul style="list-style-type: none"> Nobel laureates in medicine or chemistry Average number of citations to research documents <p>ELEMENT 10: HEALTH DIGITIZATION (20%)</p> <ul style="list-style-type: none"> Electronic health record adoption rate Information and communication technology (ICT) development 	<p>ELEMENT 11: NATIONAL SOLVENCY (40%)</p> <ul style="list-style-type: none"> Debt-to-GDP ratio <p>ELEMENT 12: PUBLIC HEALTH CARE SPENDING (40%)</p> <ul style="list-style-type: none"> Public health care spending (as share of GDP) (100%) <p>ELEMENT 13: GROWTH IN PUBLIC HEALTH CARE SPENDING (20%)</p> <ul style="list-style-type: none"> Growth in public health care spending (as share of GDP)

Source: [10]

Based on the above-mentioned evaluation methodology through the World Index of Healthcare Innovation, see Table 2.6, the Czech Republic ranked 16th out of 31 countries evaluated in 2021. See Table 2.7. for information how the CR was ranked in each dimension.

Table 2.7. Ranking of the Czech Republic based on the World Index of Healthcare Innovations in 2021

QUALITY	38.8	CHOICE	56.84
Like other eastern European countries, the Czech Republic struggles with the quality dimension, ranking 27. While it initially handled the covid-19 pandemic well, it has since seen the virus surge amidst a low vaccination rate, resulting in the second highest fatality rate in the index. On top of this, Czechs have struggled to manage chronic diseases like cardiovascular disease and cancer. On a positive note, the Czech Republic features easy access to doctors and specialists, with the fifth shortest wait times for specialty care in the index.		The level of choice in the Czech Republic is mixed, ranking 15 overall. The Czech republic’s universal health care system prioritizes affordability of health insurance (2) over freedom to choose health care services (18). Access to new treatments is low, but on par with several countries in the index.	
SCIENCE & TECHNOLOGY	15.58	FISCAL SUSTAINABILITY	79.06
The Czech Republic is weak in science and technology innovation, ranking 29 overall. The country makes an effort to develop health digitization (19). However, the Czech Republic relies on other modern countries for medical advances (21) and scientific discoveries (27) because it lacks research and development capacity across the health sector and academia.		The Czech Republic is the top country in the index for fiscal sustainability, ranking 1 overall. It’s national solvency is ranked 4, and it ranks only behind Germany in public health spending as a percentage of GDP (2). While the Czech Republic ranks 23 in growth of public health spending in the last 10 years, such growth is similar among countries with lower public health spending as a baseline.	

Source: [10]

The Czech Republic scored best in the Choice dimension and the Fiscal Sustainability dimension. In the Choice dimension, the health care system is characterised as universal, where affordability of health insurance is prioritised over freedom of choice of health services. Access to new treatments is low but comparable to several countries in the Index. The Czech Republic ranks 1st out of all 31 countries assessed in fiscal sustainability. National solvency is highlighted, but CR ranks only 23rd in growth of public health spending over the last 10 years, such growth is similar among countries with lower baseline public health spending.

The overall score (47.58), including the ranking of the Czech Republic (16th place) obtained by the World Index of Healthcare Innovation, is shown in Table 2.8.

Table 2.8. CR ranking and overall score in 2021

Overall rank	Country	Overall tier	Overall score	Quality	Choice	Science & technology	Fiscal sustainability
1.	Switzerland	Excellent	65.15	65.39	68.25	53.92	73.06
2.	Netherlands	Excellent	62.99	62.65	73.31	42.56	73.43
3.	Germany	Excellent	59.79	52.73	70.25	37.69	78.48
4.	Ireland	Excellent	58.67	58.16	61.48	32.52	74.50
5.	Israel	Excellent	55.72	63.21	59.67	38.38	61.62
6.	United States	Excellent	54.78	56.33	54.53	73.93	34.35
7.	Australia	Good	50.76	60.07	65.44	25.27	52.25
8.	Hong Kong	Good	50.72	40.56	61.58	24.96	75.77
9.	Belgium	Good	50.51	48.84	56.23	35.43	61.53
10.	United Kingdom	Good	50.21	52.15	57.04	47.18	44.46
11.	Denmark	Good	49.87	49.20	52.20	45.37	52.70
12.	Singapore	Good	49.71	46.83	66.44	32.63	52.95
13.	Taiwan	Good	49.26	50.22	60.10	17.75	68.96
14.	South Korea	Good	48.36	51.81	63.35	18.14	60.16
15.	New Zealand	Good	48.28	58.47	54.61	25.47	54.56
16.	Czech Republic	Good	47.58	38.84	56.84	15.58	79.06

Source: [10]

2.2.2. Evaluation of the Czech health care based on economic indicators at the national level

As of 31 December 2019, there were a total of 32,240 healthcare facilities in the Czech Republic, 21,581 of which were independent practices of primary care physicians and specialists. There were 313 inpatient facilities, excluding spas and convalescent homes, and 194 acute and post-acute care hospitals. In 2019, there were 50,802 physicians and dentists and 116,998 independent non-physician health workers (NPHWs) in all health care facilities. On average, there were 210 residents per 1 physician in the country. On average, there were 72.4 beds per 10 000 inhabitants in the Czech Republic (of which 56.6 in acute and follow-up care hospitals and 15.8 in specialised medical institutions). In terms of the form of care, in 2019, acute care was provided in 48,212 beds, follow-up and long-term care was provided in 28,979 beds, and overnight care was provided in 246 beds. The average length of stay in hospitals (acute and follow-up care) remained unchanged year-on-year at 9.1 days. In 2019, 2,628 pharmacies provided pharmacy care in the Czech Republic. On average, there were 4 069 inhabitants per 1 pharmacy. The pharmacy network is not evenly distributed and tends to be concentrated in larger cities. [11]

In 2019, public expenditure, including state and local budgets (CZK 22,502 million) and public health insurance (CZK 317,994 million), amounted to CZK 340.5 million. Health insurance companies have the largest share of public expenditure, with 93% in 2019.

Table 2.9. Public expenditure on health services in Czech Republic in 2017-2019

Public expenditure on health services (in mil. CZK)	2017	2018	2019
State and territorial budgets	18 373	21 518	22 502
Incl.: state budget	8 694	8 617	8 639
Territorial budgets	9 679	12 901	13 863
Health insurance corporations	275 306	295 290	317 994
Total	293 679	316 808	340 496

Source: [11]

Considering the structure of health insurance costs, most of the costs are associated with inpatient care (54.5%), followed by outpatient care (26.6%) and the cost of prescription drugs and medical devices dispensed on vouchers (14.8%), as in Table 2.10.

Table 2.10. Structure of costs of health insurance corporations on health care

Type of health care	Costs	
	In mil. CZK	Proportion in %
TOTAL INCL.:	312 352	100
Out-patient care	83 028	26,6
O.w.: general practitioners	17 261	5,5
Stomatological care	12 165	3,9
Special out-patient care	33 493	10,7
In-patient care	170 226	54,5
Prescribed drugs and medical aids	45 164	14,8
Other	12 934	4,1

Source: [11]

In 2019, health insurers spent the most on inpatient care (54.5%) of which hospitals accounted for the largest share. This was followed by outpatient care (26.6%) of which GP care accounted for most. Another significant cost item were prescription drugs. Conversely, the least amount was attributed to treatment abroad. Health insurers' costs by care segment are shown in Table 2.11.

Table 2.11. Costs of health insurance corporations by segments of health care

Type of health care	Costs			
	In mil. CZK		Proportion in %	
	2018	2019	2018	2019
Total health care	286395	312352	100	100
Incl.: health care paid from capital fund	285302	310969	99,6	99,6
Incl.: out-patient care	75094	83028	26,2	26,6
In-patient care	155361	170226	54,2	54,5
Balneal care	3387	3641	1,2	1,2
Care in convalescent homes	32	35	0	0
Transport	1582	1698	0,6	0,5
Medical emergency service	2806	2981	1	1
Prescribed drugs	36148	37820	12,6	12,1
Prescribed medical aids	7944	8344	2,8	2,7
Treatment abroad	1053	1077	0,4	0,3
Other	1895	2119	0,7	0,7
Costs for improvement of health care drawn from other funds	1093	1384	0,4	0,4

Source: [11]

The largest health insurance expenditure for men in 2018 is associated with the 70-74 age group and amounted to CZK 17 257 million. For women, the largest expenditures are also associated with the 70-74 age group and amounted to CZK 16 810 million. For both men and women, the largest increases are from the 60-64 age group to the 75-79 age group. For women, in contrast to men, higher expenditure is also associated with the 85+ age group, amounting to CZK 10 487 million. Health insurance expenditure on health care by age and gender in 2018 is shown in Table 2.12.

Table 2.12. Expenditure of health insurance companies on health care by age and gender in 2018

Age group	Expenditure on health care in mil. CZK	
	Males	Females
UP TO 4	6263	5272
5-9	3387	2729
10-14	3338	2974
15-19	2846	3128
20-24	2656	3405
25-29	3857	4475
30-34	4502	6556
35-39	5675	7395
40-44	7500	8638
45-49	7363	8267
50-54	6343	7686
55-59	9935	9403
60-64	14591	12503
65-69	17725	15808
70-74	17257	16810
75-79	11335	13033
80-84	6594	9485
85+	4692	10487

Source: [11]

The average monthly salary of employees in health services in the Czech Republic was CZK 44 344 (in 2018).

