S21VC002

# The Changing Landscape for Funding Research and Development

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**Abstract**

This research seeks to describe the predicament of R&D in the U.S. more thoroughly to provide support for a return to a higher proportion of GDP as a means of maintaining American leadership in innovation. In the past, government investment has funded most foundational scientific research leading to technological advances in communications, recording, and networks here on Earth and space, from global positioning systems to the internet. The United States has been preeminent in research and development, Still, that position of investment leadership is increasingly in question due to a trend of declining proportionate government support for R&D. The R&D function in private enterprise is ill-equipped to support long term innovation that will likely reward competitors and others. The research evidence reveals that public investment in R&D drives private investment in R&D and furthers goals of innovation and economic growth. Some of these theories will be tested over the coming years because of the unexpected disruption of declining American public research's regular criticism. The COVID-19 pandemic led to unprecedented commitments to the rapid development of vaccines, drugs, and various protective and medical equipment that was no short supply.

# Funding Research and Development

The United States has been preeminent in research and development (R&D), but that position of investment leadership is increasingly in question (Bruce and de Figueiredo, 2020; Cannon et al., 2014). Policy reforms are required to reverse what has become a trend of declining proportionate government support for R&D. Government investment has in the past funded the majority of foundational scientific research leading to technological advances in communications, recording, and networks here on Earth and space from global positioning systems to the internet (Cannon et al., 2014; Singer, 2014). There are issues of structure, role, and motivation in any expectation that the private sector alone can or will make up the difference as government R&D funding.

### The private sector role argument

Based on a belief in markets and non-interference of government, there is a common sentiment that the private sector should be the one in the R&D funding role, rather than using taxpayer-funded revenues for this purpose. The R&D function in private enterprise is ill-equipped to support long term innovation that will likely reward those competitors that did not participate in its creation (Cannon et al., 2014; Wang et al., 2020). Projecting profits from a foundational R&D project is less science and more fortune-telling, making this a risky proposition for business owners and leaders (Cannon et al., 2014). To some extent, this direction may reflect criticism of public R&D expenditures, which claim that the result of such funds is crowding out of R&D investment within the enterprise and private industry (Wang et al., 2020).

### Purpose and objective

The research evidence, however, has revealed that public investment in R&D drives private investment in R&D and furthers the shared goal of innovation and economic growth (Wang et al., 2020). This paper seeks to describe the predicament of R&D in the U.S. more thoroughly to provide support for a return to a higher proportion of GDP as a means of maintaining American leadership in innovation. The aim of providing support for this argument will be achieved by looking at the background, history, and comparative evaluation of the U. S. position as a funder of R&D in the global context.

## Background

### The U.S. R&D funding decline

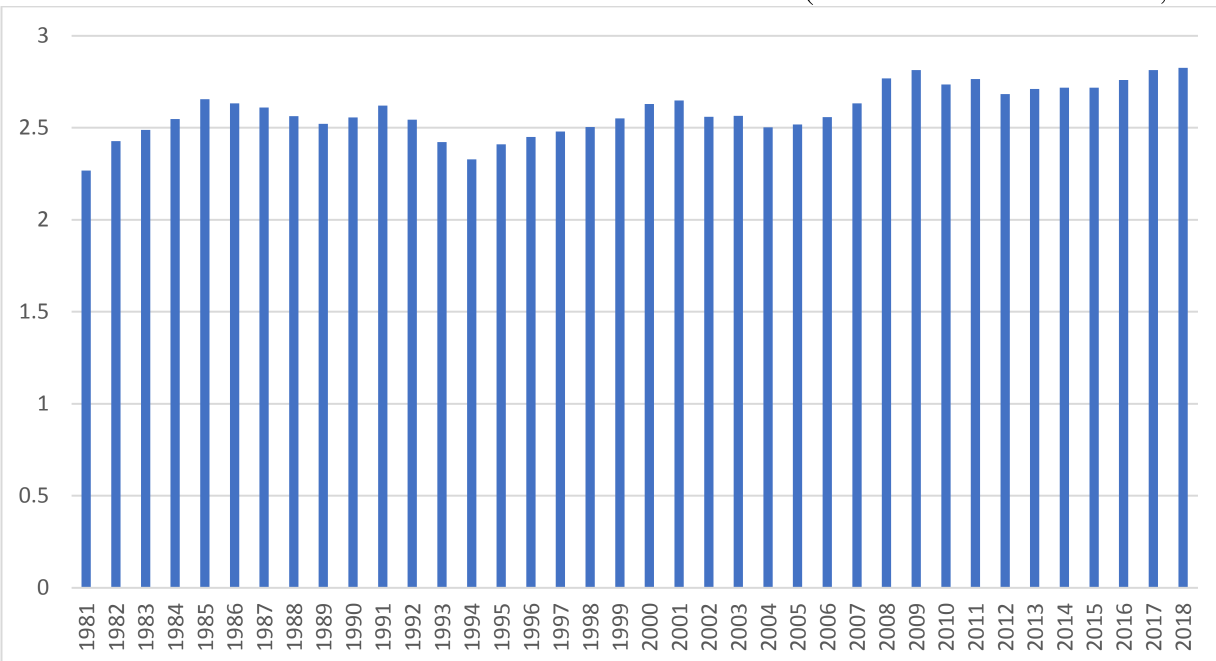
While overall funding levels for American R&D investment have increased in absolute value, the net effect when accounting for inflation and GDP growth is that R&D spending is declining as a proportion of spending and value in the American economy for a decade (Antonelli, 2019). The decreasing investment rate in R&D was already well underway before the 2020 coronavirus pandemic events and the subsequent economic impacts.

### The basis of the decline

The federal government has decreased its R&D commitment beginning with the Budget Control Act of 2011 (BCA), which created strict limitations that bound all federal departments and agencies (Hourihan & Parkes, 2016). There also is a lack of political will to support public R&D programs (Wang et al., 2020). A common sentiment is that sustaining innovations would follow from allowing the market to make investment and allocation decisions without government interference. Essentially, there is reduced political and corporate faith in R&D olutcomes, particularly science-based R&D, compared to the previous period (Antonelli, 2019).

