

# Impact of State Intervention During the Pandemic Crisis on the Implementation of Nanotechnological Innovations in the Czech Republic

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**Abstract** – The article deals with the issue of state interventions during the pandemic in the Czech Republic and the role of nanotechnology, which played an important role in increasing the production capacity of personal protective equipment. Nanotechnology has been rarely used in the long term for the filtration of bacteria and viruses due to its relatively high cost compared to conventional technologies that are commonly used to filter bacteria and viruses. Due to the positive demand shock and therefore the increased price, nanofibres became much more widely used in respirators and hoods. However, the global shortage of protective equipment, in addition to the high demand, also caused government intervention. These may have adversely affected the potential for global implementation of nanofibres in respirators. Based on empirical research, the aim of this paper is to identify the innovation environment during the pandemic and the interventions that disrupted the innovation environment in nanotechnology.

**Keywords** – Innovations, pandemic, intervention, internationalization, nanotechnology, respirators.

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## 1. Introduction

With the advent of the pandemic, there was a severe worldwide shortage of personal protective equipment to help eliminate the spread of COVID-19 [55]. Production capacity for conventional technologies to produce filter materials for respirators and face shields was insufficient, leading to a strong excess of demand over the supply [63]. This has resulted in multiple price increases, allowing innovations to enter the market in the form of relatively more expensive technologies not previously used for these purposes [13], [20]. These technologies included nanotechnology, which had better filtration properties but could not compete with conventional technologies in terms of price in the long term at a high cost. According to the OECD, the global bottleneck in production was due precisely to the lack of technology to produce microfibre or nanofibre filter membranes [42].

The technological process of industrial production of polymer nanofibres was first developed by a Czech team in 2003 and ten years later the nanofibre membrane started to be tested in drapes, where the innovation was not used on a larger scale due to high costs. With the onset of the crisis, the European Union mapped the available technologies for filter material production in Europe and found that only four countries, including the Czech Republic, would achieve self-sufficiency in production [6]. As a result, the European Commission began to create an environment that facilitated imports while restricting exports of personal protective equipment.

Interventions have also been noticeable at the state level, where export and other restrictions have accompanied most countries around the world [42]. Economic policies have thus severely limited the implementation of innovative nanofibre solutions in face masks and respirators at a global level.

Delivery of protective equipment to end customers was complicated by the introduction of export restrictions, as well as by theft or stoppage of shipments by individual countries. In many cases, state interventions obliged manufacturers to sell respirators only to the local government. This approach was evident, for example, with the largest protective equipment manufacturers in the world. The People's Republic of China, while not explicitly banning exports, did impose a rule of mandatory sales to the government over some time. A similar move could be seen in the case of the USA, whose restrictions cut off almost all of Latin America from supply. On 13 March, the European Union adopted measure (EU) 2020/403 in the form of export allowances to eliminate the shortage of protective equipment on the European market [42]. Thus, the vast majority of the actions during the protective equipment shortage were protectionist in nature.

In the Czech Republic, there was a situation of a double price ceiling, which set the maximum price of domestic respirators at a level that was half that of respirators from third countries. Given the minimal number of countries that exported protective equipment, the individual countries had to compete on price. It was therefore important at the national level to be more cautious in price regulation vis-à-vis third countries than in the case of domestic production, which was subject to export restrictions. Another impetus was the recognition of standards that had not been recognized until then, which generally allowed Chinese respirators to be sold on the European market.

This article aims to define the significance of state interventions of selected associations of the nanotechnology industry of the Czech Republic, which could have influenced the implementation of innovative solutions in the form of nanofibres in personal protective equipment and also to identify the possible impact. State interventions have created a specific environment for innovation in addressing the global shortage of medical supplies. On the one hand, there was a need to ensure a sufficient supply of protective equipment while at the same time not harming domestic production, which used innovative solutions for production, by these state actions.

## 2. Research Methodology

In this paper, thanks to the complexity of the given terrain two research approaches were applied for the better understanding of state intervention during the pandemic crisis in the implementation of nanotechnological innovations in the Czech Republic. A qualitative research design was used due to the

exploratory nature of this research and the lack of existing research on the innovation environment during the pandemic and the interventions that disrupted the innovation environment in nanotechnology [9]. This research approach has been adopted in order to gain a better initial understanding of the topic, to explore the points of view in greater depth and to identify the factors influencing nanotechnological companies and their attitude towards the phenomenon, contributing to the development of an overall better understanding of the issue [56].