2.3 Determination of problems influencing economics and management in health care

The number of health facilities, the number of physicians, the average time in hospitals, the number of residents per physician, the average length of stay in hospitals, and the number of pharmacy care providers were determined for the period 2017-2021. At the same time, based on the assessment of economic indicators in the health sector at international and national level, the following positive and negative findings emerged for the Czech health sector:

- There were 32,240 health care facilities in the Czech Republic in the period under review, 21,581 of which were independent practices of primary care physicians and specialists. There were 313 inpatient facilities excluding spas and convalescent homes and 194 acute and follow-up care hospitals. There were 50,802 physicians and dentists and 116,998 independent non-physician health care workers in all facilities.
- On average, there were 210 inhabitants per 1 doctor in the Czech Republic. On average, there were 72.4 beds per 10 000 inhabitants in the Czech Republic. The average length of stay in hospitals was 9.1 days.
- Pharmacy care was provided by 2 628 pharmacies in the Czech Republic. On average, there were 4 069 inhabitants per 1 pharmacy. The pharmacy network is not evenly distributed and tends to be concentrated in larger cities.
- The largest health insurance expenditures for men and women are associated with the 70-74 age group, with the largest increases starting in the 60-64 age group.
- The age structure is changing due to population ageing. The proportion of seniors is increasing, while the proportion of people of working age is decreasing.
- COVID-19 significantly reduced the country's economic activity and health spending increased again, yet the share of health spending to GDP in 2019 in the Czech Republic was lower than in OECD countries, at 7.8%.
- In the Czech Republic, health expenditure per capita was USD 3 417, which is lower than per capita health expenditure in OECD countries.
- In the Czech Republic, financing of health care expenditure through state or compulsory insurance is predominant (at 68%).
- The Czech Republic has the lowest health care prices of the V4 countries, at around 33% of the OECD average. On the other hand, the Czech Republic has a significantly higher level of health care volumes with respect to those of the V4 countries and 29.8% more than the OECD countries.
- All OECD countries expanded and revised their budget allocations in 2020 as part of government responses to address the impact of COVID-19. While public resources allocated to health increased, the magnitude of these increases was generally smaller than the subsidies provided to businesses suffering from economic stagnation.
- In 2019, the main source of funding for compulsory health insurance in the Czech Republic were social insurance contributions at 78%, followed by transfers from the state (21%). At the same time, the contribution of compulsory health insurance accounts for the largest share of total health expenditure in the Czech Republic.

- As in all OECD countries, medical and rehabilitation services account for the majority of health expenditure in the Czech Republic and are primarily provided through inpatient and outpatient services. These services accounted for 61% of all health expenditure. In the Czech Republic, medical goods accounted for 18% of expenditure, and the share spent on long-term care (LTC) services was 14%, identical to OECD countries. Administration and general management of the health system, together with preventive care, accounted for 9%, which is higher than in OECD countries.
- Primary health care is an effective way to improve care coordination and health outcomes and reduce wasteful spending by reducing unnecessary hospital admissions and associated costs in hospitals and other parts of the health system. Primary health care relates to spending on primary care services, including general outpatient, dental and home health care, as well as preventive services provided by outpatient providers. Primary health care accounts for 11% of health expenditure in the Czech Republic, which is slightly lower than in OECD countries (13%). At the same time, general care accounts for 5%, dental care 4.7%, home care is zero and preventive care is slightly higher than in OECD countries at 1.3%.
- Hospitals are the largest providers of health care, accounting for 42% of health system expenditure, which is 3% less than in OECD countries. After hospitals, outpatient providers are the second largest category of providers in the Czech Republic and retailers are the third largest provider. LTC facilities account for the smallest spending share in the Czech Republic (at 8%), which is 1% less than in OECD countries (9%).
- In terms of hospital expenditure, the Czech Republic has the highest share of inpatient care (57%), which is lower than in OECD countries (64%), followed by outpatient care (26%), which is higher than in OECD countries. Expenditure related to long-term care (2%) is lower in the Czech Republic than in OECD countries (4%).
- The average annual capital expenditure was 0.5% in the Czech Republic, slightly lower than in OECD countries (0.6%), but the highest compared to the V4 countries. The Czech Republic invested the most in medical machinery and equipment. These investments were higher than those of OECD countries. While it invested the least in intellectual property products, which was in line with OECD countries. Interestingly, Slovakia, Poland, and Hungary did not invest in intellectual property products at all.
- Based on the methodology of the World Index of Healthcare, it was found that the health care system in the Czech Republic is universal, prioritizing affordability of health insurance over freedom of choice of health services. Access to new treatments is low. National solvency is highlighted, but the country is among the countries with lower basic public health expenditure growth. Problems are emerging with the quality of health care; these include the failure to manage the COVID-19 pandemic and difficulties in managing chronic diseases such as cardiovascular diseases and cancer. On the positive side, the Czech Republic is characterised by its easy access to doctors and specialists with its waiting times for specialised care. The Czech Republic is weak in innovation in science and technology. It relies on other modern countries for medical advances and scientific discoveries because it lacks research and development capacity across the health sector and academia. In recent years, it has sought to develop the digitalisation of healthcare.

The following key issues can be identified from the above-mentioned findings:

- There is an increasing proportion of seniors and a concurrent decline in the proportion of people of working age, which is reflected in higher health insurance expenditures for men and women in the 70-74 age group, with the largest increases starting in the 60-64 age group.
- The pharmacy network is not evenly distributed and tends to be concentrated in larger cities.
- Per capita health expenditure is lower than per capita expenditure in OECD countries.
- The COVID-19 pandemic has required an increase in public resources for health.
- Primary health care accounts for 11% of health expenditure in the country, which is slightly less than in OECD countries (13%).
- The Czech Republic has the lowest health care prices of the V4 countries and a higher level of health care volumes relative to those of the V4 countries.
- The share of private funding is below the OECD average. Direct payments by patients are very limited and only go towards medicines, medical devices, medical supplies, and dental care.
- Average annual capital expenditure in the Czech Republic was 0.5%, slightly lower than in OECD countries (0.6%), but the highest compared to V4 countries.
- Affordability of health insurance is favoured over freedom of choice of health services.
- Access to new treatments is low.
- There are problems with the quality of healthcare, such as the failure to manage the COVID-19 pandemic and difficulties in managing chronic diseases such as cardiovascular diseases and cancer.
- The Czech Republic is weak in innovation in science and technology.
- There is a lack of research and development capacity across the health sector

Figure 2.20. Problems in health care in the Czech Republic resulting from the evaluation of economic indicators

Source: [own elaboration]

3. Use of modern digital technologies in healthcare

Digital technologies have a prominent place in innovations and thanks to the Covid-19 pandemic, they have come to the forefront of doctors' and patients' attention. In the Czech Republic, traditional models of healthcare delivery have been disrupted, the range and complexity of healthcare needs has increased, and public demand for more personalised healthcare services has grown. The speed of digital transformation plays an important role in shaping the future of healthcare, however, the level of digital transformation achieved in individual V4 countries is insufficient. Nevertheless, digitalisation can help in many areas related to health care, such as treatment (its availability and form), communication (between patients, doctors and suppliers), infrastructure, supply chain, etc. The use of telemedicine and smart devices, robot innovative tools for disease diagnosis and big data have great potential. This chapter describes the state of electronisation of healthcare in the Czech Republic and the state of use of selected modern technologies.

3.1. State of electronization in healthcare in the Czech Republic

In order to increase the quality and accessibility of health care, eHealth is included among the important objectives of health policy in the Czech Republic. The development of the eHealth concept has also been supported by the recent covid-19 pandemic which has highlighted the need for the use of electronic health services to enable the required non-personal contact between the patient and the doctor. The most recent step in the field of electronic health care in the Czech Republic is the approval of the Act on Electronic Health Care issued in 2021 [Act No. 325/2021 Coll.]. The Act defines the basic rules and framework for the computerisation of the Czech healthcare system.

The healthcare electronization is linked to the rapid development of information and communication technologies. eHealth is the collective name for ICT-based tools that support and improve prevention, diagnosis, treatment, monitoring and management of health and healthy lifestyles. In general, eHealth has a broad content, focusing mainly on the management and use of networked health information. [13], [14]

The aim of eHealth is digital service. It is a service aimed at preventing disease and maintaining or restoring the health of the population. To do this, information and communication technologies are used for diagnosis, treatment, preventive measures, monitoring and management of health and healthy lifestyles. In a broader perspective, it characterises not only technical developments, but also a way of thinking, behaving and committing to interconnectivity in order to improve healthcare locally, regionally and globally using information and communication technologies. [14]

eHealth consists of individual components including Health Information Systems (HIS), Electronic Health Record (EHR) or Electronic Medical Record (EMR), telemedicine, a decision support system or electronic documentation. [13] HIS refers to systems used for managing healthcare data. The purpose is to support healthcare professionals in the provision of healthcare services and to enable the exchange of data between service providers [15]. EHR represents the systems used by healthcare professionals to manage medical information and patient data [13]. EHR systems are among the most advanced eHealth features and can be used between different healthcare providers.

The existing eHealth tools used in the Czech Republic are as follows:

1. *Telemedicine* – distance medicine carried out through information and communication channels, is designed for doctor-patient communication and data collection from the patient via the Internet, mobile devices, telephone and on the equipment.

