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A Human Capital Model of the Defense-Growth Relationship

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THE FLORIDA STATE UNIVERSITY
COLLEGE OF SOCIAL SCIENCE AND POLICY

A HUMAN CAPITAL MODEL OF THE DEFENSE-GROWTH RELATIONSHIP

By

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Посвящается
Ив Помрой
которая научила меня писать
и
Лорен Болл
которая вдохновила меня на это.

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ABSTRACT

One of the most important questions rising out of the War on Terror and the end of the Cold War is how changes in a country's defense spending will affect its economic performance. Despite the significant amount of work on the defense-growth relationship, a consensus has failed to be reached within the literature as to whether a relationship does exist, its direction, and how it should be modeled. In this dissertation, the defense-growth relationship is investigated by looking at the effect of changes in the defense sector's human capital investments on growth. After theoretically deriving a human capital based model, the model is empirically tested with U.S. data for the time period 1949 to 2009. By doing so, previous scholarship on the defense-growth relationship is advanced by contributing to the theoretical foundation and theoretically deriving a model which uniquely captures the on-the-job training that enlisted soldiers and officers receive.

The results show that the sector's investments have a positive effect on the economic growth of the United States. This effect is both direct and indirect. Directly, the sector's investments influence the economy's growth rate as a form of on-the-job training. The results show that approximately 18.9% of economic growth can be attributed to the investments. Indirectly, they influence the production of a military good, which further influences general production. According to the calibrated parameters, a 1% increase in the military good is expected to produce a 0.034% increase in total economic output.

CHAPTER 1

INTRODUCTION

One of the most important questions arising from the War on Terror and the end of the Cold War is how changes in a country's defense sector will affect its economic growth. This question has significant policy implications for the United States given its dedication of resources to the conflicts in Afghanistan and Iraq and the current economic difficulties. Despite the significant amount of scholarly research on the defense-growth relationship, no consensus has emerged as to whether a relationship does exist, the direction of that relationship, and how it should be modeled. By exploring the relationship within the boundaries of Dunne, Smith, and Willenbockel's (2005) argument,¹ this study reconsiders the impact of the defense sector on the allocation of resources within the economy of the United States addressing the question: How do changes in the defense sector's human capital² investments influence the economic performance of the United States?

Support for addressing this question underlies much of the prior research. Deger (1986) and Dunne et al. (2005) suggested that the key to understanding the relationship might lie not in the sector's total expenditures³ but rather in the growth effects

¹After analyzing the extant literature on the defense-growth relationship, Dunne et al. (2005) concluded that any study wanting to make a contribution must address the various programs of the defense sector and must utilize modern modeling techniques.

²The term *human capital* refers to the skills and knowledge embodied in the labor force that lead to greater productivity.

³The literature on the defense-growth relationship has used the defense sector and defense expenditures as interchangeable. Although the sector is characteristic of its expenditures, it is unreasonable to assume that all expenditures are equal or that the impact of the sector is purely financial. Sim-

of the various programs. For example, defense programs focused on technological and weapons development as well as those focused on military construction might not have the same effect because the allocation of resources can vary based on the needs of the program. Although the literature has made reference to the need for a programmatic approach, no investigations have been conducted providing an impetus for exploring the relationship programmatically.

Beginning the programmatic investigation with a study of the defense sector's human capital is important because human capital is considered a primary determinant of economic growth rates and economic performance (Romer, 1990). Additionally, human capital has often been cited as a potential cause of a positive association within the defense-growth relationship (Benoit, 1978; Heo, 1999; Knight, 1996). As Sandler and Hartley (1995) pointed out, the defense sector is a significant contributor to on-the-job training for enlisted soldiers and officers, as well as a provider of vocational and technical training that can be used in the private, public, or nonprofit sectors after the completion of service. Ironically, the literature has relied heavily on the defense sector's influence on human capital as an underlying cause of a growth effect (Benoit, 1973, 1978; Heo, 1999, 2000; Huang and Mintz, 1991; Knight et al., 1996; Sandler and Hartley, 1995; Ward and Davis, 1992), but it has failed to distinguish human capital investments from the other defense expenditures in modeling and estimation (Dunne et al., 2002). This study theorizes that including the defense sector's emphasis on the development and training of its soldiers enhances the understanding of the defense-growth relationship through a theoretically derived analysis.

ilar problems have been addressed in the economic literature when dealing with the private sector, where expenditures are used in the production of the sectors good. Although this study estimates the military good of the United States, such estimates have not been previously conducted. This has left sector expenditures as a proxy for output. Because of the use of expenditures as a proxy, and to remain consistent with the discussion on past studies, the original terminology of expenditures is kept.

1.1 The Defense-Growth Relationship

The issue of how a country's defense sector affect its overall economic performance has been an area of concern and contention to both academics and politicians for some time (Aizenman and Glick, 2006; Benoit, 1973; Broadberry and Harrison, 2005; Heo, 2000; Hobson, 1911; Mintz and Huang, 1990; Russett, 1969), but the defense-growth relationship has been plagued by several methodological and theoretical problems (Dunne et al., 2005; Heo, 2010; Smith, 1992). Central to the problems is the lack of a strong theoretical background on which research in the area can be based. According to Alexander (1990), the defense-growth relationship is an empirical relationship rather than a theoretical one. As an empirical relationship, the most popular approach to modeling it has been a multi-sectoral approach, known within the defense literature as the Feder-Ram approach (Heo, 2010; McDonald and Eger, 2010). Critics, however, note that there is no theoretical reasoning underlying the models construction (Dunne et al., 2005). Despite the lack of a theoretical background acknowledged within the literature, little has been done to rectify the situation (Dunne et al., 2005). Instead, the extant work has focused on trying to "fit" a theoretical background to a previously established empirical model (Mintz and Stevenson, 1995). Tables 1.1 and 1.2 provide a summary of the key literature on the defense-growth relationship, the model used, and the direction of the findings.

Table 1.1: Summary of Key Literature on the Defense-Growth Relationship, 1960-1989

Study	Direction	Contribution
Russett (1969)	Negative	Approached the relationship for the United States from a cost-benefit standpoint, concluding that the effect of the relationship is dependent upon a guns vs. butter trade-off.
Benoit (1973, 1978)	Positive	Conducted the first empirical tests of the relationship. Using correlation analysis of 44 countries, showing a positive relationship between a heavy defense burden and high rates of economic growth.
Deger and Smith (1983)	Positive	Using an ad-hoc, simultaneous equations approach, they investigated the relationship for 50 LDCs. They concluded that the defense sector has a positive effect, but it is offset by a guns vs. butter trade-off
Weede (1983)	Positive	Arguing that defense programs solidify nation building by encouraging national provide, he used an ad-hoc regression to estimate effect of military participation on the economic development of 125 countries.
Faini et al. (1984)	Negative	Approached the relationship from an empirical standpoint, arguing a theoretical relationship is not possible. Using an ad-hoc model with data from 69 countries, their results showed a negative, but insignificant, relationship.
Biswas and Ram (1986)	Insignificant	Established a theoretical foundation of the relationship using Feder's (1983; 1986) division of the economy into a series of sectors and Ram's (1986) extension to include the government. The resulting "Feder-Ram" model explains growth as a composite of defense expenditures and the rest of the, economy.
Deger (1986)	Positive	Considered that the relationship may come through multiple channels, each producing its own effect. Although the relationship may have a positive effect it indirectly influences economic growth by disincentivizing investment.

Table 1.2: Summary of Key Literature on the Defense-Growth Relationship, 1990-Present

Study	Direction	Contribution
Mintz and Huang (1990, 1991)	Negative	Believed a two-sector approach to the Feder-Ram model was unreasonable. To eliminate any bias they expanded the Feder-Ram model to include a third sector for non-defense related government expenditures.
Mueller and Atesoglu (1993a,b)	Positive	Further expanded the Feder-Ram model to include technological progress because of the sector's investments in the area. By including technology, a key between the defense sector and the economy was captured.
Alexander and Hansen (2004)	—	Reconsidered the theoretical and empirical aspects of the Feder-Ram model, concluding that the model is subject to misspecification, misinterpretation, and questionable legitimacy. Ultimately, an alternative model is needed.
Dunne et al. (2005)	—	The authors compared the theoretical foundations of the Feder-Ram model with an Augmented Solow model. Despite the reliance of the literature on the Feder-Ram model, they concluded that the Solow-based approach is more theoretically sound.
Heo and Eger (2005)	Negative	Investigated the direct and indirect effects of the relationship by developing a multilink model centered on the Feder-Ram model that includes exports as a fourth sector. The indirect effect is not distinguishable from other types of government expenditures.
Atesoglu (2009)	Positive	Viewed the literature as providing diminishing returns While the literature has been struggling for a model, it still lacks a strong theoretical foundation on which it can be based.
Heo (2010)	Insignificant	Empirically reconsidered the debate over the Feder-Ram model and the Augmented Solow model. Although both presented similar results, concluded that the Feder-Ram is superior because it accounts for nondefense expenditures and externalities.

The lack of strong theory to direct research on the defense-growth relationship presents a problem in developing a formal model of the relationship, resulting in the inability to draw strong conclusions about the relationship's direction and size. It also makes developing accurate empirical models to explain the relationship difficult. Deger (1986) recognized that "economic theory should dictate what variables we should include . . . the growth equation . . . therefore, relatively ad hoc specifications are necessary" (p. 260). With little foundation on which to base empirical models, it should be no surprise that work on the relationship provides as many questions as it does answers. The importance of the relationship, in combination with the lack of clarity currently plaguing it, make further research into the field an important and promising endeavor for public administration.

1.1.1 Developing a Consistent Approach

Following Chan's (1985) critique of the field, Biswas and Ram (1986) attributed the mixed results and lack of consistency in the previous defense-growth studies to variation in defense budgets and programs over time. For clarity, the research had to push forward, but to do so, Biswas and Ram believed that they needed to move the understanding of the relationship at hand from the ad hoc application to a theoretical grounding. Thus, they sought a growth model that not only used economics to direct the model but also could be adapted to the defense-growth relationship.

The basis for Biswas and Ram's approach was first developed by Feder (1983), who wrote that "aggregate growth is related to changes in capital and labor through an underlying production function" (p. 60). Beginning with this understanding, Feder (1983, 1986) divided the aggregate output of the economy into two sectors: exports and nonexports. Following Feder's division of the economy, Ram (1986) proposed a two-sector model to explain economic growth comprised of a government and a private sector. The justification for the government sector was based on the

notion that government could negatively affect growth due of inefficient operations, regulatory burdens, and other distortions to the market. Government could also positively influence growth because “a larger government size is likely to be [a] more powerful engine of economic development” (Ram, 1986, p. 191). After redividing the economy into defense and private sectors, Biswas and Ram (1986) developed an understanding of the defense-growth relationship that, while not perfect, was at least “fairly well grounded in the neoclassical production function framework” (p. 367).

The acceptance of the Feder-Ram approach as the dominant framework for understanding the defense-growth relationship came quickly. This acceptance can be seen in Deger and Sen’s (1995) characterization of the approach, which they viewed as “a splendid empirical workhorse to investigate the impact of military expenditure on growth” (p. 284). Similarly, Heo (1999), defended the approach as a significant contribution to the literature on the relationship because it was “developed from a consistent theoretical structure” (p. 39).

However, the implications of such acceptance is troublesome. Rather than engaging in an intellectual debate on the merits of the approach, the open acceptance suggested that no new theoretical contributions were to be had (Sandler and Hartley, 1995; Dunne et al., 2005). For many, future research on the relationship was to come through empirical exercises. For others, the relationship was viewed empirically rather than theoretically from the start (Alexander, 1990; Heo, 2000; Mintz and Stevenson, 1995). For viewing it as an empirical problem, all that could be gained was to measure the relationship during a period of high global transition, retest past findings, and obtain new estimates for various collections and samples of countries.

Though it was misguided in the abandonment of theory, the popularity of the Feder-Ram approach has led to variations of this model used to estimate the effects of the defense sector with data for individual countries (see Bernauer et al., 2009; Heo, 2000, 2010; Huang and Mintz, 1991; Mintz and Huang, 1990, 1991; Ward et al.,

1993); cross-country data (see Biswas and Ram, 1986; Heo, 1999, 1998; Mintz and Stevenson, 1995); and time-series, cross sectional data (see McDonald and Eger, 2010; Murdoch et al., 1997). In addition to the multiple uses of the Feder-Ram approach for the defense-growth paradigm, several interesting and important advancements have been achieved in the past 24 years.

The first advancement was positing the development of a non-defense related government sector by Mintz and Huang (1990, 1991). After applying the approach to the defense-growth relationship, Biswas and Ram (1986) argued that the effect of the defense sector could differ from the effect of the private sector, assuming that all non-defense-related government expenditures would share the same effects as the private sector. As Mintz and Huang began to retest the relationship after the conclusion of the Cold War, however, it became obvious that the assumption of two sectors was unreasonable. The behavior of the United States government during the Cold War suggested an interest in effectiveness over efficiency, which, if true, meant that not only could identical effects not exist but treating the two as equals risked biasing the results. Thus, when investigating the effects of defense expenditures using the Feder-Ram approach, it is theoretically reasonable to separate the economy into three sectors: defense, non-defense governmental, and private.

A second innovation of note was the inclusion of technological progress in the relationship. Mueller and Atesoglu (1993a; 1993b) theorized that previous uses of the Feder-Ram approach were incomplete because they failed to account for the effects of technological progress on growth output. According to Solow (1957), technological progress determines the rate and productivity of capital and labor at producing economic output. Solow (1970) further wrote that a “labor augmenting form of technological progress is necessary for steady-state growth to be possible” (p. 35).

The contribution of Heo (1998) and Heo and DeRouen (1998) was their efforts towards a unified Feder-Ram approach. Research following Mintz and Huang’s (1990,

1991) division of the economy into defense, non-defense and private sectors, included Mueller and Atesoglu's (1993a; 1993b) idea of technological progress as a means of accounting for variation among countries that exhibited similar defense allocations but demonstrated different masteries of the resources. Demonstrating the revised model, Heo (1998) investigated the likelihood of a peace dividend amongst 80 countries. Although the significance of the results varies, he concluded that the relationship between defense spending and economic growth is negative based on the trend of the empirics. Heo and DeRouen (1998) also demonstrated the revised model by restricting the countries in the study to the East Asian newly industrialized countries (NIC's). The results again showed a lack of significance but continued the negative trend.

Despite the large amount of research produced on the defense-growth relationship (see Adams and Gold, 1987; Alexander, 1990; Atesoglu, 2009; Benoit, 1978; Mintz and Huang, 1990; Heo and Eger, 2005; Heo, 2010), the growth literature has never accepted the Feder-Ram model as a realistic representation of an economy's performance. Dunne et al. (2002, 2005) criticized the approach, arguing that it has the appearance of being theoretically sound, but no theoretical reason exists for why the model should work. Without the theoretical reason, the approach is subject to severe misspecification,⁴ that, in turn, is likely to produce inconsistent results (Alexander and Hansen, 2004). Heo (2000) argued that the inconsistency of results was not due to problems with the approach, but rather to the issues with available data. The effect can vary from one country to the next, and one time period to the next, depending on the country's reliance on the defense sector for employment (McDonald and Eger, 2010). Within this perspective, countries with a large defense sector and

⁴The issue of misspecification stems from the debate over which sectors should be distinguished from other residual sectors within the growth model. Without a theoretical reason to choose certain sectors, selection is based entirely on researcher desire. Ram (1995) attempted to address the issue empirically, concluding that a minimum of four sectors is necessary to limit misspecification. He did not, however, give any suggestions as to what those sectors should be. Although four sectors might be viewed as the magic number to avoid problems, Alexander and Hansen (2004) noted that about 90 percent of the Feder-Ram based models for the defense-growth relationship include only two or three sectors.

a small private sector would show a positive association while those with a small defense sector and a large private sector would show a negative association.

Acknowledging that research on the field was again producing diminishing returns (Atesoglu, 2009), researchers over the past five years have begun to question which is the best model for explaining the relationship. Although several approaches have been suggested and compared, including an augmented Solow model, a Harold-Dumar growth model, and an adaptation of Barro's growth model (Dunne et al., 2005; Heo, 2010), the field itself is still struggling between fitting a new approach to the existing literature and building a new theoretical framework from scratch. For Heo (2010), the Feder-Ram model remains the dominant model, because none of the other models could provide a clearer understanding than that currently provided by the Feder-Ram. Without clear direction, the abandonment of the Feder-Ram approach is likely to lead to a return to ad hoc investigations. Evidence of this reversion can already be observed in the recent contributions of Atesoglu (2009), Sevastianova (2009), and Yakovlev (2007).

1.2 Framework and Methodology

To address the limitations of the prior research and the research question posed, this dissertation abandons the existing approaches to the relationship, instead allowing economic theory to dictate the variables and structure of the model. Beginning from a theoretically driven approach, this dissertation grounds itself in neoclassical growth theory, which is a commonly used theoretical foundation in the study of human capital and economic growth (Lucas, 1988; Savvides and Stengo, 2009). This grounding allows for the study to draw upon the rich literature that the tradition brings and allows itself to meet Dunne, Smith, and Willenbockel's (2005) requirement of taking into account recent growth theory and modeling techniques. With this foundation, this dissertation is focused on theoretically developing a framework or environment

of economic behavior. Influencing resource allocation in the environment is a defense good which itself is drive by its human capital investments. The framework is then transformed from a theoretical environment and into analytical statements about the effects of the sectors investments through the process of calibration. That is, data are used to map or align the framework such that its properties mimic the properties of the U.S. economy. To further understand the effects of the sector's investments, the steady state values of the model variables are obtained. These values represent the optimal allocation of the resources in order to maximize the economic output. Through the calibration and steady state processes it is possible to gain an understanding of how the sector's investments influence performance and the size of the impact.

1.3 Significance of the Study

Several important implications are derived from this study. First, this dissertation develops the theoretical background needed for the study of the defense-growth relationship. It does so by clarifying the defense sector's impact on the United States and expounding upon that relationship with data and analytical testing. In addition to clarifying the relationship within the United States, the combination of a new theoretical foundation and a programmatic approach allows for inference of effects in countries with similar training and education programs. It also allows for researchers studying the relationship to begin reconciling the inconsistencies found in previous studies.

An improved understanding of the defense-growth relationship holds important policy implications. Should there be a negative association, a reduction in defense expenditures would be attractive as a structural policy element for economic reform programs designed to enhance growth. If there is a positive association, an expansion could provide additional measures of social stability and well-being for constituents.

This could reduce the need for the public provision of other services. As the demands on the U.S. military shift in response to the reduced presence in Iraq and the extension in Afghanistan, the effect of the defense-growth relationship could also determine the conversion costs of defense reduction and the initiatives needed to compensate for any potentially adverse effects.

The most important policy implication is improved efficiency in budgetary and management decisions. The efficient and effective allocation of scarce government resources among competing demands is a perennial issue for public administrators and political leaders (Mikesell, 2011; Rubin, 2007, 2010). According to Rubin (2010), a key responsibility of administrators and budget managers is to perform the budget allocation as best as possible. If the individuals crafting and modifying the federal budget do not understand how particular combinations of budgetary expenditures affect their constituents, the country, and the economy, then budgetary changes in the defense sector may produce unexpected and, at times, even disastrous outcomes.

Finally, for the greater field of defense management, this dissertation also furthers the understanding of the practices and demands of human resource management within the federal government's largest employer. This understanding includes the training and allocation of soldiers and the utility of soldiers after their military service. A key incentive for service provided by the defense sector is the application of acquired skills in post-service employment (Bound and Turner, 2002). This incentive has come under criticism in recent years as wage differentials have become evident between veterans and their civilian counterparts (Borjas and Welch, 1986; Cardell et al., 1997; Loughran, 2002). Depending on the direction of the relationship, the findings of this study could point towards a reconsideration of recruitment practice and new policies encouraging veteran employment, as well as to quantify the contribution of public servants to the United States.

1.4 Organization of the Study

This study is organized as follows: This chapter provided an overview of the defense-growth relationship and the rise of defense studies addressing the relationship. Also addressed are the framework and methodology utilized in this study and a discussion on the significance of the study to public administration. Chapter 2, “Human Capital Effects of the Defense Sector”, offers an integrated theory of human capital. Specific attention is given to the development of a theoretical foundation explaining how defense sector investments can influence economic performance. Chapter 3, “A Human Capital Model of Defense”, analytically derives the human capital model while discussing the specific aspects of the model of the defense-growth relationship. Chapter 4, “Data and Methods”, provides a description of the data sources and methods of estimation used in this study. Included in chapter 4 is a discussion on the methodological issues that are addressed, such as model calibration and simulation. The findings of the analysis and a discussion on the results are presented in Chapter 5, “Empirical Results”. Finally, Chapter 6, “Conclusion”, concludes the study with a discussion that considers the effect of the defense-growth relationship findings for defense policy and administration in the United States.

1.5 Summary

The defense sector in the United States accounts for approximately 20.4% of all federal expenditures (Bureau of Economic Analysis, 2009) and 6.4% of all federal employees (Bureau of Labor Statistics, 2009).⁵ Despite its size, the field of public administration has paid little attention to the sector. As a study on the impact of the sector’s human capital investments on economic performance in the United States, this chapter has introduced the defense-growth relationship to the public

⁵Expenditure share and employee share based on 2009 data.

administration. In doing so it has provided a brief synopsis of the history of study on the relationship and its shortcomings. This synopsis is connected to the study at hand by a discussion of the study framework and methodology. Finally, the connection of the study to public administration through an overview of the policy implications is addressed.

CHAPTER 2

HUMAN CAPITAL EFFECTS OF THE DEFENSE SECTOR

The objective of this chapter is to transition the defense-growth relationship from a generalist to a human capital-based approach. In this transition, I provide a theoretical discussion on how human capital impacts growth, how human capital is accumulated, and the effects of human capital on the economic performance of a country. Particular attention is given to the development of theory regarding formal education, on-the-job training, and societal spillovers. After establishing an economy-wide theory of human capital, the chapter focuses on a defense sector application. This chapter begins with an overview of human capital and economic growth. I then discuss the influence of three aspects of human capital: formal education, on-the-job training, and quality of life. I then associate these aspects with the defense sector, exploring military education and training and the role of an institutional, military good.