Figure 1: US Public R&D Expenditures

(Based on data from OECD, 2020)

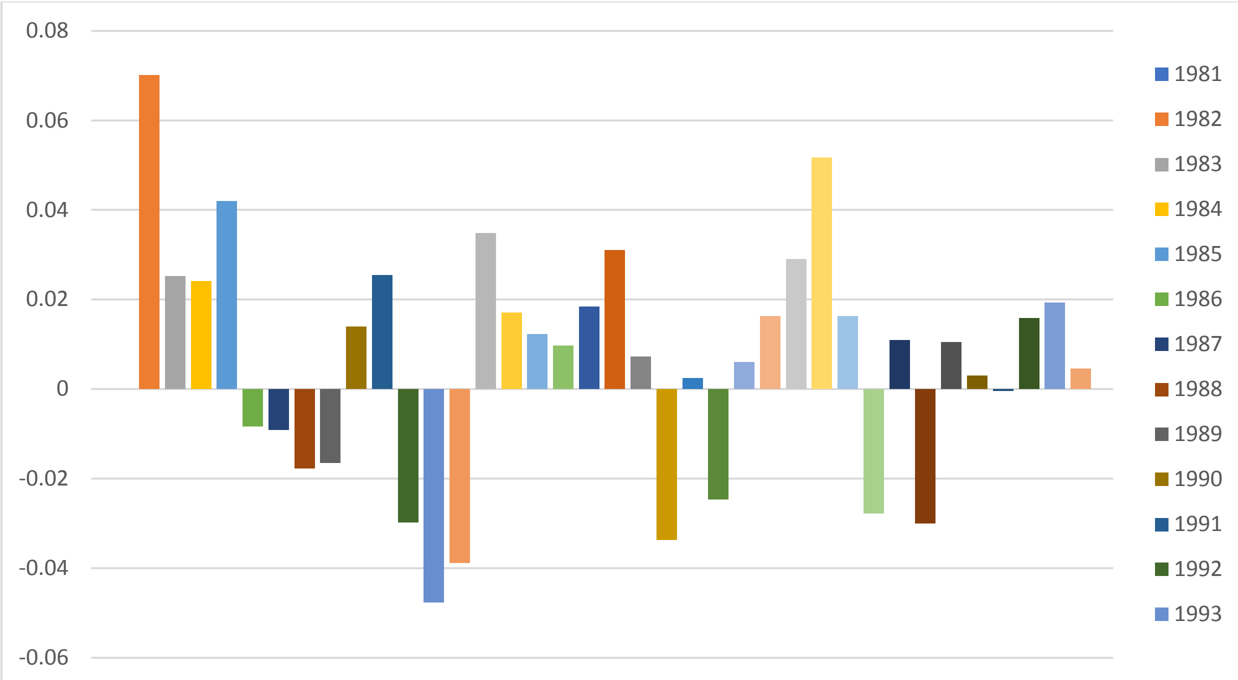



**The status quo for U.S. R&D expenditures**

According to the Organization for Economic Co-operation and Development (OECD), American gross domestic R&D expenditures in 2019 were steady at about 2.8% of GDP, representing the high range of the 2.5% to 2.83% of annual GDP represented by R&D expenditures over the past decade (OECD, 2020). The minimum reported R&D as a proportion of GDP reported in the period between 1981 and 2019 was 2.268% in 1981, while the highest levels are found over the past five years. The slight increase is that it does not make up for the failure to increase the rate while other countries were doubling their R&D investment rate. Overall, the rate of increase is negligible, even where it occurs.

Figure 2: % change in R&D funding as % of GDP, United States

(data from OECD, 2020)




The range of US R&D spending as a proportion of GDP can be compared to Israel, which consistently spends between 4.5% and 4.9% of GDP on public R&D investment, or Korea, which spends between 3.9% and 4.5% of annual GDP on R&D (OECD, 2020). Countries like China, Sweden, Austria, Germany, Denmark, and Japan consistently spend 3% and 3.5% of annual GDP on R&D (OECD, 2020). The trend in each of these countries is a gradual increase in the rate of R&D expenditures as a proportion of GDP (OECD, 2020). The United States, however, has struggled to maintain a rate above 2.7% (OECD, 2020). In 1994, the United States was third place in terms of R&D expenditures expressed as a percentage of GDP, behind Japan and Israel (OECD, 2020). At that time, 2.5% was considered to be high. Just ten years later, in 2004, Israel, Sweden, Finland, and Japan had moved past the 3% R&D rate barrier, and the US moved down into the sixth spot (OECD, 2020). Ten years after that, the rates for Israel and Sweden were above 4%, and the United States had been pushed back to the tenth spot as many European nations increased their R&D commitment beyond the 3% mark (OECD 2020). The 2019 data, just five years later, reveals that these positions have become relatively stable (OECD, 2020).

Table 1: The comparative position of R&D spending as % of GDP

(using data from OECD, 2020)

| | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|
| Israel | 4.174 | 4.265 | 4.512 | 4.816 | 4.941 |
| Korea | 4.078 | 3.978 | 3.987 | 4.292 | 4.528 |
| Japan | 3.4 | 3.282 | 3.158 | 3.208 | 3.275 |
| Finland | 3.148 | 2.872 | 2.724 | 2.732 | 2.755 |
| Sweden | 3.102 | 3.219 | 3.247 | 3.363 | 3.321 |
| Austria | 3.084 | 3.05 | 3.119 | 3.049 | 3.14 |
| Chinese Taipei | 3.007 | 3.051 | 3.154 | 3.283 | 3.462 |
| Denmark | 2.914 | 3.055 | 3.093 | 3.05 | 3.033 |
| Germany | 2.878 | 2.93 | 2.941 | 3.068 | 3.13 |

| | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|
| United States | 2.718 | 2.717 | 2.76 | 2.813 | 2.826 |
| China (People's Republic of) | 2.022 | 2.057 | 2.1 | 2.116 | 2.141 |
| European Union (28 countries) | 1.942 | 1.953 | 1.94 | 1.98 | 2.025 |

The outlook and recent history are worse when the focus is on public research funding targeting university and educational institutions (Atkinson & Foote, 2019). OECD data reveals that the U.S. is in the 28th position out of 39 OECD funding in relation to public funding of university-based R&D as a proportion of GDP (Atkinson & Foote, 2019). One-third of governments invest at about double the United States' rate (Atkinson & Foote, 2019). While other nations are also reducing their commitment to university R&D, the decline in investment is falling at a slower rate (Atkinson & Foote, 2019). It has been proposed that supporting university R&D at optimal levels would require increases of at least $5 billion US annually, along with tax credits that target more research and goes beyond energy-related issues (Atkinson & Foote, 2019). Such analysis helps to provide insight into issues that can be hidden when looking at summary statistics, such as the changing composition of R&D funding within that funding that continues to exist.