Data was collected using a semi-structured interview guide. In order to stimulate discussion, flexible open-ended questions were used. The interview guide was developed on the basis of the literature review and pre-tested for relevance to the research questions [7], [36], [38], [39], [44]. Qualitative interviews lasted approximately 40 minutes on average. In order to increase the accuracy of the data collection by allowing the interviewer to pay more attention to the interviewee, and to allow for a verbatim transcription, the interviews were audio-recorded with the consent of the interviewee.

The selection of impactful interventions concerning nanotechnology companies in the Czech Republic was founded upon a research framework that involved in-depth interviews with the chairman of the Association of the Nanotechnology Industry of the Czech Republic. In-depth interviews bring the interviewer and respondent closer together and enable mutual understanding [3].

A series of in-depth, semi-structured, individual face-to-face interviews were carried out with the chairman of the Association of the Nanotechnology Industry of the Czech Republic.

The initial stage of the research involved its preparatory phase. Initially, the goals of the in-depth interview and the desired information were delineated. In alignment with the research objectives and the existing literature review, a structured script was developed to ensure the interviewer's readiness, enabling them to articulate questions clearly and succinctly. In addition to addressing the primary subjects, the script encompassed supplementary inquiries aimed at delving further into the issue and fostering a conducive environment for the interviewee, thereby encouraging a more candid dialogue.

The rationale for conducting a series of in-depth interviews with the chairman of the Association of the Nanotechnology Industry of the Czech Republic was because the association serves as a unifying platform for over 36 Czech enterprises actively engaged in utilizing nanotechnology across diverse spectra encompassing production, development, and final product domains.

With members spanning various sectors such as textiles, biotechnology, environmental applications, optics, and energy, the association—established in 2014—strives to advocate for the interests of Czech nanotechnology entities on both national and international fronts [40]. Notably, the association holds membership within the Chamber of Commerce of the Czech Republic—an organization representing the interests of 60 of the nation's largest 100 companies, thereby amplifying the collective voice of Czech businesses [25]. Thus, the chairman could in those in-depth interviews represent the observations, comments, and attitudes of all companies from the association.

Five in-depth interviews were conducted between 24<sup>th</sup> March 2021 and 10<sup>th</sup> October 2021 with the chairman of the Nanotechnology Industry Association. During those five interviews the chairman drew attention to four main state interventions which, according to the companies of the association, negatively affected the potential of nanotechnology in the Czech Republic. First of all, the recognition of non-equivalent Chinese standards was mentioned. Secondly, he drew attention to the massive government purchases, which were made mainly from the People's Republic of China and in many cases flooded the Czech market with low-quality respirators. He marked the third intervention in the form of a different price ceiling, which in times of severe shortage allowed Chinese importers a double margin compared to domestic producers. The fourth intervention was the export ban, which disrupted supply chains and interrupted Czech exporters' trade with foreign customers for a month. He then later on subsequently summarized these interventions also in the framework of the NanoEt conference, which was held in cooperation with the Academy of Sciences of the Czech Republic and the Technical University of Liberec [41]. In an open letter to the Government of the Czech Republic, which the Association of Nanotechnology Industry sent, he drew attention to the importance of supporting Czech manufacturers in the field of strategic products in the context of the security strategy of the Czech Republic [45].

The secondary step in our methodology involved conducting an elaborate second literature search using several distinguished academic aggregators: Web of Science, Scopus, Elicit, Scite, and Google Scholar. The aim was to harness a broad spectrum of academic literature that sheds light on "Economic interventionism" and "The impact of internationalization and its operation" within the context of the COVID-19 pandemic.

For the section on economic interventionism, the search query incorporated a combination of keywords: (economic OR state) AND (interventions

OR restrictions) AND (pandemic OR COVID-19). This query was designed to capture a wide array of scholarly discussions around state-directed economic interventions and restrictions implemented in response to the pandemic. The initial search yielded a selection of twenty articles. These were meticulously reviewed based on their abstracts, from which the ten most relevant studies were chosen.

