# 政府在基础研究中的作用：来自中国高能物理研究的证据

# The Role of Government in Fundamental Research: Evidence from Chinese High Energy Physics Research

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培 养 单 位 ： 苏世民书院

学　　　科 ： 全球领导力

研　究　生 ： 赵睿

指 导 教 师 ： 李应博 副教授


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# 政府在基础研究中的作用：来自中国高能物理研究的证据

赵睿

# The Role of Government in Fundamental Research: Evidence from Chinese High Energy Physics Research

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**Jared Burleson**

Thesis Supervisor： Associate Professor LI Yingbo

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# 摘 要

没有政府投资和政策的支持，基础研究是不可能的。随着中国成为基础研究领域的全球强国，了解中国政府决定如何以及为何投资基础研究的独特制度势在必行。为了研究政府在支持基础研究中的作用，必须关注世界特别是中国的历史发展和政策方法。政府对支持特定基础研究领域的价值的认可在第二次世界大战期间的曼哈顿计划之后起飞，并从那以后继续扩大。中国的基础研究包括广泛的科学和技术研究。中国政府已经确定基础研究是促进经济和社会发展的一个关键方面。这种形式的基础研究植根于以发现为导向的有目的的研究，具有产生超出其直接研究前景范围的应用和技术效益的潜力。本文将通过选择一个受到中国政府关注的特定基础研究领域来缩小政府对基础研究的支持的定量分析范围。高能物理是基础研究的一个领域，其中以发现为导向和有目的的研究有可能产生应用和技术进步。在中国，政府通过国家自然科学基金等机构向个人研究人员提供资助，并通过与北京高能物理研究所的正负电子对撞机等重大研究合作的合同来支持高能物理研究在中国科学院。最近，中国政府承诺建造圆形正负电子对撞机，该对撞机旨在成为同类中最大的对撞机，能够突破粒子对撞机技术的界限，以研究我们宇宙的基本性质。为了响应政府的承诺，人们有兴趣了解政府究竟如何支持中国的高能物理研究。本文评估了中国政府机构的发展，以及通过提供资金、确保场地和资源分配来支持基础研究，特别是高能物理研究的机制。通过对中国国家自然科学基金委员会关于通过 Web of Science 核心合集收集的中国高能物理出版物的研究资助和高能物理出版物的公开数据进行定量分析，本文强调政府正在坚持其承诺的增加支持的目标用于中国的基础研究和高能物理研究。本文发现，从 2001 年到 2019 年，基础研究经费增加了 2458%。此外，我们发现，以高能物理研究为核心内容的国家自然科学基金委授予的基础物理研究经费增加了 880%，高能物理方面的论文发表量增加了 880%。同期增长 1792%。

关键词：基础研究；科技政策；高能物理学；中国；政府投资

# ABSTRACT

Fundamental research is not possible without the support of government investment and policy. As China emerges as a global power in fundamental research, it is imperative to gain an understanding of the unique system in China by which the government decides how and why to invest in fundamental research. In order to study the role of government in supporting fundamental research, attention must be paid to the historical developments and policy approaches in the world and specifically in China. Governments' recognition of the value of supporting specific areas of fundamental research took off after the Manhattan Project during World War 2, and has continued to expand ever since. Fundamental research in China encompasses a broad range of science and technology research. The government in China has identified that fundamental research is a key aspect of promoting economic and social development. This form of fundamental research, which is rooted in discovery-oriented and purposed research, has the potential to generate applications and technological benefits beyond the scope of its immediate research prospects. This paper will narrow the scope of a quantitative analysis of government support for fundamental research by choosing one particular field of fundamental research that has received attention from the Chinese government. High energy physics is one field of fundamental research where discovery-oriented and purposed research has the potential to generate applications and technological advancements. In China, the government supports high energy physics research through grants to individual researchers through institutions such as the National Natural Science Foundation of China and through contracts to major research collaborations such as the Beijing Electron-Positron Collider at the Institute for High Energy Physics in the Chinese Academy of Sciences. Recently, the Chinese government has committed to building the Circular Electron-Positron Collider, which is designed to be the largest collider of its kind and capable of pushing the boundaries of particle collider technology to study the fundamental nature of our universe. In response to the government's commitment, there is an interest in understanding how exactly the government supports high energy physics research in China. This paper assesses the development of government institutions in China and the mechanisms used to support fundamental research, specifically high energy physics, through providing funds and securing site and resource allocation. By performing a quantitative analysis on publicly available data from the National Natural Science Foundation of China on research grants and on high energy physics publications in China gathered through the Web of Science Core Collection, this paper emphasizes the government is maintaining its committed goal of increasing support for fundamental research and for high energy physics research in China. This paper finds that from 2001 to 2019, funding for fundamental research has increased 2458%. Additionally, we find that the grants awarded by the National Natural Science Foundation of China for fundamental physics research, of which high energy physics research is a core element of, has results in an increase in funding of 880% and publications in high energy physics has increased 1792% over the same time period.

**Keywords:** Fundamental Research; Science and Technology Policy; High Energy Physics; China; Government Investment

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# LIST OF SYMBOLS AND ACRONYMS

| | |
|---|---|
| BEPC | Beijing Electron-Positron Collider |
| BES | Beijing Spectrometer |
| CAS | Chinese Academy of Sciences |
| CCP | Chinese Communist Party |
| CEPC | Circular Electron-Positron Collider |
| CPC | Central Planning Committee (China) |
| DOE | Department of Energy (US) |
| DYS | National Science Fund for Distinguished Young Scholars (China) |
| EYSF | Excellent Young Scholars Fund (China) |
| GPF | General Program Fund (China) |
| HEP | High Energy Physics |
| IHEP | Institute of High Energy Physics (China) |
| JUNO | Jiangmen Underground Neutrino Observatory |
| KPF | Key Program Fund (China) |
| LDRF | Less-Developed Region Fund (China) |
| LHC | Large Hadron Collider |
| MIT | Massachusetts Institute of Technology |
| MOST | Ministry of Science and Technology (China) |
| MPH | Math/Physics |
| NNSF | National Natural Science Fund (China) |
| NSF | National Science Foundation (US) |
| NSFC | National Natural Science Foundation of China |
| NUSW | National Union of Scientific Workers (UK) |
| OAP | Open-Application Program (China) |
| OSRD | ABC |
| PH2 | Physics II |
| PRC | People’s Republic of China |
| R&D | Research and Development |
| SCSC | Superconducting Super Collider (US) |

| | |
|---|---|
| UK | United Kingdom |
| UNESCO | ABC |
| US | United States of America |
| USDA | United States Department of Agriculture |
| YSF | Young Scientists Fund (China) |

# CHAPTER 1 INTRODUCTION

## 1.1 Background and Motivation

Support for fundamental research has become a key aspect of science and technology policy in recent decades. In China, government and party support for fundamental research has resulted in increased spending for the Ministry of Science and Technology and the National Natural Science Foundation of China (National Bureau of Statistics of China, 2019). High energy physics is one field of scientific research that has been the target of recent Chinese government support (NSFC, 2020). Investing in high energy physics research is instrumental to executing the government and party's plan to expand support for fundamental research for the furthering of economic and cultural development. This study is motivated to provide context into the government's increasing support of high energy physics research and to present specific data to quantify the increasing support and highlight increasing outputs.

While there exists literature that discusses the historical development of fundamental research in science and technology policy, there lacks substantial direction towards the impact of this historical development in the context of China. As such, this study is interested in presenting a condensed overview of the emergence of the Chinese government and party's support for fundamental research. This study will discuss the broader origins of fundamental research and its impact on early and mid-twentieth century science and technology policy in the world and in China (see Chapter 2). The methodology of this paper, as a quantitative study of high energy physics research funding and outputs through the past twenty years, is outlined in Chapter 3. Next this study will present an overview of the development of high energy physics research and policy in China and how this development has led to modern support for China's growing high energy physics community (see Chapter 4). High energy physics research is crucial for scientific and technology advancements and the increased support of high energy physics research and projects highlights the importance placed on this research by the government and party. This study will then discuss how the government supports fundamental research and high energy physics through the use of institutions and finances (see Chapter 5), with particular attention given to certain funds that have received increased resources in recent years.

To support the literature and this study's claims about the increasing support of high energy physics and fundamental research in China, this study will present compiled public data from the MOST and NSFC as well as highlight specific recent projects in high energy physics that demonstrate the increased support of these fields (see Chapter 6.1 and Chapter 4.2). Lastly this study will look at the rate of recent publications in high energy physics in China to demonstrate how the increase in support from the government and state is beginning to lead to an increase in notable research and thus is successful in supporting high energy physics research in China (see Chapter 6.2).

The purpose of this study is to present a condensed overview of the history of fundamental research and high energy physics science and technology policy in China and to present data to measure the recent two decades of government support through contracts and grants to research and the outputs of government support through publications, citations and major discoveries.

## 1.2 Research Questions and Significance

This study will address the following research questions:

- Why does government have a responsibility to support fundamental research?
- How does the PRC and CCP support fundamental research?
- What is the current state of high energy physics research in China?
- What central government support is being directed towards high energy physics research in China?
- How is the effectiveness of government support measured in China?

This study will address each of these research questions by providing support of existing literature, commentary and data from public government sources. By presenting answers to these research questions, this study will construct an overview report of fundamental research support in China and how the high energy physics research community is benefiting from increased support by the government.

# CHAPTER 2 LITERATURE REVIEW AND ANALYTICAL FRAMEWORK

There exists substantial literature that puts into perspective the role of government in supporting fundamental research. It is crucial to understand the foundation this literature provides in historical context in order for this study to analyze how the government and party in China support the advancement of fundamental research and specifically high energy physics.

## 2.1 Framing Fundamental Research

Before discussing the historical development of fundamental research, it is crucial to define fundamental research and the surrounding terminology that appears in literature. "Fundamental research" is science and technology research that is "carried out to acquire new knowledge of the basic principles of objective phenomena and observable facts and is not intended for any…specific application or use," (Fang, 2020, p. 417), There is an additional term for the type of research, referred to in many sources as "basic research". This study chooses to treat "basic research" and "fundamental research" as synonyms, and as such this study will take their mention in literature as interchangeable. This study uses the term "fundamental research", but many of our sources frequently use "basic research" and thus it is important to note that this study will treat these two concepts as unified. Additionally, sources in Chinese will use the term "基础研究", which can be translated as either "basic research" or "fundamental research", and therefore this is also another term that for the purposes of this study we will treat as the same.