Table 2: Israel's leadership in R&D as a % of GDP

| YEAR | ISRAEL |
|---|---|
| 1999 | 3.33 |
| 2000 | 3.933 |
| 2001 | 4.185 |
| 2002 | 4.131 |
| 2003 | 3.893 |
| 2004 | 3.873 |
| 2005 | 4.048 |
| 2006 | 4.141 |
| 2007 | 4.422 |
| 2008 | 4.342 |
| 2009 | 4.133 |
| 2010 | 3.935 |
| 2011 | 4.015 |
| 2012 | 4.161 |
| 2013 | 4.096 |
| 2014 | 4.174 |
| 2015 | 4.265 |
| 2016 | 4.512 |
| 2017 | 4.816 |
| 2018 | 4.941 |

Of course, the counterargument is that the real dollar value of American public R&D spending is growing. While true to some extent, such an argument would deny the need to assess increases against factors such as real dollar value and inflation. A second argument might be that with the real dollar value of American R&D spending being so much higher than others, in part due to higher GDP, there was room to keep the actual dollar levels or value relatively stable. To more fully explore this, it is necessary to look at the conceptual framework that underlies R&D's funding as an economic and social driver.

## The Conceptual Framework

### The Solow-Swan model

Research in the postwar established a basis for the belief that technology and innovation were significant drivers of economic growth and industrial expansion (Szarowská, 2017). One outcome of this research track was the Solow-Swan model in 1956, which looked at long-term growth and determined the most efficient approach to such productivity requiring remaining up to date and driving technological advances in that area of industry or products (Szarowská, 2017). The Solow–Swan model's neoclassical economic nature was grounded in ideas of capital available, capital growth, labor growth, and productivity in relation to technological progress. The model was considered an advancement to the 1946 Harrod–Domar model and its Keynesian assumptions. The result of these decades of theory development and empirical research was that belief in endogenous economic growth based on technological advancement and the R&D that proceeds it was central to policy, and this can be seen as reflected in the R&D funding levels of the U.S. federal departments and agencies in the second half of the twentieth century (Szarowská, 2017).

### R&D drives economic growth

More recently, Szarowská (2017) confirmed the continued existence of a significant correlation between public R&D expenditures and the rate of economic growth in the European Union between 1995 and 2013. This fact provided further evidence that government R&D investments were a driver of growth, and in the European context, one which overshadowed the returns of private investment in R&D (Szarowská, 2017). Much of the last two decades of empirical research in this area looked specifically at the factors which helped to mediate or support this outcome (Szarowská, 2017). One concept was that of equilibrium between technological advance, economic growth, and the population, industry, and market's ability to absorb such positive changes (Szarowská, 2017). In other words, the equilibrium growth rate model proposed that there was an optimal rate of technological change in terms of efficiency and effectiveness (Szarowská, 2017). The research ideas and findings that drive technological change are quickly diffused across borders (Szarowská, 2017). Over time, all the best ideas are adopted by all, and in fact, global GDP can reflect this (Szarowská, 2017).

## The Historical R&D Leadership of the United States

Even while the proportion of funds spent on R&D in proportionate terms are falling in America, in real terms, the dollar value exceeds that of any other country and more than double that of China (Cannon et al., 2014). The amount spent by local, state, and federal departments and agencies on R&D continues to be equal to about one-third of the global investment of R&D by all other countries (Cannon et al., 2014). The investment of R&D, while also declining, remains about twice that of all government R&D funding (Cannon et al., 2014). At least half of all basic scientific research continues to be provided with federal funding in America (Cannon et al., 2014).

## The Rise of Venture Capital, Angels and Crowd Sourcing

Traditional government expenditures on R&D have focused on high capacity institutions and enterprises. Still, there has been a noticeable shift of attention in the innovation community to smaller, high technology research and development of startups, particularly those related to technology. This result has the attention of governments, which allow a small portion of R&D funding towards incubators for such projects and private investors and investment clubs, and the public in general. While government grants continue to have prestige, venture capital rewards can be higher, and innovators with a popular idea that does not attract either can still turn to the public in the form of crowdsourced funding raising platforms such as Indiegogo, GoFundMe, and Kickstarter. Whether venture capital or crowd sourced, attracting such sources of funds requires an idea that has already been developed to the point of being just short of marketable. It is not realistic that either source would fund basic scientific research.

Research on the position of research funding in America has produced many case studies, which are highly dependent on context. One case study explored the situation of clean energy startup businesses in the United States. It noted that firms that had not acquired research grants from the government were the least likely to capture private research funding from the venture capital community (Islam et al., 2018). This result contrasts with the general rule that firms that receive government grants are more likely to become funded by venture capital.

R&D expenditure related to pollution abatement has been an interest for both governments and private enterprises (Grover, 2017). It is surprising, given the increasing importance of sustainability, that pollution abatement research expenditures have declined since 1973 in the U.S. (Grover, 2017). Such counterintuitive findings require understanding the broader ecosystem of research and research funding, as well as substitution and displacement effects (Grover, 2017).

There is a complexity to the problem of declining R&D investment, given that recent research has documented a decline in corporate R&D, which dates back to about 1980 (Arora et al., 2018). Also, since that time, there has been a decreasing willingness of corporate researchers and development units to publish in the scholarly literature (Arora et al., 2018). While the development of R&D that may result in lucrative patents continues to be an interest of corporate leaders, sharing such information does not (Arora et al., 2018). During this time, the benefits and rewards of private investment have been declining, but it is not obvious if that is the cause or result of reduced funding commitment (Arora et al., 2018).

In part, it is clear that there is a prevailing theory in corporate decision-making, leading to declining interest in participating in research (Arora et al., 2018). In this new model, the firm may still enter into partnerships with universities towards a specified goal, and they still acquire new startups that have promising leads on technological innovation (Arora et al., 2018). an overall withdrawal from science-based R&D by private corporations since 1980 reflects this, and even the substitution of market research does not close this gap (Arora et al., 2018).

## The Global Context for R&D Investment

The global context for R&D investment includes leadership in the form of China and European nations and the European community. Also, there is an important history lesson in the form of the global diffusion of Soviet R&D human capital after the fall of the Soviet Union.

