THE RELATIONSHIP BETWEEN NIH PANDEMIC FUNDING AND RESEARCH PRODUCTIVITY

by

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Abstract

The COVID-19 pandemic has had a lasting effect on all aspects of society and required a quick response to stem the spread of the virus and mitigate its effects. In its efforts to combat the pandemic, the United States federal government appropriated research funding to the National Institutes of Health (NIH) to research the disease, its effects, and possible treatments. The NIH allocated this funding to its constituent institutes according to its mission, goals, and responsibilities in relation to the pandemic. This thesis utilized data from the NIH RePORTER website to analyze the overall changes in NIH funding for fiscal years 2017-2022. Additionally, an analysis of publication data for the same years was conducted to find a measure of research productivity over the course of the pandemic. The two analyses were then used to calculate the cost per publication for the NIH and its 27 constituent institutes. This study found that while the pandemic funding did result in a shift in NIH appropriations to its institutes, the publication costs were only indicative of a trend in research productivity for the NIH overall. A trend in publication costs could only be identified for specific institutes based on the relation of their focus of study to the pandemic.

Primary Reader and Advisor: Jeffrey Kantor, Ph.D.
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Introduction

In early 2020, the COVID-19 pandemic began spreading rapidly around the globe at a seemingly uncontrollable rate. Its virulence, combined with its ease of transmission, created a perfect storm that was unprecedented in the modern era. The situation was exacerbated by the relatively sparse knowledge surrounding the virus and the lack of preparedness and coordinated efforts to stem the spread of disease from country to country. In the United States, the Trump Administration and Congress sought to find solutions to how to stop the spread of the virus, how to treat the disease associated with it, and eventually develop a vaccine. With these goals in mind, five acts were passed over the course of 2020 and 2021 to provide relief (What COVID-19 spending does USAspending track?):

2. Coronavirus Aid, Relief, and Economic Security Act (CARES) (3/27/2020)

Among other aims, the Acts contained provisions to fund research into the pandemic and the virus that caused it. The total funding of the Acts amounted to $4.61 trillion, of which $7.991 billion was allocated to the National Institutes of Health (NIH) by the Department of Health and Human Services (DHHS) (The Federal Response to Covid-19). The NIH used these funds to fund research that could develop treatments, vaccines, diagnostics, and other efforts to combat the pandemic. Due to the NIH’s position as the preeminent agency for medical and health research, the way it disseminates funding has a broad impact on the outcomes of the pandemic. It consists of 27 institutes and centers as well as a central Office of the Director, which each have a
function to manage and support the overall research mission of the NIH and the United States (Sekar et al., 2021). While these institutes operate mostly independently, they do have to follow government mandates for allocating appropriated funds according to the assigned purposes of those funds. The 27 institutes and centers are listed in Table 1 below.