### 2.1.1 Pasteur's Quadrant and Models in Literature

Many experts in science public policy attempt to define the scope of science and technology research in order to cluster together and identify certain functions of research. There are those who present a linear-spectrum model of science and technology research (Stokes, 1997). On one end is "pure science research", that is research conducted in the pure sciences that emphasizes discovery for the sake of knowledge and understanding that does not lend itself to an applied nature, and on the other end is “applied or experimental research”, that is research focused on producing applications or technologies that serve a function and can be utilized for further study and research. However, this linear system fails to accurately depict the complexities involved in science and technology research. Scientific research conducted for the purpose of fundamental understanding has been instrumental in generating applications, and as such it is inappropriate to present the function of scientific research with respect to purpose and outcome as synonymous. This study supports the more apt classification introduced by political scientist Donald Stokes in 1997 known as Pasteur’s Quadrant in Figure 2.1 (Stokes, 1997).

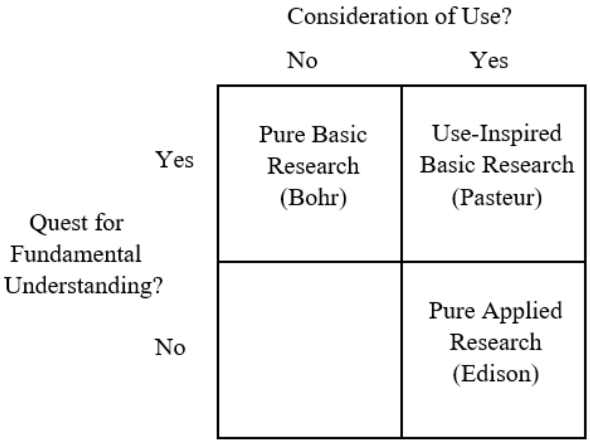


Figure 2.1 Pasteur’s Quadrant

Stokes argues that there are two separate dimensions to consider when discussing scientific research. On one axis is the quest for fundamental understanding, whether a research project is focused on uncovering the fundamental nature of a field of science. The second axis is the consideration of use, whether the research is conducted with insight into potential applications or not. This classification is incredibly important for defining “fundamental research” because such research can either be done with or without a consideration of use. This classification is particularly important when dealing with certain fields of physics, such as high energy physics, and the nature of research projects and experiments in the field. While the purpose of this study is not to present a nuanced model for defining scientific research, this study will present how the CCP and the government in China understand the value in supporting primarily "use-inspired basic research", which is the primary factor in driving increasing support for "fundamental research".

### 2.1.2 Government-Institution Model of Research Support

We present a model for the role of government in supporting fundamental research in Figure 2.2. In this figure, we highlight how government resources, collected from various sources of government revenue and finances, are allocated to central and local administrations which are directed towards research institutions, universities and individual researchers based on a system of grants and contracts that require government approval. These grants and contracts are instrumental in supporting the research, from providing financing to acquire research equipment, higher personnel and support the basic needs of researchers. Lastly, we note how individual researchers and collaborations are responsible for discoveries, publications and most importantly new technologies that can be utilized by the government and industry to generate new revenue and improve society. This model demonstrates that government is connected to the outputs of research through its investment in institutions and direct support of research through grants. Without the support of government, much of the research capabilities in fundamental research would not be possible because it would require industry support, which rarely invests in fundamental research opportunities.

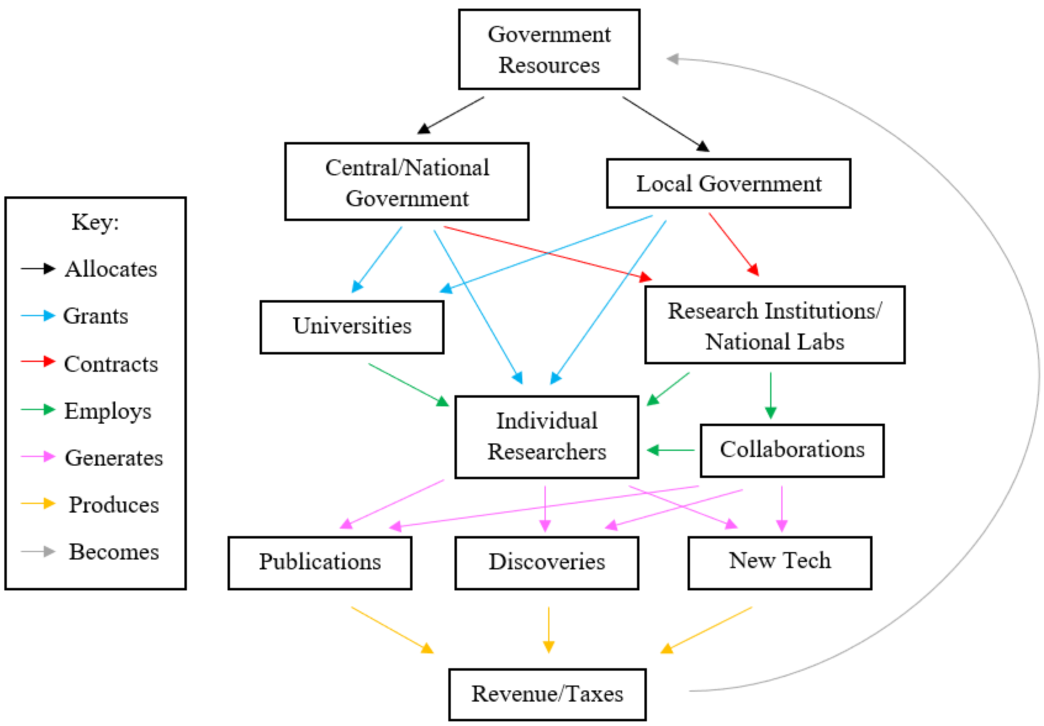


Figure 2.2 Model for Role of Government in Research

## 2.2 Emergence of Fundamental Research

Scientific research from a fundamental approach into the pure sciences has existed as far back as the Ancient Greeks (Schauz, 2014). However, fundamental research emerged as a term used to describe scientific research in the 1920s in the United States of America and the United Kingdom, and it is from this period where the story begins on the relationship between government and fundamental research (Pielke, 2012). In order to understand the context of how fundamental research relies on government support today, it is crucial to study the development and emergence of fundamental research and how it was supported and financed by governments in the twentieth century.

### 2.2.1 Pre-WW2 US and UK

Scientific research in the twentieth century was tied closely to government. Through oversight, regulation and financing, government was instrumental in supporting and framing scientific research. In the US, the first mention of “basic research” came from a Congressional hearing in 1919; however, its original usage was very different from what is defined as fundamental or basic research today (Pielke, 2012). In these Congressional hearings, officials from the USDA discussed the importance of government investment in agriculture research. While the kind of research that this hearing was concerned with is more closely associated with what is regarded as applied research today, it is important to understand that as early as 1919, government officials in the US were familiar with discussing the role of government in advocating and supporting for scientific research. It would take another twenty-five years for the idea of fundamental research in its contemporary understanding to influence government officials and politicians (Pielke, 2012).

Alongside the first mentions of “basic research” in Congress, scientists across the US and UK were writing about the value of fundamental research. In 1926, Professor Arthur Kennelly of Harvard University wrote in Science magazine that, “many cases of scientific research which have been made without any suspicion of applicability have subsequently come to be applied to very practical use,” (Kennelly, 1926, p. 2). Even in the 1920s, science policy experts were recognizing that scientific research has the potential to generate applications and value to society, even if the intended direction is not as such. In fact, "[i]t would seem that the only differences which necessarily separate a scientific research of the basic or non-applied type from one of the applied type lies in the aims and motives of the researcher… Useless scientific knowledge is now a contradiction in terms," (Kennelly, 1926, p. 2). While Kennelly's view was a minority at the time, it would later be regarded as "conventional wisdom" once governments recognized the value in supporting fundamental research (Pielke, 2012). Kennelly was among many scientists at the time that believed that scientific progress benefited immensely from a lack of application-driven thinking, instead preferring to focus on the goal of discovery.

In the UK, many scientists organized together into the National Union of Scientific Workers (NUSW) which advocated for government-supported and financed fundamental research (Pielke, 2012). The NUSW argued that fundamental research was essential to further scientific advancement and the progression of society. The NUSW argued that "fundamental scientific research is not adequately supported by the State, local authorities, or the general public," in the UK (NUSW, 1924, p. 1). The NUSW justified the need for greater investment in fundamental research by arguing that "fundamental research…though not directed purposely to practically useful results…does actually lead to them," (NUSW, 1924, p. 1). Throughout the 1920s and into the 1930s, fundamental research became a core aspect of the development framework and logic that advocated for government support for research. Fundamental research gained its most compelling argument in favor of government support during the Second World War. It was during the war that the US and the UK recruited many scientists and funded research projects in areas of radio, electronics, and most importantly nuclear physics that were ultimately instrumental in winning the war and eventually post-war society. While initial advocates for fundamental research were found in many areas of scientific research, "[b]y the time the atomic bombs exploded over Hiroshima and Nagasaki, the political center of gravity in US science policy had shifted from the agricultural community to the physical scientists," (Pielke, 2012, p. 352).

### 2.2.2 Bush's "Science The Endless Frontier"

In 1945, Vannevar Bush, an American engineer who was at the time the director of the OSRD, wrote a report to US President Truman titled "Science The Endless Frontier" which advocated for the expansion of government-supported research (Bush, 1945). This report is widely regarded as the most influential contemporary document to advocate for the role of government in scientific research. Bush, who earned his Ph.D. in electrical engineering while working with Professor Kennelly at MIT, spent most of his career advocating for the importance of government support for scientific research. In his report to the President, Bush drew upon many of the arguments prevalent in the 1920s and 1930s that advocated for government involvement in fundamental research. Bush argued that, “[a]dvances in science when put to practical use mean more jobs, higher wages, shorter hours, more abundant crops, more leisure for recreation, for study, for learning how to live without the deadening drudgery which has been the burden of the common man for ages past,” (Bush, 1945, Chapter 1). Bush asserted that scientific research could be understood to have general benefits and outcomes such as, “higher standards of living…the prevention or cure of diseases…conservation of our limited national resources…[a] means of defense against aggression,” (Bush, 1945, Chapter 1). Bush identified that in order to generate these benefits to society, “the flow of new scientific knowledge must be both continuous and substantial,” (Bush, 1945, Chapter 1). Bush wrote broadly about the value of the government investing in scientific research, noting that, “since health, well-being, and security are proper concerns of Government, scientific progress is, and must be, of vital interest to Government,” (Bush, 1945, Chapter 1). Bush provided a list of fundamental principles for government support for scientific research.

- Government should provide stability of funds over extended periods.
- Government should develop an oversight agency comprised of experts and interested persons, not uninformed politicians.
- Government should provide grants or contracts to outside institutions.
- Government should allow outside institutions to manage implementation of support of basic research.
- Government should create an agency for science policy that directly reports to the President or Congress to maintain the relationship between science and democracy.