### China

China has become a research and development powerhouse, both in terms of the number of scientists engaged and the increasing investment rate and returns on R&D at all levels of government (Boeing et al., 2016). Technology and innovation are part of state plans to support economic growth and expansion (Boeing et al., 2016). However, the productivity and performance of R&D in China have varied dramatically depending on the sector and industry, as well as the form of ownership (Boeing et al., 2016). In China, it can be seen that private R&D

investment by firms has the highest returns, in comparison to that of the R&D investment returns for firms that have minority or majority state ownership (Boeing et al., 2016). This result is accurate when measured in either dollars or patents (Boeing et al., 2016).

An area of research interest concerning Chinese funding of R&D has been the allocation of government funding and the extent to which they have effectively achieved the goals of further private R&D investment (Boeing, 2016). A notable feature of the federal R&D funding system in China is that it is inclusionary for previous grant winners, and minority state ownership has helped secure such status (Boeing, 2016). There are many variations at the provincial level in China, given that urban provinces with higher revenues also have more significant resources and higher investment in R&D (Boeing, 2016). The crowding-out problem of enterprise withdrawing from investment as Chinese governments provide R&D subsidies continues to be debated in the scholarly literature, with some consensus that it is less likely to be an issue for high technology, repeat recipients of R&D grants, and those firms with state minority ownership (Boeing, 2016). An analysis of the impact of government subsidies for R&D, as well as non-R&D, supports research in China for technology firms, revealing that both are likely to have a positive impact on later IPO performance, despite a mediating effect of state ownership (Chen et al., 2018).

Addressing the inefficiency of R&D is a concern for all countries, but it is a major concern in China, given the high levels of public funding provided for research and development (Yang et al., 2020). It is alleged that the granting of funds for R&D is improperly allocated, and the potential of R&D is incorrectly assessed (Yang et al., 2020). Over time, however, the elasticity of the output of R&D investment is stabilizing, and the human capital factor of persons qualified and trained in R&D related fields is rising (Yang et al., 2020).

**Europe**

Several Western European countries are always in the top ten countries, supporting R&D at the highest levels. Such grants and research funding can occur at the European Union (EU) level for cross border studies of interest to all member nations or federal subsidies at the country level (Dvouletý et al., 2020).

Czarnitzki and Delanote (2017) also provided further evidence from Belgium confirming the complementary effects of private and public R&D, particularly concerning the increasing interest of private enterprise in ongoing research. Overall, however, they did not find any appreciable evidence of a relationship to the market performance of products that resulted from this R&D based on public or private subsidy sources (Czarnitzki and Delanote, 2017). An evaluation of research funding in the EU found multiple indicators of positive impacts of public subsidies, including the degree of participation, dissemination and knowledge transfer, and university collaboration with the private sector (Szücs, 2018).

**Post-Soviet R&D**

In the late 20$^{th}$ century, Soviet expenditures were not available to the West; however, advancements and intelligence could be estimated. A better understanding of Soviet R&D was a matter intricately connected to foreign policy and defending against enemies. A seminal work by Les Aspin (1976) in Foreign Policy explained the issue of a missile gap, a concept describing how Soviet outspending of American defense R&D related to the growing United States' growing insecurity. Post-Soviet research and development provide a cautionary tale to how quickly research leadership and capital can become forever lost. As the Soviet empire collapsed in the late 1980s and early 1990s, so did much of the infrastructure and networks which had previously supplied it with human capital and resourcing. The U.S. did not stand still, and instead, a grant program was provided to as many as 28,000 Soviet scientists (Ganguli, 2017). Empirical research shows that these grants to assist in resettling scientists in the U.S. had the net effect of doubling publications in mathematics and other subjects where Soviet research had been strong (Borjas & Doran, 2012; Ganguli, 2017).

## The R&D Market Failure

R&D market failure refers to either interference by government in the R&D market leading to failure, represented by the crowding out private investment theory, or it refers to the business perspective of foundational research and the high market failure of R&D investment (Choi & Lee, 2017). There are further tensions between what is optimal for markets, and what is socially optimal, but failing to achieve either is ultimately a market failure. For example, if corporate R&D were to drive innovation, it would likely be proprietary, and not provide for the level of dissemination that is needed for widespread support for economic expansion based on technological advancement. There is still, however, the argument that at the individual level, the high level of market failures for early research speaks to the need to use public funds cautiously, and with accountability. The key is to pay attention to both of these needs, and to ensure value in the outcomes for R&D spending- an activity that has already taken considerable time and effort in the community.

## The Implications of Reduced R&D Investment

R&D is a driver of economic growth and employment; however, those jobs and the economic results may move to overseas locations in Europe and Asia where R&D funding remains high (Cannon et al., 2014). The more serious outcomes in the long term are those relating to the lack of growth drivers, employment, and capital accumulation. Without R&D, the loss of position may be not just in funding leadership but a competitive advantage in a global context that is focused on continuous improvement and technological advancement.

### U.S. R&D funding not keeping pace with change

One perspective positions the problem of government R&D funding as unresponsive to signal and indicators in the environment (Tassey, 2020). Domestic economic policy has focused on the status quo and is therefore not seeking out new disruptors such as those driven by technology and digital platforms. This result can be justified in part by the idea that declining GDP and performance require more attention, leaving less time or interest in innovation and advancement (Tassey, 2020). Still, the Solow-Swan model's main point is that significant expansion and growth require positive technological change, among other factors. A further factor of interest for governments, in light of performance goals and revenues from individual taxation amid declining GDP growth is the fact that workers in high-tech and cutting edge sectors and industries make about twice that of the average worker (Tassey, 2020). There is an ecosystem of potential financial and economic reasons why the reduction of R&D investment will, therefore, have negative impacts on multiple levels, including government revenues from taxation.

## The Impacts of the COVID-19 Pandemic

There are several impacts on R&D funding in relation to the COVID-19 pandemic of 2020. As a result of the fast spread of the deadly virus, economic activity came to a standstill. While productivity is at an all-time low, unemployment is at an all-time high in America and elsewhere. This result has coincided with an unprecedented need for innovation in relation to developing a vaccine, protective equipment to prevent infection spread, and ventilators for use in hospitals, among others. While nations have been harnessing their R&D capital and infrastructure with the spread of the novel coronavirus, there are many unknowns concerning the

short term requirements of research or the long term impact that this event may have on R&D spending. The R&D related to COVID-19 is considered critical to getting the world back to some normal, and both a vaccine and drugs to lessen symptoms are, therefore, the desirable outcomes of such research (Cattani, 2020). It was reported that by March 24, 2020, more than 500 clinical trials related to COVID-19 had been registered (Cattani, 2020). It was further noted that the locations of such clinical trials reflected the intensity with which countries were impacted by the novel coronavirus, with China, South Korea, and Europe leading research (Cattani, 2020). Not only has there been the commitment of public funds to research efforts, but it also is widely believed that a vaccine might be developed as early as 2021, despite the tradition of ten years or more in clinical research trials
(Le et al., 2020).