2. *eRecept (electronic prescription)* – on 1 January 2018, the obligation to write out prescriptions only electronically was introduced in the Czech Republic. An *eRecept (ePrescription)* is a prescription issued electronically and stored in the Central Repository of Electronic Prescriptions (CÚER). Each *ePrescription* is assigned its own unique indicator which is retrieved by pharmacy staff. Subsequently, the medicine is dispensed and registered in the CÚER. *ePrescription* can be obtained in electronic or paper form. [16]
3. *Sharing a patient's medication record (PMR)* – as of 1 June 2020, sharing of the patient's medication record with doctors, pharmacists and clinical pharmacists is enabled. This is one of the key functionalities of the *ePrescription* information system. It enables doctors, pharmacists and clinical pharmacists to work with the information on medicines already held in the central *ePrescription* repository for the benefit of patients when they are providing a healthcare service. [17]
4. *eSick Leave* – as of 1 January 2022 the Czech Social Security Administration (CSSA) launched the operation of the mandatory *eSick Leave* system. The aim of *eSick Leave* is to simplify the flow of information between insured persons, doctors, employers and the CSSA. The system was most used during the period of the Covid-19 pandemic.
5. *mHealth* – Czech health insurance companies offer applications such as Vitakarta. This app provides information about the insured's healthcare-related finances, an overview of doctor's fees, and includes features to support health care and healthy living.
6. *eRouška (“eFaceMask”)* – a mobile application created during the Covid-19 pandemic, as part of the Smart Quarantine system of the MoH CR.
7. *Public administration electronic information systems* – aimed at empowering patients and improving healthcare, consumer health information (e.g. the National Health Information Portal, where the aim is to provide the general public with information from the healthcare sector, guaranteed by selected experts in the field in the Czech Republic. [18]
8. *Electronic medical record* – patient medical records in the Czech Republic are kept in electronic form or in a combination of paper and electronic form. In 2004, the Czech Republic had the IZIP system of patient health records. The electronic health book contained information on the patient's health status, but it was discontinued due to its alleged non-functionality. [13] According to data from the Czech Statistical Office, although most doctors have a computer in their offices, only 10% of them use the possibility of keeping medical records in fully electronic form. At the same time, 69% of physicians prefer to use a computer combined with "traditional" paper-based documentation.³
9. *Healthcare information systems* – national and hospital systems, e.g. the ophthalmology registry, the intensive care registry are well known in the *eHealth* field. [14]
10. *Medical e-learning* – e-learning aimed at doctors and health professionals, e.g. the Czech Medical Chamber [14]
11. *Healthcare reporting system* – electronic transmission of health reports directly from healthcare provider systems. [13]

The following selected organisations and institutions are working in the field of eHealth:

- *The Ministry of Health of the Czech Republic (MoH) - X-eHealth: eXchanging Electronic Health Records in a common framework.* The aim of the X-eHealth project is to create a single interoperable format for health data or medical records sharing for the exchange

³ Research survey of the Czech Statistical Office and the Institute of Health Information and Statistics of the Czech Republic to determine the use of information technology in health care in 2020.

of discharge summaries, orders and results of laboratory tests, orders and results of imaging complements and the addition of rare diseases to the existing European Patient Summary specification. [19]

- *Czech National Forum for eHealth* - a non-governmental, non-profit organisation established to support the development of eHealth. The Czech National Forum for eHealth is an open platform. Any natural or legal person interested in active participation in the development of eHealth in the Czech Republic and the European Union can become a member of the Forum. The aim of the Forum's activities is mainly focused on expanding and raising general awareness of eHealth, supporting the development of eHealth and promoting communication in the field of eHealth. [20]
- The Czech National eHealth Center Olomouc was established as a joint workplace of the University Hospital Olomouc (FNOL) and the Faculty of Medicine and Dentistry of the Palacký University in Olomouc. Was established as a coordination and education center within a new rapidly developing branch of medicine - eHealth. [21]
- National eHealth Centre of the Ministry of Health of the Czech Republic - ensures the Ministry's competence in the field of strategic and conceptual development of digitalization of health care. [22]

3.2. Evaluation of the use of selected modern technologies including economic benefits

The use of ICT in healthcare in the Czech Republic usually means the use of a computer and internet connection, online services, electronic health records and the possibility of electronic prescription of medicines or electronic patient records, etc. A computer and internet access is already standard equipment in healthcare facilities in the Czech Republic, but the use of electronic health services is at a lower level than in some OECD countries. [13] Since 2003, the Czech Statistical Office in cooperation with the Institute of Health Information and Statistics (IHIS) has been monitoring data on the availability and use of information technology in health care⁴. A recent survey shows that by 2020, 97% of independent doctor's offices were already equipped with a computer. Almost all practices (96%) were then connected to the internet. In the case of pharmacies, the situation was better, all pharmacies had a computer and almost all of them were also connected to the internet (99%). In 2020, 69% of pharmacies had their own websites, but less than half of the doctors' offices (47%). GPs' offices for children and adolescents were the most likely to have their own websites (66%), while dentists were the least likely (31%). The availability of selected information technologies in independent doctors' offices is shown in Figure 3.1.

⁴ Doctor's offices and pharmacies were analysed as part of the survey. Doctor's offices include: general practitioners for adults, general practitioners for children and adolescents, dentists, gynaecologists, specialist doctors (allergist, ophthalmologist, urologist, etc.). Data on the equipment and use of information technology in the Czech Republic's healthcare system come from a survey by the Institute of Health Information and Statistics of the Czech Republic (IHIS). All healthcare institutions are sent the E (MH) 1-01 (Informative data on health service providers) report, which contains a module on information technology. The information technology part of the report was developed in cooperation with the Czech Statistical Office and monitors the equipment, level and use of information technology by health care facilities. The most up-to-date data refer to 2020.

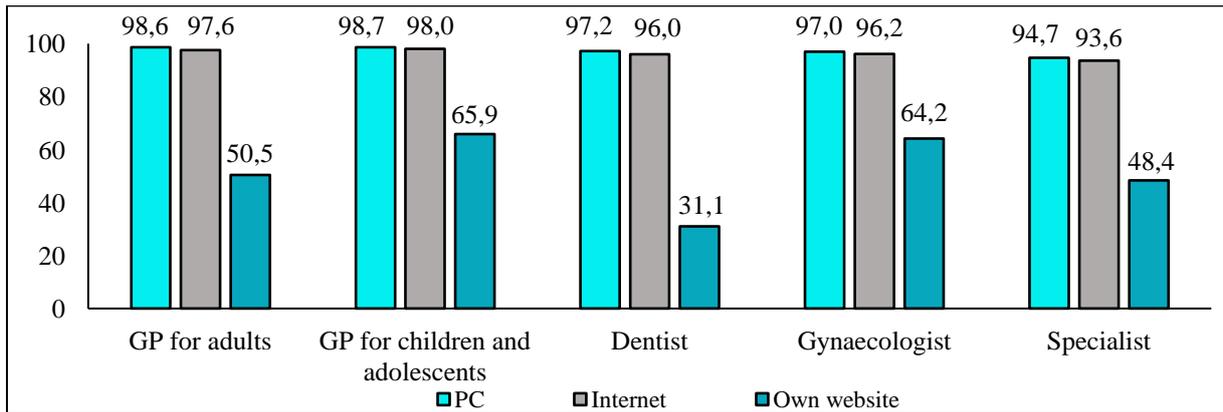


Figure 3.1. Percentage of selected information technology equipment in healthcare institutions in 2020
Source: [11]

Electronic health systems can make doctors' work much easier. According to a survey by the CSO and the IHIS, 35% of doctors are alerted by their electronic system that the medicine they want to prescribe to a patient may interact negatively with other medicines the patient is already taking. As shown in Figure. This function is most used by GPs for adults (59%) and children and adolescents (43%) and least used by dentists (only 15%). 38% of doctors order various laboratory tests for their patients via the electronic system, the results of which they can then conveniently view on their computer in the practice. This function is most frequently used by adult GPs (70%), paediatricians (62%) and gynaecologists (64%). On the other hand, this function is not widespread among dentists (6% of practices), see Figure 3.2.

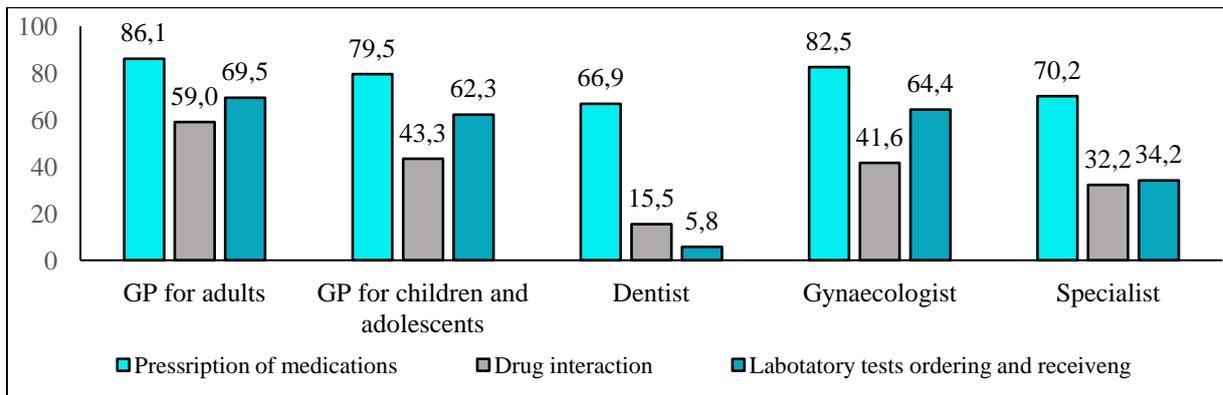


Figure 3.2. Percentage of healthcare facilities using selected functions of ehealth systems
Source: [11]

Patients' laboratory results can be further processed by doctors in the electronic system. In particular, in 29% of medical practices, the laboratory results are used to list patients by diagnosis; in 55% of practices, doctors list all patients with a certain diagnosis; and about half (49%) of medical practices list patients who should attend a preventive check-up or test and send an invitation to attend. It also shows that gynaecologists (68%) make the most use of appointments for preventive check-ups, adult GPs (73%) make the most use of listing patients by diagnosis and 48% of adult GPs list patients by laboratory results, as per Figure 3.3.