In reference to fundamental research, Bush provides a concise and important definition that “[b]asic research is a long-term process – it ceases to be basic if immediate results are expected on short-term support,” (Bush, 1945, Chapter 6). Bush asserts the importance of a government that funds scientific research that is “without thought of practical ends,” because it will “result in general knowledge and an understanding of nature and its laws,” (Bush, 1945, Chapter 3). Bush’s report came at the end of WW2, in which the scientific progress of physicists had rapidly developed nuclear fission and created the atomic bomb in a few short years, largely due to the abundance of government support for these projects. Bush, as director of the OSRD, had seen first-hand the benefit of government support for fundamental research in discovery and understood the practical application of this research. The Manhattan Project is an example of government-driven scientific research that incorporated existing fundamental research into a new form of use-inspired research in fundamental fields of study. This research had broad implications and impacts beyond the initial scientific discoveries. To Bush and to many of his contemporaries, the Manhattan Project and similar wartime scientific investments were evidence of the value of scientific research if directly and substantially supported by the government.

### 2.2.3 Fundamental Research after 1945

In 1946, US President Truman endorsed government support of “fundamental research” by saying that “as [the US] move into a new period of peace, basic research and the application of the results become even more important,” (Truman, 1946, p. 1). Four years later, Bush’s goal of establishing a government body for science policy and research was realized when the NSF was formed in 1950. In 1953, the NSF presented their annual report which outlines “basic research” and how government can support fundamental research in the US (NSF, 1953b, p. 1). The NSF viewed fundamental research as “motivated by a driving curiosity about the unknown,” and relied heavily on Bush’s report as evidence for the role of the NSF in advocating for government support of fundamental research (NSF, 1953b, p. 1). In the third year of operation, the NSF was already identifying research projects and institutions in the areas of “biological, medical, mathematical, physical and engineering sciences” that were exploring fundamental research and provided nearly $1.7 million in grants to these research projects (NSF, 1953a, p. 1). The NSF would quickly emerge as the premier institution in the US for supporting fundamental research by providing research grants to scientists at various institutions. In 2012, Pielke studied the frequency of “basic research” used in Congressional Records and Hearings and in two of the most prominent scientific magazines, Science and Nature (Pielke, 2012). Pielke notes that in both instances, “basic research” soared in popularity following the Second World War, Bush’s letter to the President and the eventual establishment of the NSF. Pielke draws a connection between the initiation of government support for fundamental and the widespread use of terminology in government and in science (Pielke, 2012).

In 1984, the Division of Statistics on Science and Technology in the Office of Statistics in the UNESCO published a “Manual for Statistics on Scientific and Technology Activities,” (UNESCO, 1984). In this manual, UNESCO, which is a branch of the UN that represents over 190 countries from all around the world, provides an outline for fundamental research. This manual contains one of the first instances of an international organization addressing the idea of government support for fundamental research. While many developed nations had already explored the importance of government support for fundamental research, the value of an international body such as the UNESCO in advocating for the importance of government support for fundamental research was immense. UNESCO tracked how recent progress in fundamental research has led to applied research and experimental developments in many areas of science and technology. The essence of the UNESCO report was that by investing in fundamental research governments were able to generate applied research and experimental development that would otherwise not have been possible. Fundamental research is essential for ensuring future economic and technological advancements and according to the UNESCO, investment in fundamental science is directly correlated to the broader development of science and technology research and development (UNESCO, 1984). It is crucial that other nations also work towards supporting fundamental research so that they too can foster economic and technological developments.

## 2.3 Fundamental Research in China

China is a nation that has seen an explosion of economic and social development in recent decades. Alongside its economic and industrial development, China has also seen a revolution in science and technology, driven by the government’s support of scientific research, in particular fundamental research and its ability to bring about economic and social development.

### 2.3.1 Zhou Enlai and Early Developments

Science and technology were crucial to CCP leaders in the early days of the PRC. Just a month after the CCP defeated the Nationalists and established the PRC, the CAS was founded on November 1st, and became the premier institution for scientific research in China (CAS, 2022). As such, science and technology became a significant focus of many early CCP members and often was a center piece of policies. In 1963, Premier Zhou Enlai, speaking at the "Science and Technology Work Conference in Shanghai" expressed the significance of modernization in science and technology and the role that the government should play in supporting research (Zhou, 1963). Premier Zhou Enlai asserted that scientific research devoted to "seeking truth from facts" was an essential element in developing the PRC in science and technology (Zhou, 1963, p. 1). Premier Zhou Enlai along with several other party officials led the campaign to empower scientists and scientific institutions to conduct research into discovery for the purposes of developing society (Zhou, 1963). Premier Zhou Enlai's work laid the foundation for future policies in the PRC that addressed how to support fundamental research for the purposes of developing certain industries and technologies.

### 2.3.2 Deng Xiaoping's "Four Modernizations"

At the Third Plenum of the Eleventh Committee of the CCP, Deng Xiaoping proposed "Four Modernizations" as a goal to strengthen the fields of agriculture, industry, defense and science and technology in China during the "reform and opening up" period (Deng, 1978). While science and technology policy had existed in China prior to Deng Xiaoping's proposal, it was at this point that science and technology policy received attention and support from the highest officials in China for modernization and advancement (Fang, 2020). Six years later in 1985, the First National Science and Technology Census was launched which officially introduced the UNESCO classification of scientific research classification (Fang, 2020). In doing so, the government separated fundamental research from applied research and experimental development and was able to lay the foundations for policy formation related to supporting the different areas of scientific research.

In 1989, the First National Basic Research Work Conference was held and it set out to define what types of scientific research are considered fundamental research (Fang, 2020). Fundamental research includes “research on general principles and laws of natural science… general principles of applied sciences… important (product, process) technologies and methods… [and] systematic collection, arrangement, and analysis of important basic data,” (Fang, 2020, p. 417). The conference identified that the current state of science and technology research and development in China lacked significant research into applied sciences that employed scientific principles of fundamental research. As a result, it was proposed that the government should “link basic research with national interests and national goals…while continuing to support pure scientific research driven entirely by curiosity and not considering the prospect of application,” (Fang, 2020, p. 417). A significant takeaway from this conference was the overwhelming support for “strategic basic research” that identified the role of government in supporting fundamental research that is purposeful to develop certain aspects that the government has a vested interest in promoting, such as national defense or public health. Deng Xiaoping’s inclusion of science and technology in his “Four Modernizations” inspired a generation of government conferences and discussions about how the PRC can support fundamental research through government institutions and financing.

### 2.3.3 Government Promotes Fundamental Research

In 1995, the CPC Central Committee and the State Council released a report on “Accelerating the Progress of Science and Technology” in which it outlined that “basic research should place national goals in an important position,” and that the core responsibility of government support for fundamental research is to identify research that, “focus[es] on solving basic theoretical and technological problems for future economic and societal development, and create[s] new technologies and methods,” (CPC Central Committee and the State Council, 1995, p. 1). In this report, focus is placed on how science and technology policy will be an important feature of the next fifty years of governance in China and the role that science and technology will play in economic development is directly the result of the efforts by government and party to support fundamental research. Lastly, and most importantly for studying government support for fundamental research, the National Assembly of the PRC adopted the “Outline of the National Medium- and Long-Term Science and Technology Development Plan” in 2006, which served as the main government policy for how science and technology policy would be executed over the next fifteen years (National Assembly of the PRC, 2006). The development plan concluded in 2020, and as there is sufficient evidence to evaluate whether the goals of the development plan, in particular to fundamental research were met.

The development plan sought to "significantly enhance the ability of independent innovation…[and] enhance the ability of science and technology to promote economic and social development," (National Assembly of the PRC, 2006, p. 1). Specifically, the plan provided outlines for how the government planned to address certain areas of research issues, such as in fundamental science. Overall, the intended impact of the plan on fundamental research was to "strength basic science and frontier technology research, especially interdisciplinary research," (National Assembly of the PRC, 2006, p. 1). The government identified frontiers of science where fundamental research must be supported. Fields such as cosmology, condensed matter, neuroscience and numerous others were identified as crucial frontiers worthy of investing in "fundamental research" projects (National Assembly of the PRC, 2006). One crucial frontier is the study of the "deep structure of matter" in which the development plan noted that importance of research direct towards studying the "structure and physical laws of matter…in extreme states such as high energy," (National Assembly of the PRC, 2006, p. 1). The last fifteen years of science and technology policy in China have been a result of the development plan laid out by the State Council. In order to understand the impact of government support on fundamental research in China, particularly since the 2006 development plan, it is first important to discuss the structure of government investment and recent policy reforms to investment structure in China.

## 2.4 Recent Studies on Public Funding

In recent years, there has been considerable attention paid to the increase in government support of fundamental research. Science policy analysts are interested in understanding what drives basic scientific achievement in China. Several analyses have focused on macro-trends in funding and resource allocation. These macro-level studies have identified several possible factors in explaining the recent scientific advancement. The generous public funding for science and technology, large science and technology workforce, increasing collaboration domestically and internationally, and a highly competitive culture at institutions have all been examined as viable explanations for macro-trends in fundamental research outputs. Recently Hu (2020) chose to look at a micro-trend to study the effects of government reforms to grant size and duration within the National Natural Science Foundation of China (NSFC) on increasing scientific output, particularly in the area of fundamental research (Hu, 2020). This report is believed to be the first of its kind to study specific grant allocation through the OAP within the NSFC and to determine the effect it has on fostering scientific advancement in China.

Hu (2020) provides an overview of the structure of the NSFC, a vice-ministerial level statutory board within the MOST. Hu describes the NSFC as one of the main sponsors of fundamental research in China and cites a report in which almost one-third of China's funding for fundamental research in 2016 was financed through the NSFC. Within the NSFC, there are two main categories of funding programs: the first is NSFC-designated research directions and priorities, the second is open to publication application and supports researcher-initiated research. The OAP falls into the second type of funding programs within the NSFC and operates similarly to the NSF in the US. The OAP annually announces grant size and duration information in December with applications due to the following March, thus the year-to-year grant size and duration changes can be tracked. The OAP reports each year the grants that it awards, the amount and the year as well as the area of study of the research. There are eight major areas of scientific research: math/physics, chemistry, life sciences, geological sciences, engineering and material science, information science, management science, and medical science.

In 2011, the NSFC announced dramatic changes to its funding specifically to grant size and duration. Hu (2020) notes that this "exogenous funding shock" was present in each of the eight areas where grants were awarded in the OAP (Hu, 2020). Interestingly; however, the increasing in funding was only reflected in an increase in the grant size and length, not in the total number of grants awarded. Hu (2020) measures the effectiveness of this funding infusion by studying the 2010 and 2011 cohorts. Hu (2020) looks at the types of grants award in 2010, before the new funding was announced, and in 2011, the first year that the funding reforms were introduced. Hu (2020) is interested in not just the amount of funding allocation, but what effect the increase in funding had on publications, and in particular on the notoriety of publications. Hu (2020) found that the increase in funding led to an increase in publications and an increase in major citations for these publications, particularly among first-time grant recipients and among researchers from less-established institutions. Rather than the specific field or area of research study serving as indicator for impact of government funding on fundamental research, Hu found that it was the access of more funds by first-time and less-established researchers that led to an increase in notable research output in publications. As a result of this study, Hu (2020) argues that a way in which the government could maximize the impact of public funding of fundamental research would be to provide more grant opportunities to newer researchers and researchers from less-established institutions because they are the group of researchers that benefited the most from the increase in funding allocation during the 2011 reforms.