The relevance criteria were primarily informed by the interventions highlighted by the chairman of the Association of the Nanotechnology Industry of the Czech Republic, ensuring a targeted focus on significant economic policies impacting the nanotechnology industry.

Similarly, for examining the impacts of internationalization and operations during the pandemic, the literature search used the keywords: (impact) AND (internationalization OR export) AND (pandemic OR COVID-19), utilizing the same aggregators. This search aimed to understand how global trade dynamics and export activities were influenced by COVID-19, particularly for industries operating within a global framework.

Following the literature search, the collection of secondary data for chapters 3.4 and 3.5 occurred through a selective process. The selection criteria were predicated on the relevance of information provided by prominent organizations involved in world trade and domestic state regulations. Special emphasis was placed on resources from the Supreme Audit Office, an associated body that evaluates the Czech Republic government's actions based on quality control and security risks.

The selected articles and secondary data sources were analyzed through a qualitative content analysis approach, focusing on extracting critical themes, patterns, and implications of economic interventionism and the repercussions of internationalization during the pandemic. The process of analyzing selected articles and secondary data sources through a qualitative content analysis approach involves delving into critical themes, patterns, and implications related to economic interventionism and the repercussions of internationalization during the pandemic. This method allows for a deep exploration of the content to extract meaningful insights and understand the complexities of these phenomena [2], [23], [33], [51].

Qualitative content analysis is particularly valuable when little is known about a phenomenon, as is often the case during a pandemic, enabling researchers to uncover new perspectives and understandings [23], [33]. By utilizing thematic content analysis, researchers can reflexively evaluate guidelines and standards, as well as illustrate phenomena that have not been previously examined [33], [51].

This involved a meticulous examination of the articles' findings, discussions, and conclusions, aligning them with the broader research objectives of understanding these phenomena in the context of the nanotechnology industry and the Czech Republic's economic landscape.

This methodology acknowledges certain limitations pertaining to the scope of literature and secondary data sources. Given the rapid evolution of the pandemic's economic and societal impacts, some relevant information might not have been captured within the timeframe of this review. Additionally, the selection process, though rigorous, is subject to the inherent bias of the researchers' perspectives and the availability of information at the time of the review.

### 3. Research Elaboration

To better understand the situation in which innovations were during the pandemic, a complex literature search was conducted. This focuses on the types and specifics of innovations that are examined in more detail in the context of government interventions. From an innovation perspective, it is important to introduce the use of nanofibers and outline issues that have not allowed for wider market adoption in the past. The issue of diffusion of a particular innovation is linked, both at the national and transnational level, to interventionism that can influence the innovation environment in which a particular innovation is located. For this reason, the literature search examines the barriers to internationalization and its impact on the business environment.

#### 3.1. Nano-Innovation

Innovation is an important foundation for entrepreneurship, business creation, renewal, and economic growth [4]. In this context, understanding the conditions in which innovation occurs can provide important insights for different market actors [27].

According to Schumpeter, innovations emerge in a decentralized way and are difficult to plan. Innovation can also be seen as a new way of using resources by entrepreneurs captured, for example, in the success of new combinations [50]. Schumpeter further argued that the greatest opportunity for new firms lies in technological change [49].

According to Valenta, innovation can be further defined as changes in the structure of an industrial unit, where innovation orders can be distinguished. The order of innovation represents a classification in the gradation of innovation and as the order increases the change itself becomes more noticeable. Within the first order, it is only a change in quantity and technologically more significant changes occur from

the fourth order onwards. Nonwovens are listed in order eight, where the very principle of the technology changes [62]. According to the innovation classification, nanofibrous membranes used in personal protective equipment during the pandemic crisis can be regarded as a top-tier innovation.

If the nanofibre membrane is not perceived as an innovation in itself, then one can follow the argument of Lundvall who understands innovation as new products, new techniques, and also new markets [37]. Due to the global shortage of protective equipment, a situation has arisen where standards from countries that were not previously recognized have become recognized in the case of non-European standards. There was a situation where products of previously unrecognized standards were allowed to expand into new markets.