Table 1. List of NIH institutes and abbreviations

<table>
<thead>
<tr>
<th>Institute Full Name</th>
<th>Abbreviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>NATIONAL CANCER INSTITUTE</td>
<td>NCI</td>
</tr>
<tr>
<td>NATIONAL EYE INSTITUTE</td>
<td>NEI</td>
</tr>
<tr>
<td>NATIONAL HEART, LUNG, AND BLOOD INSTITUTE</td>
<td>NHLBI</td>
</tr>
<tr>
<td>NATIONAL HUMAN GENOME RESEARCH INSTITUTE</td>
<td>NHGRI</td>
</tr>
<tr>
<td>NATIONAL INSTITUTE ON AGING</td>
<td>NIA</td>
</tr>
<tr>
<td>NATIONAL INSTITUTE ON ALCOHOL ABUSE AND ALCOHOLISM</td>
<td>NIAAA</td>
</tr>
<tr>
<td>NATIONAL INSTITUTE OF ALLERGY AND INFECTIOUS DISEASES</td>
<td>NIAID</td>
</tr>
<tr>
<td>NATIONAL INSTITUTE OF ARTHRITIS AND MUSCULOSKELETAL AND SKIN DISEASES</td>
<td>NIAMS</td>
</tr>
<tr>
<td>NATIONAL INSTITUTE OF BIOMEDICAL IMAGING AND BIOENGINEERING</td>
<td>NBIB</td>
</tr>
<tr>
<td>EUNICE KENNEDY SHRIVER NATIONAL INSTITUTE OF CHILD HEALTH &amp; HUMAN DEVELOPMENT</td>
<td>NICHD</td>
</tr>
<tr>
<td>NATIONAL INSTITUTE ON DEAFNESS AND OTHER COMMUNICATION DISORDERS</td>
<td>NIDCD</td>
</tr>
<tr>
<td>NATIONAL INSTITUTE OF DENTAL &amp; CRANIOFACIAL RESEARCH</td>
<td>NICDCR</td>
</tr>
<tr>
<td>NATIONAL INSTITUTE ON DRUG ABUSE</td>
<td>NIDA</td>
</tr>
<tr>
<td>NATIONAL INSTITUTE OF DIABETES AND DIGESTIVE AND KIDNEY DISEASES</td>
<td>NIDDK</td>
</tr>
<tr>
<td>NATIONAL INSTITUTE OF ENVIRONMENTAL HEALTH SCIENCES</td>
<td>NIEHS</td>
</tr>
<tr>
<td>NATIONAL INSTITUTE OF GENERAL MEDICAL SCIENCES</td>
<td>NIGMS</td>
</tr>
<tr>
<td>NATIONAL INSTITUTE OF MENTAL HEALTH</td>
<td>NIMH</td>
</tr>
<tr>
<td>NATIONAL INSTITUTE ON MINORITY HEALTH AND HEALTH DISPARITIES</td>
<td>NIMHD</td>
</tr>
<tr>
<td>NATIONAL INSTITUTE OF NEUROLOGICAL DISORDERS AND STROKE</td>
<td>NINDS</td>
</tr>
<tr>
<td>NATIONAL INSTITUTE OF NURSING RESEARCH</td>
<td>NINR</td>
</tr>
<tr>
<td>NATIONAL LIBRARY OF MEDICINE</td>
<td>NLM</td>
</tr>
<tr>
<td>CENTER FOR INFORMATION TECHNOLOGY</td>
<td>CIT</td>
</tr>
<tr>
<td>CENTER FOR SCIENTIFIC REVIEW</td>
<td>CSR</td>
</tr>
<tr>
<td>FOGARTY INTERNATIONAL CENTER</td>
<td>FIC</td>
</tr>
<tr>
<td>NATIONAL CENTER FOR ADVANCING TRANSLATIONAL SCIENCES</td>
<td>NCATS</td>
</tr>
<tr>
<td>NATIONAL CENTER FOR COMPLIMENTARY AND INTEGRATIVE HEALTH</td>
<td>NCCIH</td>
</tr>
<tr>
<td>OFFICE OF THE DIRECTOR, NATIONAL INSTITUTES OF HEALTH</td>
<td>OD</td>
</tr>
</tbody>
</table>
Review of the Literature

Before the COVID-19 pandemic, outbreaks such as the HIV/AIDS pandemic, Ebola virus, and Zika virus have underscored the urgency to prepare for new and emerging diseases, especially when they pose a global threat. In 2016 the Obama Administration commissioned the National Science and Technology Council to create a readiness plan in response to several consecutive outbreaks that could have become world-wide pandemics (The National Science and Technology Council, 2016). The report recommended that the government work with organizations and research institutions to study outbreaks and make sure that these studies are swiftly disseminated to inform policy implementation and appropriate funding allocation (The National Science and Technology Council, 2016). Figure 1 illustrates that since 2015, the NIH has consistently received a higher year-over-year increase in funding than what has been historically observed (Sekar, 2022). Sekar explains that these appropriations increases were accompanied by increasingly specific language that designated the funding towards research aims based on the specific institute or center within the NIH rather than more direct funding initiatives. According to Sekar, this method of appropriation allows a balance between scientific and health priorities without politicizing the process, giving agency to the NIH institutes to allocate funding according to what they determine is most beneficial. This follows with the recommendations made by the National Science and Technology Council (2016), demonstrating the government’s cooperation with NIH institutes in depending on their advising role and expertise rather than dictating how to best allocate research funding.

The onset of the pandemic in 2020 tested the responsiveness of the relationship between the government and the NIH, given that it presented a scenario laid out in the National Science and Technology Council (2016) recommendations. Balaguru et al. (2022) presented data that
showed how, despite the availability of funding appropriated by congress, the NIH response was slow and disproportionate to the magnitude of the pandemic as it spread throughout 2020. Instead of general funding appropriations, the US Government leveraged specific programs such as the Biomedical Advanced Research and Development Authority (BARDA) for more directed funding towards the development of vaccines through partnerships with individual companies and institutions (Kuter et al., 2021). According to Kuter, these collaborations sought to consolidate the research and regulatory pipeline to expedite the research process and clinical trials that would have been slower if the funding was issued in the form of grants. According to Riccaboni and Verginer (2022), grant funding that existed prior to the pandemic was shifted away from the original grant’s purpose towards COVID-19 research (Riccaboni & Verginer, 2022). Riccaboni & Verginer (2022) suggest that this shift in focus came at the expense of other research areas, particularly in clinical trials, and conclude that the NIH will need to re-incentivize other basic science research that was left behind due to the “covidization of research”. Overall, from 2015 onwards, NIH appropriations proposed by Congress and the President have become increasingly restricted towards specific programs or goals, which contrasts with the flexible appropriations towards broad research goals based on the NIH research institute’s specialization or mission (Sekar, 2022). Program-specific funding shifted towards COVID-19 research during the pandemic years, with the COVID-19 relief acts as contributing factors (Sekar, 2022).
In reviewing grant-to-article linkage data from 1980 to 2009, Boyack and Jordan (2011) found that NIH funded grants averaged just under 2 articles per year, with a median time to publication of 3 years. Ádám Kun (2020) found that the average time to publish from submission for a publication in medical sciences globally would have been eight to nine months prior to the pandemic. In the first months of the pandemic, however, Kun (2020) found that the average time to publish reduced drastically to just three days for acceptance. The expedited research publication pipeline, while necessary to combat the pandemic, also resulted in a high rate of retraction among COVID-19 publications, even in comparison to past pandemics and epidemics (Syed et al., 2023). The U.S. Department of Health and Human Services (DHHS), which contains the NIH, was responsible for funding the largest number of unique COVID-19 related publications globally (Mugabushaka et al., 2022).
Problem Statement