2.1 Human Capital and Economic Growth

The relationship between economic growth and human capital has been subject to an extensive discussion within the economic literature as researchers seek to understand what kinds of training and education influence economic performance. Although it is widely considered a determining factor of a country's growth rate, interest

in the importance of human capital has historically fluctuated (Savvides and Stengo, 2009). Adam Smith (1776) was among the first to address human capital, having distinguished four types of fixed capital within an economy. In discussion of the fourth type that Smith wrote about capital as

[T]he acquired and useful abilities of all the inhabitants or members of the society. The acquisition of such talents, by the maintenance of the acquirer during his education, study, or apprenticeship, always costs a real expense, which is a capital fixed and realized, as it were, in his person. Those talents, as they make a part of his fortune, so do they likewise that of the society to which he belongs. The improved dexterity of a workman may be considered in the same light as a machine or instrument of trade which facilitates and abridges labor, and which though it costs a certain expense, repays that expense with a profit. (Smith, 1776)

Although Smith’s capital typology was an early reference to the importance of human capital, the contribution went relatively unnoticed (Crafts, 2005). Indeed, for much of economic history, the role of human capital has been deemphasized, and physical capital has been viewed as the key driver of the economy.

The modern growth theory surrounding human capital has roughly followed the establishment and expansion of the Solow (1956) model. According to the Solow growth model, it was expected that the growth rates of economies would converge over time. Comparison across economies, however, have provided little evidence of a convergence, instead suggesting rates would progressively diverge (Crafts, 2005; Lucas, 1988). To further account for diverging growth rates, the expansion of the model the following year allowed for a country’s total factor of productivity (TFP), commonly understood as a measure of technology, to influence production of total output (Solow, 1957). In this tradition, the neoclassical growth model can be represented as

$$y_t = Ak_t^\alpha \tag{2.1}$$

Here the notation y represents output per laborer, k is physical capital per laborer, A the TFP, and α indicates the responsiveness of production to change in levels of

the resources used. Though the inclusion of TFP improved the “fit” of the model to observed data, a full explanation of the divergence was still lacking. As economists sought to further explain the variation, it became increasingly evident that factors other than physical resources and access to technology contribute to economic performance (Jones, 2002).

It was not until the 1960s, however, that interest in the contribution of human capital to the growth model began to emerge. In these early contributions, the focus was on the impact of human capital investments on standards of living (defined as per capita income) and aggregate wealth. Following the pioneering works of Schultz (1960, 1961), Becker (1962), and Denison (1962), research began shifting towards treating human capital as a key contributor in the growth equation. Schultz (1960) identified human capital as an investment in a person’s education, proposing that “important increases in national income are a consequence of additions to the stock of this form of [human] capital” (p. 571). It was believed that the skills acquired by laborers can influence their ability to use available physical capital efficiently in the production of a good. Because wages were believed to be based on the ability to perform, increases in per capita income in the United States could be attributed to its investment in education.

Understanding that individuals can gain useful skills through other means, Becker (1962) broadened the definition of human capital to include accumulation from a variety of sources, including on-the-job training (both general and specific on-the-job training) and other informal transference of information (e.g., skills passed through families or among friends). Although many of the skills learned by individuals are acquired in a classroom setting, many laborers increase their productivity by learning or acquiring new skills and perfecting existing skills while on the job. Becker concluded that individuals invest in human capital based on the rationale of benefits and costs, that is, how much financial return an individual expects to receive from

the improved capital as compared to the cost associated with acquiring it. Factors influencing this return include uncertainty and differences in job opportunities. Thus, while he agreed with Schultz (1960) that a relationship between human capital and income did exist, Becker posited that income determined willingness to investment in human capital rather than the other way around.

Following the early success of the Solow (1956) model, it has continued to serve as the workhorse of human capital studies for the past 50 years. In this tradition, an economy's output is determined by a neoclassical production function. Although some variation does exist across studies, the general neoclassical form of human capital influencing the production process can be described as

$$y_t = Ak_t^\alpha [uh_t]^{1-\alpha} \quad (2.2)$$

where h is the stock of human capital and u is the fraction of time that individuals spend in production. All other variables remained as previously defined. That is, y is output per laborer, k is physical capital per laborer, A the TFP, and α the responsiveness of production to change in levels of the resources used.

The theory of human capital behind the production function is one that focuses on how individuals allocate their time over the varying activities that affect productivity of goods in the economy. Rather than relying solely upon the TFP of an economy to efficiently utilize physical capital, the inclusion of human capital assumes that both TFP and physical capital can be maximized based on a user's skill set (Lucas, 1988). As noted by C.I. Jones (2002), all other factors being equal, the stock of human capital allocated towards production determines the efficiency at which the other factors are utilized. The presumption is that a labor force with high levels of human capital is better at "creating, implementing, and adopting new technologies, thereby generating growth" (Benhabib and Spiegel, 1994, pg. 144). As individuals further their stock of human capital, the skills acquired will lead to an increase in

their ability to use available resources productively, and, hence, to higher per capita growth (Barro, 1991).

While approach and technique do vary, the general disagreement is not whether human capital impacts growth but whether human capital is exogenous or endogenous to the growth model. Early approaches treated human capital as exogenous to the growth model, that is, assuming that human capital is important to production but its accumulation is externally driven. Becker (1962, 1964), for example, viewed human capital in a similar fashion as the technology used in production: Individuals can choose where to invest. By investing in technology, economic output is increased due to the ability to more efficiently produce the economy's good using the existing stocks of physical and human capital. Alternatively, investments in human capital increase economic output due to the ability to more effectively use the existing technology in the production process. As a means of production, additional investments in human capital yield additional output. If they are substitutes for the same output, as Becker (1962) suggests, the impact of technology and human capital would be identical. The inclusion of human capital, however, changes the nature of how firms invest. Rather than being forced to invest in new technology, a firm also has the choice to invest in laborers by employing those with desired skills at higher wages. Thus, if wages are paid based on the individual's capacity, investments in human capital are undertaken if and only if the expected salary is greater than the cost of education.

Mankiw et al. (1992) treated human capital as an input into the aggregate production function that assumes decreasing returns to the reproducible factors of production. By augmenting the Solow (1956) model, they developed an approach to growth that places emphasis on human capital as well as physical capital in the production process. According to the augmented model, the accumulation of physical capital and laborers can have a greater impact on income when human capital is considered because any rate of human capital leads to a higher level of income. The utility of the

augmented-Solow model and its inclusion of human capital in the form of education is evident in that it is capable of predicting cross-country income.

Following a traditional growth accounting methodology, Benhabib and Spiegel (1994) argued that economic growth is determined by the accumulation of inputs and TFP. Their approach distinguishes itself from others, however, in that only physical capital and labor are considered inputs. The role of human capital is redirected solely as a contributor to TFP. Thusly, human capital determines the rate of TFP growth or catch-up and the pace at which an economy can adapt.

Having grown increasingly dissatisfied with the inability of exogenous models to explain long-term economic growth, a series of endogenous arguments began to arise in the 1980s. Highlighting the accumulation of human capital in the growth model, Lucas (1988) presented a model in which both physical and human capital enter the economy's production function. Combining Schultz's (1960, 1961) theory of human capital and Solow's (1956) model of economic growth, Lucas established a model of the economy that allows individuals to split their time between production and obtaining additional shares of human capital. He posited that only a fraction of a laborer's human capital is used in the production process, and the remainder is allocated towards formal education and improving his or her overall level of human capital. The accumulation and growth of this type of capital in the economy is dependent on receiving formal education and the productivity parameter of that education, that is, how efficient the education is in increasing human capital. A key assumption of the Lucas model is that both physical and human capital exhibit constant returns. Just as in earlier discussions of the impact of human capital, individuals can use their level of human capital to improve overall productivity in production and levy higher wages. Unlike the exogenous discussions, however, by including accumulation of human capital in the growth model, Lucas allowed for per capita GDP to grow as long as some time is dedicated to education.

However, Rebelo (1991) argued that in order to produce perpetual growth, a factor that can be accumulated without diminishing returns must be included in the model. To accomplish this end, he extended the Lucas (1988) model to consider a human capital accumulation that includes both human and physical capital inputs. The final output of the economy's production is similar to that of the Lucas model, except for spillovers between aggregate human capital and productivity. Mankiw (1995) pointed out, however, that lifetime is limited. Given man's finite nature there is a maximum amount of human capital that can be accumulated. While increasing human capital may extend the length of the transition period, it is not capable of being the source of long-term growth. To solve this problem, Mankiw argued for defining knowledge as the combination of all technological and scientific discoveries, whereas human capital is defined as the stock of knowledge an individual holds. Therefore, it is more conceivable that aggregate knowledge, rather than the individual's accumulated human capital, contributes to long-run economic growth.

Furthermore, Nelson and Phelps (1966) argued that the rate of technological innovation in the economy is endogenously driven by human capital. To explore the role of human capital in technological progress, Romer (1990) developed a research and development model in which growth and productivity are viewed as the result of specialization and division of labor. In this model, the economy produces two goods: an intermediate good, referred to as *technological innovation*, and a final good. Although a portion of human capital is used in the production of the economy's final good, similar to Lucas' (1988) model, the remainder of human capital is allocated toward the technological innovation of research and development activities. As time is dedicated towards research and development, labor becomes increasingly specialized, ensuring more efficient innovation. New innovations are then used in the production of the final good. Greater stocks of human capital will lead to improved economic growth by innovation-promoting effects. Consequently, new innovations are developed that

improve the productivity of production for the economy's final good.

The distinguishing of endogenous human capital is important. As an exogenous factor, education is sought after and obtained regardless of its return on income. Exogenous explanations can account for growth by one-time investments in human capital, providing improvement in the performance of the economy temporarily above its steady state. Alternatively, by including human capital as an endogenous factor, investments in it can impact the long-term growth rate. Because an individual's human capital does not depreciate over time, economic output continues to increase so long as some time is allocated toward acquiring additional measures of human capital. The increase in output is the result of the constant return from human capital. In the short-term, both exogenous and endogenous explanations imply similar results, each dependent on the specification of the model used. However, when accounting for the accumulation of human capital, endogenous models imply significantly higher rates of return from human capital investments.

Regardless of the theoretical leaning preferred, there is strong evidence that higher levels of education lead to increased productivity and levels of economic growth. Schultz (1960) estimated that university-level education accounted for 2% of physical capital formation in 1900 and 12% by 1956. The rise of human capital in physical capital formation matches the unexplained component of income growth in the United States after accounting for increases in man-hours, physical capital, and land. Becker and Chiswick (1966) argued that different investments in human capital and the corresponding rates of return determine a large share of the wage differential across the United States. Estimating the return on education for those with low, medium, or high levels, they found that 12% of the distribution of earnings within each state and about a third of the differences across states can be attributed to the level of education.

In Mankiw et al.'s (1992) study on the comparison of different versions of the Solow model, they found that the inclusion of human capital in the model accounted for approximately 80% of cross-country variation in income. The results indicate a capital share of factor income of approximately 0.60. Less developed countries do not have the established institutions for widespread education, leaving them incapable of investing the necessary stock of human capital needed for higher rates of technological growth. Allowing for human capital also eliminates problematic abnormalities and nearly eliminates the model's residual variance.

Bernanke and Gurkaynak (2001) re-estimated Mankiw et al.'s (1992) model with an extended sample period and updated the data from the Penn World Tables. Although the results supported the augmented Solow model developed by Mankiw et al., they were less than supportive of the original claim. Rather than a capital share of 0.60, Bernanke and Grkaynak estimated a share of about 0.25.

Sianesi and Van Reenen (2000) surveyed the literature on macro-economic growth, looking for a consensus on how large the human capital effect is. After comparing the empirical results from a variety of model specifications, they argued that a 1% increase in the rate of school enrollment is expected to produce an increase of between 1 and 3% in GDP per capita. Model comparison also suggested that every year of secondary education that increases the stock of available human capital leads to over a 1% increase in economic growth.

Having introduced the issue and theoretical impact of human capital on economic performance, the remainder of this section is focused on the channels through which human capital is accumulated and the corresponding societal spillovers. Following Becker's (1962, 1964) broadened definition, attention is given to both formal education and on-the-job training. A third channel, quality of life, is discussed in terms of the societal spillover into the household's benefit.

2.1.1 Formal Education

That accumulation of human capital contributes to the economic performance of a country is theoretically supported in the extant literature (Becker, 1962, 1993; Jones, 2002; Lucas, 2002; Mankiw et al., 1992; Savvides and Stengo, 2009). However, how human capital is accumulated is still highly debated. In his study on human capital in the United States, Schultz (1960) accounted only for capital accumulation as formal education. Similar restrictions have been placed on many of the empirical studies of the last 40 years. Following the definition of human capital, that is, the skills and knowledge embodied in the labor force that lead to greater productivity, the formal education received by individuals can be understood as the main form in which human beings invest in human capital (Lucas, 1988, 2002; Savvides and Stengo, 2009).

The theoretical connection between education and human capital accumulation begins with the skills needed for laboring in production. In his influential article on the contribution of formal education to the growth process, Lucas (1988) posited that individuals in the economy can divide their time between production of the economy's good and pursuing formal education or schooling. This constraint upon time can be represented as

$$u_t + z_t = 1 \tag{2.3}$$

where u is the share of time devoted to production and z is the share devoted to education. Following the ability of individuals in the economy to allocate time towards formal education, the assumption becomes that capital is expected to accumulate as the additional knowledge obtained through education becomes embodied within the individual. Although formal education does not capture all of the human capital accumulation process, it is believed that it likely captures the most important component (Gemmell, 1996). That is, most generalist knowledge is developed over years of instruction in schools. For example, while physicians undergo internships and

residencies to practice and hone their medical skills, the foundations on which the skills are based are acquired in a medical school program. Capital, then, accumulates according to

$$h_{t+1} = \zeta z_t h_t \tag{2.4}$$

where, growth in human capital, h , is a function of the existing level of the capital, h ; time devoted to education, z ; and the efficiency with which the economy transfers education into accumulated human capital, ζ .

Of central importance is the implication of what the ability to devote time to education and its role in human capital accumulation means. In the traditional neo-classical model, individuals produce at a rate of uh , that is, the time devoted to production, u , and the stock of human capital available during that time, h . In the beginning stages of market involvement, all individuals start with the same stock of human capital and the same constraint upon their time. It is generally believed that effectiveness and production-relevant skills are embodied in the extent to which individuals have acquired education (Gemmell, 1996). If individuals can withdraw from production in order to accumulate additional measures of capital, the productivity and effectiveness of individuals in the market would differ depending on how much production time was foregone. More highly educated and better trained laborers would be expected to be more productive than their uneducated counterparts, thus implying that, the more time devoted to education, the better individuals can use available resources and maximize their output during market involvement.

A second expansion by Lucas (1988) is the inclusion of the aggregated stock of human capital, represented as h_A , available in the economy. As Weisbrod (1962) noted, an investment into education expands the knowledge acquired by the individual as well as that which is available to the economy. In Lucas' model, such investment leads to further advances in technology and system processes, which improve the productivity of goods production by laborers. Lucas captured the external effect by

allowing the summation of the human capital from each individual in the economy to influence the production process. Given that knowledge does not depreciate over time in Lucas' model, the aggregated capital is then expected to grow at rate γ . This conclusion suggests that, while education can influence the production process of individuals, it can also have a spillover effect by influencing the means or skills with which they produce.

Although slight variation does exist across applications, Lucas' (1988) model has become a standard for understanding the role of formal education in human capital and economic growth (Savvides and Stengo, 2009). Accounting for the division of time and the aggregate stock of human capital, the Lucas model establishes the production of the economy as

$$y_t = Ak_t^\alpha [(1 - z_t) h_t]^{1-\alpha} h_{At}^\gamma \quad (2.5)$$

which is subject to both the time constraint and capital accumulation equations previously established.

In addition to the explicit relationships established in Lucas' expansion, a number of explicit implications should be noted. Following its potential to influence the efficiency of resource allocation throughout the entire economy, formal education is viewed as one of the principle means of investment. This investment comes in two forms. First, for the firm, employing laborers with higher levels of accumulated human capital is an investment in the production of output. Considering the different capacities of individuals, when firms replace a laborer, they do so with someone who is able to accomplish the assigned task with greater efficiency. The end result of the replacement is a boost in the firm's output per laborer.

Second, for the individual, the acquisition of education is an investment in future income. The breadth of knowledge acquired through formal education contributes to the rate of production of the employing firm, but it also has value to other firms in a competitive market. As firms seek to maximize their own production with a more

highly educated labor force, they also compete against each other for the limited supply of educated laborers. While the benefit to the firm from education is a boost in its output, a key benefit of education to laborers is higher income from their participation in the market (Jorgenson and Fraumeni, 1992). Competition, then, allows for individuals to maximize their income by working towards production in firms with the highest wages.

Given the time constraints on individuals from laboring towards production and pursuing education, schooling restricts the time available for students to work. For individuals' forgoing education, income is significantly less (Becker, 1993). In terms of the reduced income in the short term, the expected return from educational investment must be at least as large as the income lost during the schooling process. Otherwise, individuals would have no incentive for the accumulation of human capital. To compensate for lack of skill and to ensure competitiveness in the market, formal education is then used to obtain skills prior to entering the labor force. This increase in income is essential to understanding the link between investment in education and economic performance.

In support of the effects of human capital, the extant economic literature includes empirical studies quantitatively investigating the relationship between education level and economic growth. For example, Schultz (1960), in his early study on the role of human capital in the United States, concluded that investment in education grew faster than investment in physical capital between 1910 and 1950. In a comparison of education and income across the United States, Becker and Chiswick (1966) showed that investments in formal education can account for the difference in average wages between southern and non-southern states and that the rate of return for each level of education was higher for individuals in the southern states. Other notable studies include that of Denison (1985), who argued that formal education accounted for approximately 25% of the economic growth of the United States between 1929 and

1982, and Jorgenson and Fraumeni (1992), who concluded “that investment in human capital . . . accounts for an overwhelming proportion of the growth of the U.S. economy” (p. 52-53).

Although the studies previously mentioned are specific to the United States, the global experience, since the 1960s, suggests that investments into formal education are a significant contributor to human capital accumulation and, in turn, economic growth (Barro, 1991). Lucas’ (1988, 2002) own global estimations showed that countries with low educational investments have fallen behind economically while those with high levels have forged ahead. After reviewing a number of cross-national studies, Savvides and Stengo (2009) reported that data indicates that higher levels of education have stronger effects on growth. Despite the methodology adopted or country estimated, the inclusion of human capital can explain the tendency of the ratio of capital-to-income to fall during periods of high growth because capital is measured without considering human capital (Jones, 2002). Furthermore, these studies suggested that differences in the productivity and education of a country’s labor force can account for divergences of growth rates, despite similarities in the economies in all other aspects.

2.1.2 On-the-Job Training

Thus far, this discussion of human capital has largely been an issue of an individual’s education. Romer (1990) began to address other forms of accumulation by broadening the definition of *human capital* to include all knowledge obtained. Although individuals do accumulate human capital during their high school and college experiences, few are well prepared for the labor force upon graduation. Rather, graduation serves as the completion of a preparatory stage of an individual’s career. As graduates enter the labor force, they gain expertise and occupational skill that both supplements the formal education previously received and impacts the productivity of the individual (Becker, 1962, 1964). This finding suggests that, while formal edu-

cation does contribute to the accumulation of human capital, it can also be obtained through other less formal means.

This second stage of human capital accumulation is referred to as *on-the-job training*, in which individuals acquire skills, knowledge, and experience relevant to their productivity while laboring towards production. The process of capital accumulation is modeled in a similar fashion to formal education (Lucas, 1993). Individuals face a constraint upon time, suggesting the choice to labor towards production, u , or pursue schooling.

$$u_t + z_t = 1 \tag{2.6}$$

The distinction between this approach and Lucas' formula is in its treatment of human capital accumulation. Not only does capital accumulate based on time spent pursuing education, but it accumulates during the labor process, albeit at a separate, but present rate, exhibited as

$$h_{t+1} = h_t (\zeta_1 z_t + \zeta_2 u_t) \tag{2.7}$$

where growth in human capital, h , is a function of the existing level of the capital, h ; time devoted to education, z ; time devoted to labor, u ; and the efficiency with which the economy transfers education and on-the-job training into accumulated human capital, ζ_1 and ζ_2 , respectively.

Here, accumulation occurs, first, through formally organized programs, such as apprenticeships or internships; second, through other, less formal programs; and finally, through the informal process of experience. According to Temple (2001), the failure to include on-the-job training in any human capital discussion is a critical omission. Although formal education is shown to be a significant driver of economic performance, on-the-job training has historically been the primary source of human capital accumulation for individuals. This historical role suggests the importance of on-the-job training not only as a supplement to formal education but also as an alternative or substitute (Mincer, 1962). It is also theoretically reasonable to assume

that, if on-the-job training is a substitute for formal education, it may also serve as a key factor in the growth of the economy (Arrow, 1961; Lucas, 1993).

Although on-the-job training is widely preformed, it is the extreme variation across countries that make it difficult to measure and account for, though its firm-specific nature suggests that, while on-the-job training does contribute to the accumulation of human capital, it does so at a rate lower than formal education (Broadberry & Wagner, 1996). To simplify the problem of detection and rate of contribution, Becker (1964, 1993), in his influential book on human capital, classified on-the-job training either as “general” or “specific,” dependent upon its utility to the market. *General on-the-job training* refers to the skills acquired through training and working that increase marginal productivity elsewhere in the economy. That is, the human capital accumulated during production at one firm has transferability to the production of a good at a different firm. The effects of general training are easy to account for because they are similar to those of formal education. New skills can be directed towards increasing the income of the individual in the current firm of employment, but can also be used as a tool for maximizing income among all firms following an individual’s mobility. General on-the-job training is also closely connected to strategies for corporate production (Broadberry and Wagner, 1996). The firm can use the new skills of employees for maximizing its own productivity and production, thus exhibiting a return on its investment and a boost to total output.

Unlike formal education, however, the decision process behind general on-the-job training is dependent on the firm and its needs for the production process. Although on-the-job training lowers current receipts of the firm by temporarily reducing the productivity of the labor force involved, firms profit by providing on-the-job training when the skills taught sufficiently improve productivity of the workforce or lower the expenditures involved in production. Thus, the decision to provide training is determined by the firm and the likelihood of an increase in laborer production be-

ing greater than the cost of training and any subsequent wage increase. Given the competitive nature of the labor market, Becker (1964) argued that wages paid after training are equal to the laborer's marginal product. As the return from the general training is directed to the laborer, it is the laborer, not the firm, that receives the returns of general training and, therefore, bears the cost.

Alternatively, on-the-job training is considered specific if it provides an individual with skills that increase his or her productivity in the firm that provides the training but that have limited use elsewhere in the economy. As an extreme form of human capital accumulation, specific on-the-job training corresponds to instances of monopsony (Stevens, 1994). That is, there is no competition in the labor market for the skills acquired. Unlike other forms of human capital, however, the economic output of specific on-the-job training is not usually witnessed by the individual due to the lack of labor competition for the skills, but rather benefits are received solely by the firm. Resources are consumed by firms in the process of familiarizing new employees with their organization and training employees in equipment or processes specific to the firm's needs. For the individual, income that he or she is capable of receiving elsewhere is independent of the amount of specific training received, given the lack of utility the training provides. Thus, current income is dependent solely on formal training and general on-the-job training. For the firm, economic output is a function of the return of investment on its own productivity. While the rate of economic response to specific training would be expected to be positive, absent the increase in income, it is also expected to be less than other forms of human capital.