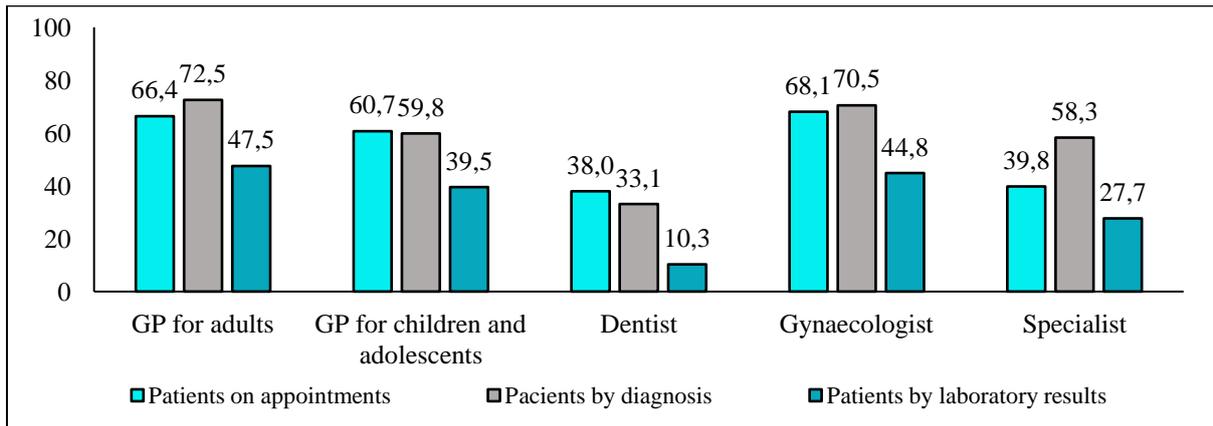


Figure 3.3. Percentage of healthcare facilities using selected patient records in healthcare e-systems
Source: [11]

In healthcare, information technology is used to improve online services for patients. Online services include making appointments for tests, consultations offered by independent doctors' offices and requesting new or repeat prescriptions. Most healthcare facilities (35%) implemented an online service in the form of a new or repeat prescription, followed by online appointment making for patients (21%) and online consultations via websites (17%), see Figure 3.4.

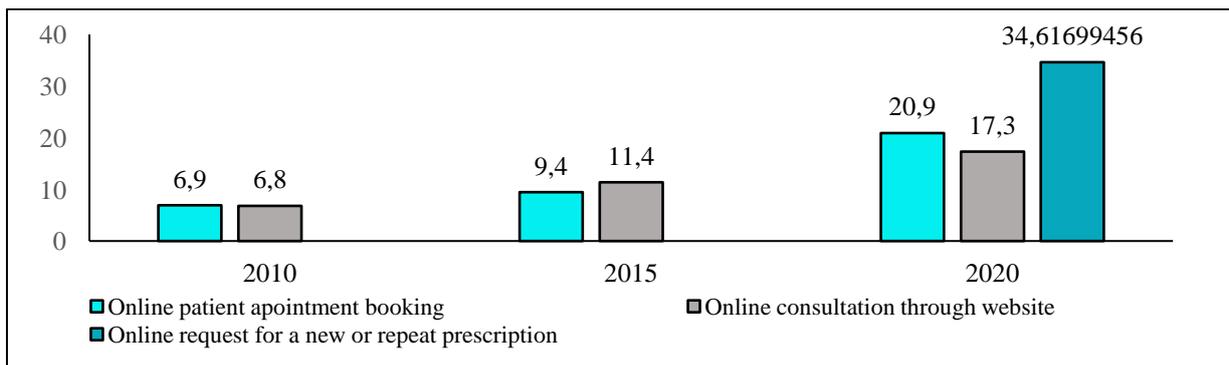


Figure 3.4. Percentage of healthcare facilities providing online patient services on their websites in 2020
Source: [11]

The figure below shows that online patient appointment (34%), online consultation through website (32%) and online prescription (54%) are mostly issued by gynaecologists. On the other hand, dentists provide the least of these online services; see Figure 3.5.

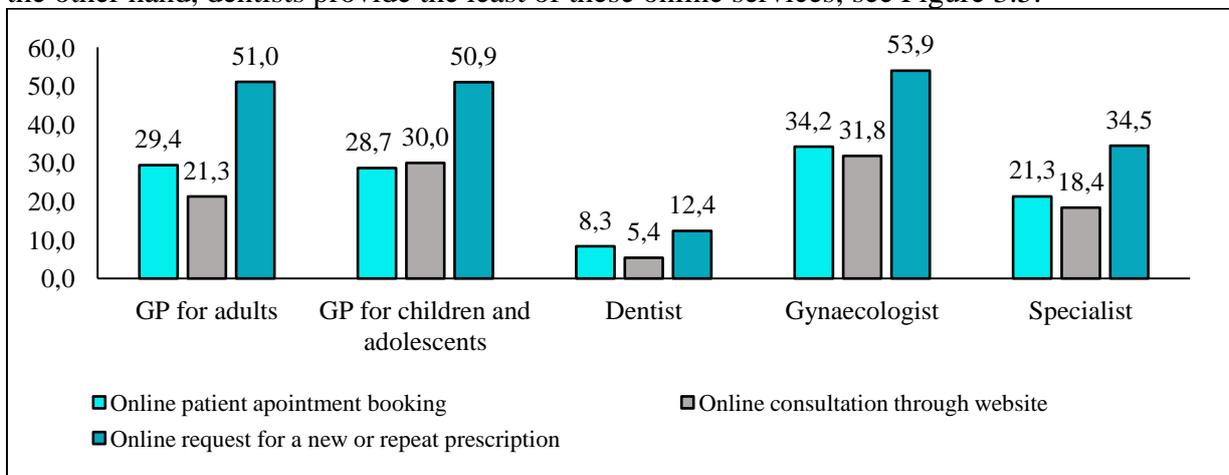


Figure 3.5. Percentage of healthcare facilities by type of online services provided to patients on websites in 2020
Source: [11]

The CSO, in cooperation with the IHIS, provides only an assessment of the use of information technology in health care, but no longer deals with the use of communication technologies, including the application of innovative tools for disease diagnosis, robots and big data. For a comprehensive view of the use of digital technologies by doctors at EU level, see Table 3.1.

Table 3.1. Digital usage in the EU in 2019

Digital usage in the EU in 2019	
Electronic health record (81%)	Patients apps/wearables (22%)
Prescribing (62 %)	Remote vital sign monitoring (22%)
Online appointment booking (54%)	Automation of other clinical tasks (19%)
Apps for clinicians (51%)	Voice recognition tools (16%)
Online access platforms/tools for primary or hospital care (46%)	Robotics (8%)
Telemedicine (43%)	Genomics data (storing or using 8%)
Rostering (37%)	Radio frequency identification tags (6%)
Automation of pharmacies/drug dispensing (30%)	Artificial intelligence technologies (5%)
Point of care diagnostics (26%)	Virtual reality (5%)

Source: [23]

The data in the table show that electronic health record (81%), prescribing (62%) and on-line appointment booking (54%) are the most widely used digital technologies in the EU. On the contrary, virtual reality (5%), artificial intelligence technologies (5%), and robotics (8%) are used the least.

The Institute of Health Economics and Technology Assessment (iHETA), a public benefit organization, monitors health care outcomes, including cost-benefit assessments in the Czech Republic. The iHETA also supports research, education and training in the fields of economics and public health, pharmacoeconomics and HTA/health technology assessment.

There is increasing pressure from manufacturers, regulators, managers, payers, government officials, physicians and patients for information to support decision-making about what technologies shall be used, reimbursed and developed in clinical practice. This situation is creating pressure for the growth and development of a multidisciplinary health technology assessment (HTA) process through the procedures used in many countries to decide whether to include new items (e.g., drugs, diagnostic procedures, or therapeutic interventions) in the reimbursement mechanism. When the evaluation process is carried out at the level of health care providers, it is called hospital-based HTA.

3.2.1 Telemedicine and smart devices

Telemedicine – a medicine carried out remotely (distance medicine) – is part of eHealth. Telemedicine is a way of providing healthcare where doctors care for patients remotely using information and telecommunication technologies, not just for their own care, but for easy access to data and information, sharing and using it for the benefit of the patient's treatment. Consequently, this results in better diagnosis and therapy, thereby improving the overall level of patient care. In 2005, the WHO officially recognized eHealth as a means of achieving effective and safe use of information and telecommunication technologies in public health and related fields. The WHO defines telemedicine as an umbrella term for health activities, services and systems operated remotely through information and communication technologies to support global health, prevention and health care, as well as education, health management and health research. According to the WHO, there are 4 forms of telemedicine - *consultation between a remote patient and care provider, telemonitoring of health and diagnostic data, transmission of data/images to a care provider (specialist), and consultation between care providers for case management.*

In the Czech Republic, the use of telemedicine for remote patient-provider consultations started to be used mainly during the period of the Covid -19 pandemic from September 2020 to March 2022. These were remote health consultations with a general practitioner and a general practitioner for children and adolescents. Gradually, from July 2020 to March 2022, video consultations via remote access started. It was found that more than half of people (52%) used the option of a telephone consultation with a doctor. In particular, it was remote consultation of registered GP and paediatric and adolescent GP patient health status.

The Association of Health Insurance Companies has defined the performance of telemedicine (video consultation by remote access) and established the rules of provision and reimbursement mechanism. The service can be used in the context of dispensary care of a patient or in the event of a change in the patient's health condition or the need for monitoring, control or treatment advice when a personal visit is not necessary or possible for serious reasons. The procedure cannot be used in the case of a preventive check-up. [24]. At the same time, the doctor must provide proof of treatment to the insurance company. The procedure - telemedicine is covered by the following insurance companies: Česká průmyslová zdravotní pojišťovna (CPZP), Revírní bratrská pojišťovna (RPB), and the General Health Insurance Company (*Všeobecná zdravotní pojišťovna (VZP)*).

As for the practical applications of telemedicine in the field of telemonitoring of health and diagnostic data in the Czech Republic, there is the issue of telemedicine and diabetes. A pilot study has been conducted in which elderly patients with diabetes had access to interactive food scales, a tonometer and a glucometer. The data were being sent through mobile networks. The system was effective but ran up against the inability of the elderly to work with modern technology. The solution is to send the measured data automatically. Similarly, Home monitoring - an internal and general practitioner's helper, for instance, the eVito monitoring system which monitors weight, blood pressure and glucose. The BIOTRONIK cardiac monitoring device reduces patient's travel costs to the doctor and doctor and patient time. In addition, a system for remote monitoring of implanted devices, e.g. Home monitoring.