The debate on the importance of innovation in times of crisis often relies on previous disasters. Fast-growing and highly innovative companies can effectively seize opportunities to meet unmet market needs. As a rule, small firms and startups are able to react quickly to a crisis and find solutions [12]. This is exactly the situation that occurred with the advent of the pandemic when nanofibrous membranes started to be used more extensively to trap bacteria and viruses.

Conventional protective aids have different layers to obtain different properties and purposes. For example, a typical surgical mask has three layers: a hydrophobic layer, a filtering layer, and an inner layer. With the integration of nanomaterials into personal protective equipment, a multi-functional layer can be produced to potentially replace the function of the others. Due to the porosity of nanomaterials, the air permeability increases, and thus the percentage of pathogens filtered through the membrane [28].

For mechanical capture of dust particles, bacteria, and viruses with a capture efficiency of up to 99.9 %, nanofibre membranes were used in the Czech Republic in 2013 by Nanovia in the form of nano face masks. A year later, Skaria and Smaldone designed a prototype of a nanofibre-based filter membrane drape. This product significantly reduced the pressure gradient and was comparable in filtration capacity to KN95 class respirators [52]. In February 2021, the Government of the Czech Republic made the wearing of respirators or nanofiber face mask mandatory [22]. This confirms the fact that the nano-mask has proven itself and has reached a comparable level with respirators in terms of filtration efficiency.

The Czech Republic is one of the world leaders in the production of nanofibers [5], [15], [31]. The technological process of industrial production of polymer nanofibres was first developed by a Czech team, as mentioned above.

Until then, it was not possible to use nanofibres on a mass scale in the industry[61]. Before the pandemic, the production of nanofibre protective equipment itself faced the problem of low prices of competing products [47]. According to information from CzechInvest, 200,000 respirators per month were produced domestically before the pandemic. At the beginning of September 2020, this production exceeded eight million respirators per month, which means that the Czech Republic became fully self-sufficient within six months of the pandemic outbreak, with the potential to export respirators abroad. According to the chairman of the Association of the Nanotechnology Industry of the Czech Republic, a great deal of credit for this goes to companies working with nanomaterials[48]. During the crisis, they were also significantly affected by the economic policy of the state, namely the institutional environment and state intervention.

### **3.2. Economic Interventionism**

Economic interventionism, also known as state interventionism, is an economic policy position favoring government intervention in the market process with the intention of influencing market failures and promoting the general welfare of the people. It is an act carried out by the government or international institutions in a market economy to influence the economy [30]. It seeks to eliminate fraud, ensure enforcement of contracts, and provide public goods and services. In other words, it is the building of institutional policy [64]. Economic interventions can be aimed at various political or economic objectives such as promoting economic growth, increasing employment, raising wages, raising or lowering prices, promoting income equality, managing the money supply and interest rates, increasing profits, or addressing market failures [65].

Market failure can be captured in the monopoly position of the seller or the insufficient quantity of publicly needed goods or services. In the short term, the pandemic created this situation and motivated national governments to intervene. For example, the state intervention that emerged during the pandemic was price regulation aimed at protecting the final consumer. The regulation reflects the direct steering of price levels by state authorities. It is therefore a situation where the price cannot be set directly by the sellers themselves. There are two basic forms of price regulation, namely price floors and price ceilings. In the case of a price ceiling, which is set only in one country, a situation of so-called arbitrage may arise.

Since the free movement of goods cannot be restricted within the EU, traders may gain economic rents by buying products in countries with low prices and selling products in countries where price regulation does not operate [54]. Empirical evidence is also consistent with the hypothesis that price regulation reduces the propensity to invest in R&D [35].

The most significant government intervention that entered into the price of protective equipment was the promotion of imports in the form of recognition of other standards and bulk government purchases. These steps were intended to expand the availability of personal protective equipment for the duration of the COVID-19 public health emergency [17], [42].

Another state intervention is the export ban. This is likely to be introduced by governments to favor the interests of domestic consumers over producers. These are usually extreme situations where there is a threat of a shortage of a given commodity [1]. A side effect of this is also downward pressure on the price in the local market, which in turn can negatively affect the quantity produced and reduce, thus increasing returns to scale [46].