Policymakers and research funders are warned that reactive funding that cannot be sustained over the long term is unlikely to add real value as an investment (Prudêncio & Costa, 2020). Despite $100 million in SARS research funding in 2004, or the €400 million contributed by European organizations to fight Ebola, there is still no vaccine, no cure, and no licensed drugs to help for either disease (Prudêncio & Costa, 2020). This result also underscores the point that the research was available, and the evidence clear, in relation to a possible SARS pandemic that comes from reservoirs of infectious bats (Abi Younes et al., 2020). This result did not provide the strong signaling that governments would have needed to create the political will to invest in prevention at higher levels (Abi Younes et al., 2020).

In terms of funding levels, early reports by the OECD in relation to self-reported commitments of governments to COVID-19 research reveals that in terms of the actual dollars, the U.S. is the top funder of such R&D. While many countries reported that further R&D commitments were still to be determined, the overall funding level of nearly 3.9 billion dollars committed by the US is more than twenty times the reported investment of any single country (OECD, 2020b).

Table 3: Top funders of COVID-19 R&D (OECD, 2020b)

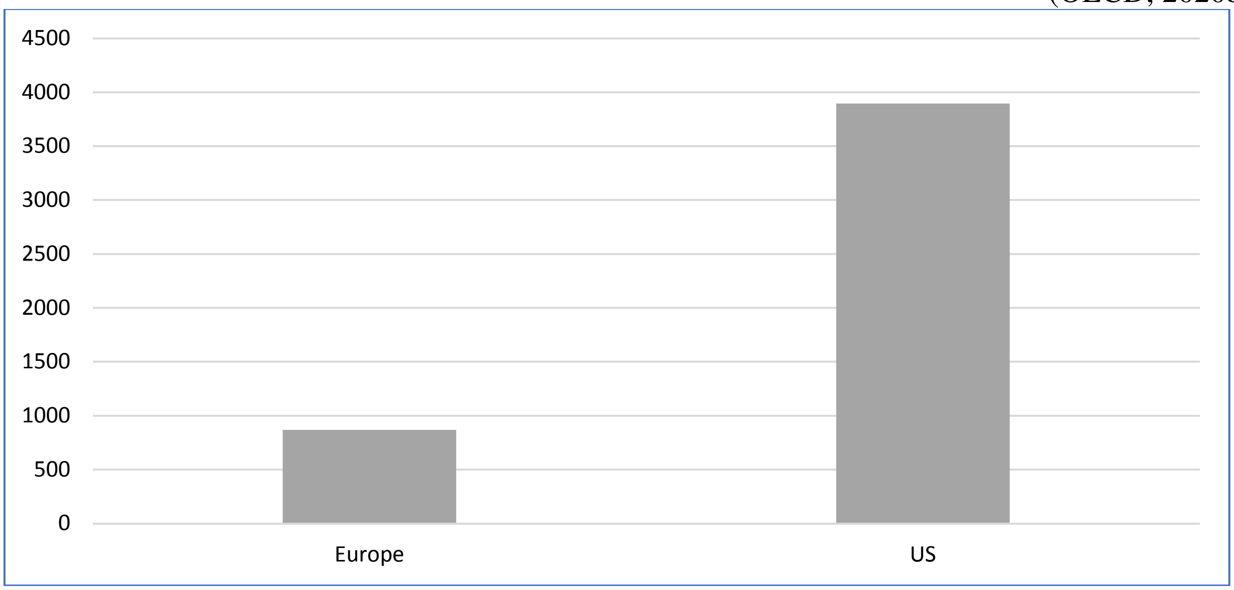
(see Appendix for raw data tables)

| **COUNTRY** | | **TOTAL EXPECTED FUNDING LEVEL (IN US millions )** |
|---|---|---|
| United States | $ | 3,895.4 |
| European Union | $ | 490.56 |
| Korea | $ | 176.00 |
| Japan | $ | 121.30 |
| United Kingdom | $ | 107.10 |
| Canada | $ | 55.86 |
| Netherlands | $ | 48.50 |
| France | $ | 42.60 |
| Luxembourg | $ | 36.00 |
| Spain | $ | 34.85 |
| Germany | $ | 33.00 |
| Austria | $ | 27.20 |
| Australia | $ | 26.55 |
| Brazil | $ | 20.45 |

| COUNTRY | TOTAL EXPECTED FUNDING LEVEL (IN US millions ) | |
|---|---|---|
| Russian Federation | $ | 20.00 |
| Denmark | $ | 14.20 |
| Israel | $ | 13.00 |

While the European Union commitment of nearly $500 million, combined with more than $300 million from other countries in Europe, is sizeable, it represents the contribution of a coalition of countries, and it is less than a quarter of the American R&D commitment to COVID-19 research.

Figure 3: Comparing US and European funding allocations to COVID-19 R&D (OECD, 2020b)




**Recommendations and Conclusions**

**The political will to support the R&D sector**

If the U.S. fails to protect its leadership position in R&D investment, it consequently risks its leadership in science, technology, productivity, and innovation, which is the basis of the nation's employment and economic activity. The post-Soviet example is a warning in relation to the loss of R&D infrastructure and human capital, which can occur when these research and development systems are not supported, which brings us to the next recommendation.

**Support for scientists and human capital in R&D**

While the United States has strong infrastructure such as the Academies of Science, the rising levels of R&D funding in other nations may provide more appealing circumstances for researchers and research. It is the sustained research context, rather than that of the short-term, which determines the direction in which the human capital of R&D, including scientists, analysts, and specialized research assistants which to migrate.

**Long term commitment and direction**

With the global COVID-19 pandemic creating a changed dynamic across governments, the expected short-term increases in commitments specific to this threat have also become realized; however, history tends to repeat itself. Similar previous efforts have not proven to be effective investments.