Organizations and institutions working in the field of telemedicine:

- The Czech National eHealth Center Olomouc was established as a joint workplace of the University Hospital Olomouc (FNOL) and the Faculty of Medicine and Dentistry of the Palacký University in Olomouc. Was established as a coordination and education center within a new rapidly developing branch of medicine - eHealth. [21]
- *ARTAK the Czech Association of Robotics, Telemedicine, and Cybernetics* - disseminating and promoting the application of robotics, telemedicine and cybernetics for rehabilitation, medicine and assistive technologies in clinical, home and community care, in the care of temporarily or permanently disabled populations. [25]
- Alliance for Telemedicine, Digitalization, Healthcare and Social Services - to support the development of digitalization of healthcare and social services in the Czech Republic. [26]
- DIGI2 Health - Digital Innovation Hub (DIH) is an ecosystem that serves as a contact point for several supportive services for small and medium companies with focus on healthcare in the region and beyond. It enables access to knowledge, technology, prototype solutions and testing devices, as well as the involvement in the innovative ecosystem in the region. [27]
- First Faculty of Medicine, Charles University in Prague provides eHealth and telemedicine education through the eHealth and Telemedicine Centre. By linking

computer technology with medicine, a new field has been created, which uses the name eHealth.

3.2.2 Robots

Surgical robots can already be found in operating theatres today. But they cannot work by themselves. Each of their movements is controlled by the surgeon using a joystick and other controls. One of the advantages of robotic surgery system is that it eliminates the tremor of their hand and improves the movement of the scalpel. Another advantage is that the robotic arm can reach the corners of the body where it would be difficult for a person to operate, thus, the procedure can be more precise. [28]

After all, Czech surgeons belong to the world leaders in the use of these robots. The first robotic surgery in the Czech Republic was performed by doctors from Prague's Na Homolce Hospital (Homolka) back in 2005. Since then, other workplaces have acquired using surgical robots. Doctors from Homolka also travel abroad to teach this type of surgery. They work with the American, the world's most widespread device called Da Vinci. The latter is used for laparoscopic operations, which are minimally invasive procedures that do not require a large surgical incision. During a laparoscopic procedure, surgeons usually make three to six small openings in the abdomen, most often around the navel. They slide a small camera with light and surgical instruments inside. Thanks to the camera, they can see inside and can perform an operation that leaves only small marks on the abdomen. The Da Vinci system does the same. It has four movable arms with surgical instruments and a camera that are inserted into the body through small holes, but then controlled from the outside by the surgeon. The terms "robotic surgery" and "robot-assisted surgery" have caught on for this type of surgery, with the latter being clearly more accurate. [28]

Homolka is one of the centres of robot-assisted surgery. In 2005, it was the first hospital in the country to acquire a Da Vinci operating robot, on which doctors performed almost one and a half thousand operations. There were world-unique performances among them. Homolka is also a training centre in robotic surgery. In particular, Homolka's vascular surgeons have trained a number of domestic and foreign doctors on the robot, and their vascular surgery is considered the world's leading robotic workplace in the field. In 2016, the hospital acquired a more modern type of robot, the second-generation robot – Da Vinci Xi. The device became part of a newly built multidisciplinary workplace with two operating theatres for hybrid and robotic procedures.

Robotic equipment is used by surgeons from several departments at Homolka, particularly: urology, vascular surgery, cardiac surgery, general surgery and gynaecology. [29] According to the website of the Ministry of Health, there are robotic surgery centres at:

- Na Homolce Hospital in Prague,
- Central Military Hospital, Prague
- University Hospital in Motol, Prague,
- Masaryk Hospital in Ústí nad Labem,
- the Faculty Hospital Hradec Králové,
- Olomouc University Hospital,
- Polyclinic and Hospital Agel Nový Jičín, and
- the Mostiště Hospital.

Facing a lack of staff during the coronavirus crisis, hospitals were getting help from all sides – students of medicine, medics who had long left the profession and soldiers. However, a hospital in the town of Hořovice, west of Prague, has gone a step further. The staff is being assisted by a humanoid robot there. Patients arriving at Hořovice Hospital are greeted by the latest addition to the staff – a humanoid robot called Dr. Pepper. Dr. Pepper was originally

intended for the children's ward to bring a bit of cheer to the smallest patients, but at the height of the coronavirus pandemic he was redirected to the hospital's reception to give incoming patients directions, to dissipate tension and enhance goodwill in meeting specified safety requirements. [30]

Dr. Pepper is 120 cm tall, weighs around 30 kilograms and can do a straight 12-hour shift before he needs an electricity refill. He rolls on wheels and is able to move his arms and head. His eyes contain cameras and sensors that enable him to identify where and how far away each patient is and whether his directions are being followed. When a patient enters, he approaches them, introduces himself and asks to be allowed to make a presentation. He then asks the patient to use a sanitizer, keep a safe distance from others and move to the marks on the floor, where their temperature will be taken.

ROBOTSYSTEM is a highly creative research and implementation company specialising in breakthrough project solutions in the field of service robotics and mechatronics – focusing on Industry 4.0, Smart Cities, breakthrough medical multifunctional treatment rehabilitation and transport multirobots (ROBOCOUCHAR, SMART WALKER, ROBOSTRETCHER), physiotherapy mobile robots for telemedical processes, in order to support life without assistance and simultaneously transport immobile persons by using an autopilot. Furthermore, it also focuses on fully robotised workstations in the field of nuclear energy, as well as research and implementation of insular energy centres based on RES. ROBOTSYSTEM. [31]

3.2.3 Innovative tools for disease diagnosis

In the eHealth field there have been few innovative solutions under development supporting early diagnoses. CEREB B MODE ASSIST of Tesco SW is a software tool for analysing medical images of brain in order to diagnose Parkinson disease before symptoms appear. Start-up Aireen is using retina images to diagnose diabetic retinopathy, age-related macular degeneration and Glaucoma. Start-up Carebot is specialising on reading X-Ray images.

As part of coronavirus testing, Czech researchers have developed a new self-sampling method that will allow people to do PCR tests without any pain by themselves at home. These are gargling PCR tests for Covid-19 which were developed by the scientists from the Institute of Molecular and Translational Medicine of the Medical Faculty of Palacký University in Olomouc, the Czech Republic, and from AUMED a.s. and IntellMed, s.r.o. This unique Gargtest method addresses the downsides of traditional PCR tests – discomfort during sampling and the need to visit a sampling point. With this test, all you have to do is to order your test kit and just take a sample by gargling. The test kit is delivered and taken away by courier. The Czech company Bioinova has started production of coronavirus (Covid-19) test kits. These test kits can be used both for the nasopharyngeal sampling method and for oral or saliva sampling methods, which means these tests should be cheaper and gentler for patients, and they are also faster. Use of these tests has been authorised by the State Institute for Drug Control. [31]

3.2.4 Big Data Processing

The growing volume of medical records and data generated from near-future IoT and mobile devices mandates the adoption of big data analytics (BDA) in healthcare and related contexts. As part of the national strategy for BDA adoption in healthcare, the Czech Republic healthcare institute (IHIS) has aligned its strategy with the European Union. With over 100 complex requirements, in line with statutory regulations, included in the national public tender, was the inclusion of a reported subset of criteria regarding performance, cost-effectiveness, robustness, and fault tolerance. Such a BDA solution, running on Linux-based open-source

software (e.g., Talend Open Studio, Python, R, Java, Scala environments), had to be capable of achieving competitive and above-expected threshold results regarding overall system performance evaluation, based on TPC-H industry-standard decision support benchmark. The tender-winning BDA solution reported here represents a snapshot in time, which exceeded expected operation on healthcare-specific TPC-H benchmark tests. The BDA solution and its control was transferred to IHIS, which over the past seven months has unified the isolated healthcare systems into one eSystem. In addition to demonstrated tests and real-life performance, the current eSystem has great potential to improve national healthcare in the Czech Republic, as well as to accommodate of 23 evolving expectations and future data needs. The produced eSystem based on Vertica analytic database management software is future-proofed in terms of stream and high-volume processing, scalability (based on consumer/commodity hardware) and fault tolerance (e.g., shutting down cluster nodes would not cause data loss). Horizontal scalability tests using commodity hardware demonstrate a performance improvement of over 25% by increasing the number of cluster nodes from three to five, providing sufficient evidence of a scaled-out design based on cost-effective commodity hardware. Currently, the produced BDA healthcare eSystem is physically isolated from the Internet infrastructure by being installed in an on-premises mode within the national geographical boundaries and therefore is considered highly secure, supporting industry standards regarding data security and protocols. The BDA healthcare eSystem supports a variety of open-source software, including various Linux distributions with a growing number of machine-learning libraries and integration of commercial tools such as Tableau. In light of the recent Coronavirus outbreak, the presented eSystem provides regional data geo-mapping visualisation of the Czech Republic within 10s updates and can exchange data with other healthcare eSystems. In addition to data integration, the geo-mapping functionality provides near real-time pandemic/epidemic tracking, outbreak spread monitoring, and risks data visualisation. [32]

The next steps in the future development of the presented healthcare BDA platform includes:

- BDA platform extensions supporting medical IoT and mobile apps data streaming so that the existing solution remains ‘the blueprint’ architecture,
- support for data-driven decisions during high-traffic events,
- ongoing horizontal scaling and an increase from 100 TB to 1 PB (Petabyte) processing capability,
- new approaches to data cleaning, storing, and retrieval with minimal latency,
- integration with other national registers (e.g., to manage and facilitate drug distribution logistics),
- strategic planning using healthcare data. [32]

But more commonly, people can meet pharmaceutical artificial intelligence working with big data and medical images. *Microsoft Inner Eye technology*, which is currently being tested at the General University Hospital in Prague, is a great example. This artificial intelligence system, equipped with machine learning technology, plots and analyses radiological images of prostate cancer patients, helping to accurately identify endangered tissues, and set up the best treatment. Similar helpful AI solutions that work with different kinds of pictures and data are now being developed globally. And solutions like the Inner Eye are currently the main direction of AI use in healthcare. [33]

Artificial intelligence in healthcare is not only available to doctors but also to patients. Most often in the form of artificial intelligence chatbots, which can advise them twenty-four hours a day, seven days a week, and thus help with various situations. For example, an AI

chatbot can use information about a patient's symptoms to identify possible diseases. And does it more precisely and responsibly than, for example, the Google search engine – it only works with relevant data. The apps that you can confide in with your symptoms are, for instance, *Healthily or Ada*. [33]

But you don't even have to be sick to contact a chatbot erudite in health issues. In the Czech Republic, for example, there is a *chatbot developed by the Born Digital* start-up, which advises those interested in donating blood plasma. Thanks to the solution, potential donors will find all the necessary information about the rules of plasma collection, compensation, and future use of plasma in one place – at the chatbot on the website of the sanaplasma collection centres. Many other chatbots globally help people with, for example, health insurance, and claims handling.