While NIH institutional funding is well-documented and readily available, there has not been significant research into how the NIH has allocated funding to its constituent institutes over the course of the pandemic. Each NIH institute has a focus or mission that guides how it distributes the funding it receives for research in the form of grant awards.

In addition to the allocation of funding, understanding the productivity associated with increased funding during the pandemic is crucial. Research publications, being a tangible outcome of grant funding, offer a measure of productivity. This understanding becomes even more vital in the context of a public health emergency when efficient use of resources and timely research outcomes are paramount.

The objective of this study, therefore, was to explore the following research questions:

1. How much did NIH funding change over the course of the pandemic?
2. Which institutes received funding allocations and how did those allocations change over the course of the pandemic?
3. Can the effects of the funding changes be measured via publications metrics and their associated costs?

Methodology

The NIH publishes research funding data in the RePORTER tool via the NIH RePORT website (NIH, 2023). The tool can be used to access grant funding data and the publications that were associated with that funding. Using the ExPORTER feature, the project data for each fiscal year were downloaded into a Microsoft Excel spreadsheet. The data for fiscal years 2016\(^1\) – 2022

\(^1\) Data for fiscal year 2016 was downloaded and manipulated to calculate changes between that year and fiscal year 2017 for the 2017-2018 pre-pandemic period.
were downloaded for the purposes of this research to correspond with the pre- and post-pandemic periods. These spreadsheets contain all pertinent information for each project, but for the purposes of this study the data were organized based on fiscal year, project identifier number (grant ID), funding institute, and total grant funding. In addition to the project data, ExPORTER provides data linking PubMed IDs (PMIDs) from the NIH publication repository, PubMed, and the grant IDs associated with those PMIDs. Spreadsheets with the publication linking data were downloaded for each year. The United States federal government’s fiscal year runs from October 1\textsuperscript{st} through to September 30\textsuperscript{th} of the following year. To establish a timeline for funding, fiscal years 2017 and 2018 were considered pre-pandemic. Fiscal years 2019 and 2020 were considered transitory years pre- and post-pandemic. The federal budget process begins in June of the prior year, usually effective on October 1\textsuperscript{st}; however, the first pandemic-related Acts were passed into law after March of 2020, halfway through the fiscal year 2019, taking effect throughout 2020. While the pandemic was still ongoing during fiscal years 2021 and 2022, they were considered post-pandemic for the purposes of this thesis because policies shifted towards recovery and prevention rather than an emergency requiring urgent research to understand and treat an unknown virus and disease. The resulting data were manipulated using Microsoft’s Power BI application.

In Power BI, the data were separated into two reports. The first combined all project data for the grant IDs from 2016-2022 with the associated funding institute, total project/subproject funding, and the fiscal year. This filtered out any other NIH funding that was not associated with NIH institutes, such as other federal agencies (for example, Veterans Affairs or the Food and Drug Administration). The resulting data contained grant IDs for the years 2016-2022. The publication linking data were organized by PMID and Grant IDs. To associate the publication
linking data to the project data, a relationship was created between the Grant ID columns in both reports, then the funding institute was identified for each grant ID in the publication linking data. This column was also used to filter out any extraneous PMIDs that were not associated with the grant IDs and institutes from those years. After establishing the relationship between the linking data and project data, a third table was created to summarize the data from the two reports to identify each unique instance of PMID, grant ID, and funding institute by fiscal year, resulting in a table of each individual publication and its funding institute for the years 2016-2022. This table was created to account for PMIDs being supported by multiple funding institutes and projects.