While Becker's (1964, 1993) classification does provide a basic understanding of work-related education, others have chosen a less extreme approach in which training is neither perfectly general or perfectly specific (Stevens, 1994). Perceiving that some specific training may, in practice, still be of use in other firms, Hyman (1992), I. Jones (1988), and Ritzen (1991) redefined general training as that which has some

use to at least one other firm in the market. This expanded definition suggests that, at least in practice, specific skills will have occasional utility outside of the firm where they were acquired. For example, training and experience in a corporation's processes, though company specific, may be useful to other firms planning to establish or revamp their own organization systems. Following the broadened definition, all on-the-job training, whether considered general or specific, would be expected to impact economic performance through the process established by Lucas (1993).

2.1.3 Quality of Life

Human capital is narrowly understood as education and training for an individual. However, in addition to the private benefits from human capital—increased wages and firm output—investments in capital accumulation can also produce a social benefit to others within the economy (Moretti, 2003). That is, the accumulation of human capital contributes not only to the individual receiving the capital investment but also to those with whom the individual has contact and communication.

In an early contribution, Marshall (1890) argued that the accumulation of human capital has a peer effect, such that the interaction between laborers creates an environment for learning. While the choice to pursue formal education or additional training produces an immediate return on investment for the individual, those who come into contact with someone with a higher education are the recipients of learning opportunities that influence their own productivity without undergoing the cost associated with capital accumulation. Looking at classroom achievement, Hoxby (2000) concluded that students are positively affected by the achievement level of their peers. Similar results were demonstrated by Falk and Ichino (2006) and Zimmer and Toma (2000). To expand the research on peer effects to include the informal transference of knowledge between laborers, Moretti (2003) estimated the impact of education on 282 metropolitan cities in the United States between 1980 and 1990. Concluding that

a social benefit from capital accumulation does exist, he found that a 1% increase in the labor force's share of formal education produced an increase in the income of laborers with little or no education by about 2%. A surprising outcome of the study was that the investments in education also benefit other highly educated individuals within the economy: Even highly educated individuals receive better wages when residing in cities that are populated with a labor force that is better educated.

Following Rousseau's (1979) classic role that the parent is both an early instructor and lifetime contributor to a child's interest in knowledge and specialization, Ciccone and Peri (2006) expanded the recipients of a human capital spillover to include the children of educated individuals. As was previously noted in the discussion on formal education, the aggregate human capital of the economy does not decline over time due to the transference of knowledge and skills from one individual to the next. Although the size of the spillover and its impact may be difficult to quantify due to its informal nature, the transference has received anecdotal support. For example, much literature from sociology and education supports not only the belief that children receive some level of informal schooling at home, but that the educational choices of a child are likely to be similar to the decisions previously made by their parents (Choy, 2001; Pike and Kuh, 2005; Sewell and Shah, 1968). Thus, if an individual's human capital contributes to income and, therefore, the economic performance of a country, the transference of some of this capital to the individual's children will produce similar, albeit depreciated, results (Becker et al., 1990).

Through a spillover effect, human capital can also influence the economic performance of a country by improving the quality of life of its citizens (Manton et al., 2007). Human capital dynamics have been changing over the past century. Not only has the average age of the labor force increased with growth of life expectancy, but the improvement in health care has allowed individuals better access to new technologies that improve the standard of living and age-specific care. These quality of life

improvements enhance the productivity of older laborers by extending work life and increase the economic value of additional years of life. Furthermore, as quality of life improves, individuals are able to achieve increased income, which returns itself as an additional improvement in the quality of life. As noted by Weisbrod (1962), there is a “positive correlation of educational attainment with family wealth [suggesting] that those with more education may live longer and consequently tend to receive greater lifetime incomes, education aside” (p. 108). According to Murphy and Topel (2006), the economic benefits of health quality improvements could be twice those of mortality reductions. For the general population, they estimate that the productivity gained from the decline in mortality between 1970 and 2000 were worth \$95 trillion, \$60 trillion of which were not health care related.

2.2 Human Capital and the Defense Sector

Having established the means by which human capital impacts economic growth and the process by which human capital is accumulated, the remainder of this chapter is focused on the human capital investments made by the defense sector. Although we generally discuss human capital in terms of the economy at large, Becker (1993) noted the importance of discussing the human capital investments of the military. The defense sector’s human capital investments are important not only because they have been cited as a cause of the defense-growth relationship (Benoit, 1973; Heo, 1999; Ward and Davis, 1992), but also because they are the largest, unified investment in human capital in the United States (Bryant and Wilhite, 1990). Historically, the defense sector’s investment has accounted for approximately 15% of its total budget (U.S. Department of Defense, 2010).

As an investment in human capital, military training presents a cost with the expectation of a future benefit. That is, the sector’s investments in training ensure its continued ability to serve the public good of national defense. The distinguishing

feature of human capital investments made by the defense sector is that, while the sector bears the cost, the soldier is the recipient of the long-term benefits (Asch et al., 2007). The knowledge and skills acquired are vested within the individual and cannot be separated from the soldier at the completion of his or her service. The defense sector uses this long-term benefit as an inducement for military service (Borjas and Welch, 1986; Cardell et al., 1997). In the short-term, however, the defense sector receives a benefit from its investments in the form of increased productivity in the production of a military good (Ban, 1996; Sandler and Hartley, 1995).

Human capital investments by the sector take several forms, primarily general and specific on-the-job training. Becker (1964, 1993) and Sandler and Hartley (1995) acknowledged the importance of the distinction in terms of its impact on economic growth after service. General on-the-job training, henceforth referred to as *military education*, is provided by the defense sector in skills that are useful for production in the rest of the economy. For example, the defense sector provides training in advanced computer skills, medicine, aircraft piloting, and vehicle repair, which veterans can utilize for employment after their military service. Training in other, specific skills, henceforth referred to as *military skills*, which are essential in the production of a military good, are also provided. These skills are characterized by their lack of utility in the rest of the economy. Examples include accession training, missile operations, and aerial dog-fighting.

To better understand the impact that military education and military skills have on the economic performance of the United States, the nature and extent of investments that are either general or specific are discussed. Attention is given to relating the formal education that is subsidized by the defense sector as general training. The social impact of the investments on the quality of life of soldiers, veterans, and their families is also discussed. The chapter concludes with a discussion on a secondary, indirect means by which the defense sector's human capital investments impact eco-

conomic growth. This discussion centers on the contribution of military training to the production of a military good which influences the production of the economy's good.

2.2.1 Military Education

General on-the-job training is any training that is provided by a firm or industry outside of formal education and that is useful to other firms in the market. Not only does general training raise the future marginal productivity of laborers for the firm that provides the training, but it increases the marginal productivity of other firms in the market. For the defense sector, this form of training—military education—comprises the education of forces in skills and knowledge required by soldiers for their assigned positions in the production of the military good. These investments in training not only provide income during service but continue to do so after the completion of service because the skills can be used in the private, public, or nonprofit sectors.

Benoit (1978) wrote that the defense sector provides both technical and vocational training that can be utilized for production in the private sector after service. Active duty soldiers who retire or exit from military service generally enter the civilian work force for a second career until they exit the labor force (Asch et al., 2007). For example, Air Force pilots often serve as civilian pilots after discharge, and individuals trained as either medical or legal professionals may obtain employment in a similar field after military service (Heo, 1999). The defense sector also trains soldiers in a variety of vocational skills, including automotive repair and computer technology. Though taught in a military setting, the certificates of completion for these vocational programs are recognized by firms in the market.

This fact suggests an expansion of the previously defined time constraint in that individuals can divide their time between production, u ; pursuing formal education,

z ; and laboring in the defense sector, d . This time constraint is represented as

$$u_t + z_t + d_t = 1 \tag{2.8}$$

Furthermore, if both military education and formal education contribute to an individual's human capital, accumulation would be expected to proceed as

$$h_{t+1} = h_t (\zeta_1 z_t + \zeta_2 d_t) \tag{2.9}$$

where growth in human capital, h , is a function of the existing level of the capital, h ; time devoted to education, z ; time devoted to laboring in the defense sector, d ; and the efficiency with which the economy transfers education and on-the-job training into accumulated human capital, ζ_1 and ζ_2 , respectively.

Considering the large number of veterans entering the market at the end of World War II, Schickele and Everett (1945) suggested that time spent on military education rather than formal education was not a loss to the productivity of the economy as a whole, but rather a gain. The general on-the-job nature of military education suggests that soldiers return to the market after the completion of service with a set of skills that are both marketable and useful in civilian pursuits. For example, included in the basic training of soldiers are skills that are essential to military service, but mimic the formal education soldiers could have received in the private sector. These skills include basic algebra, military history and philosophy, and simple vocational and technical skills. The ability of the training in these simple tasks to mimic private education is a key to the accumulation of human capital through military education.

The utility of human capital accumulated through military education is demonstrated by the labor decisions of soldiers at the completion of the first service contract. Soldiers who received more military education are more likely to exit the defense sector and pursue employment in the market at higher wages. Both Becker (1964) and Sandler and Hartley (1995) noted that the post-service utility of a free military education is what attracts new recruits into military service. Indeed, the defense sector

uses the existence of this future utility as an incentive to enlist. As a result, for military education, the defense sector has ready access to students and trainees, but heavy losses of graduates and skilled soldiers (Becker, 1964).

This constant flow of highly educated soldiers from the defense sector into the market suggests that the defense sector receives the short-term benefit of the training, witnessed by the output of the military good, but the firms receive the long-term benefit, witnessed by the economy's output and total productivity. For the soldiers, the benefit is twofold. Not only do they receive income during the military education process, but they are also not subject to the same investments in education as formally educated counterparts.

A classic example of the utility of military education is the role of Army engineers on the construction of the railroad in the United States. Although the railroad had a positive benefit for market involvement, it also had a strategic benefit by allowing the U. S. Army to move troops and resources around the country quickly (Angevine, 2004). Despite the public benefit, the railroad's development and construction was overseen by the Army Corp of Engineers. The wealth and possibilities associated with the railroad, however, led companies to make a practice of hiring Army engineers away from public service as soon as they gained sufficient knowledge and experience. Similar exoduses have been witnessed over the past 60 years, typically following the development of new technologies by the defense sector (DeGrasse, 1983; Redmond and Smith, 2000).

According to Knight (1996), "military [education] in developing countries may contribute to improving the education level and discipline of the labor force as a stabilizing force in the society" (p. 2-3). For countries with little to no education provided in the economy, enrollment in military service may be viewed as the only means of achieving the skills needed to excel financially (Heo, 1999). Although perfect transferability of military education to the market might not be possible, in countries

with low literacy rates, some education is better than no education. This suggests that the effects of military education on human capital accumulation might not be an issue of transferability to the market, but an indication of how much capital could have been accumulated had the individual forgone military service.

Two views exist regarding the effects of military education on the individual. First is the belief that has been argued here: Education received during military service enhances the productivity and earnings potential of veterans in the market economy after the completion of service. The second view is that military service sends a signal or “veterans premium” to employers in the market (Bryant and Wilhite, 1990; Sandler and Hartley, 1995). A premium on potential productivity exists as a consequence of the stock of human capital believed to be acquired during military service. Little and Fredland (1979) argued that the veterans premium exists because of the enhanced productivity that accompanies military education and the detailed screening soldiers undergo prior to service. However, believing that military education contributes little to the accumulation of human capital, De Tray (1982) argued that any premium that exists does so only because of screening prior to service. Thus, having a military education signals to potential employers a reduced risk of loss from any training they provide. That is, the successful completion of military service suggests a dedication and character that is not verifiable in other job candidates. The preference for hiring veterans over other job candidates would be an expected short-term gain because the risk of loss from additional training would not be as high as it would if provided to non-veterans.

However, Sandler and Hartley (1995) challenged the premium, suggesting instead that it is a cost or veterans warning. In this argument, while military education contributes to the accumulation of human capital, it does so at a lower rate than formal education in the private sector. Time spent in military education could have been better spent in formal education. Assuming equal time in education, veterans

would then have a lower productivity and should expect lower wages. Other unfavorable signals arising from military education include a conformity and dependence on orders and a strict military discipline.

2.2.2 Military Skills

In addition to the general on-the-job training, considerable resources are spent by the defense sector on skills necessary for national security, that have little use in other industries. Such training includes little of the systematic subject matter discussed in formal education, perhaps other than physical education and basic healthcare, but rather the details necessary for production. This training falls within the scope of specific training because productivity is raised in the military, but not elsewhere. For instance, while basic flying skills learned by fighter pilots can be applied to serving as a pilot in other sectors, the aerial dog-fighting skills acquired do not.¹ Other examples include accession training, defined as the basic soldering skills required for military service. Although these skills do contribute to the income growth of the individual during service, they are independent of income decisions after service Becker (1964, 1993). While the training in military skills are essential to the production of the defense sector, their lack of transferability to the market suggests that firms disregard the military-specific training when presented with the situation of determining wages for veterans.

The contribution of military skills to the accumulation of human capital is determined by how specific the training is, the prevailing belief being that, the more specific the training, the less utility it provides to other firms in the market (Becker, 1964, 1993). For the defense sector, the provision of national security is the ideal public good, defined as non-rivalrous and non-excludable (Holcombe, 2006). When specific on-the-job training is provided under the circumstances of a monopsony sit-

¹Basic flying skills are understood to be all essential skills needed to fly an aircraft, including, but not limited to, advanced maneuvering for emergency situations.

uation, there is no alternative firm to which a laborer can move that can utilize the skills. Without a market of militaries in the United States, training in military skills would raise the productivity of military good production, but the impact ends there.

However, consideration must be given to whether military skills truly have no other use, or whether the redefined understanding of specific on-the-job training applies. Under the redefined understanding, all military skills are of use to the defense sector and at least one other firm. Although the defense sector has historically operated in a monopsony situation, growth in the number of defense contractors over the past 30 years suggests that the redefined understanding is more likely to be accurate. For example, skills as a tank gunner are essential to the defense sector, but are also essential for the operation of companies such as Drive a Tank Experience, Inc., which provides tank-oriented war games to wealthy clients. Thus, while military skills might be pivotal in the production of the military good, they do have some use in the market, albeit significantly devalued.

Although the defense sector comprises both general on-the-job training and specific on-the-job training, Stevens (1994) suggested that, as long as specific on-the-job training has some utility outside of the firm providing the training, the spillover for training is strictly the sum of the general and specific components. When applied to the defense sector, this relationship is modeled as

$$\zeta_2 d_t = \zeta_{2,1} m_t + \zeta_{2,2} s_t \tag{2.10}$$

where the transfers of military education, $\zeta_{2,1} m$, and military skills, $\zeta_{2,2} s$, to the accumulation of human capital equal the transfer from total time spent laboring in the sector, $\zeta_2 d$.

King et al. (2007) reached an interesting dilemma when estimating the market utility of these types of skills. Their study of veterans in the United States from the 1970s showed a negative relationship between the length of military service and

the wages received upon entering the labor market. The belief is that the nature of the human capital acquired during military service can depend on the soldiers' total length of service. Although all new recruits undergo some military education, future on-the-job training is largely in military skills. Extended durations of service, though contributing to an individual's stock of human capital, provide little return on future income. Upon reviewing the trends of veterans from the United States between 1979 and 1985, Bryant and Wilhite (1990) also concluded that veterans receive lower wages from the market for long periods of military service. Bryant and Wilhite did note, however, that becoming increasingly specialized in military skills contributes to the efficient production of the military good, which, in turn, influences the productivity of the economy as a whole.

While the spillover of military education to the market might be obvious, Bryant and Wilhite (1990) argued that measuring the economic utility of military skills is fundamentally different. The general nature of military education suggests a utility of the knowledge and skills obtained by all or most branches of service. Alternatively, the military skills necessary for the production of the military good can vary between branches of service. That is, the military skills acquired by soldiers in the Army are fundamentally different than the skills acquired by sailors in the Navy. In determining the utility of use for military skills after service, Bryant and Wilhite (1990) considered the general utility of the skills and the market of firms that would be interested in acquiring them. Given the mechanically oriented nature of the Air Force and the competition in the airline industry, they concluded that the military skills acquired during service to the Air Force are most likely to provide some form of use outside of service.

2.2.3 Social Spillover

Human capital accumulated during military service also provides a military-specific societal spillover that impacts veterans and their families, as well as the firms that

employ them.

For veterans, the accumulation of human capital does not end with military education or military skills. Rather, the defense sector subsidizes the formal education of soldiers after the completion of their service through such programs as the G.I. Bill, which provides 36 months of education assistance to participants (Congressional Budget Office, 2004). These programs allow veterans to receive the benefits of formal education without the cost of investment. Upon investigating the benefits of the G.I. Bill, Bound and Turner (2002) compared the level of educational attainment of veterans and non-veterans. They found a substantial gain in the level of post secondary education attained, with an increase in the college completion rate of about 50%. Moreover, through non-military-related education, veterans can maximize their utility in the market by building upon capital previously obtained. Such programs give veterans a unique capacity in the production process and the opportunity to obtain high paying jobs. Angrist (1993) estimated that the combined utility of the human capital acquired during military service and post-service educational benefits results in an increase of income of about 6%.

Secondary to its promise of education, the defense sector in the United States incentivizes military service with the promise of health care for life. In the United States, post-service medical care is provided to veterans by the Department of Veterans Affairs. Not only does this medical care prolong the life of an individual, but the quality of health care and nutrition individuals receive contributes to the quality and duration of their productivity in the market. From the increased wages due to the human capital acquired during military service, veterans can also choose to spend additional portions of their income on health care-related costs to maximize the economic value of an additional year of life, thereby enhancing their productivity later in life.

To demonstrate the improved quality of life of veterans, Fogel and Costa (1997)

compared the long-term changes in morbidity, disability, and longevity of Union Army veterans and survey respondents of the National Health Interview Surveys between 1900 and 1910. Based on the results of the surveys, Fogel and Costa found that the health and fitness of veterans correlated to increases in life expectancy and duration of employment.

In addition to the improved health care of veterans, a number of social spillovers exist. As noted earlier, an increase in income brings an increase in access to advanced medical care. For the veteran, the public provision of medical care allows for private sector income that would have had to be spent on health care to be spent on other goods that may contribute to an overall increase in quality of life. This use of income includes such purchases as a new house or the allocation of funds to savings or investments. Firms that employ veterans also receive a benefit in terms of employee productivity and reduced cost of operations. This reduced cost is associated with the drop in health care-related expenses of employees.

Other societal benefits include the ability of soldiers to break the familial pattern of their parents. Status-attainment research has indicated that aspirations for educational attainment of parents are associated with the aspirations of children (Astone and McLanahan, 1991). This association is tied to the relationship between a parents and a child's educational success (Sewell and Shah, 1968). Education and labor choices of an individual typically depend on the options presented by their parents (Nam, 1965), leading the market involvement of individuals to replicate the choices that the parents have made. That is, the children of poor, uneducated individuals become poor and uneducated, whereas children of rich, educated individuals tend to become so themselves (Clark, 1983). Those who may wish to break the pattern are faced with extreme difficulty, both economically and socially. Given the dependence of the defense sector on the poor for recruitment (Appy, 2006), recruiters may present military service as the only viable option to exit the pattern. Military service repre-

sents an education and improved quality of life that individuals might have otherwise been unable to attain. For those choosing enlistment, military service effectively breaks the previous familial cycle and establishes a new path.

Black et al. (2008) demonstrated the familial divergence in their study on veteran employment. Investigating the success of young veterans in the United States to gain employment after service, they found that veterans were able to enter the labor market more quickly than equally educated individuals in the private sector. Furthermore, veterans were able to maintain employment by a single employer for longer durations of time. Of greater interest is the conclusion of the study that the employment rates and wages of minorities were higher for veterans than for those who resided in the cities and neighborhoods from which the veterans came.

2.2.4 Military Good

The effects of the defense sector's human capital investments differ from those of the rest of the economy in terms of the productivity of the economy as a whole. Rather than contributing to production directly, the defense sector's capital investments are used in the production of a second good, a "military good," which has a spillover effect on resource decisions (Ram, 1993). According to the new institutional economic (NIE) literature, a primary role of government and governmental institutions is to reduce uncertainty. As the prescription for the organization and structure human behavior (Ostrom, 2004), institutions aim to "reduce uncertainty by establishing a stable . . . structure to human interaction" (North, 1990). Although countries have a variety of institutional choices for internal stabilization, defense sectors have historically played the role externally. Thus, the belief is that military institutions are a key means of providing peace and a stable environment (Mearsheimer, 1995).

A military good influences economic performance in two ways: by reducing transaction costs and by securing property rights. As noted by North (1990) and Williamson

(1981), when transaction costs are high, the likelihood of economic growth is reduced because resources are moved from investment possibilities and allocated towards pre-existing projects. For example, funds may be allocated towards infrastructure repair rather than the development of new energy technology. In a globalizing economy, a factor of high transaction costs is the stability of the economies involved, such that countries with weak and unstable economies have high transaction costs while strong and stable economies are thought to have low transaction costs (North, 1990). In the absence of a stable economy, the defense sector serves as an indication of societal stability. Driven by security needs rather than rent seeking (Heo, 1998), it reduces transaction costs on market exchange by ensuring a degree of stability during uncertain times (McDonald and Eger, 2010; Sevastianova, 2009), for example, guarding against the likelihood of the loss of investment due to government overthrow or citizen uprising (Klare, 1972; Luckham, 1994). It then stands to reason that the reduced transaction costs from an increase in the production of a military good would positively impact the production of the economy's good.

As a tool for reducing uncertainty (North, 1990), property rights are also an important characteristic in market economies by providing a clear record of ownership and transactions. Without the security of property rights, individuals would not have the incentive to invest in more capital (whether human or physical) or purchase and adopt new technologies. Following more of a classical economic tradition, Romer (1986) noted the necessity of property rights as a precursor to investment. Viewing these rights as a tool of limiting the risk of investment from loss, Heo (1999) wrote that “[i]n order to attract foreign investment or to enjoy high levels of economic growth, a secure social and economic environment is a necessary precondition” (p. 36). Here, NIE indicates that the security of the citizenry and their property from external threat is central to the incentive to invest and the effective operation of markets (North, 1990). The impact of the military good on property rights is similar

to its impact on transaction costs. Rather than reducing the cost of doing business, however, a strong military provides insurance of good marketability. The defense sector provides an environment in which the ownership of a good is secure. From this environment comes an increased likelihood of economic interaction and growth.