This study is useful in discussing the effectiveness of one particular aspect of the fifteen-year development plan that the government initiated in 2006 to dramatically increase fundamental research. This paper intend to utilize a similar study on NSFC data and publication reports to highlight trends in government support and output, though the scope of the data this study addresses will be more encompassing of pre-2010 and even pre-2006 NSFC grant information, Additionally, since the primary focus of this study's micro-level analysis is around high energy physics funding, Hu's analysis on macro-trends and even department-level trends within the NSFC is insufficient to our study because it lacks a specificity in high energy physics research data.

## 2.5 Data Analysis on Fundamental Research in China

Each year the National Bureau of Statistics of China publishes a China Statistical Yearbook that highlights government expenditure and statistics through different departments and functions. For the interest of this study, we can use this annual report to present reporting on science and technology research and development expenditure. The data that we collected spans 2001 to 2019 and focuses on two aspects: 1) total R&D expenditure and 2) basic research R&D. Figure 2.3 presents the total R&D funding (in units of 100 million RMB) from 2001 to 2019, this includes central government expenditure, such as the Ministry of Science and Technology, and local government expenditure. Figure 2.4 presents the basic research R&D funding (in units of 100 million RMB) from 2001 to 2019 with the same parameters on data inclusion. Lastly, Figure 2.5 presents the yearly rate of basic research compared to total R&D in China.

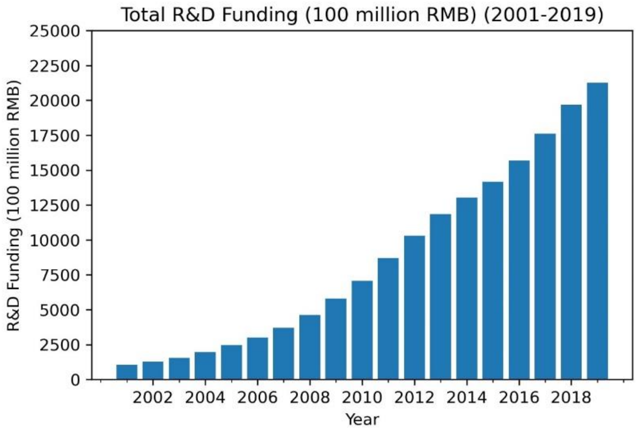


Figure 2.3 Total R&D Funding in China (2001-2019)

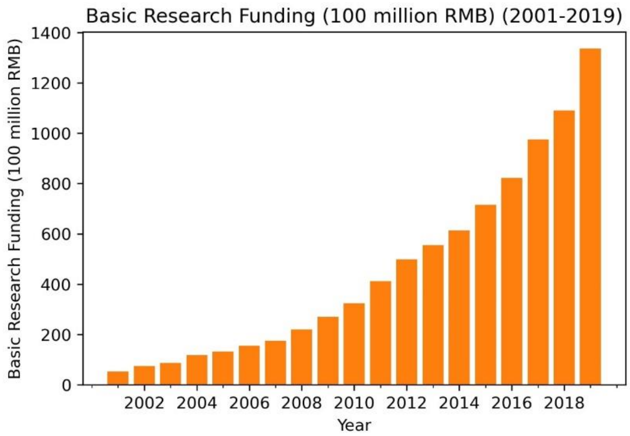


Figure 2.4 Basic Research R&D Funding in China (2001-2019)

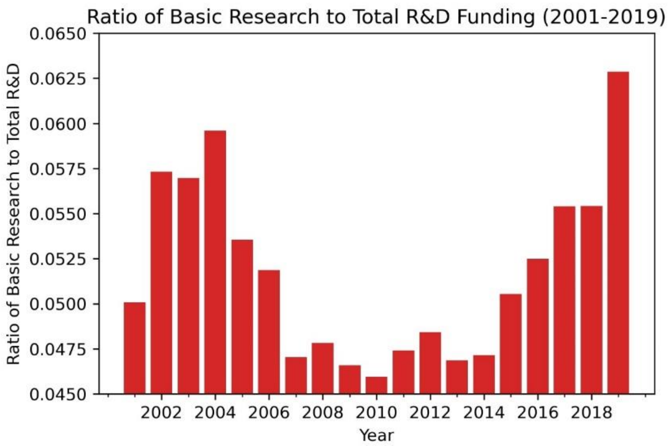


Figure 2.5 Ratio of Basic Research to Total R&D Funding in China (2001-2019)

From these graphics, we note the steady increase in both total R&D and basic research R&D in China. With regards to evaluating government support for fundamental research, the most notable trend is in Figure 2.5, in which we can see that the rate of basic research funding was around 5.5% in the early 2000s, but sharply decreased and remained below 5% from 2007 to 2014. However, in 2015, government investment in basic research relative to total funding began to grow and in 2019 reached a high-point of over 6%. While it is difficult to assess the exact motivations of this increase, we note that this data highlights a potential shift in government policy to increase the portion of R&D expenditure in fundamental research. This macro-level trend in fundamental research involves numerous fields and disciplines. Data on these fields and their financing exists, but to study each aspect within fundamental research would require an enormous study, well beyond the intentions of this paper. Instead, we choose to look at one aspect of fundamental research, high energy physics, to study the impacts and effects of government investment in scientific research.

## 2.6 Historical Development of High Energy Physics in China

The previous portion of this chapter was dedicated to providing a broad overview of fundamental research, both internationally and in China, and connecting it to government financing trends in the last twenty years. Fundamental research is a vast and ever-growing expanse of science and technology research. For the purposes of this paper, we are interested in dealing with a particular type of fundamental research known as high energy physics (HEP). High energy physics concerns the study of particles and fields in both theoretical and experimental work aimed at answering questions about the fundamental laws of nature and physics. High energy physics research is nearly universally reliant on government support due to a wide range of factors such as the scale, cost, and discovery-oriented approach to research. The high energy physics research community in China is no different. In order to contextualize the current state of high energy physics in China, we will provide a brief overview of the historical development of high energy physics in China.

Scientific research in China that probes the unknown boundaries of atomic, nuclear, and particle physics traces its origins back to the beginnings of the PRC. In the same year that the PRC was founded, 1949, so too was the Chinese Academy of Sciences (CAS) (CAS, 2022). A year later, in 1950, the Institute of Modern Physics at the CAS was established to direct modern physics research, such as in the emerging atomic, nuclear and particle fields (IHEP, 2022a). In fact, the importance of particle research was even discussed by Chairman Mao when he invited renowned Chinese physicist Qiang Sanqiang along with other top scientists to attend a meeting of the Secretariat of the CCP's Central Committee in 1955 (Cheng, 2006). In that meeting, and in subsequent conversations with Qiang, Chairman Mao highlighted his theory of divisibility in which even the components of our universe, at the time believed to be protons, neutrons and electrons, were in fact made up of other smaller components, and that through scientific research and experiment, Chinese physicists could and would prove his theory to be true. From the early days of the PRC, Chairman Mao and the CCP leadership identified the importance of supporting high energy physics research, both as a means of discovery and scientific advancement and as a means to support Maoism and Marxism doctrine.

High energy physics research in China was made possible by both physicist researchers and by government officials who valued the economic, technological and purely scientific benefits of this research. Premier Zhou Enlai was one such individual who left a profound impact on high energy physics research in China by advocating strongly for the establishment of an Institute for High Energy Physics (IHEP) within the CAS as well as for China to begin production of its own accelerators and major experiments to test prevailing theories in fundamental physics. In 1972, Premier Zhou Enlai sent a letter to Zhang Wenyu and Zhu Guangya and asserted that, "the study of high energy physics and the research and development of a high energy accelerator should be one of the main projects of the CAS," further arguing that "this issue should not be delayed any further," (IHEP, 2022a, p. 1). Just six months later, Zhou Enlai approved plans to establish the Institute of High Energy Physics (IHEP) within the CAS with Zhang Wenyu as the first director of the new institute, and six years later the first proposal for a high energy particle collider was approved (IHEP, 2022a).

A "high energy accelerator" or collider is one of two major types of experiments that are crucial for observation and analysis in high energy physics. "High energy accelerators" involve producing, isolating, accelerating, and sometimes eventually colliding channels of particles for the purposes of analyzing properties and output in massive machines with advanced detectors and sensors. The second type of experiment in high energy physics is large-scale observatories that study nature processes at the particle-level, such as with neutrinos. Premier Zhou Enlai's proposal for a "high energy accelerator" prompted physicists all across the country to seek government approval of the first large-scale high energy physics experiment in China.

# CHAPTER 3 METHODOLOGY

This paper will employ a quantitative analysis of publicly available data to explore both the inputs and outputs of government support for fundamental research and specifically high energy physics research. In order to study the inputs and outputs of government support in these areas of research, this study will utilize public data on financing, reports on government-supported projects and experiments, and publications. The purpose of gathering the data and presenting it in this study is to provide context into the development of support of fundamental research and specifically high energy physics in the last twenty years. This paper will also highlight past, current and future government-supported major research collaborations in high energy physics as a form of presenting evidence of institutional mechanisms supporting fundamental research. The case of the National Natural Science Foundation of China will provide concrete data on support for research grants in fundamental research and high energy physics. Due to availability of data, this study will analyze publicly-available information from 2001 to 2019. Specific data sources, qualifications and presentation are presented later in this study. The data will be presented without modeling or without any attempt to create a system to correlate inputs and outputs. The purpose of this study is not to create a system to measure the effectiveness of government support, but merely to track the development of said support and identify how agencies allocated support and how results are expressed through publications and citations in China.

# CHAPTER 4 SUCCESSES IN GOVERNMENT SUPPORT OF HIGH ENERGY PHYSICS IN CHINA

Since Zhou Enlai and the CCP's support of high energy physics research in the 1970s, the high energy physics community has expanded greatly and has conducted numerous research experiments and made incredible discoveries, contributing greatly to the breakthroughs in particle physics. Government support for high energy physics research can be directed either towards an individual researcher or to an institution or collaboration project. Therefore, in order to highlight the successes of high energy physics research in China, it is important to present the existing major collaborations in high energy physics research in China.

There are three types of high energy physics research in China. The first type is research conducted with an oversees experiment or collaboration, such as the work done at the Large Hadron Collider (LHC) in Geneva, Switzerland. Chinese physicists work on research at these institutions and the government in China supports both their work and provides funding to the foreign experiments. The second type is research conducted not directly with any existing or proposed collaboration or experiment, but is instead focused primarily through research with a university, and is thus primarily theoretical. The third type is research that involves a domestic experiment or project and is supported by various institutions or the government. There is of course often overlap between the three types, in fact many collaborations and experiments utilize the work of theorists and as such the line between these types is often blurred. Regardless, it is important to understand that there are differences among the functions of high energy research in China, especially when comparing research directed towards domestic projects compared to international projects.