If empirical evidence is implemented on interventions made due to the lack of protective equipment in the domestic market, the following impacts could occur. Regulating the price of protective equipment would lead to a lower propensity to invest in R&D. Import promotion in the form of massive government purchases from third countries would increase the supply on the domestic market by leaps and bounds, thereby suppressing the need to increase production by domestic producers. Recognition of previously unrecognized standards would allow a large number of producers who did not meet the European standard to enter the market. This would result in a renewed increase in supply on the domestic or European market, which would reduce the need to increase or maintain European production of protective equipment. Another intervention is an export ban, which would push down the price on the local market, which would again reduce the incentive to produce and implement nanofibre innovations in protective equipment.

### **3.3. The Impact of Internationalization and Obstacles to its Operation**

Internationalization is a relatively broad concept that can be viewed from several different directions. Glaum looks at internationalization from an economic perspective and sees it as the gradual development of business activities directed across borders [21]. Internationalization creates positive expectations in entrepreneurs by offering to expand abroad [8].

Expansion into foreign markets is a traditional economic activity that is highly sought after by corporate managers around the world for many reasons: it utilizes unused production capacity and increases production efficiency, raises technological standards, enhances corporate competitiveness, provides better profit opportunities, generates more funds for reinvestment that accelerate growth, and diversifies business risks [11], [34]. It is for these reasons that internationalization is a welcome process for firms.

Von Zedtwitz and Gassmann consider the internationalization of R&D to be the greatest phenomenon [66]. One way to understand the impact of internationalization on the returns to innovation is to focus on the factors that influence the increasing economic benefits. Internationally diversified companies can take advantage of a wider range of resources available globally. They can promote innovation by establishing global contacts in the form of forming alliances, and collaborations with research centers and universities [24]. Kotabe pointed out that one of the main objectives of firms is to minimize the costs associated with innovation. It is internationalization that can reduce these costs for firms. As a result of access to many markets around the world, they can purchase materials and R&D inputs from the cheapest available sources and locate their departments in the most productive regions [32]. On the other hand, a high degree of internationalization increases the risk of knowledge leakage and know-how spillovers to competitors [18].

Barriers to internationalization are a key theme in the literature on this issue. Barriers refer to constraints that prevent a company from starting to develop business operations across borders. Barriers can either be internal, reflecting the distribution within the firm (e.g., lack of finance or managerial capabilities), or they can be external (e.g., the institutional environment of the home country and the institutional environment in the importing country) [58].

Internal barriers in terms of financial capacity and infrastructure reflect the consequences of lower rates of expansion in foreign markets or complete withdrawal. This is due to the lower financial stock of the firm, which is, however, very important for foreign market entry. Another internal barrier is the attitude of management toward expansion into foreign markets itself. If management is risk averse, then its propensity to enter a new market is likely to be lower than that of management with the opposite preference. External barriers are seen as a key obstacle to growth in foreign markets. These influences include culture or legislation. It is legislation that sets the norms and constraints that exporters need to know and follow [26].

Standards belong to non-tariff barriers to trade, which also include quotas, embargoes, sanctions, or voluntary export restrictions [53]. Non-tariff measures are policy measures that can have an economic impact on international trade in goods. They fundamentally affect who trades with what, and how much. Although many non-tariff barriers are primarily focused on protecting public health, they significantly affect trade by influencing process costs or compliance with standards and regulations [60]. Non-tariff barriers can rapidly increase the price of foreign products or prevent imports altogether. However, calculating the impact of their introduction is very challenging. UNCTAD and other organizations have quantified non-tariff barriers in order to more accurately analyze economic impacts. A well-known method is a price-based calculation, which relies on the difference between the domestic price of products and the international price [29].

With the advent of the COVID-19 pandemic, UNCTAD has registered a decline in global trade of around 9% in 2020 compared to 2019. Overall, demand for products in most sectors saw a decline in the first half of 2020. However, trade in products that were essential for pandemic suppression was subject to a strong excess of demand over supply, as well as export restrictions. This affected foreign trade in pharmaceuticals, which recorded only a small increase of 2% in the first six months of 2020 compared to the previous year. In the second half of 2021, the increase was already 35% [59].