Due to a limitation in Power BI, PMIDs couldn’t be directly associated with grant IDs given their many-to-many relationship, where multiple grants can be associated with multiple PMIDs and vice versa, which would create a duplication of the data when attempting to create one single table to produce high level analyses. To address this limitation, an Excel Spreadsheet was created to manually record the total funding and publication counts for each institute by fiscal year based on the measures created in Power BI. The data from this new spreadsheet were then uploaded into Power BI to calculate the following metrics used for data analysis: cost per publication, average funding changes, and year-over-year percent changes for the NIH overall and for each institute. The resulting PowerBI reports allowed for visualizing the publication and funding data by fiscal year and institute for data analysis.
Data Analysis

The first analysis compared the overall funding data for the three periods to establish whether there was a funding trend over the course of the pandemic. Figure 2 shows the total funding that was allocated to the NIH institutes by period, and demonstrated that funding in each period increased over the prior period. Each fiscal year is also represented in Figure 2, with the total funding of each consecutive year increasing over the previous year for all years. Since the data indicates the overall funding increased over the course of the pandemic for all periods and years, it is necessary to review how the funding changed over the same period, which is shown in Figure 3. Although the funding increased year-over-year for all years, the funding change was markedly higher during the pandemic years 2019 and 2020, followed by a comparatively smaller increase during the post-pandemic years 2021 and 2022. Fiscal year 2020 represents the single largest funding change of any year, increasing by over $4.4 billion dollars from fiscal year 2019. 2020 would therefore represent the largest increase in funding, and this increase was carried into the budgets for the post-pandemic period, with marginally higher increases year over year.

The information rendered in Figures 2 and 3 allowed for further in-depth analyses concerning the evolution of funding over time and the impact of the pandemic on total funding. As displayed in Table 1, the total annual funding saw a consistent rise over the span from 2017 to 2022, mirroring the trend presented in Figure 2. Figure 3, in turn, provided the basis for the creation of Table 2, which demonstrates the percentage change in funding from the baseline.
Figure 3. Total funding by two-year period

Figure 2. Funding change by two-year period
year of 2017. Remarkably, the funding grew by 37.59% from 2017 across the five-year period, signifying a substantial surge in NIH funding amidst the pandemic. For a more granular representation of annual variations in funding, Table 3 details the year-over-year percentage change in NIH annual funding. This data reveals the years with the most dramatic funding changes, particularly emphasizing the substantial changes during the 2019 to 2020 period, particularly in fiscal year 2020. While the increments in the 2021 to 2022 period might appear marginal in comparison to the onset of the pandemic, they signal that the considerable pandemic-related funding increase in 2019 to 2020 was sustained in the subsequent years. The persistent upward trend following these increases points to a continued commitment to heightened investment in the post-pandemic era.

Table 1. Total NIH annual funding 2017-2022

<table>
<thead>
<tr>
<th></th>
<th>FY 2017</th>
<th>FY 2018</th>
<th>FY 2019</th>
<th>FY 2020</th>
<th>FY 2021</th>
<th>FY 2022</th>
</tr>
</thead>
<tbody>
<tr>
<td>$</td>
<td>$34,186,320,901</td>
<td>$36,487,177,511</td>
<td>$39,382,017,030</td>
<td>$43,772,247,662</td>
<td>$45,272,551,697</td>
<td>$47,036,896,987</td>
</tr>
</tbody>
</table>

Table 2. Percent increase of NIH Annual funding from baseline year 2017

<table>
<thead>
<tr>
<th></th>
<th>FY 2017</th>
<th>FY 2018</th>
<th>FY 2019</th>
<th>FY 2020</th>
<th>FY 2021</th>
<th>FY 2022</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6.73%</td>
<td>15.20%</td>
<td>28.04%</td>
<td>32.43%</td>
<td>37.59%</td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Percent year-over-year increase of NIH annual funding

<table>
<thead>
<tr>
<th></th>
<th>FY 2017</th>
<th>FY 2018</th>
<th>FY 2019</th>
<th>FY 2020</th>
<th>FY 2021</th>
<th>FY 2022</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6.73%</td>
<td>7.93%</td>
<td>11.15%</td>
<td>3.43%</td>
<td>3.90%</td>
<td></td>
</tr>
</tbody>
</table>