When considering the production of the military good, it is important to note that larger defense sectors have a distinct military advantage. That is, they are better able to protect and secure investments made within their borders. Increases in the sector's human capital investments impact the production of the military good in the same manner as human capital accumulated by individuals in the private sector. Larger investments in human capital lead to a defense sector that is able to produce its military good more efficiently with the available resources. By investing in additional skills and training for the military, the economy receives a positive spillover both in terms of increased productivity of the military good and a boost in economic growth due to the added security.

2.3 Summary

The effect of the defense sector's human capital investments on the economic growth of the United States remains uncertain. However, extensive literature in economics testifies to the relationship between human capital accumulation in the economy at-large and the economic performance of a country. This chapter included a brief overview of that literature while establishing the defense sector's investments as part of the theoretical grounding of this study. Central is the conceptualization that, during time spent in military service, soldiers receive both military education and military skills. Given the in-service nature of the acquisition of these skills, the defense sector's investments are expected to behave in an on-the-job training fashion. To further explore the sector's investments, Chapter 3 includes a theoretical model of the economy that combines this conceptualization with the literature's tradition

of human capital accumulation. That is, individuals choose to accumulate human capital either by serving in the military or by pursuing formal education.

CHAPTER 3

A HUMAN CAPITAL MODEL OF DEFENSE

The uncertainty behind the defense-growth relationship holds many important policy and military implications. As noted in the introductory chapter the existing defense literature provides little in terms of what the relationship looks like and how it can best be modeled. Dunne, Smith and Willenbockel (2005) argue that any research wanting to make a significant contribution to the understanding of the relationship must address the various programs of the defense sector and recent advances in growth theory. Having established the role of the defense sector's human capital investments in economic growth in Chapter 2, this dissertation now focuses on how the role can best be modeled. To accomplish this task, this chapter is structured as follows: First, a brief introduction to the development and evolution of economic growth models is provided. Second, the base structure of the model is developed and explained. Third, the concept of the social planner and the use of the planner's problem as a tool for deriving the model's solution are introduced. The planner's solution for the steady-state of the model concludes.

3.1 Evolution of the Growth Model

Interest in the determinants of economic growth has historically ebbed and flowed. During the first half of the 20th century, interest was directed towards understanding

the extended period of disequilibrium that produced the Great Depression (Hacche, 1979). Macroeconomic theories of that time placed their primary emphasis on the short-term departure of full employment, characterized by the publication of Keynes' 1936 book, *The General Theory of Employment, Investment and Money*. Under the influence of Keynesian economics, it was common for determinants of economic growth to be modeled as individual equations; only then were the equations brought together to form a single model of the economy (Snowdon and Vane, 2005). Soon after its publication, Harrod (1939, 1948) and Domar (1946, 1947) became some of the earliest by-products of Keynes' general theory, both of whom aimed to extend Keynes' analysis into the long-run.

By the 1950s a new wave of interest in economic growth began to rise, rooted in the neoclassical school of thought. In early contributions, the emphasis was on the explanation of growth as a series of aggregate inputs, such as labor and physical capital (Hacche, 1979). Later, emphasis shifted to other factors, including technological progress and human capital accumulation, as contributors to aggregate growth. The pioneering works of Solow (1956, 1957) and Swan (1956) contributed significantly to this move of modern macroeconomics away from Keynesian economics and into a renewed interest in neoclassical economics. Furthermore, their work pointed the way to the modeling of economic growth that would dominate the next 50 years (Jones, 2002).

The publication of Solow's (1956, 1957) two famous papers in the 1950s broadened the understanding of economic growth to be an aggregated increase of key inputs. Solow's growth model, commonly referred to as the Solow-Swan neoclassical growth model, was independently discovered by Swan (1956) and published in *The Economic Record*. As the originator of "sources-of-growth accounting," Solow used a single model to estimate the separate effects on economic growth of technological change, physical capital, and labor. Prior to the publication of Solow's model, capital

and labor were generally thought to be the main causes of economic growth. Central to his contribution was the clarification of the importance of technological progress. Solow's 1957 empirical analysis showed that technological progress successfully explained about four fifths of per-laborer output in the United States. Solow was also the first to develop a growth model with different vintages of capital. The idea was that new capital is more valuable than old capital because capital is produced with known technology and technology is constantly improving. Given the ease of utility that the model provides when including other variables of interest, a variety of models of economic growth have been proposed since Solow and Swan's initial works. These models includes the works of Romer (1986) and Lucas (1988), who emphasized the contribution of ideas and human capital to economic growth.

A third wave of interest began in the mid 1980s and continued throughout the 1990s with the modernization of macroeconomic modeling, characterized as a dynamic general equilibrium system (Wickens, 2008). Origins of the dynamic general equilibrium in growth modeling can be traced to Lucas (1975), Kydland and Prescott (1982), and Long and Plosser (1983). As a combination of macroeconomic drivers and microeconomic choice, these modern approaches contrasted the traditional view of an aggregated economy with a reflection of the collective decisions of all rational individuals, referenced as households, over a range of choice variables in both the present and the future (Wickens, 2008). Decisions of individuals are then coordinated through markets in order to produce the macroeconomy. The economy is viewed as being in a state of continuous equilibrium, such that individuals make optimal decisions given the information they have available. When errors in the allocation of available resources do occur, they are attributed to information gaps and shocks to the economy.

The decisions of individuals are assumed to be based on maximizing the discounted sum of current and future expected utility subject to preferences and constraints on

behavior; such as available resources, time, and technological endowment. Central to the decision process is the choice of whether to consume in the present or invest for future consumption, which entails the ability to transfer income for future use or borrowing against future income for use in the present, and the preference to pursue leisure over consumption. The focus of modern macroeconomic modeling, therefore, is on the response of the individuals to shocks and how the shocks are likely to affect markets in both the present and in the future.

The starting point for these modern growth models is a small general equilibrium model. Attention is given to include the main macroeconomic variables of interest to the respective study. Activity in the model is based on a single household that produces the economy's good and can choose to consume or invest in future output and consumption. Though viewed as modern macroeconomics, this style of modeling is commonly referenced as the Ramsey (1928) model or the representative agent model. This approach to the economy allows for the analysis of its key features without having to explicitly introduce them. This includes features such as consumption and savings, savings and investment, technological progress, and the short-run and long-run behavior of the economy.

3.2 Model

To model the effect between the defense sector's human capital investments and economic performance of the United States, this dissertation adopts a two stage plan. First, it relies upon neoclassical growth theory, which is a commonly used theoretical foundation in the study of human capital and economic growth (Lucas, 1988; Savvides and Stengo, 2009) and is consistent with the theoretical relationship between human capital, the defense sector, and economic growth as discussed in the preceding chapter. Based on the work of Solow (1956) and Swan (1956), this approach uses a supply-side description of changes to aggregate output, which, in turn,

explains growth as the efficient utilization of labor and capital. Growth in neoclassical economics is understood as the allocation of resources within a household given the constraints placed by the economic system. Statements about macroeconomic effects are then derived from the aggregation of the systems microeconomic relationships.

Second, having established the theoretical foundation for the study, attention is turned towards the means and structure of the dissertation's model. New research wanting to make a significant contribution to the defense-growth relationship must take recent advances in growth theory and modeling techniques into account. As previously noted, modern growth literature has increasingly relied upon a dynamic general equilibrium (DGE) environment to explain systems of economic growth. Given the necessity of the defense-growth relationship to establish itself in modern macroeconomic methods and the understanding of neoclassical economics as a system of micro-relationships, a DGE environment is adopted. Of further interest is the ability to extend the DGE environment to account for various fluctuations and impacts of the defense sector's human capital investments while maintaining the rich theoretical tradition that neoclassical economics holds.

Following these traditions, I start with a closed economy where the representative household maximizes its lifetime utility by choosing the optimal consumption vs. savings and time allocation decisions. The household derives utility from consumption, c_t , and leisure, l_t , and can be expressed as the semi-log-linear function

$$\max \sum_{t=0}^{\infty} \beta^t U(c_t, l_t) = \ln c_t + \eta l_t \quad \beta \in (0, 1), \eta > 0 \quad (3.1)$$

where $\eta > 0$ is a preference parameter that determines the relative value that the household gives towards leisure over consumption. The discount factor of period utility, β , is then understood as the discount on future utility due to the subjective weight given to future utility by the household.

The decision of the household to maximize its lifetime utility is subject to a series of resource constraints that inform its behavior. The household is first presented with

a budget constraint. A budget constraint is an accounting identity that describes the consumption options available to the household given the limited income it can allocate among the economy's good. That is, the household's choice to consume or save is restricted by the income it receives from laboring towards production of the economy's good. Letting k denote the per-capita stock of physical capital and δ as the depreciation rate of physical capital, then $k_{t+1} - k_t(1 - \delta)$ is understood as its gross investment. It is then reasonable to assume that per-capita output of the economy is equal to capital investment in capital plus consumption, c_t . Production of the economy's good takes the standard neoclassical form and exhibits a constant return to scale. That is, it is assumed to depend on available technology, A , dedicated physical capital, k_t^e , and time allocated towards labor, N_t^e , where the superscript e denotes the share of resources allocated towards production of the good. The household is endowed with a stock of human capital, h_t , which influences its productivity in production. Also influencing production is the output elasticity, α , that measures the responsiveness of production to change in levels of the resources used. Production of the economy's good is further influenced by the defense sector, whose presence in the economy serves as a military good, m_t , which influences production at rate γ according to

$$c_t + k_{t+1} - k_t(1 - \delta) \leq A [k_t^{e\alpha} (h_t N_t^e)^{1-\alpha}]^{1-\gamma} m_t^\gamma \quad (3.2)$$

The second constraint on the economy is the defense sector, whose military good is shown to influence the economy's production. Just as the production of the economy's good, the defense sector uses physical capital, k_t^m , and labor, N_t^m , where the superscript m denotes the share of the resources allocated towards the defense sector. Laborers are endowed with a stock of human capital, h_t , that is essential to the production process. Furthermore, the defense sector uses the technology available to it in production, represented as B . Given the lack of information on the structure of defense production, structure of the good is assumed to be given by a constant

elasticity of substitution (CES) production function, which exhibits a constant percentage change in factor proportions due to a percentage change in the marginal rate of technical substitution. Production of the military good is defined by

$$m_t = B [\theta k_t^{m\tau} + (1 - \theta) (h_t N_t^m)^\tau]^\frac{1}{\tau} \quad (3.3)$$

Here θ is the share parameter and τ determines the degree of substitutability of the inputs.

Of importance is the accumulation of the stock of human capital. Individuals are able to accumulate human capital through two means: formal training, denoted as S_t^e , in which human capital is acquired through an economy-wide formal education technology, and laboring in the military, N_t^m , in which human capital is acquired through an on-the-job training process in the production of the military good.¹ The technology parameter for acquiring human capital from formal education is ω^e and through on-the-job training in the defense sector is ω^m .

$$h_{t+1} = h_t (\omega^e S_t^e + \omega^m N_t^m) \quad (3.4)$$

Two additional constraints address the behavior of the household. First is the division of physical capital between its uses in production. In the model developed for this study, stocks of physical capital are used in the production of the economy's good and in the production of the military good. The sum of the shares of physical capital stock consumed in each process equal the total capital available, described as

$$k_t^e + k_t^m = k_t \quad (3.5)$$

Second is a constraint on the allocation of time in the household. It is assumed that the household allocates its time between leisure, laboring towards production of the

¹Although human capital accumulates through other means, such as on-the-job training in the general production process, this study is restricted to just the variables of interest. Such a restriction is consistent with the modeling techniques of economics. Once the relationship between the sector's investments and economic growth is understood, future studies can expand the venues by which the household can accumulate human capital.

economy's good, laboring towards the production of the defense sector, and pursuing formal education. This constraint is specified as follows

$$N_t^e + N_t^m + S_t^e + l_t \leq 1 \tag{3.6}$$

where the total time for each period is normalized to one, such that the allocation of time cannot exceed the time available.

3.3 The Social Planner's Solution

The description of the economic environment provides a framework that can be used to study the effects of the defense sector's human capital investments. The discussion of the environment, however, only provides a description of the household preferences and the resource constraints placed upon it. To move from a description into a theoretical relationship, the environment can be optimized using the social planner's problem concept. Developed by Negishi (1960) and clarified by Kehoe (1989), the social planner's problem is a useful device from welfare economics² that helps find the economy's first-best outcomes (Barro and Sala-i Martin, 2004).

The social planner's problem is the treatment of the economic environment as though it were run by a benevolent dictator, or "social planner". Central to the planner is the assumption that he is all knowing, all powerful, and well intentioned. Although the market is interested in the behavior of the marginal household, the social planner is interested in the welfare of the representative, or average, household, to which his own interests align. As such, he dictates the choices of consumption and leisure over time and seeks to maximize the lifetime utility of the household. This is accomplished by working to optimally allocate the resources in the economy, subject to the same resource constraints and information limitations as the households in the economic environment.

²The term *welfare economics* refers to the branch of economics that uses microeconomic techniques to evaluate the general equilibrium within an economy.

In the resource allocation process, the planner seeks to establish two solutions for the environment. The first solution is for a Pareto optimal outcome, where the social planner maximizes the utility of the household without making any other household worse off. Here, there is no market to determine resource allocation, rather the planner adjusts the inputs of production while forcing the household to supply the appropriate quantities of labor. Consumption goods are then distributed to the households, making them as well off as possible. The second solution is to determine the competitive equilibrium. At the competitive equilibrium, the planner determines the point at which the value of the goods produced by the economy equal the resources needed to produce it. That is, households maximize lifetime utility given their resource constraints. Under the social planner the first fundamental theorem of welfare economics is achieved, such that the competitive equilibrium allocation is also a Pareto optimal allocation. Further, under strict conditions, the second theorem can be witnessed, such that any Pareto optimal allocation can be supported as a competitive equilibrium allocation with a suitable allocation of resources. Once achieved, the need for a social planner vanishes and a competitive market takes over.

Given the above, the planner's problem can be stated as the maximization of the household's utility, where the decision variables available to the social planner during the allocation process are listed in the subscript of that maximization.³ This is represented as

$$\max_{\{c_t, l_t, S_t^e, N_t^e, N_t^m, m_t, k_{t+1}^e, k_{t+1}^m, h_{t+1}\}} \sum_{t=0}^{\infty} \beta^t U(c_t, l_t) = \ln c_t + \eta l_t \quad \beta \in (0, 1), \eta > 0 \quad (3.7)$$

During maximization, the social planner's allocation of resources is subject to the constraints on the household as previously established in equations 3.2-3.6. These constraints are

$$c + (k^{e'} + k^{m'}) - (k^e + k^m)(1 - \delta) = A [k^{e\alpha} (hN^e)^{1-\alpha}]^{1-\gamma} m^\gamma \quad (3.8)$$

³Within the planner's problem, *decision variables* are understood to be variables whose value the planner can choose.

$$m = B [\theta k^{m\tau} + (1 - \theta) (hN^m)^\tau]^{\frac{1}{\tau}} \quad (3.9)$$

$$h' = h (\omega^e S^e + \omega^m N^m) \quad (3.10)$$

$$N^e + N^m + S^e + l = 1 \quad (3.11)$$

where all variables are defined as before and the physical capital constraint has been removed by substitution throughout the environment. Given that the planners solution can be obtained by considering just the long-run growth, the functional notation of time has been dropped. Prime notation, however is adopted to signify the forward time period.

3.3.1 Characterizing the Solution

Although several methods of solving the planner's problem are used in the economic literature, one of the most common is a Lagrangian function (Barro and Sala-i Martin, 2004; Snowdon and Vane, 2005; Wickens, 2008). Borrowed from mathematics and physics, the Lagrangian function is a technique that applies differential Euler equations to issues of constraint optimization (Brizard, 2008; Calkin, 1996). In a planner's problem, the social planner can use the technique to maximize the utility of the representative household given its available resources. This is accomplished by expanding the household's maximization function to include the constraints, multiplying the constraints by a *Lagrangian multiplier*, λ_i , and setting the derivatives of the new function to zero.

To begin deriving the solution, I first define the Lagrangian function as constrained

for each time period by the resource constraints. The Lagrangian takes the form

$$\begin{aligned}
\mathcal{L} = & \sum_{t=0}^{\infty} \beta^t \{ \ln c + \eta l \\
& + \lambda_1 \left[A [k^{e\alpha} (hN^e)^{1-\alpha}]^{1-\gamma} m^\gamma - c - (k^{e'} + k^{m'}) + (k^e + k^m) (1 - \delta) \right] \\
& + \lambda_2 \left[B [\theta k^{m\tau} + (1 - \theta) (hN^m)^\tau]^{\frac{1}{\tau}} - m \right] \\
& + \lambda_3 [h (\omega^e S^e + \omega^m N^m) - h'] \\
& + \lambda_4 [1 - N^e - N^m - S^e - l] \}
\end{aligned} \tag{3.12}$$

where λ_i is the marginal value of the constraint, reflecting the rate of which the optimal value of the household's utility changes if you change the constraint. The function is then maximized with respect to the decision variables: c , l , S^e , N^e , N^m , m , $k^{e'}$, $k^{m'}$, and h' . This is accomplished by taking the partial derivatives of the decision variables from the Lagrangian function. The resulting equations are the first-order conditions, which are necessary and sufficient conditions for a competitive equilibrium. The first-order conditions are

$$\{c\} : \frac{1}{c} - \lambda_1 = 0 \tag{3.13}$$

$$\{l\} : \eta - \lambda_4 = 0 \tag{3.14}$$

$$\{S^e\} : \lambda_3 h \omega^e - \lambda_4 = 0 \tag{3.15}$$

$$\{N^e\} : \lambda_1 A (1 - \gamma) (1 - \alpha) \left[\left(\frac{k^e}{hN^e} \right)^\alpha h \right] [k^{e\alpha} (hN^e)^{1-\alpha}]^{-\gamma} m^\gamma - \lambda_4 = 0 \tag{3.16}$$

$$\begin{aligned} \{N^m\} : & \lambda_2 B [(1 - \theta) (hN^m)^\tau]^{-1} h [\theta k^{m\tau} + (1 - \theta) (hN^m)^\tau]^{\frac{1-\tau}{\tau}} \\ & + \lambda_3 h \omega^m - \lambda_4 = 0 \end{aligned} \tag{3.17}$$

$$\{m\} : \lambda_1 \left[\gamma A [k^{e\alpha} (hN^e)^{1-\alpha}]^{1-\gamma} m^{\gamma-1} \right] - \lambda_2 = 0 \tag{3.18}$$

$$\begin{aligned} \{k^{e'}\} : & \lambda_1' \beta \left[A (1 - \gamma) \alpha \left[\frac{k^{e'}}{h'N^{e'}} \right]^{\alpha-1} [k^{e'\alpha} (h'N^{e'})^{1-\alpha}]^{-\gamma} m'^\gamma + (1 - \delta) \right] \\ & - \lambda_1 = 0 \end{aligned} \tag{3.19}$$

$$\begin{aligned} \{k^{m'}\} : \lambda'_1 \beta (1 - \delta) + \lambda'_2 \beta B \left[\theta (k^{m'})^{\tau-1} \right] \left[\theta k^{m'\tau} + (1 - \theta) (h' N^{m'})^\tau \right]^{\frac{1-\tau}{\tau}} \\ - \lambda_1 = 0 \end{aligned} \quad (3.20)$$

$$\begin{aligned} \{h'\} : \lambda'_1 \beta A (1 - \gamma) (1 - \alpha) \left[\left(\frac{k^{e'}}{h' N^{e'}} \right)^\alpha N^{e'} \right] \left[k^{e'\alpha} (h' N^{e'})^{1-\alpha} \right]^{-\gamma} m'^\gamma \\ + \lambda'_2 \beta B \left(\frac{1}{\tau} \right) \tau \left[(1 - \theta) (h' N^{m'})^{\tau-1} N^{m'} \right] \left[\theta k^{m'\tau} + (1 - \theta) (h' N^{m'})^\tau \right]^{\frac{1-\tau}{\tau}} \\ + \lambda'_3 \beta (\omega^e S^{e'} + \omega^m N^{m'}) - \lambda_3 = 0 \end{aligned} \quad (3.21)$$

These first-order conditions represent the maximum or minimum value of the function as stationary on the slope of the growth curve. Although the conditions represent the extreme value of the respective decision variable, they are not able to differentiate between a maximum and minimum. As the social planner seeks to establish the economy at its optimal value, the first-order conditions can be used as guidance for finding the maximum allocation.

3.3.2 Solve for the Lagrangian Multipliers

In order to obtain the Euler equations, whose role in the solution will be discussed later, the Lagrangian multipliers must be solved. This is accomplished by using the first-order conditions of the household's optimization problem. For example, from equation 3.13, it is known that λ_1 is

$$\lambda_1 = \frac{1}{c} \quad (3.22)$$

Further, equations 3.18 and 3.22 can be used to show that

$$\lambda_2 = \frac{1}{c} \left[\gamma A \left[k^{e\alpha} (h N^e)^{1-\alpha} \right]^{1-\gamma} m^{\gamma-1} \right] \quad (3.23)$$

and equations 3.14 and 3.15 can be used to obtain a solution for λ_3 , where

$$\lambda_3 = \frac{\eta}{h\omega^e} \quad (3.24)$$

Finally, from equation 3.14 the remaining multiplier can be derived as

$$\lambda_4 = \eta \quad (3.25)$$

3.3.3 Equilibrium Euler Equations

Having solved for the Lagrangian multipliers, the solutions can be substituted into the first-order conditions to acquire the necessary Euler equations. An Euler equation is a differential equation that is an intertemporal version of a first-order condition for a dynamic choice problem. It describes the evolution of the variables along the optimal path. Further, since Euler equations are versions of the first-order conditions, they are a necessary, but not sufficient, condition for an optimal dynamic path. They are particularly useful in characterizing the theoretical implications of a household's dynamic behavior. As there are nine decision variables in the planner's problem and four constraints, it is expected that the substitution of the solutions to the Lagrangian multipliers into the first-order conditions will produce five Euler equations.