# Appendix: Data Tables

Table: Research and Development Spending as % of GDP

| YEAR | US R&D AS % OF GDP | % CHANGE |
|---|---|---|
| 1981 | 2.268 | |
| 1982 | 2.427 | 7.0% |
| 1983 | 2.488 | 2.5% |
| 1984 | 2.548 | 2.4% |
| 1985 | 2.655 | 4.2% |
| 1986 | 2.633 | -0.8% |
| 1987 | 2.609 | -0.9% |
| 1988 | 2.563 | -1.8% |
| 1989 | 2.521 | -1.6% |
| 1990 | 2.556 | 1.4% |
| 1991 | 2.621 | 2.5% |
| 1992 | 2.543 | -3.0% |
| 1993 | 2.422 | -4.8% |
| 1994 | 2.328 | -3.9% |
| 1995 | 2.409 | 3.5% |
| 1996 | 2.45 | 1.7% |
| 1997 | 2.48 | 1.2% |
| 1998 | 2.504 | 1.0% |
| 1999 | 2.55 | 1.8% |
| 2000 | 2.629 | 3.1% |
| 2001 | 2.648 | 0.7% |
| 2002 | 2.559 | -3.4% |
| 2003 | 2.565 | 0.2% |
| 2004 | 2.502 | -2.5% |
| 2005 | 2.517 | 0.6% |
| 2006 | 2.558 | 1.6% |
| 2007 | 2.632 | 2.9% |
| 2008 | 2.768 | 5.2% |
| 2009 | 2.813 | 1.6% |
| 2010 | 2.735 | -2.8% |
| 2011 | 2.765 | 1.1% |
| 2012 | 2.682 | -3.0% |
| 2013 | 2.71 | 1.0% |
| 2014 | 2.718 | 0.3% |
| 2015 | 2.717 | 0.0% |
| 2016 | 2.76 | 1.6% |
| 2017 | 2.813 | 1.9% |
| 2018 | 2.826 | 0.5% |

Table: R&D as a % of GDP 2014 – 2018

| COUNTRY | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|
| Argentina | 0.592 | 0.619 | 0.53 | 0.557 | |
| Australia | | 1.877 | | 1.787 | |
| Austria | 3.084 | 3.05 | 3.119 | 3.049 | 3.14 |
| Belgium | 2.37 | 2.428 | 2.523 | 2.661 | 2.678 |
| Canada | 1.714 | 1.693 | 1.729 | 1.669 | 1.563 |
| Chile | 0.375 | 0.381 | 0.369 | 0.356 | 0.35 |
| China (People's Republic of) | 2.022 | 2.057 | 2.1 | 2.116 | 2.141 |
| Chinese Taipei | 3.007 | 3.051 | 3.154 | 3.283 | 3.462 |
| Colombia | 0.303 | 0.323 | 0.296 | 0.262 | 0.286 |
| Denmark | 2.914 | 3.055 | 3.093 | 3.05 | 3.033 |
| Estonia | 1.421 | 1.457 | 1.246 | 1.28 | 1.404 |
| European Union (28 countries) | 1.942 | 1.953 | 1.94 | 1.98 | 2.025 |
| Finland | 3.148 | 2.872 | 2.724 | 2.732 | 2.755 |
| France | 2.276 | 2.267 | 2.222 | 2.203 | 2.193 |
| Germany | 2.878 | 2.93 | 2.941 | 3.068 | 3.13 |
| Greece | 0.833 | 0.961 | 0.994 | 1.131 | 1.18 |
| Hungary | 1.349 | 1.347 | 1.19 | 1.332 | 1.533 |
| Ireland | 1.523 | 1.183 | 1.169 | 1.237 | 0.997 |
| Israel | 4.174 | 4.265 | 4.512 | 4.816 | 4.941 |
| Italy | 1.338 | 1.339 | 1.366 | 1.37 | 1.426 |
| Japan | 3.4 | 3.282 | 3.158 | 3.208 | 3.275 |
| Korea | 4.078 | 3.978 | 3.987 | 4.292 | 4.528 |
| Latvia | 0.688 | 0.623 | 0.44 | 0.515 | 0.641 |

| | | | | | |
|---|---|---|---|---|---|
| Lithuania | 1.031 | 1.044 | 0.842 | 0.896 | 0.942 |
| Luxembourg | 1.264 | 1.302 | 1.298 | 1.269 | 1.211 |
| Mexico | 0.435 | 0.43 | 0.388 | 0.328 | 0.313 |
| New Zealand | | 1.232 | | 1.347 | |
| Norway | 1.715 | 1.935 | 2.045 | 2.099 | 2.061 |
| OECD - Total | 2.319 | 2.31 | 2.302 | 2.342 | 2.379 |
| Poland | 0.94 | 1.003 | 0.964 | 1.034 | 1.21 |
| Portugal | 1.29 | 1.243 | 1.281 | 1.319 | 1.355 |
| Romania | 0.382 | 0.488 | 0.48 | 0.503 | 0.501 |
| Russia | 1.072 | 1.101 | 1.102 | 1.11 | 0.983 |
| Slovak Republic | 0.878 | 1.163 | 0.791 | 0.886 | 0.838 |
| Slovenia | 2.365 | 2.196 | 2.011 | 1.866 | 1.951 |
| South Africa | 0.771 | 0.798 | 0.819 | | |
| Spain | 1.242 | 1.222 | 1.19 | 1.21 | 1.243 |
| Sweden | 3.102 | 3.219 | 3.247 | 3.363 | 3.321 |
| Switzerland | | 3.372 | | 3.293 | |
| Turkey | 0.861 | 0.882 | 0.945 | 0.96 | 1.035 |
| United Kingdom | 1.643 | 1.65 | 1.66 | 1.68 | 1.729 |
| United States | 2.718 | 2.717 | 2.76 | 2.813 | 2.826 |