Since the data in Table 3 indicated the impact of pandemic-related funding, the next step was to look at the funding changes for individual institutes over all fiscal years, which would help to indicate the change in the NIH’s funding priorities before, during, and after the pandemic. The data in Table 4 represent the five institutes with the largest percent change (increase or
decrease) in funding by fiscal year. An initial observation was that the largest changes in institutional funding for all institutes were positive for all years except the post-pandemic years 2021 and 2022. Those institutes that had decreased funding for those years (the National Institute of Biomedical Imaging and Bioengineering (NBIB) in 2021; the National Heart, Lung, and Blood Institute (NHLBI) and the National Center for Advancing Translational Sciences (NCATS) in 2022) were also among the largest percent increase in funding the prior year, which could indicate that they were recipients of funding that was particularly directed, and that funding was not continued into the following year. The National Institute on Aging (NIA) is present in all years except for 2020; likewise, the Office of the Director (OD) is present in all years except the post-pandemic period 2020 and 2021. The National Institute on Drug Abuse (NIDA) has the largest overall increase of all institutes, receiving a 40.56% increase in fiscal year 2019, followed by the National Institute of Arthritis and Musculoskeletal and Skin Diseases (NIAMS) in the same year with 32.41% and the National Institute of Allergies and Infectious Diseases (NIAID) in 2020 with 31.10%. NIAID is the only one of these three to appear in the top funding again in 2022. The National Institute on Minority Health and Health Disparities (NIMHD) appears with the second largest and largest increases in 2020 and 2021 respectively, but no other years. The National Center for Complementary and Integrative Health (NCCIH) was among the largest funding changes for 2018 and 2019, then again in 2022 after the pandemic. Of all the institutes, the National Cancer Institute (NCI), the National Institute of Neurological Disorders and Stroke (NINDS), the National Human Genome Research Institute (NHGRI), the National Institute of Mental Health (NIMH), and the National Institute of Nursing Research (NINR) appear only once and only in years prior to the pandemic.
The next step was to evaluate the impact of those changes on the productivity of pandemic research. As previously mentioned, publications are a tangible outcome of grant funding from the NIH institutes, and therefore were used as an indicator for the efficiency of funding. First, the average cost per publication was calculated for all institutes per fiscal year, as shown in table 5. The average cost decreased in the pre-pandemic period from 2017 to 2018, followed by a significant increase in 2019. The average cost per publication decreased for the following two years by a significant amount, until another large increase in 2022. When considering the change in overall funding for the period, fiscal year 2019 and 2022 are remarkable because the cost per publication increased despite the fact that funding also increased for those years, in contrast to 2020, which saw the largest increase in overall funding. Table 6
represents the percent change of average NIH cost per publication with 2017 as the baseline year. The table shows that cost per publication decreased overall, with the sole increase occurring in 2019 when compared to the baseline of 2017.

The year-over-year changes in cost per publication in Table 7 likewise demonstrate the significant increases in 2019 and 2022. While the cost per publication decreased over the course of the pandemic, the overall funding increased over the same period. This could indicate that the volume of publications was lower in 2019 even though funding increased by 7.93%. By contrast, 2020, which received the largest increase in overall funding at 11.15%, saw the largest drop in cost per publication at -10.04%, which could signify a greater overall volume of publications as the pandemic began that continued into 2021, which also saw a drop in costs, albeit to a lesser extent at -3.77%. Costs once again increased by 6.09% in 2022, which could indicate that the volume of publications decreased as the pandemic was winding down. This follows with the overall funding data for that year, which saw a marginal gain of 3.90% over fiscal year 2021, a year which similarly received a marginal increase of 3.43% in comparison to the increases in 2019 and 2020. Fiscal year 2018 merits discussion as well, considering that the overall funding changed by 6.73% from 2017, which is similar to the 7.93% funding increase that was received in 2019. Unlike 2019, however, the 2018 cost per publication dropped by -5.90% from fiscal year 2017, which could corroborate the fact that the number of publications decreased in 2019 as the pandemic began.
To provide a more granular look at the cost per publication data, an analysis was done to calculate the percent change in average cost per publication for the individual NIH institutes. The results of this analysis were then summarized into the five NIH institutes with the largest percent increase or decrease for the cost per publication by fiscal year, as shown in Table 8.

Table 5. Average NIH cost per publication, 2017-2022

<table>
<thead>
<tr>
<th>FY 2017</th>
<th>FY 2018</th>
<th>FY2019</th>
<th>FY 2020</th>
<th>FY 2021</th>
<th>FY 2022</th>
</tr>
</thead>
<tbody>
<tr>
<td>$302,106.55</td>
<td>$284,287.94</td>
<td>$311,609.59</td>
<td>$280,312.85</td>
<td>$269,739.67</td>
<td>$286,175.29</td>
</tr>
</tbody>
</table>

Table 6. Percent change of average NIH cost per publication from baseline year 2017

<table>
<thead>
<tr>
<th>FY 2017</th>
<th>FY 2018</th>
<th>FY2019</th>
<th>FY 2020</th>
<th>FY 2021</th>
<th>FY 2022</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>-5.90%</td>
<td>3.15%</td>
<td>-7.21%</td>
<td>-10.71%</td>
<td>-5.27%</td>
</tr>
</tbody>
</table>

Table 7. Percent year-over-year change of average NIH cost per publication, 2017-2022

<table>
<thead>
<tr>
<th>FY 2017</th>
<th>FY 2018</th>
<th>FY2019</th>
<th>FY 2020</th>
<th>FY 2021</th>
<th>FY 2022</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>-5.90%</td>
<td>9.61%</td>
<td>-10.04%</td>
<td>-3.77%</td>
<td>6.09%</td>
</tr>
</tbody>
</table>

Table 8. NIH institutes with the largest percent increase or decrease in average cost per publication by fiscal year