Moreover, chatbots using artificial intelligence today orient themselves not only in matters of physical, but also mental health. For instance, *the Woebot chatbot* can not only provide basic information about various mental problems but also works as a therapeutic tool for patients suffering from anxiety or post-traumatic stress disorder. [33]

4. Mechanisms supporting creation of start-ups in health care

The Czech Republic declared Innovation Strategy 2030 in 2019, which set the goal for science, research and innovation, focusing on knowledgebased production, technology solutions and services. National start-up and spin-off environment was one the areas to be developed. According to the analysis of 2019 there was a weaker investment environment to incentivise the creation and financing of new projects/start-ups. Universities supported the emergence of start-ups/spin-offs haphazardly because they were generally considered to be risky in the academic environment. From the point of view of business practice, there was insufficient motivation to use academic outputs, and the approach of corporations and SME to cooperation with start-ups was inflexible. From the point of view of young Czech innovative companies themselves, their ability to expand abroad was lower due to low internationalisation. No explicit focus was on health start-ups. [34]

4.1. The existing system of state and private support and conditions for establishing start-ups

Start-ups are key engines of all successful innovation ecosystems, they work across different areas of expertise, they can aggregate talent for reaching a goal. Their existence is essential also in the eHealth. A start-up is by definition a human institution to create new products and services under conditions of extreme uncertainty. At the founding stage start-ups usually do not yet know who their consumers is or what their product should be. The goal of a start-up is to built as quickly as possible the things customers want and will pay for. [35] However, a start-up needs for it successful development environment, in which it could flourish.

Leading innovation ecosystems in eHealth throughout the world have had four key drivers:

- High Start-up Activity
- Available Capital
- Enabling Institutions
- Favorable Government Policies

Start-ups provide enterprises with specific targets to engage, aligned to strategic priorities while also providing innovation ideas. It is important, that relevant and widespread start-ups across different stages of maturity and focus exist in the ecosystem. They can not succeed on their own. Presence of universities, healthcare providers, and other cross-industry player that provide expertise and infrastructure necessary to develop, test, and launch innovations is essential. Governments and their institutions can play more and more a critical role in fostering innovation by providing support to guide innovation priorities, offering funding, test innovation locally, and enable and incentivize the enterprises to enter the ecosystem. Necessary condition for healthy development of start-ups is their access to capital. Financial institutions, corporate and private venture capital funds must understand needs of start-ups and the ecosystem functioning. [36]

The Czech eHealth ecosystem has been underdeveloped in all key drivers. An external assessment of that situation can give the World Index of Healthcare Innovations 2021, presented by the Foundation for Research on Equal Opportunity. [37] The Czech health care system was ranked by the Foundation as 16th overall in the World Index of Healthcare Innovation, with an overall score of 47.58. The Czech Republic ranked #1 for Fiscal Sustainability (79.06), achieving universal coverage with a relatively low level of public health care spending. Czechs enjoy a decent number of choices for coverage and care (ranked #15 for Choice, with a score

of 56.84). The Czech Republic scored toward the bottom of the Index on Science & Technology (#29, 15.58) and Quality (#27, 38.84), driven by low marks for scientific discoveries, acute care, and cancer survival rates. In addition, the Czech Republic scored last in the Index on response to COVID-19.

Startup Report 2019/2020 [5] gives overview of all startup areas in the Czech Republic. A poll was done among 150 Czech startups. 65 % were younger than 3 years, 28 % form 3 to 5 years, 7 % older than 5 years. On average Czech start-up has about 8 coworkers and Majority (91 %) of startups are established as limited liability company. The Report claims that startups has been more and more established in other cities than Prague. There were 66 % of startups in Brno, Ostrava, Olomouc, Hradec Králové, Pardubice, Zlín, Karlovy Vary, Liberec Ústí nad Labem in 2021. According to the Report only 7 % start-ups are active in the area of Healthcare/Medtech/Clenatech. Some relevant startups for Health/care are probably also included in the category Agriculture/Food/Life Science (16 %). This is consistent with our finding only a few dozen Healthcare startups in the Czech Republic.

CzechInvest is a leading institution responsible for supporting startups in the Czech Republic. It was established in 1992, it is a state contributory organization subordinate to the Ministry of Industry and Trade of the Czech Republic. CzechInvest has an ambition to play a key role in the area of supporting business and investments in its comprehensive form. One of CzechInvest's main objectives is transformation of the Czech Republic into an innovation leader of Europe. The agency offers combination of regional, central and international operations. CzechInvest has been working with startups from 2011. During that time 395 startups participated in its programs and they received about CZK 700 million. We accompany startups on the path of doing business. CzechInvest helps them in the early phases of their development, with introduction of initial prototypes to the market, with formulating a proper sales strategy, with addressing domestic and foreign partners, customers and investors, and with establishing branches around the world. Since 2011 CzechInvest assisted to establish 35 startup branches abroad. CzechInvest is focused on 5 key sectors:

- AI & Digital
- EcoTech
- Life Sciences
- Aerospace
- Mobility
- Advanced Engineering

While the Healthcare startups are not explicitly mentioned, eHealth fits into AI & Digital category and key players of Life Sciences have had successful outcomes with pharmaceutical industry. The Czech government set development of new pharmaceutical treatments and diagnostics as one of the top priority areas and allocated public funding of over EUR 2.5 billion in the last decade to strengthen the sector's research infrastructure. New state-of-the-art research facilities have been completed in Prague, Brno, Olomouc and Plzeň to complement the existing institutes of the Czech Academy of Sciences and universities. [38]



Figure 4.1 Multinational Pharma Companies and Key Players in the Czech Republic
Source: [39]

The leading institution in the field of Life Sciences is i&i Prague, which is focused on the transfer of new technologies into practice. It was established at the Institute of Organic Chemistry and Biochemistry of the Czech Academy of Science and is dedicated to innovations in the field of drug development, diagnostics and medical devices originating from academic institutions. It supports the creation of spin-off companies and the sale of licenses. So far, the company has participated in the creation of, or otherwise supported, 15 spin-off companies from 5 countries, has an equity stake in 10 of them and has invested over CZK 70 million. Overall, the spin-offs in i&i Prague's portfolio have raised more than CZK 1.8 billion from other investors. In addition to direct financial investments, i&i Prague also assists more than 15 research institutions and universities in the Czech Republic and abroad in the commercialization of innovative technologies. Among other things, it has participated in the sale of more than 10 licenses with a value exceeding CZK 5 million. In 2021, i&i Prague established the i&i Bio Investment Fund in cooperation with the European Investment Fund [40].

An essential player of the Czech eHealth innovation ecosystem is DEX Innovation Centre (DEX IC) in Liberec. The Centre was founded in August 2012 as a non-profit organisation, based on previous many years research and innovation work under the brand of the Czech DEX company. DEX IC acts as EIT HEALTH HUB in the Czech Republic since 2018. Its main HUB activities are:

- 4Digital Health Accelerator – Acceleration program for startups pursuing digital health innovation
- EIT Health RIS Innovation Call – It aims at funding (€75,000 euro) the proof of concept phase of targeting EIT Health's six Focus Areas to be developed by local actors including both business and academic/research/health care institutions.
- EIT Health Startups Programmes – It offers different workshops for each phase of startup journey

- Morning Health Talks – Opportunity for members of innovation ecosystem to meet and exchange information
- Educational programmes for students and graduates

Depo Ventures was established in 2016, when it launched its first angels fund. Today it is the leading investment VCs in pre-seed stage startups in the Czech Republic. There are 31 companies in its portfolio today. Only company Kardio AI is an eHealth startup.

Startups can join one of many local innovation centers. A network of innovation centers under the name Ynovate was founded in 2021, its goal is strengthen Czech Innovation ecosystem through the networking with experts across all regions. Regional innovation centers offer support and programs for innovative SME and startups. They offer networking, office space, advising on grants and financing, advising on business development etc.