### ***3.4. Intervention due to Lack of Price of Protective Equipment***

In response to the growing impact of the COVID-19 pandemic in Europe, several countries have introduced national controls to restrict the export of medicines and medical equipment such as respirators, respirators, and protective clothing. The European Commission, despite discouragement from Member States to take restrictive measures against EU countries, has imposed a temporary ban on the export of certain protective equipment to third countries. As of 15 March 2020, it was thus impossible to export protective equipment outside the EU, regardless of whether it originated in the EU. With this measure, for the next six weeks, the European Commission sought to prevent shortages of essential medical products in the territory [14]. The Czech Republic adopted a measure on March 3, under which manufacturers, distributors, and importers of personal protective equipment were banned from selling respirators outside the Czech Republic and its organizational units. This ban was lifted after more than a month [10].

According to the OECD, these actions had a negative impact on the increasing price of PPE and disrupted global supply chains [42].

Another intervention that has entered into the pricing of respirators can be found in price regulation and subsequent government purchases. Due to the strong excess of demand over supply of protective equipment, the prices of respirators and face shields have increased by hundreds of percent and their price has been highly volatile almost everywhere in the world depending on supply [20], [43], [67]. The Ministry of Finance of the Czech Republic moved to regulate prices for the final consumer with the advent of the pandemic, responding specifically to the rising prices of protective equipment, effective March 4, 2020 [68].

For respirators manufactured in the EU, the maximum price was set at €7, while for respirators manufactured outside the EU, the limit was set at €14. It is important to mention that even after more than a year after the issue (11 April 2021), the regulation was still valid [68]. Although in 1990 in Czechoslovakia it was decided to liberalize prices by abandoning central market control, this did not mean the absolute resignation of the state in influencing price development. Until that year, only about 10% of prices in the country were negotiated on the basis of a conflict between supply and demand. Since 1990, Act No 526/1990 Coll. on prices, as amended, has defined very strictly when the state may intervene in price formation. Price regulation has gradually been limited to sectors where there is a so-called natural monopoly, an unbalanced relationship between supply and demand, and where there is a real danger of abuse of the more advantageous economic position of the seller in particular, while at the same time, there is a need to protect the final customer.

Due to the unprecedented pressure in the early stages of the COVID-19 pandemic on the supply of European certified virus protection products, the European Commission published Recommendation (EU) 2020/403 of 13 March 2020 on conformity assessment and market surveillance procedures [16]. The Recommendation offered important options for Member States to eliminate the shortage of protective equipment in this territory. First, it allowed the import of respirators that were certified in a non-European regulatory environment. For example, the Belgian federal government provided guidelines that allowed the import of certified respirators from Australia, Brazil, China, Korea, Japan, Mexico, and the USA [19]. Importantly, the EC recommendation included respirators manufactured to the Chinese standard GB2626-2006, which was considered equivalent to the European standard EN149:2001 + A1:2009 under the circumstances (Vanhooydonck et al., 2021).

However, the Chinese standard is not entirely equivalent in its product requirements, as it allows for lower cost production compared to those required under the more demanding EU standard for member state firms [57]. The vast majority of the protective equipment purchased through government purchases were from the People's Republic of China, which lacked equivalent EU certification. After recognizing the Chinese certification, the SAO decided to examine some of the test reports of the respirators tested, out of a total of 28.3 million, 13.3 million failed the first test [57]. This can be considered as a verification of the above claim of non-equivalence of standards. This step led to a rapid increase in the supply of respirators from the People's Republic of China on the European market and thus to a reduction in the excess of demand over supply. The reduction in the overhang in the protective equipment market is pushing down prices, leading to a less profitable industry and thus less inclination for companies to enter the sector. Put simply, the flooding of the market with Chinese respirators is positively correlated with a lower propensity of European firms to either start or expand their current production of protective equipment. Thus, dependence on a single supplier will not be reduced over this horizon. This will have a particularly negative impact on countries with the potential to produce personal protective equipment. There will be a state of lost opportunity, with the European market saturated by massive imports in the form of government purchases but also private sector imports. These factors play a major role in the pricing of protective equipment and, consequently, in the individual demands of individual domestic manufacturers of respirators and face masks.

### ***3.5. Protective Equipment Pricing Based on Government Purchases***

Government purchases are an important factor in the pricing of protective equipment on the Czech market and it is important to mention the Supreme Audit Office of the Czech Republic report in this context. It examined the purchases of protective equipment by the Ministries of Health and the Interior, which were mandated by a government resolution of 19 March to procure respirators almost exclusively from the People's Republic of China [22]. According to data from Supreme Audit Office the costs and volumes of individual protective equipment are shown below.