For the purposes of this study, we are interested in domestic projects in high energy physics research. We have chosen to call attention to several recent, on-going and planned experiments and projects in high energy physics. Our aim in presenting this information is to highlight the current objectives of high energy physics research in China and the role that the government is playing in supporting these objectives. We will discuss four major high energy physics research projects in China and discuss the role of the government in approving, supporting and utilizing these experiments.

## 4.1 Beijing Electron-Positron Collider

The Beijing Electron-Positron Collider (BEPC) was the first high-energy particle accelerator in China. Inspired by Premier Zhou Enlai's call for a high energy accelerator in 1972 and the founding of the IHEP in 1973, high energy physicists working with the State Planning Commission submitted a proposal to the State Council to construct the BEPC at IHEP (IHEP, 2022a). BEPC was approved in 1983 and construction began in 1984 with Deng Xiaoping and other major party leaders in attendance of the groundbreaking ceremony (IHEP, 2022a). On October 16, 1988, the BEPC was turned on and the first electron-positron collisions in China began (Gao, 2018). Chinese physicists studied these collisions using the Beijing Spectrometer (BES), the detector located at the interaction region of the BEPC. The first iteration of the BEPC was an immense success for China. After only several years of running, BEPC produced many highly cited papers and important physics results in the area of charm physics and hadron physics, such as the tau mass measurement (IHEP, 2022b).

While the BEPC was still colliding particles and producing important results, many high energy physicists in China were interested in upgrading the BEPC and the BES detector (which was now BESII) in order to reach higher energy collisions and produce more amounts of data. In the late 1990s, the first proposals to upgrade the BEPC to the BEPCII were submitted and between 1999 and 2003 various government agencies and administrations approved of the proposal (IHEP, 2022a). At around the same time, the United States was failing to maintain government support for its own particle collider project. In the US, the Superconducting Super Collider (SCSC) began construction and was subsequently abandoned during this period after $2 billion were wasted on what is now just empty tunnels (Appell, 2013). However, in China, due to continued government support, the proposed upgrades were approved and finally, in 2004, the BEPCII began construction on upgrading the BEPC. The contrast between the failed construction of the SCSC and the successful construction of the BEPCII highlights the stark differences in the approach to the role of government in supporting fundamental research in China and the US. In China, the emphasis of long-term planning accentuates the need for patience and foresight into future projects beyond the immediate, an area where government officials and the scientific community in the US have failed to reach consensus on in recent years. After four years of upgrades, the new BEPCII and its detector BESIII were turned on in 2008 and have been collecting data on electron-positron collisions since 2008 (IHEP, 2022a). According to the BEPCII's homepage, the BEPCII and the BESIII are fully supported by the IHEP in the CAS, although the research conducted with the BEPCII and BESIII involve numerous domestic and international institutions and universities (BESIII Collaboration, 2016). The BEPC and BES detectors are the first of their kind in China and have paved the way for future particle colliders in China.

## 4.2 Daya Bay Neutrino Experiment

High energy physics research in China involves more than particle accelerators and colliders. The Daya Bay Neutrino Experiment (referred to colloquially as Daya Bay) was the first high energy physics neutrino-observation experiment in China (Daya Bay Collaboration, 2022). Inspired by the success of the BEPC experiments, neutrino physicists in China sought government approval and funding for an experiment that would allow them to study properties of the neutrino, an important fundamental particle that has received notable study in the US and in Europe. Neutrinos are particles that are produced in various kinds of reactions, and are most abundant in nuclear reactions, such as at a nuclear power plant. In 2003, the first proposals to study neutrino oscillations in China were submitted to both Chinese government agencies, such as the MOST and the CAS, as well as to the US Department of Energy (Cao and Luk, 2016). In 2007, the Chinese government approved construction of the Daya Bay Neutrino Experiment (Cao and Luk, 2016). Additionally, the US DOE approved to provide foreign funding for the Daya Bay Experiment, making it a domestically and internationally supported high energy physics research experiment. The experiment is located at the Daya Bay Nuclear Reactor along the southern coast of the Guangdong province. The neutrino experiment was chosen to be built adjacent to the existing nuclear reactor because the nuclear reactions at the power plant provide a neutrino-rich environment. The Daya Bay Neutrino Experiment involves studying the oscillation of neutrinos, in particular anti-neutrinos. After four years of construction, the Daya Bay experiment began recording data in 2011 and the eight detectors that made up the Daya Bay experiment collected data until 2020, when the Daya Bay Neutrino Experiment was completed (Daya Bay Collaboration, 2022). Throughout the nine years of operation, the Daya Bay Neutrino Experiment produced numerous important results in neutrino oscillation physics. In particular, in 2012 the Daya Bay Collaboration published precision measurements on the mixing angle known as theta13 by using anti-neutrinos gathered from the nuclear power plant (Daya Bay Collaboration, 2007). The Daya Bay Neutrino Experiment's conclusion in 2020 coincided with the beginning of the next generation neutrino observation experiment, the Jiangmen Underground Neutrino Observatory (JUNO).

## 4.3 Jiangmen Underground Neutrino Observatory

The Daya Bay Neutrino Experiment was only the first phase of neutrino study planned by Chinese high energy physicists. As early as 2008, plans were already being made to construct a second-phase neutrino experiment. When the Daya Bay Neutrino Experiment made its breakthrough discovery of the non-zero mixing angle theta13 in 2012 (Daya Bay Collaboration, 2007) it inspired further research into neutrino experiments that study reactor anti-neutrinos. The Jiangmen Underground Neutrino Observatory (JUNO) was approved by the CAS in 2013 and received financial support through the Strategic Priority Research Program (JUNO, 2014). JUNO is the experimental successor to the Daya Bay Neutrino Experiment and is constructed next to two major nuclear power plants with the intention of measuring similar neutrino oscillations using anti-neutrinos as Daya Bay did. Additionally, JUNO is interested in determining the mass hierarchy of neutrinos, a physics goal similar to that of other major neutrino experiments in the US and Japan (Cerna, 2019). According to Yifang Wang, a JUNO spokesperson and director of the IHEP, JUNO is currently concluding construction and plans to begin collecting data in late 2022 or early 2023 (Xin, 2020). JUNO is currently the next major high energy physics experiment to be completed in China and plans to be an important tool in furthering neutrino physics in China and around the world.

## 4.4 Circular Electron-Positron Collider

Lastly, the Circular Electron-Positron Collider (CEPC) is a proposed high energy particle collider designed to push the boundaries of electron-positron colliders to search for new physics and advance current measurements (Tang et. al., 2022). Motivated by the discovery of the Higgs boson by the LHC in Geneva in 2012, Chinese high energy physicists sought to create a domestic collider capable of generating Higgs bosons and study other particle properties at increasingly higher energy thresholds. In high energy physics, there is immense value in the existence of multiple experiments designed to produce and study similar physical processes because it helps to confirm or refute additional studies. The ability to challenge existing and contemporary work allows high energy physicists to work towards reaching a clearer understanding of our universe by consistently retesting and reaffirming the principles of our universe. Thus, for Chinese physicists, the CEPC, and future proposed upgrades to it, offer an opportunity to test recent existing concepts while also push the boundaries to begin searching for future discoveries and limits to our understanding of the universe and the laws that govern nature. These efforts have been well received by the party leadership, who have approved the construction and financing of the CEPC. In 2016, China's MOST allocated 36,000,000 RMB for the study of constructing the CEPC, and in 2018 allocated an additional 32,000,000 RMB (Gao, 2018). Currently, the CEPC is still in the planning phase, with a goal of selecting a site and starting construction sometime around 2030 (CEPC, 2013). The CEPC represents the long-term planning of the Chinese high energy physics community and the various government agencies and party officials who support the efforts of the high energy physics community in China. By investing in long-term projects that are not expected to produce results for another 20 years, the party is emphasizing the long-term prospects of science and technology research.

# CHAPTER 5 GOVERNMENT INVESTMENT AND POLICY: THE CASE OF THE NSFC

The previous three chapters have dealt with the historical development and current landscape in fundamental research and high energy physics in China, as well as the motivation for government providing support for such research projects. Government support of high energy physics and other frontier research fields is crucial for these fields to make breakthrough discoveries. Without government support, it would not be possible for institutions of high learning, such as universities, or major labs to finance the work of scientists aimed at discovery and understanding. Instead, alternative means of financial support would require research to be rooted purely in outcome-oriented and application-focused work. While this type of research has its merit, the existence of science and technology research that is not outcome-oriented nor application-focused is of the outmost importance to the purpose of conducting research. As such, in China, the government has implemented certain investment mechanisms and outlined certain policy practices that are instrumental in supporting and often directing research goals while not restricting the ability of individual researchers to conduct fundamental research.

There are two main types of government investment in research. The first is government research grants, which are often directed towards individuals or a group of researchers. The main institution that provides grants is the National Natural Science Foundation of China (NSFC), which provides yearly application cycles for various types of grants in funding science and technology research in China. These grants are often multi-year grants that are directed towards specific research projects approved by the funding agency and conducted by the researchers who receive the grants. There are numerous types of research grants through the NSFC, which will be discussed later. The second is government research contracts, which are often directed towards a lab or major institution. These contracts often outline long-term planning and are granted in large-sum for the purposes of advancing a major project or initiative. These contracts, and the funds associated with them, may be allocated by the central government, such as through the Ministry of Science and Technology (MOST), or by local governments. The National Key Basic Research Development Plan (referred to as the “973 Program”) is a major source of science and technology funding that was established in 1997 by the

State Science and Education Steering Group (Consulate General of the PRC, 2016). The 973 Program is organized to finance and "implement key projects to meet the national strategic needs" that are outlined by the party and state in various development plans (Consulate General of the PRC, 2016, p. 1). The 973 Program is aimed at fundamental research projects that emphasize expanding understanding and discovery, and its goals are closely aligned with that of high energy physics research. This program, along with additional programs supported by the MOST and CAS are essential to providing large funding for projects through contracts in China. Through our research, we struggled to find concrete documentation of year-by-year reporting on government contracts in fundamental research and high energy physics. However, we know of their existence because of case-by-case reporting on government approval and financing of major projects, such as the government's allocation of over 600,000,000 RMB for the BEPCII upgrades in 2008 (BES, n.d.). The bulk of our study is dedicated to grant-based funding by government agencies, though we provide high-level funding information from the MOST and from total reports on science and technology research and development.