Table: COVID-19 related R&D inputs reported to the OECD
(all data from OECD, 2020)

| COUNTRY /REGION | COUNTRY/REGION ACRONYM | PROGRAM NAME | EXPECTED FUNDING LEVEL (IN US ) |
|---|---|---|---|
| United States | US | BARDA Broad Agency Announcement (BAA | 2000.00 |

| COUNTRY /REGION | COUNTRY/REGION ACRONYM | PROGRAM NAME | EXPECTED FUNDING LEVEL (IN US ) |
|---|---|---|---|
| United States | US | Notice of Special Interest (NOSI) regarding the Availability of Emergency Competitive Revisions for Research on Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) and Coronavirus Disease 2019 (COVID-19) | 836.00 |
| United States | US | Notice of Special Interest on the 2019 novel Coronavirus | 550.00 |
| European Union | EU | European Commission call for Innovators for COVID-19 EIC Accelerator | 177.00 |
| Korea | | vaccine commercialization technology development project | 176.00 |
| European Union | | Horizon 2020 | 145.00 |
| United States | US | Notice of Special Interest on the 2019 novel Coronavirus | 103.40 |
| European Union | EU | Development of therapeutics and diagnostics combatting coronavirus infections | 101.80 |
| Japan | COVID-19 supplement to existing call | Cyclic Innovation for Clinical Empowerment (CiCLE) | 95.00 |
| United States | US | RAPID | 75.00 |
| United States | | Peer Reviewed Medical Research Program Clinical Trial Award | 75.00 |
| United States | | Peer Reviewed Medical Research Program Investigator-Initiated Research Award | 75.00 |
| United States | | Peer Reviewed Medical Research Program Technology: Therapeutic Development Award | 75.00 |
| European Union | EU | Advancing knowledge for the clinical and public health response to the [COVID-19] epidemic | 65.00 |
| United States | | National Institute of Biomedical Imaging and Bioengineering (NIBIB) | 60.00 |
| United Kingdom | | | 58.00 |

| COUNTRY /REGION | COUNTRY/REGION ACRONYM | PROGRAM NAME | EXPECTED FUNDING LEVEL (IN US ) |
|---|---|---|---|
| Netherlands | | Additional appropriations for emergency corona research | 46.50 |
| Canada | CAN | Canadian 2019 Novel Coronavirus (COVID-19) Rapid Research | 36.40 |
| United States | US | Notice of Special Interest (NOSI): Repurposing Existing Therapeutics to Address the 2019 Novel Coronavirus Disease (COVID-19) | 36.00 |
| Luxembourg | | "new aid linked to the development and production of products in the fight against Covid-19" | 36.00 |
| Spain | | | 30.00 |
| Austria | AUT | Emergency Call for research into COVID-19 in response to the Sars-CoV-2 outbreak | 25.00 |
| United Kingdom | UK | COVID-19 Genomics UK Consortium | 23.50 |
| United Kingdom | UK | COVID-19 Rapid Response Call | 23.00 |
| Russian Federation | | | 20.00 |
| Japan | | Drug Discovery Support Program: Development of Covid-19 vaccine | 19.00 |
| Germany | | Funding announcement for research on COVID-19 in the wake of the SARS-CoV-2 outbreak | 18.00 |
| France | FRA | Flash Call COVID-19 | 16.00 |
| Germany | | Call for Multidisciplinary Research into Epidemics and Pandemics in Response to the Outbreak of SARS-CoV-2 | 15.00 |
| France | | Call for projects for innovative solutions to fight COVID-19 | 13.00 |
| Israel | | | 13.00 |

| COUNTRY /REGION | COUNTRY/REGION ACRONYM | PROGRAM NAME | EXPECTED FUNDING LEVEL (IN US ) |
|---|---|---|---|
| Australia | | UQ - University of Queensland research - COVID-19 vaccine project | 11.00 |
| Canada | | Pandemic Response Challenge Program | 10.70 |
| Brazil | | | 10.00 |
| Brazil | | | 10.00 |
| United States | | Centers for Disease Control COVID-19 Broad Agency Announcement | 10.00 |
| Finland | | Special call for applications for research into COVID-19 | 9.20 |
| France | FRA | COVID-19: 20 projects' | 8.60 |
| Thailand | | | 8.00 |
| Denmark | DNK | [no specific program] | 7.10 |
| Denmark | | Extraordinary Grand Solutions call: COVID-19 | 7.10 |
| Colombia | | Call MinCienciatón | 6.40 |
| Portugal | | Emergency Fund Covid-19 | 6.00 |
| Australia | AUS | Fast-tracking research into treatments for COVID-19 | 5.10 |
| Argentina | | COVID-19 - Convocatoria Extraordinaria | 5.00 |
| Canada | | COVID-19 Challenge: Made in Canada filtration material for the manufacture of N95 respirators and surgical masks | 5.00 |

| COUNTRY /REGION | COUNTRY/REGION ACRONYM | PROGRAM NAME | EXPECTED FUNDING LEVEL (IN US ) |
|---|---|---|---|
| France | | Règlement de l'appel à projets flash COVID-19 SUD de l'ANRS | 5.00 |
| Sweden | | Finding new ways in the time of a crisis | 5.00 |
| Spain | | | 4.85 |
| Japan | JPN | AMED support for research on the novel coronavirus disease (COVID-19) | 4.70 |
| Belgium (French part) | | CUR (Credit Urgent de Recherche) and PER (Projets exceptionnels de Recherche) | 3.30 |
| Portugal | | AI 4 COVID-19: Data Science and Artificial Intelligence in the Public Administration to strengthen the fight against COVID-19 and future pandemics - 2020 | 3.30 |
| Australia | AUS | Fast-tracking research into treatments for COVID-19 | 3.20 |
| Belgium | | Special call for COVID-19 research projects | 3.00 |
| Australia | | Covid-19 National Health Plan | 2.90 |
| United Kingdom | | The Joint Initiative on Research in Pandemic Preparedness and Response (JIREP), | 2.60 |
| Norway | | COVID-19 Emergency Call for Proposals: Collaborative and Knowledge-building Projects for the Fight Against Coronavirus Disease (COVID-19) | 2.50 |
| Poland | | EXPRESS CALL TO FUND RESEARCH ON COVID-19 | 2.40 |
| Austria | | no specific program | 2.20 |
| Netherlands | | | 2.00 |
| Canada | | COVID-19 challenge – Low-cost sensor system for COVID-19 patient monitoring | 1.90 |

| COUNTRY /REGION | COUNTRY/REGION ACRONYM | PROGRAM NAME | EXPECTED FUNDING LEVEL (IN US ) |
|---|---|---|---|
| Canada | | COVID-19 Challenge — Point of Care and Home Diagnostic Kit for COVID-19 | 1.86 |
| Australia | | Covid-19 National Health Plan | 1.70 |
| Norway | | COVID-19 Emergency Call for Proposals: Collaborative and Knowledge-building Projects for the Fight Against Coronavirus Disease (COVID-19) | 1.70 |
| Portugal | | RESEARCH 4 COVID-19 | 1.64 |
| South Africa | | | 1.60 |
| Peru | | | 1.50 |
| Japan | JPN | Research Program on Emerging and Re-emerging Infectious Diseases in FY2019 | 1.40 |
| Australia | AUS | Fast-tracking research into treatments for COVID-19 | 1.30 |
| Estonia | | RITA | 1.20 |
| New Zealand | | 2020 COVID-19 and Emerging Infectious Diseases Grant | 1.14 |
| European Union | | Fighting COVID-19 Open Call 2020 | 1.10 |
| Australia | | Medical Research Future Fund (MRFF) | 0.95 |
| South Africa | | | 0.665 |
| European Union | | EIT Health COVID-19 “Rapid Response” in 2020 for on-going and new projects | 0.66 |