<table>
<thead>
<tr>
<th>FY 2017</th>
<th>FY 2018</th>
<th>FY2019</th>
<th>FY2020</th>
<th>FY2021</th>
<th>FY2022</th>
</tr>
</thead>
<tbody>
<tr>
<td>NIMHD (+58.41%)</td>
<td>NIMHD (-20.03%)</td>
<td>NIAMS (+33.47%)</td>
<td>FIC (-34.99%)</td>
<td>FIC (+21.76%)</td>
<td>NIAID (+24.11%)</td>
</tr>
<tr>
<td>NCATS (+25.86%)</td>
<td>FIC (-13.15%)</td>
<td>NIDA (+31.42%)</td>
<td>NIAMS (-30.26%)</td>
<td>NHGRI (-14.50%)</td>
<td>NIAMS (+14.67%)</td>
</tr>
<tr>
<td>NIA (+20.81%)</td>
<td>NLM (-13.14%)</td>
<td>OD (+18.93%)</td>
<td>NINR (-19.25%)</td>
<td>NINR (-13.51%)</td>
<td>NIDCD (+10.92%)</td>
</tr>
<tr>
<td>NCI (+18.13%)</td>
<td>NCCIH (-12.17%)</td>
<td>NBIB (+16.54%)</td>
<td>NLM (-18.31%)</td>
<td>NHLBI (+11.59%)</td>
<td>NIAAA (+10.56%)</td>
</tr>
<tr>
<td>NIMH (+12.87%)</td>
<td>NHGRI (-9.46%)</td>
<td>FIC (-16.11%)</td>
<td>NIDA (-16.92%)</td>
<td>NIMH (-10.12%)</td>
<td>NIDDK (+10.43%)</td>
</tr>
</tbody>
</table>
The data presented in the table for individual institutes largely mirrors the changes in the average cost per publication for the entire NIH for each fiscal year. One notable exception is the year 2021, which exhibited the smallest percent changes in both funding and average cost per publication. This could be due to a decrease in the speed at which new research was initiated or perhaps a consolidation of ongoing projects, given that this was a later stage of the pandemic.

Focusing on 2019, NIAMS and NIDA stood out with the largest increases in the average cost per publication. Interestingly, these institutes also received a significant increase in funding that year. Similarly, OD experienced an increase in both funding and cost per publication. The following year, 2020, saw a decrease in the average cost per publication for NIAMS and NIDA, aligning with the overall trend for that year across the institutes. 2020 marked a significant point with the largest percent increase in total funding among all years studied. Interestingly, this influx of funds seemed to have immediately impacted on the number of publications. This is evident from the overall decrease in average cost per publication for institutes in 2020, indicating an increased publication volume. In contrast, 2019 saw an increase in costs despite a boost in funding, suggesting that the impact of funding on the volume of publications may not have been instantaneous, but rather may have had a lag effect. This effect is similarly reflected in the change in average cost per publication for institutes during 2022. Given that all institutes experienced an increase, the volume of publications may have stabilized. This is particularly apparent for NIAID, which was among the institutes with the largest increases in funding for 2020 and 2022. The increased average cost per publication for that institute in 2022 would indicate less publications overall for that year compared to prior years. Of those institutes listed
in 2017, NCI, NCATS, and NIA do not appear in any subsequent year, and NIMHD is included in 2018 and no other year. Notably, NIA experienced a consistent year-over-year increase in its funding, but this was not reflected in its average cost per publication, except for 2017. This could indicate that its publication volume was on par with the changes in funding, which could mean that its funding was relevant to the pandemic.

**Discussion of Data Results**

The purpose of this thesis was to answer the following questions as mentioned in the problem statement chapter above:

1. How much did NIH funding change over the course of the pandemic?
2. Which institutes received funding allocations and how did those allocations change over the course of the pandemic?
3. Can the effects of the funding changes be measured via publications metrics and their associated costs?

In response to the first question, the results of the data analysis indicate that NIH funding increased over the course of the pandemic, with the largest increases in 2019 and 2020 (7.93% and 11.15%, respectively). These years coincide with the start of the pandemic. While the post-pandemic years 2021 and 2022 increased to a lesser extent (3.43% and 3.93%, respectively), they are still significant because this indicates that emergency funding that was appropriated during fiscal years 2019 and 2020 was maintained through those years, and additional funding was granted on top of the pandemic funding that was already available. When using 2017 as a baseline year, the funding overall increased by 37% over the course of the pandemic, which
indicates that the pandemic funding the NIH received from the federal government did affect a significant, lasting change in total NIH funding from 2019 onwards.