The National Natural Science Foundation of China (NSFC), was established in 1986 as an institution under the authority of the state council with the mission of "supporting basic research, fostering talented researchers, developing international cooperation and promoting socioeconomic development," (NSFC, 2020, Foreword). In order to fulfill its mission objective, the NSFC oversees the National Natural Science Fund (NNSF) which is responsible for funding research projects in China. The NNSF is the largest fund provider for grants for fundamental research in China. The NSFC employs a "rigorous and objective merit-review system" in order to assess applications for funding and review of existing projects (NSFC, 2020, p. 1). The amount of available funds for NSFC research grants has increased greatly since 1986, and in 2011 an immense funding increased was announced to the fund in order to increase scientific output in fundamental research fields (Hu, 2020). From 2010 to 2011, funding for the NNSF increased by 90% (NSFC, 2011). In 2018, the NSFC was reorganized to become managed by the MOST, while still maintaining its independence of operation. The NSFC has numerous programs and funds that are aimed at not only supporting certain research fields and initiatives, but also emphasize research conducted by under-represented groups. Previous work has studied broadly the NSFC's financing of research projects, and paid specific attention to individual funds, but this study will focus on six major funds/programs within the NSFC that each emphasize increasing research opportunities and expanding the types of research the government finances.

## 5.1 Research Classification

The NSFC application for research grants employs a research classification system that is useful for the reporting of funding allocation and assessing trends within the NSFC grants. The NSFC requires that every application for funding provide an application code, which is determined based on the field of research the application is requesting funding for. In the NSFC's Annual Reports and Guide to Programs, funding information is provided based on department-level and clusters of sub-departments. For this study, we are interested in high energy physics research that is supported by NSFC grants; however, the NSFC does not report on the number of research projects and grants specifically allocated to high energy physics research. Instead, it uses the research classification system. Therefore, it is important to understand where high energy physics research is classified within the NSFC. Within the "Department of Mathematics and Physics" (A 数学物理科学部), there exists 30 sub-departments, of which five (A26-A30) are grouped together as "Physics II" (物理学II). Within Physics II, A26 is the application code for particle physics research and A28 is the application code for accelerator physics and technologies. Therefore, the "Physics II" classification of research grant applications is the most appropriate identifier of high energy physics research grants within the NSFC. For the purposes of studying funding allocation through the NSFC for high energy physics research, we will use the Physics II classification as the identifier of these research projects. While this is not exactly the most accurate measurement, as some of the research projects within Physics II are likely not related to high energy physics research, since Physics II is the most specific level of funding reported by the NSFC for high energy physics research grants, this is the farthest our study is able to go using publicly available information on NSFC funding.

## 5.2 General Program Fund

According to NSFC's Guide to Programs for 2020-2021, the General Program Fund (GPF) is a fund managed by the NSFC that "supports scientists engaged in basic research on self-selected topics" in which the function of their research is "to conduct innovative research…[in] all disciplines," (NSFC, 2020, p. 1). The General Program requires that all applicants have research experience, in particular basic research experience, and "hold senior professional position (title) or doctoral degree" or receive recommendation from at least two equivalent professionals within the same field (NSFC, 2020, p. 1). The GPF provides funding for four years with variant amounts allocated depending on the specific requests of the research project. The General Program Fund accounts for the largest individual fund within the NSFC and is instrumental in supporting research across all departments within the NSFC and across all sub-departments and disciplines. The GPF provides yearly information on the number of applications, number of awards, and direct funding received for the all departments and selected sub-departments.

## 5.3 Young Scientists Fund

The Young Scientists Fund (YSF) was established by the NSFC to support "young scientists to freely select their research topics…to conduct basic research," (NSFC, 2020, p. 151). The goal of the YSF is to foster "the ability of young scientists to independently undertake research projects and conduct creative research," (NSFC, 2020, p. 151). The NSFC, and by extension the Chinese government, recognize the value in investing in up-and-coming scientists who have the potential to become leaders in their respective fields on fundamental research. This program offers funding opportunities to researchers who have research experience, have a senior professional title or doctoral degree, and are younger than 35 years old (for male applicants) or 40 years old (for female applicants). The YSF funds research for a period of three years and has fixed allocation amounts for financing research projects, which are outlined each year in the Guide to Programs manual (NSFC, 2020). The YSF provides yearly information on the number of applications, number of awards, and direct funding received for the all departments and selected sub-departments.

## 5.4 Key Program Fund

Unlike the previous two funds, the Key Program Fund (KPF) provides yearly "research directions" that highlight areas where "new growth points of scientific disciplines might emerge" in order to "promote disciplinary development and breakthroughs in important areas or scientific frontiers," (NSFC, 2020, p. 103). As such, the application process involves associating a research proposal to one of the selected "research directions" for the KPF. The requirements for application are the same as the GPF, but with the additional expectation that the research objectives of the project align with a specific direction of the KPF. For example, in the Guide to Programs 2020, "[p]recision verification of standard models and new physics beyond standard models" is listed as one of the research directions, which is a particular area of interest for high energy physicists looking to utilize collider experiments and observatories to study fundamental properties of particles (NSFC, 2020, p. 107). The KPF provides research grants to a project for a period of 5 years. Additionally, the KPF provides yearly information on the number of applications, number of awards, and direct funding received for the all departments and selected sub-departments.

## 5.5 Less-Developed Region Fund

In addition to acknowledging the value in investing in young scientists and researchers as a means to further scientific progress for the future and development, the NSFC also identifies the importance in providing research grants to regions and institutions that are under-represented and less-developed through the Less-Developed Region Fund (LDRF). The LDRF aims "to stabilize and gather outstanding talents to facilitate the construction of the regional innovation system as well as the social and economic development of the regions," (NSFC, 2020, p. 161). Each year, the NSFC designates which regions qualify for the LDRF, and researchers may apply for the LDRF if they work at an institution in a less-developed region and meet the same requirements as the GPF. The LDRF grants funding for four years. The LDPF provides yearly information on the number of applications, number of awards, and direct funding received for the all departments and selected sub-departments.

## 5.6 National Science Fund for Distinguished Young Scholars

The National Science Fund for Distinguished Young Scholars (DYS) is an additional fund allocating resources to up-and-coming researchers in China, with a particular emphasis on existing researchers, "who have made outstanding achievements in basic research" and are capable of "select[ing] their own research directions," (NSFC, 2020, p. 179). Additionally, the DYS is open to international applicants who conduct basic research and work exclusively at an institution in China. Applicants to the DYS must be under 45 years of age and in addition to holding a senior professional position or Ph.D. degree, must have experience in basic research (NSFC, 2020). Research projects supported by the DYS are financed for five years. The DYS provides yearly information on the number of applications, number of awards, and direct funding received for the all departments and selected sub-departments.

## 5.7 Excellent Young Scholars Fund

The Excellent Young Scholars Fund (EYSF) is the most recent addition of the major funds/programs to the NSFC, with its first year of recording fund in 2015. The EYSF has near identical requirements to the YSF with the additional expectation of demonstrated research experience in basic research (NSFC, 2020). Additionally, current recipients or applicants of the DYS may not apply for the EYSF, as the two funds are aimed at increasing opportunities for young scientists. The EYSF supports research projects for three years. The EYSF provides yearly information on the number of applications, number of awards, and direct funding received for the all departments and selected sub-departments.

# CHAPTER 6 DATA ANALYSIS ON HIGH ENERGY PHYSICS IN CHINA

## 6.1 Measuring Government Input through NSFC Funding

This study has thus far provided context into the process for government support for fundamental research and high energy physics research. Additionally, this study has highlighted the NSFC as a major supporting institution for fundamental research and for high energy physics research. We will now utilize public data reporting to support the claim that the government is increasing support for high energy physics research in China by increasing allocation of funding to projects and collaborations. We will also present recent and relevant information on publications in high energy physics in China that highlights the connection between government support through contracts and grants and the output of scientific advancement through publications and citations.

The NSFC publishes both an Annual Report and Annual Guide to Program which contain detailed information on annual statistics on grant numbers and funding allocation amounts. This information is presented in terms of the total NSFC's allocation of funding and in terms of individual programs, such as the GPF. Individual programs, like the GPF, provide more specific classification of research projects, containing information on not only across all disciplines, but also in Math and Physics, and in Physics II (defined in the previous chapters as A26-A30 research projects). As such, we must look at individual programs and funds to determine the allocation of resources to high energy physics research projects. There are six major programs/funds that together account for over 75% of the annual funding of the NSFC. They are the GPF, YSF, KPF, LDRF, DYS, and EYSF. We study these six funds with respect to the number of applications, number of applications approved and the amount of funding approved by the NSFC for these grants. The data collected is all publicly available and is from 2001 to 2019.

In Figures 6.1–6.3, the number of applications, number of applications approved, and the total amount of direct funding received across all six major funds within the NSFC are shown from 2001 to 2019. In Figure 6.3, the jump in funding between 2010 and 2012 highlights the NSFC's drastic increasing in grant-size allocation during this period, which has maintained an amount above 15 billion RMB per year.

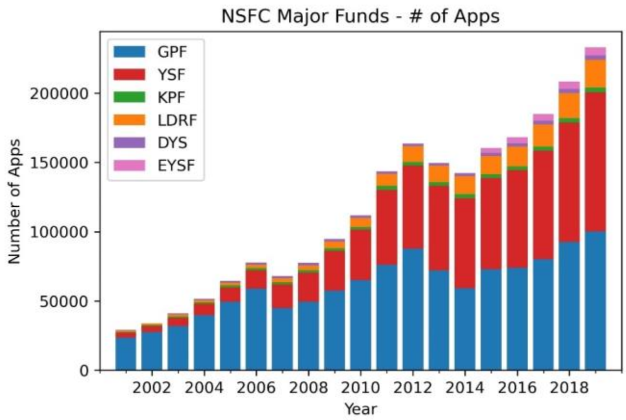


Figure 6.1 NSFC Major Funds: Total Number of Applications (2001-2019)

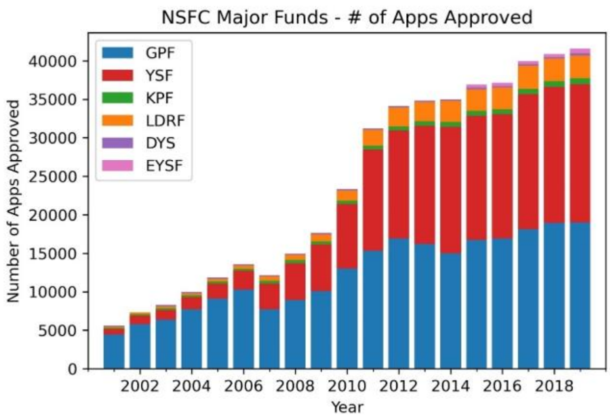


Figure 6.2 NSFC Major Funds: Total Number of Applications Approved (2001-2019)

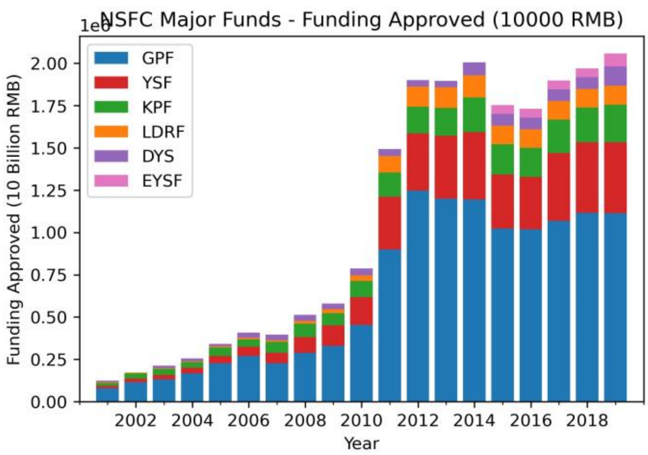


Figure 6.3 NSFC Major Funds: Total Funding Approved (2001-2019)

The same trends in present in all departments of the NSFC are also represented in the Department of Math and Physics in Figures 6.4–6.6, and lastly in the Physics II classification within the Department of Math and Physics in Figures 6.7–6.9.