| COUNTRY /REGION | COUNTRY/REGION ACRONYM | PROGRAM NAME | EXPECTED FUNDING LEVEL (IN US ) |
|---|---|---|---|
| Japan | | J-RAID | 0.60 |
| Japan | | Supplement to on-going projects of Strategic Basic Reserach Porgrams (CREST, PRESTO) | 0.60 |
| New Zealand | | 2020 COVID-19 New Zealand Rapid Response Research | 0.57 |
| Brazil | | | 0.45 |
| Australia | | Fast-tracked funding for the COVID-19 pandemic to support critical research areas | 0.40 |

## References

Abi Younes, G., Ayoubi, C., Ballester, O., Cristelli, G., de Rassenfosse, G., Foray, D., ... & Zhou, L. (2020). COVID-19: Insights from innovation economists. *Science and Public Policy*. https://doi.org/10.1093/scipol/scaa028

Antonelli, C. (2019). *The knowledge growth regime: A Schumpeterian approach*. Springer.

Arora, A., Belenzon, S., & Patacconi, A. (2018). The decline of science in corporate R&D. *Strategic Management Journal*, *39*(1), pp. 3-32. https://doi.org/10.1002/smj.2693

Aspin, L. (1976). Opinion: How to Look at the Soviet-American Balance. *Foreign Policy*, (22), pp.96-106.

Atkinson, R. D., & Foote, C. (2019). *US funding for university research continues to slide*. Information Technology and Innovation Foundation. https://itif.org/publications/2019/10/21/us-funding-university-research-continues-slide

Boeing, P., 2016. The allocation and effectiveness of China's R&D subsidies-Evidence from listed firms. *Research policy*, *45*(9), pp.1774-1789.

Borjas, G. J., & Doran, K. B. (2012). The collapse of the Soviet Union and the productivity of American mathematicians. *The Quarterly Journal of Economics*, *127*(3), pp.1143-1203.

Boeing, P., Mueller, E. and Sandner, P., 2016. China's R&D explosion—Analyzing productivity effects across ownership types and over time. *Research policy*, *45*(1), pp.159-176.

Bruce, JR and de Figueiredo, JM, 2020. *Innovation in the US Government* (No. w27181). National Bureau of Economic Research.

Cannon, N.J., Ulferts, G.W. and Howard, T.L., 2014. Research and development investment. *Journal of Business & Economics Research (JBER), 12*(3), pp.291-294.

Cattani, M. (2020). Global coalition to accelerate COVID-19 clinical research in resource-limited settings. *Lancet*, 30798-4. https://doi.org/10.1016/S0140-6736(20)30798-4

Chen, J., Heng, C. S., Tan, B. C., & Lin, Z. (2018). The distinct signaling effects of R&D subsidy and non-R&D subsidy on IPO performance of IT entrepreneurial firms in China. *Research Policy*, *47*(1), pp. 108-120.

Choi, J., & Lee, J. (2017). Repairing the R&D market failure: Public R&D subsidy and the composition of private R&D. *Research Policy*, *46*(8), pp.1465-1478.

Czarnitzki, D., & Delanote, J. (2017). Incorporating innovation subsidies in the CDM framework: empirical evidence from Belgium. *Economics of Innovation and New Technology*, *26*(1-2), pp. 78-92. https://doi.org/10.1080/10438599.2016.1202514

Dvouletý, O., Srhoj, S., & Pantea, S. (2020). Public SME grants and firm performance in European Union: A systematic review of empirical evidence. *Small Business Economics*, pp.1-21.

Ganguli, I. (2017). Saving Soviet science: The impact of grants when government R&D funding disappears. American Economic Journal: Applied Economics, 9(2), 165-201. DOI: 10.1257/app.20160180

Grover, D. (2017). Declining pollution abatement R&D in the United States: theory and k;frt/evidence. *Industrial and Corporate Change*, *26*(5), pp. 845-863.

Hourihan, M., & Parkes, D. (2016). Federal R&D Budget Trends: A Short Summary. *American Association for the Advancement of Science, report*.

Islam, M., Fremeth, A., & Marcus, A. (2018). Signaling by early stage startups: US government research grants and venture capital funding. *Journal of Business Venturing*, *33*(1), pp. 35-51.

Le, T. T., Andreadakis, Z., Kumar, A., Roman, R. G., Tollefsen, S., Saville, M., & Mayhew, S. (2020). The COVID-19 vaccine development landscape. *Nat Rev Drug Discov*, *19*(5), 305-306.

OECD (2020). Gross domestic spending on R&D (indicator). doi: 10.1787/d8b068b4-en https://data.oecd.org/rd/gross-domestic-spending-on-r-d.htm

OECD (2020b). COVID19 Research funding worldwide. https://community.oecd.org/docs/DOC-171875

Prudêncio, M., & Costa, J. C. (2020). Research funding after COVID-19. *Nature Microbiology*, *5*(8), p. 986-986.

Singer, P.L., 2014. Federally supported innovations: 22 examples of major technology advances that stem from federal research support. *ITIF, February*.

Szarowská, I. (2017). Does public R&D expenditure matter for economic growth?. *Journal of International Studies*, *10*(2).

Szücs, F. (2018). Research subsidies, industry–university cooperation and innovation. *Research Policy*, *47*(7), pp.1256-1266.

Tassey, G. (2020). Globalization and the High-Tech Policy Response. *Annals of Science and Technology Policy*, *4*(3–4), p. 211-376.

Wang, Y., Chen, Y., Li, W., Wang, T., Guo, L., Li-Ying, J., & Huang, J. (2020). Funding research in universities: do government resources act as a complement or substitute to industry funding?. *Economic Research-Ekonomska Istraživanja*, *33*(1), pp. 1377-1393.

Yang, Z., Shao, S., Li, C., & Yang, L. (2020). Alleviating the misallocation of R&D inputs in China's manufacturing sector: From the perspectives of factor-biased technological innovation and substitution elasticity. *Technological Forecasting and Social Change*, *151*, p. 119878.