Equation 3.16 and the solutions for λ_1 and λ_4 , as defined in equations 3.22 and 3.25, can be used to obtain

$$\eta = \frac{1}{c} A (1 - \gamma) (1 - \alpha) \left[\left(\frac{k^e}{hN^e} \right)^\alpha h \right] \left[k^{e\alpha} (hN^e)^{1-\alpha} \frac{1}{m} \right]^{-\gamma} \quad (3.26)$$

Using equation 3.17 and the definitions established in equations 3.23, 3.24, and 3.25 yields

$$\begin{aligned} \eta = \frac{1}{c} \left[\gamma A \left[k^{e\alpha} (hN^e)^{1-\alpha} \right]^{1-\gamma} m^{\gamma-1} \right] B \left[(1 - \theta) (hN^m)^{\tau-1} h \right] \left[\theta k^{m\tau} \right. \\ \left. + (1 - \theta) (hN^m)^\tau \right]^{\frac{1-\tau}{\tau}} + \frac{\eta \omega^m}{\omega^e} \end{aligned} \quad (3.27)$$

Then, upon using equation 3.22, equation 3.19 produces

$$\frac{1}{c} = \frac{1}{c'} \beta \left[A (1 - \gamma) \alpha \left[\frac{k^{e'}}{h'N^{e'}} \right]^{\alpha-1} \left[k^{e'\alpha} (h'N^{e'})^{1-\alpha} \frac{1}{m'} \right]^{-\gamma} + (1 - \delta) \right] \quad (3.28)$$

Plugging the definitions established in 3.22 and 3.23 into equation 3.20 gives

$$\begin{aligned} \frac{1}{c} = \frac{1}{c'} \beta (1 - \delta) \\ + \frac{1}{c'} \left[\gamma A \left[k^{e'\alpha} (h'N^{e'})^{1-\alpha} \right]^{1-\gamma} m'^{\gamma-1} \right] \beta B \left[\theta (k^{m'})^{\tau-1} \right] \left[\theta k^{m'\tau} \right. \\ \left. + (1 - \theta) (h'N^{m'})^\tau \right]^{\frac{1-\tau}{\tau}} \end{aligned} \quad (3.29)$$

and finally, equations 3.22, 3.23, and 3.24 can be used to retrieve the remaining Euler equation from 3.21. This yields

$$\begin{aligned}
\frac{\eta}{h\omega^e} &= \frac{1}{c'}\beta A(1-\gamma)(1-\alpha) \left[\left(\frac{k^{e'}}{h'N^{e'}} \right)^\alpha N^{e'} \right] \left[k^{e'\alpha} (h'N^{e'})^{1-\alpha} \frac{1}{m'} \right]^{-\gamma} \\
&+ \frac{1}{c'} \left[\gamma A \left[k^{e'\alpha} (h'N^{e'})^{1-\alpha} \right]^{1-\gamma} m'^{\gamma-1} \right] \beta B \left[(1-\theta) (h'N^{m'})^{\tau-1} N^{m'} \right] [\theta k^{m'\tau} \\
&+ (1-\theta) (h'N^{m'})^\tau]^{\frac{1-\tau}{\tau}} + \frac{\eta}{h'\omega^e} \beta (\omega^e S^{e'} + \omega^m N^{m'})
\end{aligned} \tag{3.30}$$

These Euler equations have the following economic interpretations. Equations 3.26 and 3.27 represent the optimal labor-leisure decisions. The left hand side of the Euler equations represent the increase in the household's utility that is associated with a one unit increase in the allocation of time directed towards leisure. The incremental loss is on the right-hand side, where the reduction in output associated with a one unit decline in labor is given by the marginal product of labor. Based on the Euler's, the marginal cost of leisure must be equal to the marginal benefit of consumption for the decision to be optimal. A similar relationship is depicted in equation 3.30, which describes the household's choice between leisure in the current period and consumption in the future. This choice characterizes the willingness of the household to forgo current leisure in exchange for saving for the future. Just as the labor-leisure decisions, the marginal benefit from the future consumption must be equal to the marginal cost of leisure in the present for the decision to be optimal.

Further, equations 3.28 and 3.29 portray the optimal consumption-savings decisions of the household. They describe the consumption choice between the current and future periods. The left-hand sides represent the decrease in utility associated with a one unit reduction in consumption during the current period. Each unit of lower consumption then corresponds to either an increase in investment or an increase in capital stock. The household's willingness to invest is determined by the rate they are compensated for saving. As long as $\frac{c'}{c} > 0$, the household is willing to sacrifice

some present consumption in order to save for future consumption. Thus, the optimal decision requires that the value of current consumption be equal to the discounted present value of future consumption.

3.4 Balanced Growth Path

Rather than solving the problem at hand for the explicit Pareto optimal and competitive equilibrium solutions, the strategy for characterizing the model that is presented in this study is to solve for its balanced growth path. The balanced growth path is a concept of macroeconomics that refers to an equilibrium in which the key elements of a model grow at the same rate over time. A key assumption is that the economy is either at or moving towards a consistent rate of growth. According to Krueger (2002), an economy growing along a balanced path exhibits characteristics similar to a steady-state. Thus, while not the explicit solutions desired, a balanced growth solution does provide the necessary answers for the social planner. First, as the social planner is maximizing the utility of the representative household, there is only one household in the economy. It is, by definition, Pareto optimal. Second, in the competitive equilibrium solution, the social planner searches for the optimal allocation of the economy's resources over time. This resembles the balance growth path, which argues that the economy progressively moves toward an optimal allocation of resources as it moves towards a sustainable growth in the long-run. Thus, in the long-run, a balanced growth solution encompasses the competitive equilibrium solution (given that military resources are consistent with an optimal policy).

A balanced growth path is a path of the decision variables, such that c , m , k^e , k^m , and h grow at constant, yet to be determined rates. Further, the time allocation of N^e , N^m , S^e , and l are constants. Moreover, in the balanced growth path, the growth rates of m , k^e , k^m , and h equal that of c . Although one could assume that the economy will reach a balanced growth, it remains to verify that the constraints are consistent with

the path. To demonstrate this relationship, the model must be normalized so that the social planner can derive the optimal allocation of the household's time. The final stage of model derivation is to write its steady-state form. In this form, the structure of the model is presented in accordance to its balanced and optimal allocations. It is also this steady-state form that presents a model of the U.S. economy in the long-run that is usable for the study of defense policy alternatives.

I begin by defining the growth rate of consumption as ϕ which must be found. This definition is demonstrated in equation 3.31.

$$\frac{c'}{c} = \phi \quad (3.31)$$

Next, it is useful to show the constant growth rates involved in the production of the economy's *military good*. This is accomplished by dividing equation 3.9 by h , from which I arrive at

$$\frac{m}{h} = \frac{B [\theta k^{m\tau} + (1 - \theta) (hN^m)^\tau]^{\frac{1}{\tau}}}{h} \quad (3.32)$$

Equation 3.32 can then be simplified. This is accomplished in two steps. These are

$$\frac{m}{h} = B \left[\theta \left(\frac{k^m}{h} \right)^\tau + (1 - \theta) \left(\frac{hN^m}{h} \right)^\tau \right]^{\frac{1}{\tau}} \quad (3.33)$$

and

$$\frac{m}{h} = B \left[\theta \left(\frac{k^m}{h} \right)^\tau + (1 - \theta) (N^m)^\tau \right]^{\frac{1}{\tau}} \quad (3.34)$$

Given that B , θ , and τ are all constants, $\frac{m}{h}$ and $\frac{k^m}{h}$ must be growing at the same rate. This also implies that m , k^m , and h grow at the same rate, exhibited as

$$\frac{m'}{m} = \frac{k^{m'}}{k^m} = \frac{h'}{h} \quad (3.35)$$

The growth rate of consumption can be found by multiplying equation 3.28 by c' . From this I arrive at the expression

$$\frac{c'}{c} = \beta \left[A(1 - \gamma) \alpha \left(\frac{k^{e'}}{h'N^{e'}} \right)^{\alpha-1} \left[k^{e'\alpha} (h'N^{e'})^{1-\alpha} \frac{1}{m'} \right]^{-\gamma} + (1 - \delta) \right] \quad (3.36)$$

where the definition of growth of consumption as established in equation 3.31 can be substituted into equation 3.36 to produce

$$\phi = \beta \left[A(1 - \gamma) \alpha \left(\frac{k^{e'}}{h'N^{e'}} \right)^{\alpha-1} \left[k^{e'\alpha} (h'N^{e'})^{1-\alpha} \frac{1}{m'} \right]^{-\gamma} + (1 - \delta) \right] \quad (3.37)$$

Equation 3.37 can then be rewritten in growth terms. This is accomplished by taking the logs of both sides of the equation and then taking its derivatives with respect to time. The outcome of this process can be shown as

$$0 = (\alpha - 1) \left(\frac{k^{e'}}{k^e} - \frac{h'}{h} \right) - \gamma \left[\left(\alpha \frac{k^{e'}}{k^e} + (1 - \alpha) \frac{h'}{h} \right) - \frac{m'}{m} \right] \quad (3.38)$$

This can be simplified by grouping the variables around like-terms.

$$0 = [(\alpha - 1) - \gamma\alpha] \frac{k^{e'}}{k^e} + (1 - \alpha)(1 - \gamma) \frac{h'}{h} + \gamma \frac{m'}{m} \quad (3.39)$$

Using the relationship established in equation 3.35, $\frac{m'}{m}$ can be substituted for $\frac{h'}{h}$. A simplification shows that

$$\frac{m'}{m} = \frac{k^{e'}}{k^e} \quad (3.40)$$

The remaining relationship essential to the balanced growth path can be easily found. This is accomplished by multiplying equation 3.26 by c and then dividing the answer by h to get

$$\frac{\eta c}{h} = A(1 - \gamma)(1 - \alpha) \left[\left(\frac{k^e}{hN^e} \right)^\alpha \right] \left[k^{e\alpha} (hN^e)^{1-\alpha} \frac{1}{m} \right]^{-\gamma} \quad (3.41)$$

Equation 3.41 can then be written in growth terms, following the process previously established. The result is

$$\frac{c'}{c} - \frac{h'}{h} = \alpha \left(\frac{k^{e'}}{k^e} - \frac{h'}{h} \right) - \gamma \left[\alpha \frac{k^{e'}}{k^e} + (1 - \alpha) \frac{h'}{h} - \frac{m'}{m} \right] \quad (3.42)$$

The relationships established in equations 3.35 and 3.40 can be used to simplify equation 3.42. Through simplification it can be shown that

$$\frac{c'}{c} = \frac{h'}{h} \quad (3.43)$$

From equations 3.31, 3.35, 3.40, and 3.43, it can be shown that c , m , k^e , k^m , and h grow at the same rate

$$\frac{c'}{c} = \frac{m'}{m} = \frac{k^{e'}}{k^e} = \frac{k^{m'}}{k^m} = \frac{h'}{h} = \phi \quad (3.44)$$

Hence the long-run behavior of the model is predicted to converge to a balanced growth path subject to the social planner's allocation of resources.

3.4.1 Model Normalization

Convergence to the balanced growth path, however, is contingent upon the planner's optimal allocation of the households time. As noted in equation 3.11, the planner can divide the households time between four activities. Although each activity does provide some utility to the environment as a whole, a misallocation of time can lead to a stalled economy that is neither at nor moving towards the balanced growth path. For example, if all time was dedicated towards leisure then the economy would produce no goods and consumption would cease. Given the interest of the household in maximizing its utility in consumption and leisure, it is important for the social planner to optimally allocate the household's time between the activities such that consumption and leisure can be maximized and the economic growth rate can reach its balanced path.

In order to facilitate the necessary computations for the optimal time allocations, the household's economic environment must be *normalized*, or deflated, by h . That is, the model's constraints and Euler equations need to be divided by the measure of human capital. Normalization is necessary due to the number of variables in the model, 10,⁴ and the number of equations available, nine.⁵ Without the normalization it would not be possible to obtain the time allocation as a single variable, remaining undefined.

⁴These variables are c , m , k^e , k^m , h , N^e , N^m , S^e , l , and ϕ .

⁵These are the four constraints of the household, as listed in equations 3.8, 3.9, 3.10 and 3.11, and the Euler equations, as listed in equations 3.26, 3.27, 3.28, 3.29, and 3.30.

The process of normalizing the model implicitly defines a new set of decision variables. I begin by defining these four new terms, such that

$$\hat{c} = \frac{c}{h} \quad (3.45)$$

$$\hat{m} = \frac{m}{h} \quad (3.46)$$

$$\hat{k}^e = \frac{k^e}{h} \quad (3.47)$$

$$\hat{k}^m = \frac{k^m}{h} \quad (3.48)$$

Beginning with the household's budget constraint, as shown in equation 3.8, the forward time period is updated using the properties of ϕ from equation 3.44. The result is then normalized by dividing through by h to achieve

$$\frac{c}{h} + \phi \frac{k^e}{h} + \phi \frac{k^m}{h} - \left(\frac{k^e}{h} + \frac{k^m}{h} \right) (1 - \delta) = \frac{A [k^{e\alpha} (hN^e)^{1-\alpha}]^{1-\gamma} m^\gamma}{h} \quad (3.49)$$

Equation 3.49 is then updated with the new definitions to reach its normalized form.

This is expressed as

$$\hat{c} + \phi \hat{k}^e + \phi \hat{k}^m - \left(\hat{k}^e + \hat{k}^m \right) (1 - \delta) = A \left[\hat{k}^{e\alpha} (N^e)^{1-\alpha} \right]^{1-\gamma} \hat{m}^\gamma \quad (3.50)$$

Next, attention is directed at normalizing the production of the military good. Here equation 3.9 can be divided by h and updated with the new definitions to show that

$$\hat{m} = B \left[\theta \hat{k}^{m\tau} + (1 - \theta) (N^m)^\tau \right]^{\frac{1}{\tau}} \quad (3.51)$$

Furthermore, the normalization of human capital accumulation is found by dividing 3.10 by the usual h and using equation 3.44 to simplify yields

$$\phi = \omega^e S^e + \omega^m N^m \quad (3.52)$$

The final constraint of the household, that is the time constraint from equation 3.11, does not need special attention for the normalized model given the absence of h in its setup.

Following the role of the Euler equations in the planner's problem, attention must be directed at finding their normalized forms. Although each of the Euler equations can be normalized, the process is not as convenient as that of the household constraints. For example, the first Euler equation, as shown in 3.26, which represents a labor-leisure decision of the household, must be multiplied by c prior to dividing by h , as shown here

$$\frac{c\eta}{h} = A(1-\gamma)(1-\alpha) \frac{[k^{e\alpha} (hN^e)^{-\alpha} h] [k^{e\alpha} (hN^e)^{1-\alpha}]^{-\gamma} m^\gamma}{h} \quad (3.53)$$

This can then be updated with the new definitions and further simplified by dividing both sides by η

$$\hat{c} = \left(\frac{1}{\eta}\right) A(1-\gamma)(1-\alpha) [\hat{k}^{e\alpha} N^{e-\alpha}] [\hat{k}^{e\alpha} (N^e)^{1-\alpha}]^{-\gamma} \hat{m}^\gamma \quad (3.54)$$

As A , α , η , and γ are constants, simplification can be taken one step further. Defining ζ_1 as

$$\zeta_1 = \frac{A(1-\gamma)(1-\alpha)}{\eta} \quad (3.55)$$

equation 3.54 can be grouped around like terms to yield its normalized form.

$$\hat{c} = \zeta_1 \hat{k}^{e\alpha(1-\gamma)} N^{e-\alpha-\gamma(1-\alpha)} \hat{m}^\gamma \quad (3.56)$$

The second labor-leisure decision of the household, as previously displayed in equation 3.27, must be simplified prior to normalization. This is accomplished using 3.9 and multiplying by c . Upon normalizing the result by h , I arrive at

$$\frac{c\eta}{h} = \frac{1}{h} \left[\gamma A [k^{e\alpha} (hN^e)^{1-\alpha}]^{1-\gamma} m^{\gamma-1} \right] B [(1-\theta) (hN^m)^{\tau-1} h] m^{1-\tau} + \frac{c\eta\omega^m}{\omega^e h} \quad (3.57)$$

Updating the Euler with the new definitions, equation 3.57 can be simplified to show

$$\hat{c} = \frac{\gamma}{\eta} AB (1-\theta) \hat{k}^{e\alpha(1-\gamma)} N^{e(1-\alpha)(1-\gamma)} N^{m\tau-1} \hat{m}^{\gamma-\tau} + \hat{c} \frac{\omega^m}{\omega^e} \quad (3.58)$$

The Euler that represents that household's optimal consumption-savings decision in equation 3.28 is then normalized in the following manner. After multiplying by c'

and updating the lefthand side with ϕ , I multiply both sides of the Euler by $(h'N^e)^{\alpha-1}$. This produces

$$\begin{aligned} \phi (h'N^e)^{\alpha-1} &= \beta A (1 - \gamma) \alpha (k^{e'})^{\alpha-1} \left[k^{e'\alpha} (h'N^e)^{1-\alpha} \right]^{-\gamma} m'^{\gamma} \\ &+ \beta (1 - \delta) (h'N^e)^{\alpha-1} \end{aligned} \quad (3.59)$$

As previously done with ζ_1 in equation 3.56, two new definitions can be established for the constants in 3.59. These are

$$\zeta_2 = \beta A (1 - \gamma) \alpha \quad (3.60)$$

$$\zeta_3 = \beta (1 - \delta) \quad (3.61)$$

3.59 is then updated with 3.60 and 3.61. Given the dynamic nature of the Euler it is normalized using h' .

$$\frac{\phi (h'N^e)^{\alpha-1}}{h'} = \frac{\zeta_2 (k^{e'})^{\alpha-1} \left[k^{e'\alpha} (h'N^e)^{1-\alpha} \right]^{-\gamma} m'^{\gamma}}{h'} + \frac{\zeta_3 (h'N^e)^{\alpha-1}}{h'} \quad (3.62)$$

Using the definitions from equations 3.45 through 3.48 and dividing by $(N^e)^{\alpha-1}$, equation 3.62 can be simplified to show that

$$\phi = \zeta_2 \hat{k}^{e'(\alpha-1)-\gamma\alpha} N^{e(1-\alpha)(1-\gamma)} \hat{m}'^{\gamma} + \zeta_3 \quad (3.63)$$

The normalization of equation 3.29, which represents the second optimal consumption-savings decision, is accomplished in the following manner. First, I multiply by c' and update the left-hand side of the equation with ϕ . Collecting the constants, this yields

$$\begin{aligned} \frac{c'}{c} &= \beta (1 - \delta) + \beta \gamma \theta AB \left[k^{e'\alpha} (h'N^e)^{1-\alpha} \right]^{1-\gamma} m'^{\gamma-1} (k^{m'})^{\tau-1} \left[\theta k^{m'\tau} \right. \\ &\left. + (1 - \theta) (h'N^m)^{\tau} \right]^{\frac{1-\tau}{\tau}} \end{aligned} \quad (3.64)$$

After factoring out $(h'N^e)^{1-\gamma}$, 3.9, 3.31, and 3.61 can be used for simplification.

$$\phi = \zeta_3 + \beta \gamma \theta AB \left[k^{e'\alpha} \right]^{1-\gamma} (h'N^e)^{(1-\gamma)(1-\alpha)} m'^{\gamma-1} (k^{m'})^{\tau-1} m'^{1-\tau} \quad (3.65)$$

Multiplying both sides by $(h'N^e)^{\gamma-1}$ and normalizing with h' produces

$$\frac{\phi (h'N^e)^{\gamma-1}}{h'} = \frac{\zeta_3 (h'N^e)^{\gamma-1}}{h'} + \frac{\beta\gamma\theta AB [k^{e'\alpha}]^{1-\gamma} (h'N^e)^{1-\alpha} m'^{\gamma-1} (k^{m'})^{\tau-1} m'^{1-\tau}}{h'} \quad (3.66)$$

Using the normalization definitions, this can be simplified as

$$\phi (N^e)^{\gamma-1} = \zeta_3 (N^e)^{\gamma-1} + \beta\gamma\theta AB [\hat{k}^{e'\alpha}]^{1-\gamma} (N^e)^{1-\alpha} \hat{m}'^{\gamma-1} (\hat{k}^{m'})^{\tau-1} \hat{m}'^{1-\tau} \quad (3.67)$$

Finally, equation 3.67 can be divided by $(N^e)^{\gamma-1}$ and simplified for the normalized form to show that

$$\phi = \zeta_3 + \beta\gamma\theta AB \hat{k}^{e'\alpha(1-\gamma)} N^{e(1-\alpha)+(1-\gamma)\hat{k}^{m'\tau-1}} \hat{m}'^{(\gamma-\tau)} \quad (3.68)$$

The complexity of the remaining Euler, which represents the optimal decision between consumption in the future and leisure in the present as established in equation 3.30, requires extra attention and simplification. Included in this attention is the use of equations 3.26 and 3.27 to make the Euler manageable. To start, equation 3.26 must be divided by h and multiplied by N^e . Bringing the result forward one period, this gives

$$\frac{\eta N^{e'}}{h'} = N^{e'} \frac{1}{c'} A (1-\gamma) (1-\alpha) \left(\frac{k^{e'}}{h'N^e} \right)^\alpha \left[k^{e'\alpha} (h'N^{e'})^{1-\alpha} \frac{1}{m'} \right]^{-\gamma} \quad (3.69)$$

Turning to equation 3.27, I bring the η terms to the left-side of the equation and divide by h .

$$\frac{\eta}{h} - \frac{\eta\omega^m}{h\omega^e} = \frac{1}{c} \left[\gamma A [k^{e\alpha} (hN^e)^{1-\alpha}]^{1-\gamma} m^{\gamma-1} \right] B [(1-\theta) (hN^m)^{\tau-1}] [\theta k^{m\tau} + (1-\theta) (hN^m)^\tau]^{\frac{1-\tau}{\tau}} \quad (3.70)$$

Multiplying equation 3.70 by N^m and bringing the result forward one period yields

$$N^{m'} \left(\frac{\eta}{h'} - \frac{\eta\omega^m}{h'\omega^e} \right) = N^{m'} \frac{1}{c'} \left[\gamma A [k^{e'\alpha} (h'N^{e'})^{1-\alpha}]^{1-\gamma} m'^{\gamma-1} \right] B [(1-\theta) (h'N^{m'})^{\tau-1}] [\theta k^{m'\tau} + (1-\theta) (h'N^{m'})^\tau]^{\frac{1-\tau}{\tau}} \quad (3.71)$$

Using the two derivations, equation 3.30 can be simplified as

$$\frac{\eta}{h\omega^e} = \beta \frac{\eta N^{e'}}{h'} + \beta N^{m'} \left(\frac{\eta}{h'} - \frac{\eta \omega^m}{h' \omega^e} \right) + \beta \frac{\eta}{h' \omega^e} (\omega^e S^{e'} + \omega^m N^{m'}) \quad (3.72)$$

Upon multiplying both sides of 3.72 by $\frac{h'}{\eta}$, additional simplification can be undertaken to show that

$$\frac{h'}{h\omega^e} = \beta (N^{e'} + N^{m'} + S^{e'}) \quad (3.73)$$

A final version of the Euler can be found using the time constraint from equation 3.11, multiplying through by ω^e , and substituting ϕ according to its previously established properties. The result is a normalized Euler which portrays the growth rate of human capital as

$$\phi = \beta \omega^e (1 - l) \quad (3.74)$$

Following the properties of the model previously established (see equation 3.44), the growth rate given in 3.73 represents the optimal rate needed to achieve the balanced path. In the model, growth depends only on the discount factor β , the technology factor ω^e , and non-leisure time. As each of the growth drivers are constant, the growth rate itself exhibits a constant rate over the long-run.