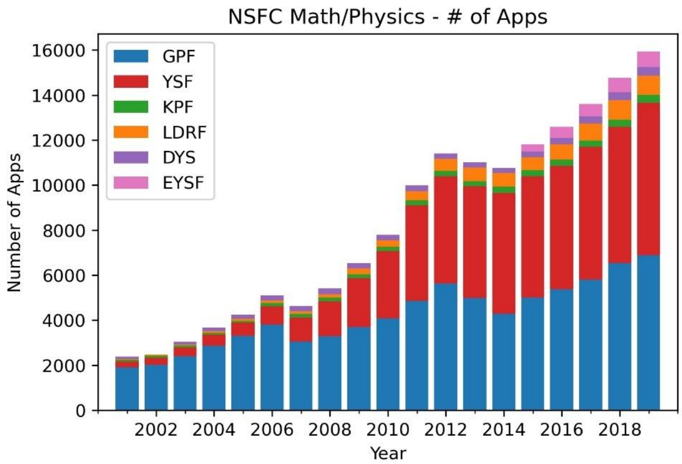


Figure 6.4 NSFC Math/Physics: Total Number of Applications (2001-2019)

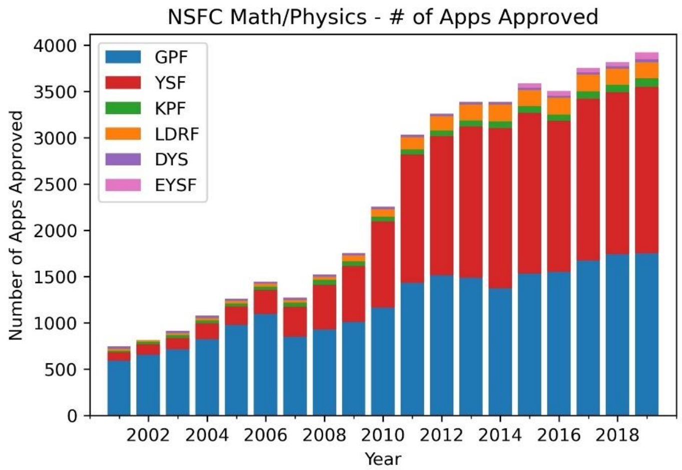


Figure 6.5 NSFC Math/Physics: Total Number of Applications Approved (2001-2019)

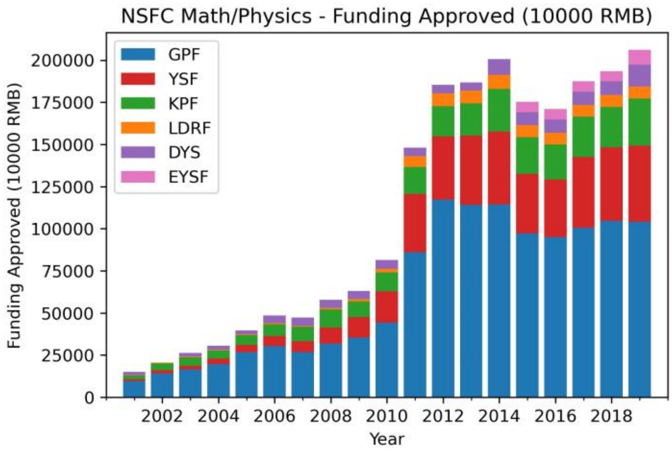


Figure 6.6 NSFC Math/Physics: Total Funding Approved (2001-2019)

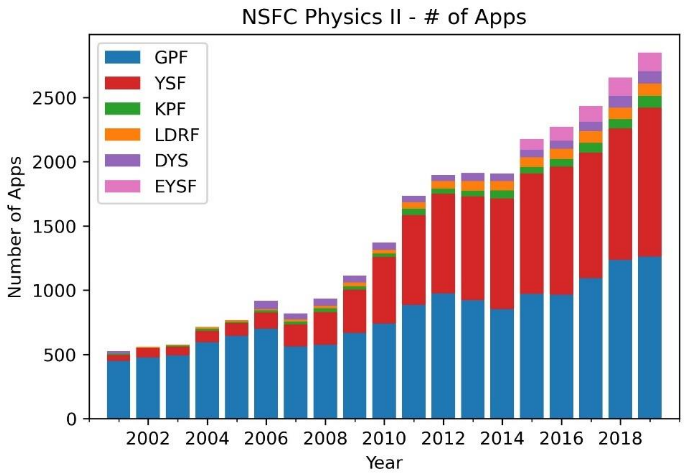


Figure 6.7 NSFC Physics II: Total Number of Applications (2001-2019)

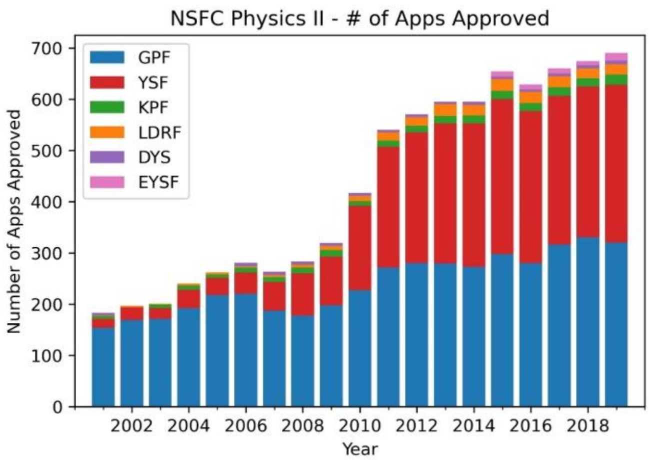


Figure 6.8 NSFC Physics II: Total Number of Applications Approved (2001-2019)

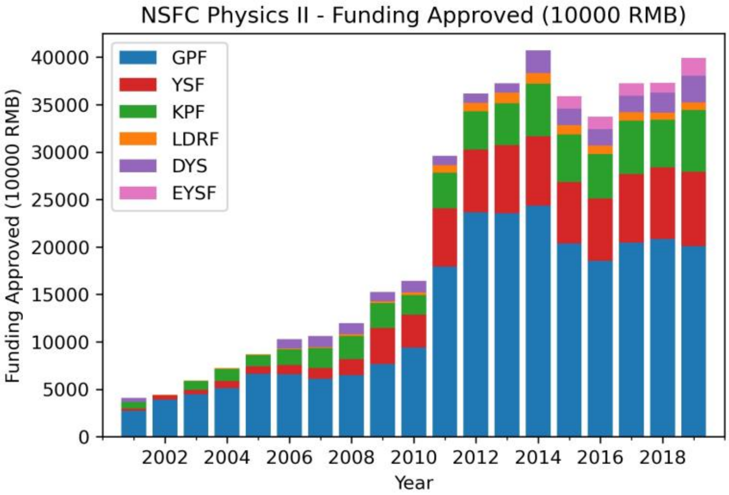


Figure 6.9 NSFC Physics II: Total Funding Approved (2001-2019)

In Figures 6.10–6.11, we compare the rate of applications approved and the funding per grant approved for the three different classifications: all grants through the six major funds, grants designated to the department of math and physics, and grants designated to Physics II research.

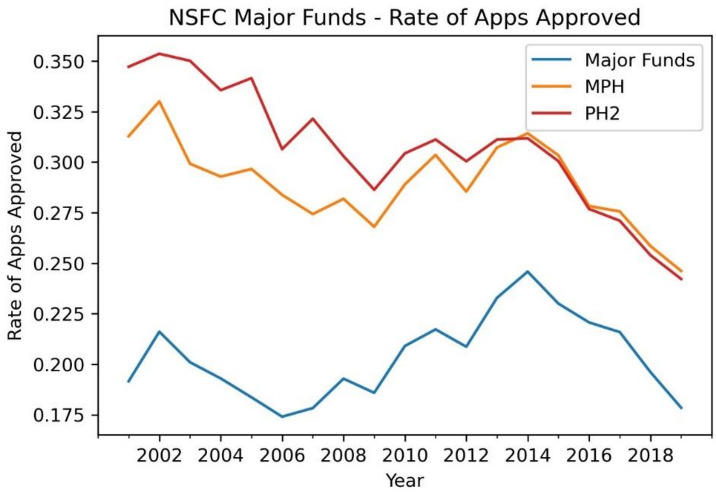


Figure 6.10 NSFC Comparative: Rate of Applications Approved (2001-2019)

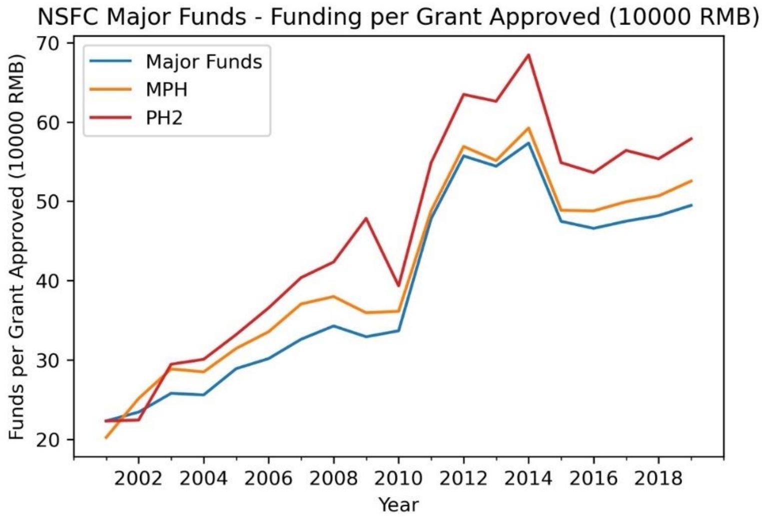


Figure 6.11 NSFC Comparative: Funding per Grant Approved (2001-2019)

These last two figures are the most crucial element of the NSFC data, because our study is the first, that we are aware of, to look exclusively at trends in Physics II funding through the NSFC through both the 2006 Medium-and-Long Term Development Plan and the 2011 NSFC funding reform. We can see through both periods, not only has the funding increased for Physics II research projects, but the number of applications and applications approved has greatly expanded. Additionally, we can see that Physics II has a higher rate of application approval than the total, and has a higher average funding per grant. The data from the NSFC shows that Physics II has experienced the same increased support in financing research that other disciplines have received within the NSFC. While this does not indicate that Physics II, nor high energy physics, is a special case for government funding, it does demonstrate that as the government and party have espoused support for fundamental research, high energy physics research has benefitted by receiving additional financing. If the government were to continue increasing funding, especially if the ratio of funding towards fundamental research increases, then it is reasonable to conclude from the data that high energy physics research would also receive substantial increases in financing and grant allocations through the NSFC.