The second question addresses the allocation of funding to NIH institutions and centers to determine the funding priorities of the NIH, particularly as they relate to the pandemic funding received by the US Government. As previously mentioned, NCI, NIMH, NINDS, NINR, and NHGRI only appear in fiscal years 2017 and 2018, which could indicate that the focus of these institutes was not emphasized during the pandemic (cancer, mental health, neurological disorders and stroke, nursing, and genome research, respectively). Whether their absence among those institutes with the largest funding changes in subsequent years was due to reduced funding or a smaller increase in funding, the fact that they no longer appear among the largest funding changes could be indicative of a shift in funding from these institutes to focus areas that were more relevant to NIH funding priorities. NIA and OD are present in those fiscal years, but also appear in the top 5 percent funding change for subsequent years during and after the pandemic. The OD is the NIH central office, and therefore its funding is directly related to managing the research initiatives of the NIH itself and its constituent institutes (Sekar et. al., 2022). As previously mentioned, the NIA appears in all years except 2020, which indicates that its focus, aging, was the focus of pre-pandemic funding initiatives, and had relevance during the pandemic. NIDA and NIAMS received the largest and second-largest percent increases in funding compared to any other institute; however, given their focus on drug abuse research and musculoskeletal diseases, respectively, it is possible that this funding allocation was associated with the government’s fiscal year 2019 funding allocation that took place in fiscal year 2018, prior to the pandemic. NIAID received the third largest percent increase in funding in 2020. This increase could be considered directly related to the pandemic considering its focus on infectious
diseases. It is present among the top five institutes in 2022, indicating that its pandemic funding continued into the post-pandemic period. NIMHD received the fourth and fifth largest percent increases of all years in 2020 and 2021, respectively, indicating that its focus on minority health and health disparities had relevance to the pandemic. NCATS likewise received an increase in 2020 and 2021, but its funding fell in 2022, which could mean that its focus on translational sciences had relevance during the pandemic that was not a priority long-term. Like NCATS, NBIB was among those institutes with the largest percent increase in 2020, but it fell in 2021, possibly indicating that its focus on bioengineering and biomedical imaging was immediately relevant at the start of the pandemic, but deemphasized afterwards. Similarly, NHLBI received an increase in 2021, followed by a decrease in 2022, which indicates that its focus on the heart, lungs, and blood was relevant to the pandemic, but this relevance did not carry into the post-pandemic. NCCIH is unique in that it appears in 2018 and 2019, which indicates it could be part of pre-pandemic funding; however, it also had the largest percent increase in 2022. Its focus on complementary and integrative health implies that its funding in 2019 and 2022 was meant for both immediate and long-term goals during and after the pandemic. The data analysis of funding changes therefore indicated that the pandemic had a significant impact on how the NIH allocated its funding to its constituent institutes.

The third question was answered by comparing the funding change data to average percent change in the cost per publication to measure the efficiency of pandemic funding and research productivity. Based on the data analysis, the volume of publications was directly impacted by pandemic funding. This is particularly evident when comparing the funding change for 2018 and 2019. Although they experienced a similar increase in funding, the cost per publication fell by -5.9% in 2018 and rose dramatically to 9.61% in 2019. This would indicate
that the pandemic either resulted in reduced productivity or its funding did not have an immediate impact on publications. This is similar to the research results of Balaguru et. al. (2022), which indicated that there was a significant delay between the NIH receiving funding and grants awarded at the beginning of the pandemic. Furthermore, in 2019 the two institutes that had the largest funding change of all institutes for all years, NIAMS and NIDA, also had the largest increases in average cost per publication, which indicates that their funding did not result in increased publications. It is the same case for OD, whose funding increased that year as well as its average cost per publication; however, as previously mentioned, OD is the central office of the NIH and is primarily an administrative entity that directs research for the rest of the institutes (Sekar et. al., 2021). In contrast to 2019, 2020 had the largest increase in overall funding, but the largest decrease in cost per publication, which indicates that the volume of publications increased dramatically during that year. This result of the analysis reflects the observations of Adam Kun (2020) that found a change in time to publish from months to just days for academic papers. It is notable that the institutes that had the largest increase in funding for that year do not appear among the institutes with the largest percent change of cost per publication. NIAMS and NIDA appear to have a decreased cost per publication 2020, which indicates that these institutes had decreased funding compared to 2019, given that they were found to be the most funded institutes during that year, but are not present among the institutes with the largest funding changes for 2020.

As previously mentioned, 2021 had the smallest percent change in overall funding and cost per publication of all years. The institutes that had the largest percent change in funding for that year are not reflected in the largest percent change in cost per publication, except for NHLBI. This indicates that the funding NHLBI received did not immediately go toward research
publications but was relevant to the pandemic. Overall, the 2021 data indicates that institutional funding shifted towards long-term goals, and this shift carried into 2022, which saw an increase in cost per publication compared to the previous two years. NIAID had the largest percent change in cost per publication and received increased funding for 2022, which further emphasized its role in the pandemic and the long-term goals for COVID-19 research. For all years, the institutional changes in cost per publication largely reflected the overall NIH change in cost per publication. Only specific institutes with the largest change in cost per publication could be compared to the institutes with the largest overall funding changes, which indicates that the institutes that were not included in the data for both analyses could only be considered as part of an overall trend rather than specifically being affected by the pandemic funding.