3.4.2 The Steady-State Model

Having demonstrated the balanced growth path of the model and normalized its structure around human capital, the final outcome of the model is provided below. In the final form, which is referred to as the model's *steady-state*, the social planner not only utilizes the balanced growth properties of the economy but also exploits the normalized form of the model in order to derive the optimal time allocation needed to maximize ϕ . The steady-state form is shown as

$$\hat{c} + \phi \hat{k}^e + \phi \hat{k}^m - (\hat{k}^e + \hat{k}^m) (1 - \delta) \leq A \left[\hat{k}^{e\alpha} (\bar{N}^e)^{1-\alpha} \right]^{1-\gamma} \hat{m}^\gamma \quad (3.75)$$

$$\hat{m} = B \left[\theta \hat{k}^{m\tau} + (1 - \theta) (\bar{N}^m)^\tau \right]^{\frac{1}{\tau}} \quad (3.76)$$

$$\phi = \omega^e \bar{S}^e + \omega^m \bar{N}^m \quad (3.77)$$

$$\bar{N}^e + \bar{N}^m + \bar{S}^e + \bar{l} = 1 \quad (3.78)$$

$$\hat{c} = \zeta_1 \hat{k}^{e\alpha(1-\gamma)} \bar{N}^{e-\alpha-\gamma(1-\alpha)} \hat{m}^\gamma \quad (3.79)$$

$$\hat{c} = \frac{\gamma}{\eta} AB (1 - \theta) \hat{k}^{e\alpha(1-\gamma)} \bar{N}^{e(1-\alpha)(1-\gamma)} \bar{N}^{m\tau-1} \hat{m}^{\gamma-\tau} + \hat{c} \frac{\omega^m}{\omega^e} \quad (3.80)$$

$$\phi = \zeta_2 \hat{k}^{e(\alpha-1)-\gamma\alpha} \bar{N}^{e(1-\alpha)(1-\gamma)} (\hat{m}')^\gamma + \zeta_3 \quad (3.81)$$

$$\phi = \zeta_3 + \beta\gamma\theta AB \hat{k}^{e\alpha(1-\gamma)} \bar{N}^{e(1-\alpha)+(1-\gamma)} \hat{k}^{m\tau-1} \hat{m}'^{\gamma-\tau} \quad (3.82)$$

$$\phi = \beta\omega^e (1 - \bar{l}) \quad (3.83)$$

where a bar is used by the social planner in order to distinguish the optimal allocation of the household's time to the respective activity. This designation of the optimal time allocation is used to ensure the distinction between the economy's long-run form and its non-maximized structure.

The steady-state described here is the long-run outcome of the model economy, where equations 3.75-3.83 are necessary conditions for optimal allocation of resources. Although the initial stages of the economy begin away from its steady-state, the balanced growth path properties present in the mode suggest that overtime it progressively moves towards the steady-state. Similarly, if an economy receives a shock, in the long-run it will return to its long-run balanced growth path. Given the nature of the social planner's solution, the social planner will use the steady-state model to guide his optimal allocation. Thus, the planner removes himself and allows the market to maintain its level (given an optimal defense policy).

3.5 Summary

The extent literature on the defense-growth relationship have used a variety of models to investigate the defense sector in the United States. Although the previous

models have been met with some success, they have been void of a strong theoretical foundation (Dunne et al., 2005). In order to advance the understanding of the relationship, this chapter has sought to develop a model of the relationship that is grounded in modern economic thought. It has done so by introducing dynamic general equilibrium (DGE) growth models to public administration and then using the DGE structure as a basis for the developed model. This modern grounding allows for a better understanding of the relationship by including theory and techniques that have proven themselves over the past 30 years.

Having established the model, this chapter concluded with the derivation of the model as a social planner's problem. The resultant solution provides the optimal allocation of the economy's resources, including its military good and the defense sector's human capital investments. In the following chapters the planner's solution is used as tool for measuring the current status of the United States in terms of optimal defense provision, as well as to gauge the impact of potential policy changes in the sector's investments.

CHAPTER 4

DATA AND METHODS

In the preceding chapter, an economic growth model was explicitly designed to depict how the economy of the United States might behave over time. Although the model provides an interesting economic environment that includes the defense sector's human capital investments, as developed it is only a theoretical description of the household preferences and the constraints placed upon them. The economic environment and the social planner concept do, however, provide a framework that can be used to study policy decisions that affect economic performance. To move from a general framework into analytical statements about the effects of the sector's human capital investments, additional steps are needed.

To assist in that transformation, this chapter offers the required mechanics of analysis. First, the chapter will introduce and define model calibration. As will be discussed, calibration refers to the process of ensuring that the properties of the model emulate, or replicate, the properties of the real economy being studied. Next, attention will be turned to the process of calibration, focusing on the mechanics of calibration. Included in the mechanics is the issue of data definition and sources. Due to availability and the structural shift produced by World War II, data will be restricted to the United States between the years 1949 and 2009.

4.1 Calibration

The process of calibration refers to the alignment of a model such that its properties emulate, or replicate, the properties of the event being studied.¹ Although the process of calibration is relatively new to the social sciences, it has a long tradition within the physical sciences, referring to the graduation of measuring instruments (Dawkins et al., 2001). For example, calibration has been used as a means of adjusting thermometers to accurately display the boiling point at high altitudes and the adjustment of computational physics to a specified parameter. It was not until Kydland and Prescott's (1982) study on the business cycle, however, that it emerged as a modeling tool for the social sciences. Following the rise of dynamic general equilibrium models (see "Evolution of the Growth Model" in Chapter 3), calibration became a predominate tool for empirical investigation in mainstream macroeconomics as early as 1990 (Gregory and Smith, 1991). Although the process of calibration as discussed here has not previously been conducted within the public administration literature, it does provide the needed utility for exploring the policy decisions of interest to this study.

The calibration of a growth model involves the setting of a model's parameters to replicate a *benchmark* or *base* data set as a model solution. Once calibrated, a model can then be used to assess the effects of an unobservable or counterfactual change in the environment, such as a change in policy on the defense sector's provision of training and education. In analysis, the benchmark solution serves as a reference point for the observed outcome of the economy under the existing policy and its allocation

¹There has been some confusion within the economic literature on the difference between calibration and estimation (Dawkins et al., 2001). Although there are some similarities between them, Kydland and Prescott (1996) distinguish between model calibration and estimation, noting that the process of calibration is the fixing of the model to emulate the economy in question whereas estimation is the determination of the approximate quantity of some variable. Estimation does provide a useful tool for understanding the influence of a set of variables, but calibration allows for a change of behavior in the model when alternative variable values, such as those provided from a simulation, are used.

of resources, whereas the counterfactual solution provides a measure of what a change in allocation may produce. The comparison of these measures offers a prediction of how the economy is likely to respond to the new policy options. This differs from traditional empirical research, in which tests are performed to ascertain how well a particular model describes the available data. Behind calibration is the idea that a counterfactual analysis is not possible without a coherent theoretical framework and that a model consistent with economic theory is the appropriate starting point. According to Dawkins et al. (2001), calibration is particularly useful for the study of policy. The adoption of a policy can often not wait until appropriate data is recorded, making policy analysis difficult. Instead, a model can be developed and calibrated to replicate the current environment. The counterfactual change would then be the environment under a proposed policy, with the comparison of the outcomes serving as the policy analysis.

4.1.1 Process of Calibration

The process of calibration used in this study follows a two-step procedure. Developed by Kydland and Prescott (1982), and clarified by Cooley and Prescott (1995) and Heer and Maussner (2009), these steps focus on the definition of the variable data and the use of that data in establishing parameter values. The first step of calibration is to construct a set of measurements for the known variables that are consistent with the parameters of the model. This requires that consideration be given to the correspondence between the environment and measurements that are performed on the economy. With a large sample of observations, accompanied by established economic theory, to define a parametric class of models, it is possible to establish the association of the model to observed data for the United States. The second and final step is to assign values to the parameters of the model. The assigning of value involves setting the parameters so that the behavior of the economic environment matches

the features of the measured data. Overtime, it can be observed that certain ratios in the U.S. economy are fairly consistent. Parameters are then chosen to replicate the economy on the dimensions associated with long-term growth. Once these steps are accomplished, the model is ready for use in studying the analytical behavior of prospective policy decisions on economic performance.

4.2 Defining Consistent Measurements

Calibrating the economic environment as developed in Chapter 3 requires that consideration be given to the correspondence between the model and measurements that are conducted on the benchmark economy. I start with annualized economic data for the United States in the 71 year period, 1949 through 2009. Although studies using a dynamic general equilibrium model typically utilize quarterly data for calibration, the nature of defense sector financing restricts this study to annualized measures. The sample period is extended as far as possible in order to increase the precision of the calibrated measures. Attention in this study, however, is limited to this time period because a larger sample period would introduce a variety of structural breaks, including the industrialization of the defense sector during World War II and the Great Depression. These structural breaks would violate the steady state assumption of those time periods. A cutoff of 2009 is used due to the availability of data on the U.S. Department of Defense's enlistments and investments. Because the model focuses on the behavior of the representative household, all measures are scaled to a per-capita basis.

As the model is built upon the neoclassical growth framework, which emphasizes the role of physical capital in determining the growth rate, the first issue of consideration is the match between physical capital as conceived in the model and as conceptualized in available data.² The measurement of physical capital, k , presents

²A synopsis of the variables, their definitions, and data sources is provided in Appendix A.

an interesting dilemma. The model economy is very abstract: containing no explicit government, firm, or import/export sectors. Rather, the economy revolves around the household, who uses its resources for the production of the two goods; the first being the economy's general output, denoted as y , the second a military good, m , which influences the general production process. To measure physical capital, previous work on the defense-growth relationship has relied upon the *National Income and Product Accounts* (NIPA) from the Department of Commerce's Bureau of Economic Analysis. According to Cooley and Prescott (1995), however, the NIPA is inconsistent in its treatment of capital across sectors. For instance, the accounts do not include the flow of services from the stock of consumer durables and incorporate additions to the stock of consumer durables with consumption rather than treating them as an investment. As an alternative, they recommend a construct that incorporates all aspects of physical capital that is based on the sum of business equipment and structures, residential structures, and the stock of consumer durables. Similar approaches have been used by Einarsson and Marquis (1999), Heer and Maussner (2009), Jones (2002), and Wickens (2008). Given the derivation of the model economy as inclusive of government activities, as established in Chapter 3, the stock of federal government structures and equipment is added to the sum to achieve the measurement of k . Data on business, residential, and government structures and equipment are from the NIPA. Information on consumer durables is from the Federal Reserve's *Federal Reserve Economic Data* (FRED) database.

Further, physical capital of the defense sector, k^m , is understood as the infrastructure or physical resources used to produce the military good and defense services. This includes resources such as machinery, buildings and bases, and vehicles built or purchased by the sector. Following the measurement of k , k^m is constructed as the sum of the stock of structures and equipment related to defense, as reported in the NIPA. Not only does this mode of measurement allow for a realistic capture of be-

havior by the defense sector, but it also allows the measurement to be consistent with the other measures in this study. To measure the private sector's share of physical capital, k^e , the physical capital constraint established in equation 3.5 can be utilized. That is, the private sector's share is measured by subtracting the defense sector's capital from the measure of total physical capital.

Attention must also be given to the measurement of the economy's general output, which includes output produced by all physical capital. Following the previous economic literature, y is measured as the sum of gross national product and the flow of services from consumer durables (see Cooley and Prescott, 1995; Einarsson and Marquis, 1999). Data sources for the computation are from the NIPA and the FRED database, respectively.

Regarding the time allocations, I turn to the classic human capital literature, where some form of the labor force share dedicated to a task is used as a proxy (see Barro, 1991; Becker and Chiswick, 1966; Mankiw et al., 1992). As the time variables are constant in the model, they are reported as the average share of the labor force. Data on the size of the labor force is obtained from the Current Statistics Program at the Department of Commerce's Bureau of Labor Statistics. Employment data on the number of active duty military personnel is from the Department of Defense's *Military Personnel Programs* (M-1) documents. The M-1 is an annual supplementary budget document from the Department of Defense Comptroller that summarizes all activities comprising the employment and personnel information for each branch of service. Formal education is operationalized as the number of students enrolled in college, where college includes both two-year and four-year institutions and enrollment is classified as attending at least 12 hours of classes during the average school week. Data on enrollment is available through the *Digest of Education Statistics* of the Department of Education's National Center for Education Statistics. Finally, the size of the private sector labor force is measured as the labor force that is neither em-

ployed in the active duty military nor enrolled in college. The measurement of leisure relies on prior economic literature and will be discussed during the establishment of parameters.

This study makes use of three other variables for which a measurement is not certain. These are consumption, denoted as c , human capital, h , and the military good, m . As an alternative to their explicit measurement, previous literature has relied on a variety of proxies. For example, defense expenditures are often used as a measure for the output of the defense sector (Benoit, 1973; DeGrasse, 1983; Dunne et al., 2005; Heo and Eger, 2005; Mintz and Huang, 1990; Ram, 1995). Although such proxies can be useful in the traditional estimation process, the absence of an error term in calibration demands precise measurement. Given its balanced-growth properties, however, the model can be calibrated and the steady-state values of the variables can be derived without previous measurement of these variables. This derivation is accomplished during the calibration process where established parameters and basic algebra can be used to solve for unknown values in a system of equations.

The measurement issues discussed above are central to the task of calibrating the model because a consistent set of measurement is essential to align the model to the benchmark data. By having a clear discussion on the relevant measurements, this study ensures that other researchers can replicate the findings within the United States and/or apply the established model to economies outside of the United States and compare the results with those established here.

4.3 Calibrating the Benchmark Economy

Assigning values to the parameters starts with an assumption that real economic data for the United States were produced by the study's model. Using a combination of economic theory, econometrics, and previously defined values, data from the sam-

Table 4.1: Labor Shares and Time Allocations

	N^m	S^e	N^e	l
Labor Share	0.031	0.109	0.859	0.642
Time Allocation	0.011	0.039	0.308	0.642

ple period can be used to derive the parameters necessary for a calibrated model.³ Parameter values are taken to be exact: no standard deviations are attached to the values. It is important to emphasize that the parameter values selected are not the ones that provide the best statistical fit. Rather, parameters are fixed such that they would produce an outcome that is near or identical to the observed data. Since the model displays fluctuations around the steady state, a valid procedure to select the value of parameters is to use long-run time series averages of known variables and parameters.

The first issue to address is the value of the time variables. According to Ghez and Becker (1975) and Juster and Stafford (1991), surveys have consistently shown that households typically allocate about a third of their discretionary (i.e. non-sleeping) time to market activity. This has led the economic literature to assign a value for l , which represents the time dedicated to leisure, of about 0.642 (also see Aguiar and Hurst, 2007). This tradition is carried forward in this study. Due to the time constraint in the model, the time variables S^e , representing the share of the labor force dedicated to formal education, N^m , the share dedicated to the defense sector, and N^e , the remaining share of the labor force, are distributed according to their weight amongst the remaining 35.8% of time. For example, while the defense sector accounts for an average of 3.1% of the labor force, N^m accounts for only 1.1% of time in this study (35.8% of 3.1% = 1.1%). Table 4.1 provides the relevant shares of the labor force and the time constrained values.

Next, the values of several of the parameters have been well established in the

³A synopsis of the parameters and their definitions is provided in Appendix B.

extant literature, supporting their adoption for this study. The first parameter established in the literature is α , an output elasticity that measures the responsiveness of production to changes in the levels of the resources used. According to Jones (2002), α can be measured as the ratio of capital to income. Overtime, the properties of the U.S. economy have produced a value for the ratio that establishes α at 0.337 (see also Mankiw et al., 1992). Further, β , the discount factor on lifetime utility, is chosen to match the steady state output-capital ratio. When considered on an annual basis a typical value within the literature assigned to β is 0.960 (see Cooley and Prescott, 1995; Heer and Maussner, 2009). Finally, δ , the rate of capital depreciation, has been shown to be fixed at 0.048 (see Barro and Sala-i Martin, 2004; Cooley and Prescott, 1995; Einarsson and Marquis, 1999; Heer and Maussner, 2009; Wickens, 2008).

According to the properties of the model, in the balanced-growth path all variables grow at a constant rate over time, denoted as ϕ . For the model economy, equation 3.77 provides the basis for establishing the growth rate, which is seen to depend on the determinants of human capital. Accordingly, in the benchmark economy ϕ is fixed as the average growth rate of personal income, as reported in the NIPA. This produces a value of 1.021. Once ϕ is assigned a value I can mathematically derive the values of ω^e and ω^m , the technology parameters for acquiring human capital through formal education and learning-by-doing in the defense sector, respectively. Using the values of ϕ , l , and β , recalling the constraint that capital accumulates only through formal education and laboring in the defense sector equation 3.83 provides the basis for establishing ω^e . This yields a value for the parameter of 21.271. Equation 3.77 can then be used to determine ω^m . Given the values for ϕ , ω^e , S^e , and N^m as previously determined, the parameter ω^m can be found. This produces a value for the technology parameter of 17.364.

According to the planner's solution to the model, all growth in the economy is the result of human capital. This requires that the technology available for use in private

good production, A , is constant. Because A does not influence the production of the military good, its human capital investments or the growth rate, it can be arbitrarily set to 1. The reason for this choice is that fixing A to a different value will not increase the understanding about the relationship of interest.

Attention is now directed at deriving the benchmark output-capital ratio, $\frac{y}{k^e+k^m}$, and the consumption-capital ratio, $\frac{c}{k^e+k^m}$ of the benchmark economy. According to the balanced growth properties of the model, the ratios should remain relatively constant over time. Calculating the annual output-capital ratio, the benchmark value is found using the average ratio of the sample period. In regards to the consumption-capital ratio, because a measure of consumption is not known additional steps are needed for its derivation. Using the definitions of the budgets constraint equation 3.75 can be rewritten as

$$\hat{c} + [\phi - (1 - \delta)] (\hat{k}^e + \hat{k}^m) = \hat{y} \quad (4.1)$$

Dividing both sides by $(\hat{k}^e + \hat{k}^m)$, equation 4.1 can be simplified to

$$\frac{y}{k^e + k^m} = \frac{c}{k^e + k^m} + [\phi - (1 - \delta)] \quad (4.2)$$

Here, the parameter values for ϕ and δ , along with the output-capital ratio can be used to find the value of the consumption-capital ratio.

To establish a value for ζ_1 , I begin by dividing equation 3.75 by 3.79. Through simplification, the division can be shown to equal

$$\zeta_1 = \frac{N^e}{1 + [\phi - (1 - \delta)] \left(\frac{k^e+k^m}{c}\right)} \quad (4.3)$$

Using other, previously determined values for the parameters and variables, the result of the division can be simplified to show that ζ_1 equals 0.298. ζ_3 can be established with equation 3.61 and the parameters β and δ , producing a value of 0.923.

The above discussion establishes values for many of the parameters and variables involved in the production of the economy's private good. I now focus on determined

the values of the parameters relating to the military good, beginning with θ , the share parameter for production inputs. According to the public administration literature, the defense sector is a public good, characterized by the lack of competition and excludability (Robbins, 2005; Savage, 2009). As a government program, it is subject to restrictions on its ability to make a profit. Applying a zero-profit condition to equation 3.76, the production of the military good, produces

$$\frac{\hat{k}^m}{N^m} = \frac{\theta}{1 - \theta} \quad (4.4)$$

where the defense sector's capital-labor ratio, $\frac{\hat{k}^m}{N^m}$, can be operationalized using the sector's annual expenditures on physical capital and the annual expenditures on personnel. Data used to establish the ratio is available from the Department of Defense's "Greenbook" documents. The "Greenbook" is an annual supplementary budget document from the Department of Defense Comptroller that summarizes all expenditures for the sector according to its function. Based on data from sample period, the long-term average of the sector's capital-labor ratio is 0.869. Using this ratio, equation 4.4 can be used to derive a value for θ of 0.465.

The defense parameters γ , which represents the rate at which the military influences general production, and τ , which demonstrates the degree of substitutability of inputs for the military good, are unknown. Not only is the necessary data for measurement not publically available, but the literature gives no indication as to their appropriate values. Thus, the process for determining their value requires some estimation and sensitivity analysis. This is accomplished by establishing an initial estimate from available data and then using the initial value along with other known parameters and values, as well as equations 3.75, 3.76, 3.79, 3.81, and 3.82 to derive values of \hat{c} , \hat{k}^e , \hat{k}^m , \hat{m} , and B . This information is then used to derive the steady state total economic output and the output of the military good.

The starting point for the parameters γ and τ are established as the average of the defense expenditures share of total output and the average of the sector's capital-

Table 4.2: Relevant Ranges for γ and τ

Parameter	Average	Median	Minimum	Maximum
γ	0.034	0.038	0.021	0.100
τ	0.195	0.189	0.095	0.291

expenditure ratio, respectively. The derivation of the variables is repeated using the minimum and maximum values of the parameter estimates to gauge how responsive the outputs are to changes in the parameter value. Table 4.2 provides an overview of the relevant range of the data.

If the steady state outputs shift dramatically with the alternative parameter values, then the model is sensitive and a precise measurement must be obtained from the available data. If, however, the outputs show only minimal response to changes in parameter values, then a “best guess” estimate can be used. From the sensitivity analysis, it can be shown that the estimates are fairly consistent over time and that the variables are not very sensitive to parameter change (see Chapter 5 for a discussion and presentation of the obtained outputs). This leads to the use of the ratio averages as values for the parameters.

The remaining step of calibration is to solve for the unknown variable y and the parameters η and ζ_2 . Solutions are obtained using a combination of the normalized model, the redefined budget constraint (see equation 4.2), and the previously determined parameter and variable values.

The process of calibration discussed here established the values of the parameters so that the model economy reflects the same features as the U.S. economy. Through calibration, I have prepared the model for use in policy analysis such that policy alternatives impacting the model inputs can be explored with the resulting parameters. This process has also found the steady-state values for the variables in the benchmark economy to serve as a reference point when the policies are imposed. The results of the calibration and values of the benchmark economy are provided in Chapter 5.

4.4 Summary

Previous attention in this study has been given to the nature of the defense sector and the establishment of a model to explain its role in the economy. In order to fully investigate the impact of the defense sector's human capital investments, this chapter has taken the model and transformed it into analytical statements about the U.S. economy. This transformation was completed through the process of calibration, during which the steady-state values of the economy were also derived. A summary of the results of calibration, along with the economy's stylized facts, are presented in Chapter 5.