COVID 19 initiated bigger public support for Healthcare innovations and it also clearly demonstrated opportunities for healthcare digitalization and telemedicine solutions. CzechInvest along with the Ministry of Industry and Trade organized a two-month virtual hackathon Hack the Crisis Czech Republic in 2020. Of the fifteen finalists, ten were focused on the field of healthcare. These included LAM-X (active nanofiltres against COVID-19), CoroVent, COVIDI, Daruj Krev, Diana Biotechnologies, MedRec AI, Oxygenerátor, a portable device for medical diagnostics, the Virtual Lab application and Virus Deflector.[41] Non of the eHealth solutions was among the top three winners in Figure 4.2:

1. DIANA Biotechnologies, prize in the amount of CZK 3 mil.
2. CoroVent, prize in the amount of CZK 2 mil.
3. LAM-X, prize in the amount of CZK 1 mil. (Active nanofiltres against COVID-19)

DIANA Biotechnologies, s.r.o. was established in 2018 as a biotech company at the **Institute of Organic Chemistry and Biochemistry (IOCB)**, Academy of Sciences in Prague, aiming to build on its global reputation and a strong track record in drug discovery. It has raised a substantial amount of venture capital funding and were awarded an exclusive global rights for the DIANA technology. The winning project developed affordable and fast tests for detecting COVID-19. <https://www.dianabiotech.com/>

CoroVent lung ventilators were developed at the Faculty of Biomedical Engineering of the Czech Technical University in Prague and paid for from the collection of citizens and companies used by the Czech hospitals. The first installation took place at the Masaryk Regional Health Hospital in Ústí nad Labem on 31 October, 2020

LAM-X is a Czech biotechnology company developing **light activated nanomaterials** for protection from bacteria, viruses and other pathogens, using innovative approaches initially developed at the Faculty of Science of the Charles University, Prague. The lead product is a **nanomembrane that generates singlet oxygen upon activation by visible light**. The clinical study on **patients suffering from ulcers proved the efficacy** of the LAM-X membrane. The LAM-X **platform technology** can be used in the fight against infections that are caused by **surface-transmitted pathogens** found in hospitals, sanitation facilities, food and water production factories. Unlike antibiotics, which target specific cell parts, the **singlet oxygen approach** is quick and rather nonspecific, making it **impossible for microbes to develop resistance mechanism**. <https://lam-x.tech/>

Figure 4.2.: Winners of eHealth solutions
Source: [41]

Since 2019 biotechnological company Roche Czech Republic has been sponsoring Czech Digi-Med Award for companies and researchers with digital innovation in healthcare. Financial support is at maximum CZK 100 thousand. During last four years more than dozen companies and projects were awarded. [42]

During COVID 19 pandemics health insurance companies were supporting telemedicine solutions as part of common medical treatment if needed. However, after this period was over, telemedicine solutions were not accepted for payments anymore. Currently some health insurance companies offer telemedicine services to its clients (e.g. OZP). There are also private telemedicine platforms, which are offering telemedicine services as private service (e.g. uLékaře.cz, EUC). The Czech National eHealth Center was established under the University Hospital Olomouc in 2012, currently it is expected to play a major in testing telemedicine solutions for wider use in the Czech healthcare.

The Ministry of Industry and Trade announced calls for the Czech Rise-Up 3.0. Programs in September 2022. Research of medical solutions in the era of digitization, which will help SME and research organizations with relevant research on medical devices, personal protective equipment, medicinal products and other IT solutions in the healthcare sector. The goal of the challenge is to complete medical solutions that do not yet exist and their implementation, which can help deal with the consequences of COVID-19. Projects with a benefit to digitization will be preferable. The call is funded from the National Recovery Plan. The allocation of the call is 100 million CZK and the level of support is 75% of eligible project expenses. [43]

The EU eHealth Action Plan emphasizes the need for development research and innovation. Digitized health care is together with quality academic institutions, high-tech companies, for example in the field of cyber security and working with large companies' data, seen as the optimal basis for the development of digital innovations. The state administration has not yet formulated a program to support the healthcare sector for the establishment and expansion of infrastructure to support research and development in the field of digital health did not even delegate responsibility for the preparation of a program ensuring consultations, legal aid and investments in healthcare projects in so-called incubators. [44]

According to our analysis eHealth startups could grow more in the Czech Republic. Opportunity for growth is connected mainly with strong IT sector, advanced AI, VR and cyber security projects. It is needed that healthcare digitalization would speed up and healthcare providers along with insurance companies would be welcoming digital innovations. e Health can grow only if startups and innovative companies can have access to health data and data are well protected against legal and cyber crime abuse.

4.2. The way in which universities, research institutes and private companies are involved in setting up start-ups in healthcare

According to the Czech law state universities should promote innovations at regional and national level, cooperate with state authorities and private companies. In 2018 the Charles University as the first university in the Czech Republic started an independent subsidiary Charles University Innovations Prague (CUIP) for the purpose of creating spin-offs. The purpose of CUIP was to broaden and improve the efficiency of the existing offer of services in the area of innovation and commercializing and mediate the contact between the academic community and external investors for the sphere of starting spin-off companies and knowledge transfers. It has created 8 startups and 3 of them are in the area of healthcare:

- LAM – X s.r.o.

- GeneSpector Innovations s.r.o.
- Flexicare s.r.o.

CUIO started to work with other universities and research institutes. Flexicare is a joint project of scientists from the First Faculty of Medicine of Charles University and the Czech Technical University. They have developed a system that will allow patients to rehabilitate in their home environment without having to necessarily go to a clinic. Flexicare s.r.o. provides know-how and licenses in the field of telemedicine technologies and can be considered an eHealth solution.

Association Transfera.cz has been managing the Transfera Technology database, where innovative and commercially usable projects from universities and RaD institutions are listed from all over Czech Republic. The section Life Science & Health has 64 projects. About 5 of them could be defined as eHealth technologies. [45]

There is also a group of eHealth startups, which were established by individual entrepreneurs and private investors. Among them are e.g. telemedicine platform uLékaře.cz, automated diagnosis of diabetic retinopathy, AMD, Glaucoma using AI Aireen, already mentioned KARDI AI, Vitadio with its mobile app to support self-management of type 2 diabetes, MEDDI hub is a joint stock company that has been developing telemedicine solutions, Mindpax is a digital therapeutics tools company tackling mental disorders (Bipolar disorder, Major Depressive Disorder, Schizophrenia, ADHD), VOS.health is a B2C & B2B application focusing on well-being, mental hygiene and prevention of psychological disorders. STORK telerehabilitation kit, which was developed by REGI BASE Czechoslovakia, significantly extends the intensity and frequency of the therapy. SW solution CEREB B Modes Assist of Tesco SW is helping to an early diagnosis of Parkinson.

4.3. Access to health data by universities and private companies

Health data are collected, processed, and used by different institutions in the Czech Republic. Primary data sources are:

- Healthcare providers claims data
- Healthcare providers periodical reports
- Health insurance companies financial performance data
- Population surveys
- ePrescription data

Data are collected and processed by Health Insurance Companies, Institute for Health Information and Statistics, Ministry of Health, Ministry of Finance, Czech Statistical Office, National Institute of Public Health, State Institute for Drug Control.

The Czech Republic does not have standardized, coherent and accessible EHRs. EHRs are mainly unstructured narrative texts. A legislation to mandate terminology standards is in process. National eHealth Centre, which operates under the Ministry of Health, is also involved e.g. in defining data standards for data exchange among healthcare providers. There is no national system for sharing EHRs among different healthcare providers. Patients do not have online access to their EHR. Institute for Health Information and Statistics collects clinical registry data provided by health care providers on selected diagnoses and hospitalisation.

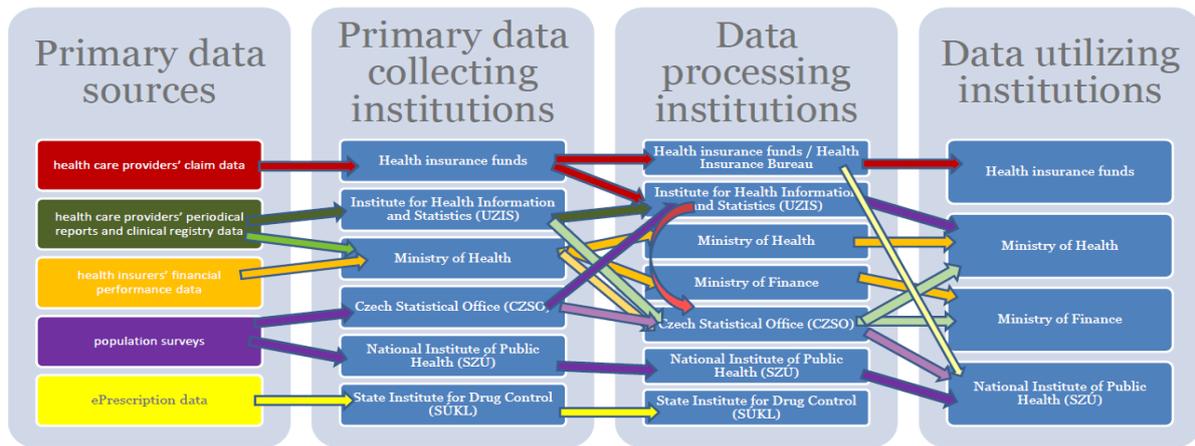


Figure 4.3.
Source: [46]

The Czech Republic is not sharing de-identified datasets for monitoring and research. Universities and companies can participate in clinical studies.