-300 million € - Total amount of money paid for the purchase of personal protective equipment.

-39, 44 million € - Funds spent for air and rail transport of materials to the Czech Republic including related services.

-15,420 pieces - Number of personal protective equipment available in state material reserves and teaching hospitals as of 31 December 2019.

-34,3 million units - Number of FFP3, FFP2, KN95, N95, GB19083-2010, and GB2626-2006 respirators purchased by central purchasing teams from the Ministry of Interior and the Ministry of Health of the Czech Republic with a total value of 112 million units. €.

-13,3 million pieces - Number of protective equipment that failed quality tests in the first testing out of a total sample representing 28.3 million pieces that were tested [57].

Both ministries paid CZK 300 million for medical supplies. € 400 million and almost € 40 million more. They paid €40 million for the transport of goods and related services. The Ministry of the Interior purchased FFP3 respirators ranging from €2.5 to €17 each, and the Ministry of Health's FFP2 respirator class was priced at €31 each. The vast majority of the protective equipment purchased by these ministries came from the People's Republic of China, which lacked certification recognized by the EU. On this basis, the SAO decided to examine some of the test reports of the respirators tested, and out of a total of 28.3 million respirators worth almost €80 million, the SAO found that the FFP2 respirators had been tested for a total of €80 million. 13.3 million units failed the test. At the same time, the state paid for the transport of medical supplies from the People's Republic of China worth €3.24 million to a private entity. [57].

#### 4. Results

The findings of this study elucidate the significant impact of state interventions on the development potential of the nanotechnology industry within the Czech Republic, as highlighted through a series of five interviews with the chairman of the Association of the Nanotechnology Industry. Four main government interventions were identified as detrimental to the sector's growth during the COVID-19 pandemic.

**Recognition of Non-Equivalent Chinese Standards:** The first intervention involved the Czech government's acknowledgment of Chinese standards for nanotechnology products, which were not equivalent to those previously established in the Czech Republic. This decision facilitated the entry of products that may not have met the country's rigorous quality requirements, thereby affecting the competitive landscape for domestic manufacturers.

**Government purchases from China:** The second point of concern was the Czech government's procurement strategy, which resulted in massive purchases from the People's Republic of China.

This situation introduced a significant number of low-quality respirators to the Czech market, which overshadowed the higher-quality products offered by local manufacturers.

**Implementation of a price ceiling:** A third intervention created a pricing imbalance by imposing a ceiling that inadvertently favored Chinese importers, allowing them a double margin compared to Czech producers during periods of acute shortages. This policy disproportionately advantaged importers at a critical time, placing domestic producers at a significant financial disadvantage. As a result of the lower price, this situation leads to a lower incentive for domestic producers to expand production, which will be replaced by imports.

**Export ban:** Lastly, the imposition of an export ban disrupted essential supply chains, severing Czech exporters' connections with their international clients for an extended period. This abrupt halt not only affected immediate economic activities but also damaged long-term business relationships and the industry's global standing. However, it is important to add that the restriction on the export of protective equipment was a global problem that was evident in almost all markets.

These interventions were substantiated with official information from the Czech government and corroborated by data from the OECD, WHO, and the European Commission. An analysis based on a comprehensive review of the literature confirmed that these state actions reduced the possible potential for the development of the nanotechnology industry in the Czech Republic. While acknowledging the complex circumstances posed by the pandemic and the severe lack of protective equipment, the study critically notes that the regulatory environment disproportionately favored imports over domestic production, which adhered to higher standards. This scenario suggests a need for recalibrated policy measures that better support local manufacturing capabilities, especially in strategic sectors vital to national security.

#### 5. Conclusion

Nanofibers in respirators and respirators are perceived as product innovations, which are among the highest in the innovation rankings, according to the OECD definition. As a result of the global demand for protective equipment, the OECD has defined the fundamental problem as the insufficient production of filter membranes. Based on their physical properties, nanofibre membranes have the ability to filter a high percentage of bacteria and viruses and have flourished in the Czech Republic over the last twenty years.