CHAPTER 5

EMPIRICAL RESULTS

The goal of this study is to determine if the defense sector's human capital investments impact the economic performance of the United States. This analysis would provide a useful vehicle for understanding the defense-growth relationship, the theoretical model of that relationship as established in Chapter 3, and the consequence of an increase or decrease in militarization. Having completed the calibration derivation processes necessary for this study, I now present and discuss the results of the analysis. I begin the discussion of the results by initially determining the direction and size of the parameter values. Next, the steady-state findings of the benchmark economy, which establishes the economic behavior of the United States, are provided. Also discussed are the economic trade-offs for defense investment. Finally, this chapter concludes with a summary of the findings that draws on both the parameter values and steady-state results.

5.1 Parameter Values of the Defense Sector

The results produced from the process of calibration come in several parts. The first of these parts are the parameter values. Based on U.S. data from 1949 to 2009, I aligned the model developed in Chapter 3 such that the properties of the model mimic the properties of the real economy.¹ Included in this process was the attainment of

¹As the process of calibration aligns the model to the real economy, the results are understood to be actual economic outcomes and no error of estimation exists.

Table 5.1: Calibrated Parameters for the United States

Parameter	Value
A	1.000
B	0.257
α	0.337
β	0.960
δ	0.048
η	2.149
γ	0.034
ω^e	21.271
ω^m	17.364
τ	0.195
θ	0.465
ζ_1	0.298
ζ_2	0.315
ζ_3	0.923

the parameter values relating to the defense sector: B , γ , ω^m , τ , and θ . Because the role of the parameters is to transition model inputs into the economy's outputs, their values are central to understanding the behavior of the economy and the defense-growth relationship. Specifically, they provide the basis for the findings of this study by establishing both the direction of the defense-growth relationship and the size of its effect. Further, the parameter values demonstrate the consistency of the results with the theoretical foundation from Chapter 2. Results of the model calibration are shown in Table 5.1.

Based on the derived values for the parameters relating to defense, the defense sector positively influences the economic performance of the United States. This influence comes from the direct and indirect effects of the sector's human capital investments. Directly, the investments influence the economic growth rate. Indirectly, the investments influence economic performance through the production of the military good and the spillover of the good to general production.

5.1.1 Parameters Relating to a Direct Effect

The defense sector's human capital investments provide a direct effect on the economy's growth rate according to the parameter ω^m , which captures the efficiency with which the economy transfers the sector's investments into accumulated human capital. As a weight factor, the value of ω^m tells us how much utility the market gains from the sector's investments. The higher the value, the better able the economy is to use the military education and military skills that soldiers acquire during service. This effect is based off the relationship previously established in equation 3.77.

Through calibration it is shown that ω^m is fixed at 17.364. This compares with the parameter for the efficiency of formal education, ω^e , which is fixed at 21.271. Although the findings show that both the sector's investments and formal education positively influence economic growth, time spent in pursuit of formal education is shown to be more efficient for use by the overall economy. To see the degree of efficiency, I look at an example of equal investments into the sector's human capital and formal education. When the shares of the labor force dedicated to the tasks are equal, approximately 44.9% (determined by the ratio $\frac{\omega^m}{\omega^m + \omega^e}$) of all growth comes from defense investments.

The findings are not all that different from the extant literature on human capital. On-the-job training does play a positive role in the growth rate by increasing the stock of knowledge available to the economy, but when any formal education is included in a growth model the contribution of on-the-job training is reduced (see Lucas, 2002). The reasoning is that skills acquired while on-the-job are specialized and are often only usable by a select number of firms, whereas skills acquired during post-secondary school are more general, allowing for their use more broadly by the market. Firms do capitalize on all in-house training because it relates to the operating processes of the organization (Ott et al., 2008), but the broader knowledge acquired in college gives a skill set more capable of adapting to changes in economic circumstances and available

technology.

To understand the importance of the values from ω^e and ω^m , I turn to the literature on veterans benefits and employment. The literature on the post-service employment of veterans, however, has been critical of military education and skills, arguing that they provide little utility compared to their private sector counterparts (Borjas and Welch, 1986; Cardell et al., 1997; Loughran, 2002). In a key study on post-service employment, Borjas and Welch (1986) used data from the 1977 *Current Population Survey* to show that veterans earn less than their civilian counterparts early in their second career. It showed a convergence in the pay gap over time, which Borjas and Welch attributed to the retooling of veterans from military-specific skills to skills that have a private sector use. Similar results were shown by Cardell et al. (1997), who employed an identical methodology on a 1996 survey of military retirees.

The debate over the utility and transferability of formal education and the sector's human capital investments can be seen in the comparison of ω^e and ω^m . If proponents of defense employment are correct, then we should have expected to see identical values for the parameters. However, since ω^e is larger (21.271 vs. 17.364) the pursuit of formal education is expected to bring a larger return on future income. This is based on the assumption that income is dependent on the efficiency with which the household produces. In the model, the household's preference for leisure and consumption will lead it to allocate a greater share of the labor force to formal education as a means of accumulated human capital. Without some form of interference, the long-run behavior of the household allocates all time accumulating human capital to the pursuit of education. Although such an allocation would be the rational choice for the household, it would not be optimal for the economy because it would end the ability of the defense sector to produce its good.

Understanding the need of the defense sector to continue production of the military good, policy can be introduced to end the flow of all labor to education. This

interference comes in the form of enlistment incentives. By providing incentives such as veterans preference in government employment, the G.I. Bill, and the transferability of on-the-job training, the sector is able to provide a financial return for active duty soldiers to make up for the loss of future income. The concept of the enlistment incentive is to subsidize the difference between ω^e and ω^m . For some, the opportunity to gain human capital through formal education is not available. According to Loughran (2002), the sector relies heavily on underprivileged households for new recruits. From the defense perspective, the results indicate a positive return that allows individuals who are unable to obtain formal education elsewhere to obtain military education and skills during their service. In this scenario, the relative values of ω^e and ω^m do not matter because the option to pursue education does not exist. Instead, human capital investments by the defense sector can be viewed as a net gain to the economic growth rate by adding contributors who would have otherwise remained inefficient producers.

Finally, capital investments provide immediate use to the sector (Ban, 1996). For example, physical training and weaponry skills are utilized immediately, due to the sector's "security-by-threat" approach. The security-by-threat approach argues that a key aspect to national defense is the threat of the sector's capacity to retaliate against enemy states (Sandler and Hartley, 1995). By providing these trainings and skills to its soldiers, the sector receives an immediate increase in its capacity to respond militarily. Sector employment also provides a post-service benefit through behavior and socialization. The unique nature of military service provides veterans with a team-player, goal setting attitude that increases their efficiency during production. The defense sector has used the ability of veterans to transfer their skills to the private sector as an incentive to enlist (Bryant and Wilhite, 1990). When the sector has low enlistment rates, it has historically increased its focus on military education to ensure the utility of capital after service, thereby increasingly enlistments (Asch et al., 2007;

Black et al., 2008).

Ultimately, the value of ω^m provides a hint as to the importance of the sector's investments. Even small changes in investment can produce large shifts in the growth rate. This finding supports the concerns addressed in Chapter 1 on the significance of the study, that misguided defense policy can have severe, unintended consequences. As the largest supplier of education and services, it also supports further interest in defense management by public administration.

5.1.2 Parameters Relating to an Indirect Effect

The sector's investments can also have an indirect effect on economic performance. Indirectly, investments influence the production of the military good. The output of the military good then spills over into the production of the economy's general economic good. The parameters utilized within the production of the military good show values in the direction as to what is expected for production. That is, all parameters are positive.

Positive values are expected because production processes rely on physical capital and technology, but also requires laborers that have the knowledge and skill to use the resources. In a defense context, however, this is somewhat controversial. Tsipis and Janeway (1984) argue that as the sector becomes increasingly reliant on technology for national security and defense the role of soliders in producing the sector's output diminishes. In this context, there should not be a positive value associated with labor. Contrary to Tsipis and Janeway, however, these findings point to the continued dependence of the government and its sectors on public servants. This is supported by the human resource management literature from public administration, which argues that public servants are vital to public good provision because of the changing needs of the populace (Lewis and Frank, 2002; Brewer, 2003). Due to their hands-on involvement in public good provision, street-level bureaucrats are able to respond

more quickly to changes in need, whereas those at the top of the bureaucratic triangle are unable to do so (Lipsky, 1980). Similarly, because the defense sector has troops on-the-ground they are able to respond more quickly to changes in the battlefield situation.

The parameter θ represents the share of factor inputs utilized in production of the military good. Because production relies on physical capital and labor, θ determines how much of the production comes from each resource. Due to a positive value for the parameter, it can be concluded that both physical capital, whose share is represented by θ , and labor, represented as $1 - \theta$, are necessary inputs into national defense.

According to Asch et al. (2007), the defense sector in the United States provides training and education in areas that are useful to the soldier but are also vital to accomplishing the mission of the Department of Defense (see also Bryant and Wilhite, 1990; Ban, 1996; Sandler and Hartley, 1995). The production of any good requires laborers instilled with a set of skills, or human capital, to utilize available physical capital and technology (Lucas, 1988, 1993). The findings of this dissertation show that the defense sector is no exception. The value of θ , which represents the share of factor inputs utilized in the production of the military good, is 0.465. While this represents nearly equal reliance upon both physical and human capital, the factor share allocated towards the sectors human capital investments, 0.535 (measured as $1 - \theta$), demonstrates the sectors reliance upon its labor force, regardless of its technological innovations. The ability to provide national security and the institutional stability spillover is dominated by the human capital investments that the sector makes.

Also influencing the production of the military good is τ , which determines the degree of substitutability of the inputs. τ is also a function of the elasticity of substitution, which measures how easy it is for the defense sector to substitute one input for another. While many of the parameters used in this study have previously defined values and clear data sources for their determination, τ is one of two parameters for

Table 5.2: Sensitivity of Military Good Output to the Relevant Range of τ

Parameter Value	Military Output
0.095	0.021
0.189	0.021
0.195	0.021
0.291	0.022

which there was no known values (the other other parameter is γ). To establish a value for τ , a sensitivity analysis was preferomed over the relevant range (see Chapter 4 for a discussion on the sensitivity analysis methodology and details on the range of values considered). Based on this analysis, the steady state value for military output was relatively stable, exhibiting only a 4.8% difference between the largest and smallest measures. Due to the lack of variation, the average ratio of the sector’s physical capital to total expenditures is used. The value assigned is 0.195. Table 5.2 provides a summary of the sensitivity results for τ over the relevant range.

A value for τ of only 0.195 suggests that while there is some transferability within defense production between physical capital and labor, the production of the military good is relatively inelastic. That is, the ability to produce the good is still dependent upon both resources for maximized output. Although advancements in the technology available to the sector, witnessed through their stock of physical capital, can be used as a replacement for some of the investment in labor it is not possible to replace all labor investment with physical capital, such as technology.

Following the production of the military good, the defense sector spills over into the general production process. As demonstrated by the normalized budget constraint in equation 3.75, the military good influences the economy’s ability to produce its output at a rate of γ . As with the value of τ , γ is also determined through a sensitivity analysis across the relevant range of the ratio of defense expenditures to economic output. Regardless of the value used, the analysis showed consistency in output, with variation of only 0.01% between the smallest and largest values. A summary of the

Table 5.3: Sensitivity of General Output to the Relevant Range of γ

Parameter Value	Total Economic Output
0.021	27.494
0.034	27.505
0.038	27.508
0.100	27.535

sensitivity results for γ are provided in Table 5.3.

Calibration has shown that while γ is positive, the military good's effect on the economic output is small with a value of 0.034. As an output elasticity, γ measures the economy's responsiveness to a change in the level of the military good. All things being equal, a 1% increase in the military good would lead to approximately a 0.034% increase in general output.² The positive contribution of the military good at the rate γ is consistent with the theoretical foundation. According to the institutionalism literature, a primary role of government institutions is to reduce uncertainty and allow economic exchange to occur (North, 1990; Ostrom, 2004). While a core service of the defense sector is the provision of national defense, it also provides a degree of stabilization for society (Mearsheimer, 1995). As a tool for reducing uncertainty, a positive impact between the military good and the general production process is expected. It is this institutional impact that is captured in the value of γ . When taken in conjunction with θ , the results support those of the Knight et al. (1996) and McDonald and Eger (2010), who argued that the impact of the military good on economic performance may come through the stability of its employment.

The lack of variation in outputs for τ and γ across the relevant ranges suggests that there is a degree of stability within the model. Stability in outcomes is a desirable quality in economic modeling by providing support on the validity of the models

²A 0.034% return on investment for each percentage increase in the military good does appear small and inconsequential. When considered in context of the defense sector in the United States, a one percent increase in its 2009 output is roughly equal to \$16.3 million. A 0.034% increase in total output for the same year is \$6.5 billion.

structure and by producing consistency in outcomes for an economy, regardless of the years included in the sample population. This compares to the dominant model used to explore the defense-growth relationship in the extent literature, the Feder-Ram model, which has been shown to be lacking in both of these areas (see Dunne et al., 2005).

One interesting finding from the parameter values can be found by comparing the values with those typically witnessed in production for an economy's private good. This kind of comparison would point to differences of efficiency between government and the private market. According to public goods theorists, the provision of any public good is inefficient (Holcombe, 2006). If the good could be produced efficiently, the private market would be involved in production. Alternatively, some have argued that government provision can make better use of resources because of the lack of interference from market conditions (Robbins, 2005). While parameters for both production process share directionality, the relative size of their values differ. For instance B , which captures the total factor of productivity (TFP) of the military good is shown to be 0.257. This compares to a historical measure of around 0.3 for the private economy (see Jones, 2002). Similar differences can be seen for both τ and θ . What this finding suggests is that the defense sector is not as efficient in utilizing its resources as the private sector. Due to the profit seeking behavior of the private economy, firms work to achieve maximum efficiency. The defense sector, however, is not subject to the same income requirements. The sector has little reason to pursue efficiency over effectiveness. To some extent, this finding is also expected due to the lack of competition within the defense sector and due to the willingness of the defense sector to undertake more risky investments in research and development where the potential payoff for defense is great but the cost is very large.

Table 5.4: Steady-State Values of the Benchmark Economy

Variable	Value
y	27.505
\hat{c}	26.748
c/y	0.972
$c/(k^e + k^m)$	2.437
\hat{k}^e	10.006
\hat{k}^m	0.970
\hat{n}	0.021
l	0.642
S^e	0.039
N^e	0.307
N^m	0.011
ϕ	1.021

5.2 Economic Performance of the U.S. Economy

With the parameters fixed by calibration, the variable values for the balanced growth path of the U.S. economy are then determined. The values represent the steady state of the U.S. growth path, as determined by its current policies. According to modern economic theory, the economy is moving towards a trajectory, or path, where all aspects of the economy grow at the same rate, ϕ , in order to maximize the performance of the economy (Krueger, 2002). Given the interest of the social planner in producing an allocation of resources that maximizes the households utility (see Chapter 3), the steady state values represent the social planner's optimal allocation. In this allocation, resources are alloted as to produce as much of the two goods without detracting from either production processes. Furthermore, no policy can be imposed to improve the economy. Any policy that would change the allocation would only hinder or restrict performance. The results of this allocation are reported in Table 5.4.

The results of the steady state variables can be interpreted as follows: The per-capita steady state value of the private economy's physical capital is \$10.01 per unit

Table 5.5: Estimates of Economic Output for 2010, billions

Year	Economic Output
2009*	\$19,060.9
2010	\$19,455.3
Analysis	Value
Difference	\$394.4
Defense Share	\$74.5

* represents the observed output

of human capital. Similarly, the steady state value of the defense sector's physical capital is \$0.97 per unit. Of particular interest is the interpretation of the military's output, \hat{m} . Based on the results, the steady state value for military output is \$0.02 for each unit of human capital, roughly estimated as 0.22% of the economy's total output (determined by $\frac{m}{m+y}$).

In order to provide clarity on the steady state values, the variables are considered through the same direct and indirect lenses as the parameter values. Directly, the sector's investments influence the economic growth rate of the economy. While the parameter ω^m gave the weight of the investments to growth, the variable ϕ gives the observed growth rate. Under the current policies of defense sector investment, the United States can expect a long-term growth rate of 1.021, where the economy will increase by an annual average of 2.1%. Utilizing the parameter ω^m , about 18.9% of this growth rate can be directly attributed to the defense sector's investment (determined by the equation $\frac{\omega^m(N^m)}{\phi}$).

The relative size of the investments effect can best be understood through application to economic output. Using the output from 2009 as established in the previous chapter, along with the steady state growth rate, we can estimate the 2010 output of the United States. The result of this calculation shows that a growth rate of 2.1% is roughly equal to \$394.4 billion in 2010 (see Table 5.5). Using the defense sector's share of economic growth, approximately \$74.5 billion of the output is related

to the sector's human capital investments ($\$394.4 \times 18.9\% = \74.5). This contribution provides further support of the existence of the defense-growth relationship. The previous section had noted that when there are identical investments in the sector's human capital and formal education, the defense sector is responsible for 44.9% of the growth rate. The findings here have shown the continued importance of the investments even when they are reduced in comparison to those of formal education.

Indirectly, the value of the military output is important because it represents the optimal size of the defense sector to achieve a maximized economy.³ That is, it represents the optimal provision of security and stability by the defense sector in order to provide an institutional environment where economic exchange can occur. As previously discussed, the defense sector serves as a public good, providing a stabilizing effect on the economic behavior of the household. Under optimal provision, uncertainty in the economy is reduced and investment occurs. Should the government choose to increase or decrease defense programs, the results would be a level of military good provision outside of its optimal supply. According to New Institutional Economics, when institutions are misplaced or misguided, the risk of loss on an investment increases (North, 1990). As risk increases individuals have little expectation of a return and their likelihood of investing decreases. Under such circumstances, policies of military reduction would reduce the country's stability and policies of militarization would produce a level of security that would stifle free market exchange. Either way, the change would inhibit growth by disincentivising investment and encourage the household to increase its consumption.

The institutional impact of the military good can be seen in the value of the consumption-output ratio (determined by $\frac{c}{y}$). Often viewed as a consumption-savings decision, the ratio depicts the willingness of the household to save for the future.

³According to the social planner concept used to derive the model solution, the planner seeks to allocate the resources in order to achieve the most economic output possible. A maximized economy is an economy that meets this condition.

During periods of economic prosperity, households are able to save and invest for the future. Due to savings, there is more physical capital for production in the next year. The result is an economic boom. In times of hardship little is left over, leaving the household to consume most or all of its available resources. A ratio value of 0.972 suggests that household is likely to consume 97.2% of its resources annually. The remaining 2.8% of output is saved for future consumption. A savings rate that is between 2.7% and 3% allows for stable economic growth (Jones, 2002). As a result of optimal military investments, the defense sector is able to provide an environment where strong investment occurs.

The results expressed in this section can also be considered in context of the inconsistency witnessed in the extant literature. While the steady state values are optimal, there is no requirement of policy makers to adopt the allocation. Instead, the policies adopted often fluctuate over time. For instance, the optimal policy of the defense sector's human capital investment is 3.1% of the labor force but the 2009 allocation was only 1.1%. As an investment outside of the steady state value, this allocation hinders the economic performance of the economy by reducing its capacity to produce the military good. By focusing on a limited number of observations as many of the extent studies do, short-term structural breaks such as that seen in 2009 could influence the average output used in analysis. The results of the analysis would then show a negative relationship. Rather, by including a large sample population and utilizing techniques of calibration, this study is able to better capture the long-run investment policies which more closely reflect the balanced growth properties of the model. This allows for a better understanding of the relationships true effects.

The social planner concept used in this study produces a set of values for the variables that maximize the economy. Any allocation outside of these values would hinder the economic performance of the United States. Such a solution makes the maintenance of the defense sector at its steady state value an attractive economic

policy. This is particularly true given the recent economic crisis in the United States and the current sector investments. As previously noted, the 2010 investment was only 1.1% of the labor force. An investment policy of this size would limit the performance of the United States and introduce a degree of economic decline. Also concerning are the recent discussions within Congress to further reduce the size of the military force (Parkinson, 2011; Shanker, 2011). Although a force depletion policy would allow more laborers to pursue formal education, previous studies on veteran behavior suggests that they will return to general labor (Angrist, 1993). A depletion should also reduce the cost of defense maintenance to the federal government, but it would also move the sectors's investments further away from its steady state.

It also makes investment policies a good choice for countries with growth issues. According to Knight et al. (1996), many less-developed countries have poorly established education systems. By directing resources to the sector, these countries may be able to improve both the accumulated human capital and its overall economic condition. The 2010 estimates also demonstrate the costs of demilitarization that must be addressed. This is particularly true given the reduction in military troops with the winding down of the wars in Afghanistan and Iraq. As troops return to the civilian labor force, policies must be discussed to offset the resulting economic decline.

Also witnessed in the results are shifts in the behavior of the household. As the defense sector's investments are reduced there is an increase in the consumption-output ratio. Under these circumstances there is less production, an unpredictable increase in inflation, and the household ceases to save for future consumption. With no savings, more is consumed annually than produced, either by borrowing on future consumption or depleting past savings. To prohibit the perpetual economic decline, it is necessary for the government to introduce supplemental policies that encourage growth. This change in behavior highlights the caution that public administrators should take when addressing issues of defense management. Decisions of force deple-

tion should be made with caution and only when supplemented with policies to offset the cost and encourage beneficial behavior.

5.3 Causality in the Defense-Growth Relationship

An issue that must be addressed on the defense-growth relationship is the issue of causality.⁴ The extant literature has given significant attention to the matter of causality following the inability of previous studies to clearly understand the relationships size and direction (Dakurah et al., 2001; Joerding, 1986). If the defense sector produces change in the economy, then the results would provide support for the existence of the relationship, regardless of its direction. However, if the inverse were true, that is changes in the economy lead to changes in the sector, then preference for the military could be understood to be dependent upon a country's economic condition (Dunne et al., 2005; Sandler and Hartley, 1995).

To explore the issue of causality within the findings of this study, the parameters can be applied to the performance of the defense sector during the sample period. Using the parameters, the established value for N^m and the known values for k^m , it is possible to estimate output of the military good over time. Figure 5.1 shows the behavior of the economy's total output, as measured in Chapter 4, and the military good for the period 1949 to 2009 plotted against time, where both variables are expressed in logarithmic form. The relation between the defense sector and GDP is pretty striking, supported by a correlation of 0.915. No inference about the direction of causality, however, can be made. Due to the high degree of correlation the causality could run in either direction.

This finding is not that different from studies that focus on a causal relationship (Kusi, 1994; Chowdhury, 1991). Traditionally, public administration has treated the

⁴Causality of the defense-growth relationship is understood as whether an increase in the defense sector produces an economic response or whether a change in the economy produces a shift in the sector.