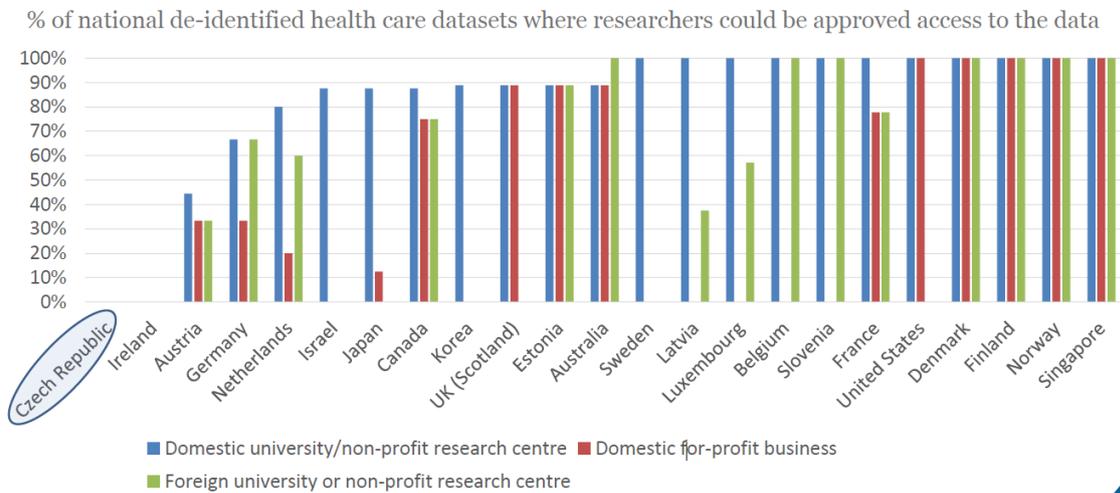


Figure 4.4.
Source: [46]

5. Proposed areas in health care including problems in order to solve joint projects

The problems resulted from the analysis and subsequent synthesis of the results of the evaluation of economic indicators in the health sector in the Czech Republic, digitalization of health care, the use of modern technologies and mechanisms supporting the creation of start-ups (Chapters 2, 3 and 4). The problems were divided into 6 problem areas.

The first area is related to the problems associated with the effective setting up of a health care system that takes into account the increasing representation of the elderly and accepts the increasing demands on the quality of health care provided with limited resources. Effective financing models and the involvement of several system participants with different views and expectations. Also challenges in investing in health infrastructure to enable equitable access to health care.

The second area of problems stems from setting up an effective support system for healthcare start-ups (funding, mentoring, training). Problems related to the difficulty of start-ups to collaborate with healthcare providers and the expectations of investors in start-ups. As well as problems with split support, small domestic market and lack of talent.

The third area includes the problems associated with slow digitalisation in healthcare, the lack of data sharing between healthcare actors and dealing with legislation and cybersecurity in data sharing. It is also related to the lack of methodology for assessing the effectiveness and quality of modern technologies used in healthcare (telemedicine, EMR, e-prescription, robots, big data, etc.).

The fourth area is characterized by problems resulting from insufficient systems and methodologies for evaluating hospital economics, insufficient systems for hospital management, and lack of studies on the relationship between hospital management and quality of care.

The fifth area of problems is mainly related to the lack of studies on patient satisfaction with the use of e-services and the lack of studies to determine patients' willingness to share their health data. There are also problems associated with disinformation in the healthcare sector.

The sixth and the last area is related to problems arising from the lack of formal training on the use of digital technologies and the lack of MBA programmes run in collaboration with foreign partners. Problems are also related to the absence of models for training hospital staff.

The 6 proposed project areas have been assigned to the identified problem areas, including a brief description of their content. The following project areas were proposed: Public Finance and Healthcare Budgets, Innovation Ecosystem for Healthcare, Health Technology Assessment, Hospital Economics and Management, Behavioural Economics to Influence Patient Decision, Education in Healthcare.

The definition of the problem area and the associated project areas, including their description, are given in Table 5.1.

Table 5.1. Proposed project areas for further cooperation with V4 partners

Number	Problem areas	Related ER chapter	Proposed project areas to be dealt with V4 partners	Project area characteristics
1.	<ul style="list-style-type: none"> ○ Financial stability of the system and expected development given population ageing, demand for healthcare ○ Financing in healthcare ○ Investment into healthcare infrastructure ○ Reform debates in healthcare (ministry level and parliament) 	Chapter 2	Public finance and healthcare budgets	<ul style="list-style-type: none"> ○ Streamlining healthcare financing ○ Spatial analysis ○ Transfer of know-how from Israel ○ Cooperation with OECD experts
2.	<ul style="list-style-type: none"> ○ Inefficient support system for start-up healthcare businesses (financing, tutoring, training) ○ Difficult cooperation of start-ups with healthcare providers ○ Investors' expectations/No Angel investors ○ Divided support ○ Small domestic market ○ Shortage of talent 	Chapter 4	Innovation ecosystem for healthcare	<ul style="list-style-type: none"> ○ Ecosystem analyses ○ Transfer of know-how from Israel ○ Policy recommendations for the effective functioning of the innovation ecosystem
3.	<ul style="list-style-type: none"> ○ Slow digitization in healthcare. Non-sharing of data by entities in the healthcare sector. ○ Lack of legislative and cybersecurity solutions for data sharing. ○ Lack of methodology for evaluating the effectiveness and quality of new technologies in the healthcare (telemedicine, EMR, e-prescription, robots etc.) 	Chapter 3	Health Technology Assessment	<ul style="list-style-type: none"> ○ The relationship between the use of new technologies and the economics and quality of healthcare ○ Evaluation methodology from Israel, OECD ○ Designing an evaluation methodology for selected technologies in healthcare (effectiveness and quality of new technologies)
4.	<ul style="list-style-type: none"> ○ Insufficient systems and methodologies for evaluating hospital economics ○ Lack of management systems in hospitals ○ Not enough studies on the relationship between hospital management and quality of care 	Chapter 2,3	Hospital economics and management	<ul style="list-style-type: none"> ○ Process and economic analysis ○ Management systems ○ Relationship between hospital management and quality of care ○ Possibility of cooperation with the Maccabi insurance company in Israel (Maccabi Healthcare Services)

5.	<ul style="list-style-type: none"> ○ Lack of studies on patient satisfaction with the use of e-services ○ Lack of studies to determine patients' willingness to share their health data ○ Disinformation in healthcare 	Chapter 2, 3	Behavioural Economics to Influence Patient Decision	<ul style="list-style-type: none"> ○ Analysis of patients' reactions to the use of e-services in healthcare ○ Willingness to share health data ○ Conducting a survey with a selected group of patients ○ Preparation of a case study ○ Healthcare and Disinformation, Covid-19
6.	<ul style="list-style-type: none"> ○ Insufficient offer of MBA programmes implemented in cooperation with foreign partners ○ Absence of models for training hospital staff ○ No formal training on the use of digital technologies. 	Chapter 2, 3	Education in healthcare	<ul style="list-style-type: none"> ○ Staff training (doctors, mid-level staff, top management - MBA programmes) ○ Digitisation of medical education ○ Models for training hospital staff in eHealth/ISR

Source: [own elaboration]

Conclusion

Pressure to provide quality health care with limited resources, population ageing, higher patient expectations and a shortage of qualified staff require healthcare innovations in the Czech Republic. It has become apparent that the foundation for an effective healthcare system is the continued digital transformation, the use of new technologies on a larger scale such as telemedicine and smart devices, robots, innovative tools for disease diagnosis and big data processing.

The aim of the expert report on healthcare innovations in the Czech Republic was to describe the current situation and to identify economic and managerial problems in health care, especially in eHealth, in the use of modern technologies and in the functioning of mechanisms supporting the creation of start-ups. At the same time, based on the results obtained from the analyses, project areas for joint solutions with V4 partners were defined. The expert report was based on available international and national data sources for the period 2017-2021 in selected areas. The expert report was inspired by the presentations of Israeli experts at the 2nd, 3rd and 4th online workshops, which were implemented as part of the project no. 22210051. The main sources of data include mainly health data processed by the Organisation for Economic Co-operation and Development (OECD), data processed by the Czech Statistical Office (CSO), data processed by the Institute of Health Information and Statistics of the Czech Republic (IHIS) and data processed by the consulting companies Deloitte and KPMG.

The analysis of economic indicators in the health sector showed that the Czech Republic has the lowest healthcare prices among the V4 countries and higher healthcare volumes compared to the V4 countries. The share of private financing is below the OECD average. Direct payments by patients are very limited and cover medicines, medical devices, medical supplies and dental care only. Access to new treatments is low. There are problems with the quality of health care, such as the failure to cope with the COVID-19 pandemic and difficulties in managing chronic diseases such as cardiovascular disease and cancer. The Czech Republic is weak in innovations in science and technology. There is a lack of research and development capacity in the health sector.

The use of ICT in the Czech healthcare sector includes the use of computers and internet connection, online services, electronic medical records and the possibility of e-prescription and electronic patient registration. Specifically, physicians use electronic health systems to check for negative integration of prescribed medications with medications the patient is already using. Patients' laboratory results are used by physicians to create a list of patients by diagnosis and to invite them to preventive check-ups and tests, including sending invitations. Computer and Internet access are common features in healthcare facilities in the Czech Republic, but the use of electronic health services is at a lower level than in some OECD countries. The existing eHealth tools used in the Czech Republic are as follows: telemedicine, eRecept, sharing a patient's medication record (PMR), eSick Leave, mHealth, eRouška, Electronic Medical Record, medical e-learning. There has been a breakthrough in the field of telemedicine. In particular, the Association of Health Insurance Companies has defined the performance of telemedicine and established the rules of its provision and reimbursement mechanism. Surgical and humanoid robots are used. Innovative solutions are being developed to support early diagnosis, or a new self-sampling method that allows people to perform PCR tests painlessly at home has been developed. The Institute of Health Information and Statistics of the Czech Republic (IHIS) has aligned its strategy with the European Union as part of the national strategy for the introduction of BDA. The BDA solution and its control was transferred to the IHIS, which unified isolated healthcare systems into one eSystem.

The Czech eHealth ecosystem is underdeveloped. Only 7% of Czech start-ups are active in the fields of Healthcare/Medtech/Clenatech. Czech Invest is the main institution supporting start-ups in the Czech Republic. The DEX Innovation Centre is another important institution of the Czech eHealth innovation ecosystem. Spin-offs are supported by the Charles University Innovations Prague (CUIP) company. There is also a group of eHealth start-ups founded by entrepreneurs and private investors.

The results obtained from the analyses in the field of eHealth, the use of new technologies and mechanisms supporting the creation of start-ups will be compared with the results from the analyses carried out by the universities in PL, HU and SK involved in the project no. 22210051 will be processed in the e-brochure.

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- **Visegrad Fund**
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