The first observation of this study was that the pandemic not only had a clear impact on NIH funding, but that impact could be identified through the percent change in funding for individual research institutes. First, NIAID was the primary institute to receive pandemic research funding, due to its mission focus on infectious disease research. Apart from NIAID, funding was allocated to institutes whose focus was related to those populations that are most vulnerable to the virus and its disease, COVID-19. According to the CDC (2023), older adults are at the highest risk of more severe illness due to COVID-19, and most COVID-19 deaths occurred in people 65 and older. The increased severity and mortality in older populations would therefore merit investigation by the NIA, which is focused on research related to aging and received increased funding during the pandemic. Due to social disparities such as healthcare access, the CDC (2023) indicated that minority groups and people with disabilities are also at an increased risk of severe illness and death, which is the primary focus of the NIMHD, which received increased funding in 2020 and 2021. The CDC also states that those with pre-existing
health conditions are at risk of severe illness and death, which is relevant to the NHLBI and its focus on diseases related to the heart, lungs, and blood (NHLBI, n.d.). Due to its focus on biomedical imaging and bioengineering, the NBIB was relevant to assisting in developing methods for testing and diagnosis of the virus via two NIH pandemic programs: Rapid Acceleration of Diagnostics Tech and Advanced Technology Platforms (NBIB, n.d.). Likewise, with its mission focusing on translational medicine, the NCATS was important for finding methods of quickly translating lab research into clinical trials (NCATS, 2023). The focus for NCATS and NBIB would have been immediately relevant at the start of the pandemic, but it is possible that this relevance did not continue into the post-pandemic period as the priorities likely shifted from short-term needs to long-term research, such as on the impacts of the pandemic or long-term effects of the disease.

The second observation of this study was that the average cost per publication only qualified as a measure of overall trends of research productivity and funding efficiency at the NIH during the pandemic when compared to funding changes. At the institutional level, only certain institutes that experienced a change in average cost per publication could be inferred to be related to their funding changes. The results of the data analysis indicated that the cost per publication lead to increased publications particularly at the beginning of the pandemic, during fiscal years 2019 and 2020, which reflects the urgency of the pandemic and the impact of emergency funding. The changes in cost per publication and funding changes for NIAMS and NIDA could reflect the effects of the “covidization of research” as observed by Riccaboni & Verginer (2022), wherein the grant funding that existed prior to the pandemic was shifted to pandemic-related projects. The data for the post-pandemic years indicate that time to publish began to increase, possibly as a normalization of the research timeline and shifting goals to post-
pandemic initiatives as part of recovery. To further this point, the increased cost per publication and funding for NIAID in 2022 particular indicates a prioritization of longer term goals for pandemic recovery. These goals include researching the long-term health effects of those who were infected by the disease (such as “long COVID” and multisystem inflammatory syndrome in children) and further vaccine development in response to variations of the SARS-COV-2 virus (NIAID, 2022).

Conclusion

As stated in the problem statement section of this thesis, the purpose of this study was to answer the following questions:

1. How much did NIH funding change over the course of the pandemic?
2. Which institutes received funding allocations and how did those allocations change over the course of the pandemic?
3. Can the effects of the funding changes be measured via publications metrics and their associated costs?

In answering these questions, the study found that pandemic funding did have an overall impact on the funding changes for the NIH as a whole and its constituent institutes. Identifying those institutes with the largest change in funding provided evidence for how the NIH utilized pandemic funding and shifted the focus of the NIH to specific institutes with a particular focus. The effects of the funding changes via publications costs was not conclusive for individual institutes, except in specific cases; however, it did indicate an overall trend in NIH publications that identified the years where the pandemic funding was most urgent and its shifting goals. Given the recency of this data and the length publication timeline, further research would be
necessary to determine the longer-term impacts of the pandemic and the outcomes of pandemic funding. In particular, while this study did find trends in the impacts of cost per publication, there are other measures that could be explored to determine the impact of pandemic funding, such as citations metrics. Nevertheless, it is clear that pandemic funding had a real impact on how the NIH allocated its funding and the volume of publications over the course of the pandemic.
Cited References


PMID: 35545399; PMCID: PMC9096053.


https://doi.org/10.1136/amiajnl-2011-000213


https://doi.org/10.1016/j.vaccine.2021.03.077


https://www.niaid.nih.gov/diseases-conditions/coronaviruses


https://www.nhlbi.nih.gov/covid/research-strategy


https://doi.org/10.1371/journal.pone.0263001


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Appendix A. Total funding by funding institute and year
Appendix B. Total Publications by funding institute and year
Appendix C. Year-over-year percent funding change by funding institute
Appendix D. Change in number of publications compared to prior two-year period by funding institute
Appendix E. Overall funding change by funding institute and two-year period
Appendix F. Cost per publication by period and average cost per publication for all years
by funding institute