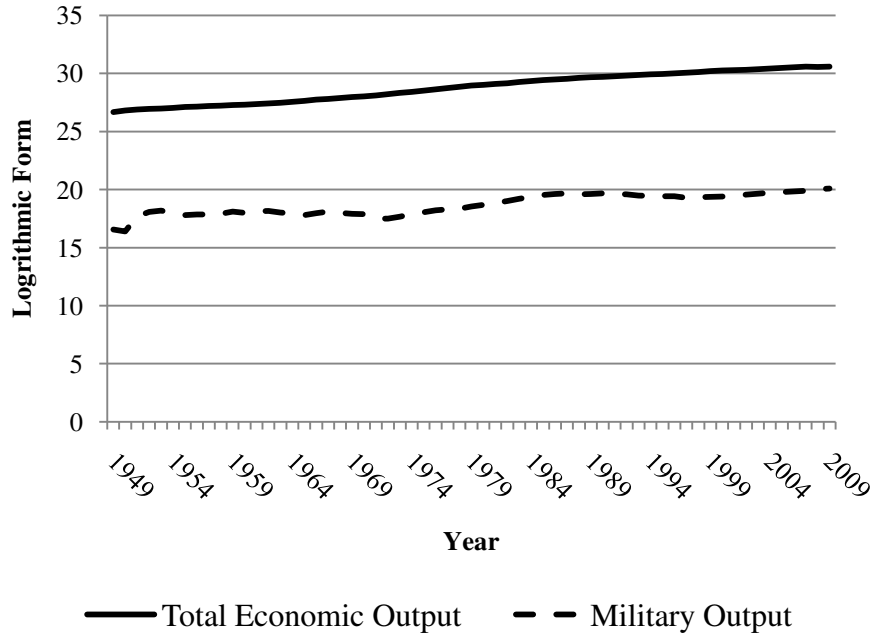


Figure 5.1: Log of U.S. Economic Outputs, 1949-2009

defense sector as a solitary entity. The sector provides a measure of national security but has little other interaction. If this separation were true then the lack of inference on causality can support claims that the defense sector and economic performance are not closely related (see Dakurah et al., 2001). However, the lack of statistical evidence for a causal relationship can also suggest a mutual reliance. That is, the defense sector needs the general economy for its resources and the general economy needs the stability provided by the military good for its own production.

A mutual reliance is most likely given the dependence of the economy on the defense sector. This dependence is seen not only in the sector's need for resources, but also in the impact of the military good on production and the role of the sector's human capital investments on the growth rate. According to the balanced growth properties of the model and the behavior of the United States as it moves along that path, it is expected that both outputs would grow at the same rate, ϕ . As the economy

does grow at the rate of 2.1%, there is no reason to suspect that outputs would have a causal relationship. Rather, the balanced growth path ensures that causality does not exist. This is important because a mutual reliance would further highlight the importance of defense policy and management for public administration. Little is understood about defense management but the management of the sector's resources is a key political issue and misallocation can lead to other resource problems within government (Carroll, 2006).

5.4 Economic Trade-offs for Defense Investment

Given the results of the analysis presented in this chapter, the trade-offs of a change in defense sector investments are as follows: First, an increase of investment would draw resources from other activities that many have a higher rate of return. A “guns vs. butter” trade-off, the household must give up time and physical capital, both of which could be utilized in the production of the general good. Because of the high rate of return that production provides, an increase beyond the steady state would lead to a loss of overall economic productivity.

Second, there is a trade-off following a reduction of the investment. The institutional stability and security provided by the defense sector is dependent upon the sector's need for resources, such as human capital investments. As the investments decrease the capacity of the sector to provide its military good declines. While a reduction in investment might be a preferred policy option, it is linked to a trade-off in the level of stability and security the sector is capable of providing. This leads to a decline in economic growth and an inefficiency in the general production process.

5.5 Summary

The results presented in this chapter found support for the defense-growth relationship both in terms of the defense sector as a whole and in terms of its human

capital investments. In line with expectations, the results of the analysis reveal that the sector's investments have a positive effect on the economic performance of the United States. This effect is both direct and indirect. Directly, they are a key driver of the economic growth rate. During the studies sample period, 1949 through 2009, the sector's investments account for approximately 18.9% of U.S. growth. Indirectly, they influence economic performance as an element in the production of the military good. As the production relies on the sector's human capital investments⁵, an increased investment further allows the sector to provide the stabilizing and security influence on general production.

⁵Demonstrated by a factor share of 0.535, or $1-\theta$.

CHAPTER 6

CONCLUSION

One of the most important questions rising out of the War on Terror and the end of the Cold War is how changes in a country's defense sector will affect its economic performance. Despite the amount of extant research on the defense-growth relationship within the policy and economic literature, a consensus has failed to be reached as to whether a relationship does exist, its directionality, and how it should be modeled. This dissertation has sought to contribute to the discussion on the defense-growth relationship through a theoretical examination of the relationship in context of the defense sector's human capital investments. To accomplish this goal, Chapter 2 reviewed the human capital and defense literatures to establish a consistent theoretical foundation on which the dissertation would be based. In Chapter 3 a model of the relationship was established from that theoretical foundation. The benefit of the derived model is that it uses traditional economic theory and modern modeling techniques as a guide, thus allowing the study to meet the requirements of future work as established by Dunne et al. (2005). Chapters 4 and 5 prepared the model through the process of calibration and estimated the impact of the sector and its investments, respectively. This study concludes with this final chapter, which provides summary of the study and its findings. A discussion of the linkages of the findings to policy decisions and implications, and recommendations for future research on the defense-growth relationship concludes.

6.1 Summary

This study began with a question of does the defense sector influence the economic performance of the United States, an effect termed as the *defense-growth relationship*. Although previous studies have explored the relationship, the literature has failed to successfully address what the relationship looks like. To improve the understanding of the relationship, this dissertation adopts a programmatic approach. It was hypothesized that the effect is determined by how the sector allocates its resources rather than its total expenditures. As the first programmatic approach to the defense-growth relationship, the effect was investigated under the guise of the sector's human capital investments. Beginning with a human capital based study was appropriate given the size of the sector's investments in this area and because of the impact of human capital on economic growth as seen in the economic literature.¹

The sector's investments have both a direct and indirect effect on economic performance. Directly, the investments provide a positive influence on the economic growth rate through a learning-by-doing process. Here, the skills learned and acquired during military service produce a social benefit by increasing the stock of capital available to the country. Indirectly, the investments influence the ability of the defense sector to produce its military good. Investments made by the defense sector are directed at meeting the needs of the sector as it produces national defense. Since the military good provides an institutional stability on the production of the economy's general good, the increase human capital investment leads to higher levels of economic output. These findings are consistent with the theoretical foundation established in this study, as well as the popular belief that enlistment in the military can provide training and education useful to the soldier after the completion of service.

At last, the findings of this study help explain the inconsistencies of the rela-

¹For a discussion of the results of other government programs on long-run education, see Heckman and Masterov's (2007) study on preschool educational investment.

tionship present in the literature. The insensitive nature of the model, as previously demonstrated across the relative range of values for γ and τ , suggest that the model is fairly stable. In return, the results will be relatively consistent for the United States regardless of the sample used. This compares to the Feder-Ram model prominent in the defense-growth literature (see Heo and Eger, 2005; Heo, 2010; McDonald and Eger, 2010) which has demonstrated extreme sensitivity through the spurious results it produces (Dunne et al., 2005).

Furthermore, this study contributes to the literature by moving away from the use of defense expenditures as a proxy for sector output. While the extant literature has focused on the sum of the sector's expenditures, it is possible that the allocation of expenditures can vary over time. For instance, during the Cold War sector expansions were human capital intensive. During the 1990s, however, focus changed to investing in physical capital and new technology. When studied outside of the steady-state concept or through a limited sample, these variations in allocation can produce seemingly contradictory results. By using sector inputs as a means of estimating defense output, this study provides a means of investigating the relationship that accounts for changes in expenditure allocation. By using defense output, the findings of this dissertation show that when defense buildup or reduction impacts the sector's ability to recruit or maintain troops, even a small change can produce a significant shift in the U.S. economy. This is important given the changing involvement of the United States in national defense affairs over the past 20 years. The findings are also important given the current discussions in Congress about troop reduction from the winding down of the wars in Iraq and Afghanistan and because of the current recession with which we are presented.

6.2 Linking Study Findings to Policy Implications

This study has focused on the effect of the defense sector on the economic performance of the United States; however, the findings hold important policy implications for political leaders and public administrators considering a change in national priorities. To aide in the application of these findings by administrators and further bring the discussion of the defense-growth relationship into the field of public administration, a clear connection between the study findings and their policy implications is needed. This section provides that linkage in three parts: First, it discusses the implications of the greater defense-growth relationship for public administration. Second, the implications of the sector's human capital investments are discussed in light of the wars in Afghanistan and Iraq. Third, the findings are connected to the literature on budgetary theory through the need for careful and efficient resource allocation within government programs.

Accounting for 20.4% of all federal expenditures (Bureau of Economic Analysis, 2009) and 6.4% of all federal employees (Bureau of Labor Statistics, 2009), the provision of national defense is a core responsibility of government (Holcombe, 2006; Smith, 1776). Despite its size and importance, little is known about how the sector operates and how it can best be managed. There is significant interest, however, in its efficient and effective operation. According to the program evaluation literature, before any recommendations can be given to improve a government program, an evaluation must be conducted to determine what it does and how it operates (Wiemer and Vining, 2011; Stokey and Zeckhauser, 1978). In a defense context this determination has been characterized as the defense-growth relationship (Sandler and Hartley, 1995; Mintz and Huang, 1990; Heo, 1998).

As an introductory study on the sector, the findings show that the defense sector is not a solitary sector and should not be treated as such. Not only is the sector

responsible for national defense, but it also provides other public services that have a positive impact on society. These services include education to soldiers in areas that are useful after their service and institutional stabilization.² Although changes to the sector will influence its ability to produce the military good, the changes are also likely to influence the provision of these other services. Understanding that these services are provided gives public administrators a better starting point for the consideration of how to provide the military good and what other services could continue to be provided by the sector or consolidated with other government agencies working in similar areas.

The findings also determine the conversion costs of defense reduction and the initiatives needed to compensate for any potentially adverse effects. As the wars in Afghanistan and Iraq begin to come to a conclusion increasing discussion has taken place on the reduction of military troops (Parkinson, 2011; Shanker, 2011). The number of troops needed to conduct the two wars is different than the number needed to maintain the defense sector during peacetime. Furthermore, as the United States continues to struggle with the “Great Recession” many of these discussions have alluded to the drain that military employment has had on skilled labor. The primary belief here is that the United States spends too much of its money on defense programs at a time when its constituents have other needs. By reducing defense spending (i.e., guns), the federal government could reallocate the funds to much needed social service programs (i.e., butter).

Although such policies do appear to make rational sense, they should be undertaken with care and consideration given the findings of this study. Had there been a negative association between the defense sector and economic growth, then a reduction in defense outlays would have served as an attractive policy to pull the United States out of its current economic slump. That is, a reduction in the sector would

²Though not the focus of this study, other areas of service provided include humanitarian/social assistance, healthcare research, and non-military related technological research.

be viewed as a growth policy. The findings here, however, do not support such a stance. Rather they suggest that policies directed at force depletion should not be taken lightly. As a key provider of education and training in the United States, the defense sector has taken on some of the roles of civilian authority in human resource development, easing the task of public education by federal and state authorities. The sector has used these investments as an incentive for enlistment. Critics of such enlistment tactics have pointed out that education for service policies feed on those unable to afford the cost of education themselves (Bound and Turner, 2002). Although a reduction in defense programs might redirect some of the labor-force to the pursuit of formal education, many are expected to pursue other options, including laboring in industrial and low-wage positions (Loughran, 2002). Under this circumstance a trade-off in budget allocations between different types of publically funded goods could be expected. That is, to compensate for the decline of the defense sector's human capital investment federal and state investments in education would have to be increased. In order to ensure stable growth, a trade-off policy would need to ensure the outcome of the investments roughly equal the loss witnessed by the defense sector.

According to the human resource management literature from public administration, public servants are vital to public good provision because of the changing needs of the populace (Lewis and Frank, 2002; Brewer, 2003). Due to their hands-on involvement in public good provision, street-level bureaucrats are able to respond more quickly to changes in need, whereas those at the top of the bureaucratic triangle are unable to do so (Lipsky, 1980). Similarly, because the defense sector has troops on-the-ground they are able to respond more quickly to changes in the battlefield situation. Because the investments into the defense sector's labor force (i.e., its public servants) has such a strong impact on the performance of the United States, a change in investment would require a consideration on how government is managed and its services performed.

A third policy implication of this study deals with improved efficiency in budgetary and management decisions. The efficient and effective allocation of scarce government resources among competing demands is a permanent issue for public administrators and political leaders (Mikesell, 2011; Rubin, 2007, 2010). According to Rubin (2010), a key responsibility of administrators and budget managers is to perform the budget allocation as best as possible. To assist in the allocation process, administrators perform an assessment of the needs of government programs in order to determine where the resources would be most effective (Kettl and Fesler, 2009). As other needs arise in the United States, one of the first areas to come under fire for budget cuts is the defense sector (Heo, 1999; Savage, 2009; Shanker, 2011).

If the individuals crafting and modifying the federal budget do not understand how particular combinations of budgetary expenditures affect their constituents, the nation, and the economy, then budgetary changes in the defense sector may produce unexpected and, at times, even disastrous outcomes. For instance, a blind cut to the sector's human capital investments can produce negative growth when the cuts are not matched with other productive investments.

Traditionally defense budgeting is a two-stage process. First, the federal government decides the level of the defense spending and then administrators decide how the budget should be allocated (Office of the Under Secretary of Defence, 2009; Savage, 2009). With downsized budgets, the policies of the Department of Defense are likely to be directed at maximizing effectiveness by focusing on technological programs. Since the end of conscription in the 1970s, the defense sector has struggled to secure enough manpower to undertake a full scale war. As an alternative to the draft, new weaponry has been developed which removes the soldier from harm's way and allows fewer soldiers more power on the battlefield. Although these programs have produced technologies now taken for granted in the private sector (Heo and Eger, 2005; Tsipis and Janeway, 1984), the distaste for the loss of American soldiers in battle seen dur-

ing the recent wars in the Middle East suggest that the sector will once again turn its attention towards a force depletion accompanied by investments into new weaponry.

According to the principles of public budgeting, this focus on technology is an appropriate means of allocation (see Mikesell, 1978; Robinson, 2007). The findings of this study, however, suggest that the allocation is misguided. By moving resources away from productive endeavors, the government would be faced with additional cuts in the future.³ When the impact of budget allocations is large, such as the sector's human capital investments, a more practical approach to budgeting is to select a given input as the starting point for budgetary allocations. Given a fixed budget, other budgetary allocations should then be determined residually.

Issues of defense management have been largely ignored within academia. Although the defense sector does give some attention to this area (see Bland, 2005; Savage, 2009), their primary concern is training in their current processes. Administrators within the Department of Defense are largely open and accepting to researchers doing work on management processes and issues of efficiency. As a beginning study on the defense sector, this section has introduced some of the policy implications that the findings, and indeed the greater defense-growth relationship, have on the field of public administration. Although three linkages are provided, they are by no means exhaustive. Instead, the implications highlight the necessity of future study and consideration of defense management to public administration.

6.3 Study Limitations

Despite the relative size of the defense sector's human capital investments, this study is subject to a series of limitations. The primary limitation of the study is

³The public administration literature on tax policy suggests that as economic performance declines, the government receives less revenue to distribute amongst its programs (Carroll, 2006; Robins, 2005). This expectation is because of the decline of resources on which taxes are paid and the change in behavior of the household to be increasingly tax adverse.

its assumption that all growth in the economy comes through the accumulation of human capital and that human capital accumulates only through formal education and laboring in the defense sector. In the economy, it is known that growth comes through a variety of processes (Jones, 2002). In economic modeling, however, the economy is reduced to just the variables of interest in order to remove unnecessary complications. For the model of this study, the variables of interest included focus on the production of the military good and the general production process. Factors that are not included but are known to influence economic performance include the export sector, tax rates and technological progress. By excluding such factors and assuming that all growth in the model comes from the accumulation of human capital, the results overstate the role of human capital on economic performance and understate the role of other influences.

Furthermore, the assumption behind the accumulation of human capital also leads to a potential overstating of the role of the sector's investment and the contribution of formal education. While the model restricts its focus to these two contributions, it is known that human capital can accumulate through other means. These other means include on-the-job training in general production and training received outside of four-year academic institutions. By not differentiating such influences in the model, the values for ω^e and ω^m include some measure of the weighted transfers of those processes. This risks an overstating of the contribution of the investments and formal education. Although such risks are not desirable, the restrictive focus of this study is necessary to provide a clear understanding of how the impact occurs, even if the empirical size of the effect is overstated. Having provided an initial study into the sector's investments, future studies should add these other processes into the model to provide additional clarification.

A second limitation is the availability of data. Modern economic growth models are commonly calibrated using quarterly data, though annualized data is used

here. Quarterly data allows for a calibrated model to more closely capture changes in an economy's behavior. Annualized data produces a smoothing effect on trends in behavior, giving a long-run understanding of economic performance where the responsiveness to changes in investment are minimized. While quarterly data was available for all general economic variables in the model, it is not publically available for those variables relating to the defense sector. This limitation on data potentially minimizes the effects of the defense sector's human capital investments on the economy of the United States.

6.4 Future Research

I have provided some evidence in support of both the defense-growth relationship as a whole and for the effects of its human capital investments. Although the findings of this study are important, they should be interpreted and applied with caution. Specifically, the findings suggest that the concepts behind the defense-growth relationship are more complex than the simple transfer of skill from the defense sector to the private sector. Other defense spillovers are believed to exist, including the physical capital transfer and a technology spillover (Heo, 2010). These other spillovers must also be investigated in future studies.

We have come a long way in the understanding of the relationship between the defense sector and economic growth. As the literature continues to adopt more sophisticated and theoretically sound models of the defense-growth relationship, the linkage between the effects of different programs and economic performance requires further clarification and study. Certainly a clear understanding of the defense-growth relationship has important policy implications for the United States, but it also has important policy implications for the growing number of transition economies. A big movement within the defense literature in recent years has been the investigation into the consistency of the defense-growth relationship across nations (Knight,

1996; Bernauer et al., 2009). The next logical extension of this research is to compare the findings with models calibrated to other economies. The results of these comparisons would provide an understanding of the relationship in a wider, global context, as well as to open the door for side-by-side comparisons of this study to the extant literature and their methodological approaches. It would further determine if defense-growth relationship is consistent in its impacts and directionality or whether the findings of this study are applicable only to the United States. Following access to consistent and reliable international data sources, the application of the model in developed economies, such as the United Kingdom, Germany, and Russia, or developing economies, such China and Egypt, is the first step in this direction.

APPENDIX A

VARIABLE DEFINITIONS

The model developed for this study uses 12 variables to explore the relationship between the defense sector's human capital investments and economic performance. Nine of the variables have known measurements. The variables c , h , and m , however, are known to exist but are not clearly measurable based on available data. This study uses the values of variables in two ways. First, the long-run, annualized averages of the measurable variables are used to establish the parameters as discussed in Chapter 4. These data cover a 70 year period for the United States from 1949 through 2009. All data are reported in per-capita terms using population estimates from the U.S. Census Bureau. Second, the steady-state values of all variables are derived using the calibrated parameters and normalized model solution. An overview of the definitions and data sources for the measurable variables are provided in Table A.1. Table A.2 provides the definitions of the unmeasured variables.

Table A.1: Variable Definitions, Measurements, and Data Sources

Variable	Description
y	<u>Definition</u> : Total Economic Output <u>Measurement</u> : Gross National Production + Flow of Services from Consumer Durables <u>Source</u> : National Income and Product Accounts, Federal Reserve Economic Database
k	<u>Definition</u> : Total Physical Capital <u>Measurement</u> : Business Equipment and Structures + Residential Structures + Government Structures and Equipment + Stock of Consumer Durables <u>Source</u> : National Income and Product Accounts, Federal Reserve Economic Database
k^m	<u>Definition</u> : Physical Capital Allocated to Military Production <u>Measurement</u> : Stock of Structures and Equipment Relating to Defense <u>Source</u> : National Income and Product Accounts
k^e	<u>Definition</u> : Physical Capital Allocated to General Production <u>Measurement</u> : Total Physical Capital - Physical Capital Allocated to Military Production
N^m	<u>Definition</u> : Time Allocated to Laboring toward Military Production <u>Measurement</u> : Share of the Labor Force in Active Duty Service <u>Source</u> : Department of Defense M-1 Documents, Bureau of Labor Statistics
S^e	<u>Definition</u> : Time Allocated to Formal Education <u>Measurement</u> : Share of the Labor Force Enrolled in Post-Secondary Education <u>Source</u> : Digest of Education Statistics, Bureau of Labor Statistics
N^e	<u>Definition</u> : Time Allocated to Laboring toward General Production <u>Measurement</u> : Share of the Labor Force not in Active Duty or Enrolled in Post-Secondary Education
l	<u>Definition</u> : Time Allocated to Leisure <u>Measurement</u> : Average Share of Time Allocated to Discretionary Activities <u>Source</u> : Aguiar and Hurst (2007); Ghez and Becker (1975); Juster and Stafford (1991)
ϕ	<u>Definition</u> : Economic Growth Rate <u>Measurement</u> : Average Growth Rate of Personal Income <u>Source</u> : National Income and Product Accounts

Table A.2: Unmeasured Variable Definitions

Variable	Definition
<i>c</i>	Household Consumption
<i>h</i>	Human Capital
<i>m</i>	Output of the Military Good

APPENDIX B

PARAMETER DEFINITIONS

The model developed for this study relies on 11 parameters, each of which reflects certain properties about the economy of the United States. Using the process of calibration outlined in Chapter 4, the values of the parameters are estimated using long-run, annualized data on the United States for a 70 year period, 1949-2009. An overview of the parameter definitions is provided in Table B.1.

Table B.1: Parameter Definitions

Parameter	Definition
A	Technology Available for General Production
B	Technology Available for Military Production
α	Output Elasticity of General Production
β	Discount Factor of Period Utility
δ	Depreciation Rate of Physical Capital
η	Preference for Leisure over Consumption
γ	Responsiveness of General Production to Changes in Military Output
ω^e	Weight for Transferring S^e into Human Capital
ω^m	Weight for Transferring N^m into Human Capital
τ	Degree of Substitutability of Inputs in Military Production
θ	Share of Factor Inputs Utilized in Military Production

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