In 2003, for the first time, it was possible to produce nanofibres industrially in the Czech Republic. Thanks to these facts, the Czech Republic was one of the four countries in Europe with the highest potential for the start-up of production of protective equipment. As a result of this finding, the European Commission recommended that the export of protective equipment be restricted, joining the vast majority of countries that have controlled or otherwise restricted trade in respirators.

If expansion into foreign markets is perceived as a traditional economic activity sought by corporate managers around the world, it is essential to point out aspects that may have negatively affected this activity. The barriers associated with the internationalization of nanofibre innovations in personal protective equipment were evident during the pandemic, both external barriers to internationalization and internal barriers. In terms of external barriers, there was a complete ban on the export of respirators outside the Czech Republic, which lasted for one month. During this period, the internationalization of domestic nanofibres in respirators and face masks was very difficult. Another external barrier that also interfered with the internal barrier was price regulation. Price capping reduces the potential sales and financial stocks of domestic firms, which are an internal barrier to foreign market entry. Interestingly, it is due to the increased prices of respirators and face masks that nanofibres have started to be used more extensively in protective equipment.

In this context, it is crucial to mention the uneven playing field in the form of the different maximum prices for respirators coming from EU and non-EU countries. There will be a greater incentive to increase the production capacity of respirators due to the higher capped price in non-EU countries. They can sell at double the price in times of shortage, which allows them to manage more capital and increase production faster. These firms will experience increasing returns to scale, where the cost per unit produced will be lower than for smaller firms. The lower marginal costs of these firms will strengthen their position in the global market and, as a result of the possibility to lower the price more than competitors, these firms will be sought after even after the crisis. This step, therefore, deepens the dependence on imports of personal protective equipment from third countries even in the longer term, which may again lead to abuse of a more advantageous economic position in the need to protect the final customer, see Act No 526/1990 Coll. on prices, and also negatively affects domestic firms implementing nanofibres in personal protective equipment.

Another factor that worked against the internationalization of innovation was the recognition of previously unrecognized Chinese KN95 standards and the government's controlled purchases of Chinese protective equipment. For these, the Czech Republic spent nearly CZK 340 million on behalf of importers. This step increased competition in the European market and reduced the need to increase production capacity here, also in view of the greater demanding nature of EU standards for these products. At the same time, the money supply of Chinese protective equipment manufacturers has increased rapidly, eliminating an internal barrier to internationalization. The external barrier to internationalization that has been overcome during the crisis is the recognition of previously unrecognized Chinese standards. Because of this step, the domestic market was able to increase supply by leaps and Nanofibers in respirators and respirators are perceived as product innovations, which are among the highest in the innovation rankings, according to the OECD definition. As a result of the global demand for protective equipment, the OECD has defined the fundamental problem as the insufficient production of filter membranes. Based on their physical properties, nanofibre membranes have the ability to filter a high percentage of bacteria and viruses and have flourished in the Czech Republic over the last twenty years. In 2003, for the first time, it was possible to produce nanofibres industrially in the Czech Republic. Thanks to these facts, the Czech Republic was one of the four countries in Europe with the highest potential for the start-up of production of protective equipment. As a result of this finding, the European Commission recommended that the export of protective equipment be restricted, joining the vast majority of countries that have controlled or otherwise restricted trade in respirators.

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The paper aimed to define the importance of individual interventions in the implementation of specific innovations from the nanotechnology sector based on theoretical background. For this reason, the literature search focused on state interventions that had a major impact on the creation of a market environment for nanotechnological innovations.

The pandemic created a situation where policymakers had the opportunity to set the direction of growth by making strategic investments in nanotechnology. By doing so, the nanotechnology sector could further develop and increase economic stability, but this requires a specific policy framework that embraces the idea of using industrial and innovation policy to address extraordinary or grand societal challenges. Using such an approach, the state apparatus can become a central actor in the creation and exploitation of innovation, functioning in a good sense as an "entrepreneurial state" that has an active industrial and innovation policy aimed at promoting knowledge creation, linked to the identification of conditions for the functioning of a competitive market. All the mentioned state interventions can negatively affect the application of new technologies in the present but also in the future. Thus, it is important to address the risks of state interventions in the context of new technology development further and in more depth.

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