## 6.2 Measuring Scientific Output through Publications and Citations

Through Tsinghua University's Library Portal, we have access to the Clarivate online collection of published articles. We use the Web of Science Core Collection to search for publications in Chinese high energy physics from 2001 to 2019. We are interested in studying papers and articles that are supported by the government and are conducted by Chinese physicists in high energy physics research. As such, we select publications if they satisfy one of two criteria.

1. The publication is labeled from one of the major high energy physics collaborations or experiments in China, such as the BEPC, Daya Bay, JUNO, or CEPC (along with additional smaller projects), since these collaborations and experiments are financed largely through contracts with the government.
2. The publication contains BOTH of the following: a corresponding/primary author from a Chinese institution and have a government grant listed as a source of funding.

These two qualifications allow us to produce a data set of publications from 2001 to 2019 that include significant information about Chinese high energy physics research directly supported by the government. Yearly data on the number of publications and citations is presented in Figures 6.12–6.13, and in Figure 6.14 we show the average number of citations that a publication receives based on the year of original publication.

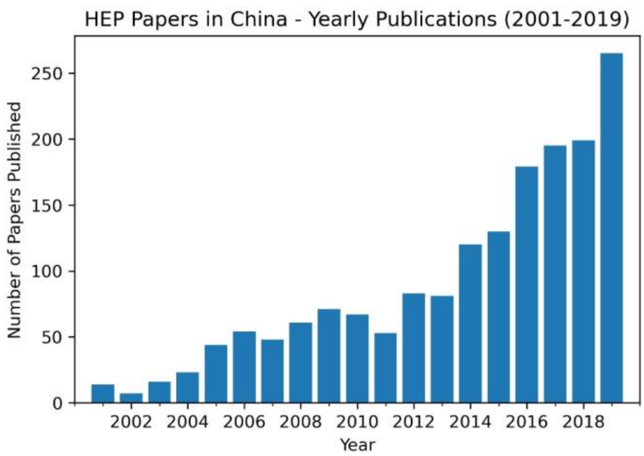


Figure 6.12 HEP in China: Number of Publications per Year (2001-2019)

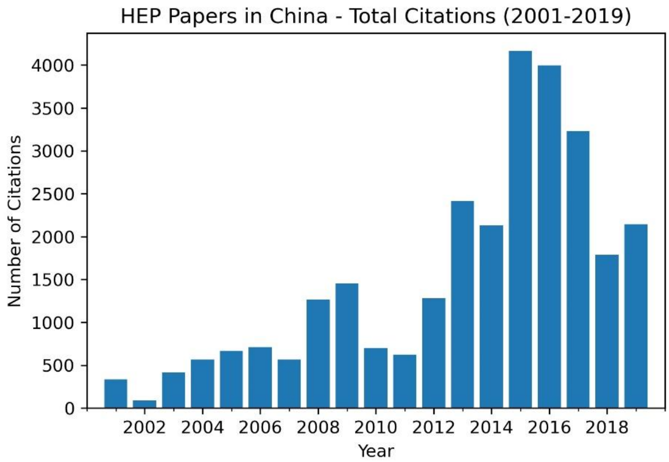


Figure 6.13 HEP in China: Number of Citations by Publication Year (2001-2019)

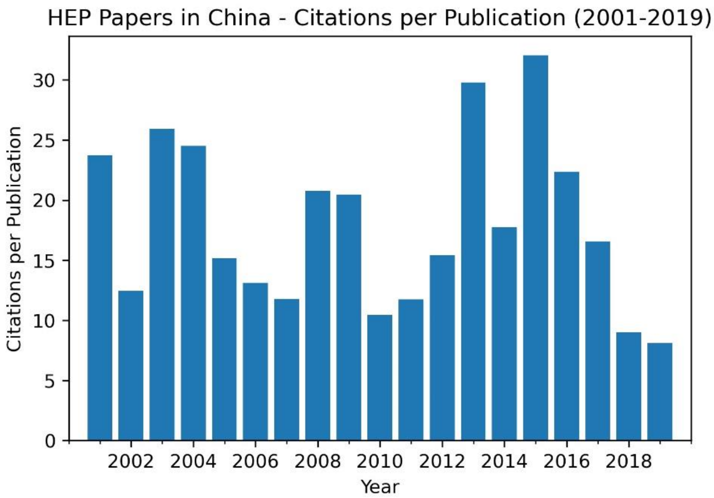


Figure 6.14 HEP in China: Number of Citations per Publication by Year (2001-2019)

From 2001 to 2019, we found 1,710 publications with over 28,500 citations, averaging 16.7 citations per publication. We note that a considerable number of publications have well over 100 citations and there is a growing number of publications from Chinese high energy physicists that are contributing greatly to breakthrough discoveries in high energy physics, such as the non-zero measurement of theta13 by the Daya Bay Neutrino Experiment, or the discovery of complex particles by the BEPC.

# CHAPTER 7 CONCLUSION

In this paper, we provide evidence from various government sources that highlight how party officials in China identify fundamental research as an instrument of furthering economic and social development. In recent decades, the Chinese government has promoted fundamental research and increased funding for fundamental research in both the central government and in local governments. In 2006, the National Assembly of the PRC released an “Outline of the National Medium- and Long-Term Science and Technology Development Plan” which commitment to providing funding for areas of science and technology research that are instrumental to national interests and economic and social development. In this development plan, the government identified research relating to the “deep structure of matter” as crucial to national interests and development. High energy physics research produces environments and conducts observations into the “deep structure of matter”. As such, by studying the government’s investment in high energy physics research, it is possible to understand the implications of the development plan.

High energy physics is one area of fundamental research where it is possible to use publicly available data from the NSFC and existing reports on government-contracted collaborations to show the increasing support for fundamental research in China. Additionally, this increasing support has led to not only an increase in publications during the same time period, but also an increase in the production of highly cited papers in high energy physics. This paper provides a quantitative study on the Chinese government’s investments into high energy physics research in China and attempts to provide one way to measure the outputs of said investments through publications and citations in addition to major scientific breakthroughs in collaborative experiments. High energy physics research in China has led to numerous important discoveries about the nature of charm and hadron physics in collider experiments and about antineutrino mixing angles in nuclear power plants.

This paper is by no means an all-inclusive study on high energy physics in China. In fact, it is very likely that there exists more information on this topic than presented in this paper. However, the information provided, we believe, is sufficient to present a valid interpretation of the current state of high energy physics research in China and is sufficient to support the claim that the government is following through on its promised support for fundamental research in China. Future studies should build upon the foundational work presented here and construct a more focused quantitative analysis, using a more in-depth approach to identifying sources of financing research that relates exclusively to high energy physics.

The research conducted in this thesis is profoundly insightful to those who are seeking to gain insight into how fundamental research, and specifically high energy physics research, is supported in China. Additionally, by highlighting major research collaborations in China, this paper provides insight into the current and future state of high energy physics in China, which is very likely to be expanding and become not just a regional center for research, but a global center.

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# 声　明

本人郑重声明：所呈交的学位论文，是本人在导师指导下，独立进行研究工作所取得的成果。尽我所知，除文中已经注明引用的内容外，本学位论文的研究成果不包含任何他人享有著作权的内容。对本论文所涉及的研究工作做出贡献的其他个人和集体，均已在文中以明确方式标明。

签　名：Jared Burleson　日　期：2022/05/30

# RESUME

Jared Burleson 赵睿 was born on 4th September 1998 in Grapevine, Texas, USA.

He began his bachelor's study in the Dedman School of Humanities and Sciences, Southern Methodist University in August 2017, and received a Bachelor of Science in Physics with Distinction and a Bachelor of Science in Pure Mathematics degree in May 2021.

He began his master's study at Schwarzman College in Tsinghua University in September 2021 and will receive a Master of Management Science degree in Global Affairs in June 2022.

He will pursue a Ph.D. in Physics at the University of Illinois in Urbana-Champaign starting in August 2022. His area of study is high energy particle physics with an emphasis on data science and machine learning applications to particle physics analysis, and physics public policy and science communication.

# COMMENTS FROM THESIS SUPERVISOR

The thesis discusses the governmental role in fundamental research and provides the policy perspective for strengthening connection between government and academies. The research has practical sense and academic contributions. The thesis shows that the student has a good academic sense and interest in Chinese issues.

Firstly, the thesis introduces the studying background in terms of scientific progress. Based on the literature review, the thesis analyzes the historical development in Chinese fundamental research. By adopting statistical data, the thesis discusses the role of central government and its influencing factors of research output. Lastly, the thesis brings forward policy implications for developing fundamental research.

The research goal and logic are clear. The methodology is feasible to support the research conclusions. The handwriting is normal. The thesis has reached the level of master degree. I agree to let the student join the oral defense.

# RESOLUTION OF THESIS DEFENSE COMMITTEE

1）Overview

The thesis elaborates the scope of the role of government in fundamental research: evidence from Chinese high energy physics research, and assesses the development of government institutions in China and the mechanisms used to support fundamental research, specifically high energy physics, through providing funds and securing site and resource allocation. The author has presented new findings that represent academic contribution to the field through challenging research.

2）Comments

This project has chosen an important and timely topic with bearing on the role of government in fundamental research: evidence from Chinese high energy physics research.

The current draft report is insightful, well-written, well-structured and appropriately documented. It reflects an excellent command of the work with higher level thinking, intellectual engagement and high theoretical or practical value.

The student Jared BURLESON has provided satisfactory answers to the questions raised by the panel.

The panel agrees that this work meets the requirements for a master degree report.

3）Decision

Unconditional Pass (with minor revision):

By a process of anonymous grading, Jared BURLESON's Capstone Presentation Grade given by the panel is __92___out of 100 (counts for 50% of the overall grade). Since his/her written report grade is __98____out of 100 (given by advisor, counts for 50% of the overall grade), Jared BURLESON's overall grade of Capstone Project is ___95____.

Jared BURLESON's report has passed this Capstone presentation with suggested revision. He/ she will be recommended to the degree committee to be awarded the degree of Master of Management Science in Global Affairs.