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A human capital model of the defense-growth relationship

Bruce D. McDonald

North Carolina State University, School of Public and International Affairs, 209A Caldwell Hall, Raleigh, NC 27695

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ABSTRACT

This paper develops a model to illustrate how human capital investments made by the defense sector impact economic performance. Emphasizing the on-the-job accumulation of human capital during military service, the model demonstrates the effect of investments on the accumulation of human capital and output of the defense sector, whose military good has a spillover effect on general production. Calibrated with data from the United States for the years 1949 to 2014, investments are shown to positively impact both the accumulation of human capital and economic growth. The measured benefits are seen to be lower than investments made into formal education.

A major task facing public officials is the allocation of government resources to programs and services in a manner that maximizes the utility of the country. One daunting apportionment is the resources allocated to the defense sector. In 2017, the United States spent $590.2 billion on national defense, about 14.8% of total federal expenditures, making the defense sector one of the largest functions of the federal government (Office of Management and Budget, 2019). The relationship between these expenditures and economic performance, commonly referred to as the *defense-growth relationship* or the *defense-growth paradigm*, has been an issue of interest to political scientists for some time (Dunne & Tian, 2015; Heo & Ye, 2016; Mintz & Huang, 1991; Russett, 1969; Ward & Davis, 1992). Although defense programs provide critical national security, they have often been criticized for drawing resources away from other more productive areas, such as education and health (Heo & Eger, 2005; Mendieta & McDonald, 2013; Ramey, 2011; Zhao, Zhao, & Chen, 2017). Interest in understanding the relationship gained renewed attention following the War on Terrorism and recent debates on the federal budget; however, there is little sound empirical evidence on whether a relationship exists and what that relationship looks like (Ando, 2018; Dunne & Tian, 2016; Hendrickson, Salter, & Albrecht, 2018; McDonald & Reitano, 2016).

The aim of this paper is to examine the interaction between the defense sector and the economic performance of the United States. I focus on a little-studied area, the contribution of military service and investment on human capital accumulation.[1] Not only does the sector provide training to soldiers in the form of vocational and technical skills, but soldiers also receive on-the-job training during their military service. On-the-job training contributes to increased productivity within the defense sector and can be utilized by soldiers after the completion of their service. Some research has been critical of the investments, arguing that capital acquired during military service provides little utility for soldiers and employers in the marketplace (Borjas & Welch, 1986; McDonald, 2013). The focus of my analysis is whether these investments contribute to a sol-

E-mail address: bmcodna@ncsu.edu

[1] Human capital is defined as the stock of knowledge and skills that are acquired through personal experience or through education and training (Becker, 1962).

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dier's stock of human capital and the degree to which that contribution shapes the economy.

To accomplish the above goal, I establish a dynamic general equilibrium model that is dependent upon human capital for economic growth. Constraining the economy is the defense sector, whose military good is shown to influence the economy's production, utilize its resources, and contribute to the total stock of human capital. Demonstrating the effect of the defense sector's human capital investments, the model is calibrated with data from the United States for the years 1949 to 2014 and its steady-state values are derived. The main finding is that the investments have an influence on economic growth that is both direct, through a learning-by-doing process, and indirect, through an improved capacity of the sector to produce its military good. Although the influence is positive, the overall size of the effect is less than that provided by formal education.

This work relates to several strands of literature. First, a number of studies argue that a country's defense expenditures can affect its economic performance (Aizenman & Glick, 2003; Alexander, 1990; Dunne & Tian, 2015; Ohanian, 1997; Ramey, 2011; Ward & Davis, 1992). This literature has been highly criticized because of its inability to consistently determine whether the relationship is positive or negative (Compton & Paterson, 2016; Dunne, Smith, & Willenbockel, 2005; Hendrickson et al., 2018; Heo, 2010; McDonald, 2012). Instead, critics have pointed towards the need for a programmatic focus on the defense-growth relationship (Biswas, Kabir, & Rafi, 2019; Deger, 1986; Dunne et al., 2005). Second, there is a significant literature that analyzes the effect of human capital on economic growth, focusing on capital acquired either through formal education or employment in the general market (Becker, 1962; Becker, Murphy, & Tamura, 1990; Lucas, 2002; Savvides & Stengos, 2009). Finally, there is literature that studies the post-service employment of veterans (Cardell, Lamoreau, Stromsdorfer, Wang, & Weeks, 1997; Loughran, 2002).

The paper is structured as follows: Section 1 provides the relevant background on defense sector investments into human capital. Utilizing this background, Section 2 establishes a theoretical model of economic growth dependent upon a military good and the defense sector's contribution to the accumulation of human capital. Steps detailing the process of calibration and the results of the empirical analysis are provided in Sections 3 and 4, respectively. A discussion of the defense sector and its investments with respect to the findings is provided in Section 5 concludes.

1. Background

The relationship between economic growth and human capital has been subject to an extensive discussion as researchers seek to understand what kinds of training and education influence economic performance and how that capital accumulates (Becker, 2017; Savvides & Stengos, 2009). Although human capital is generally discussed in terms of the economy at large, Becker (1993) noted the importance of discussing the human capital investments of the military. Not only has the defense sector's human capital investments been cited as a cause of the defense-growth relationship (Benoit, 1973; Heo, 1999; Ward & Davis, 1992), but they are the largest, unified investment in human capital in the United States (Bryant, Samaranyake, & Wilhite, 1993; Bryant & Wilhite, 1990; Savage & Caverly, 2017).

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, Hosek, & Warner, 2007; Eynde, 2016). 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, and the sector uses this long-term benefit as an inducement for military service (Borjas & Welch, 1986; Cardell et al., 1997). In the short-term, 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 & Hartley, 1995).

1.1. On-the-job training in the military

The defense sector's human capital investments take several forms, primarily general and specific on-the-job training. 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 (Becker, 1993, 2017; Savvides & Stengos, 2009). 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—referred to here as *military education*—comprises the education of military forces in the skills and knowledge required of soldiers for their assigned positions in the production of a military good. These investments in training provide income during service and continue to do so after the completion of service as the skills can be used in the private, public, and nonprofit sectors (MacLean & Elder, 2007; McDonald, Jin, Camilleri, & Reitano, 2016).

The defense sector provides both technical and vocational training that can be utilized for production in the private sector (Benoit, 1978; MacLean & Elder, 2007). Active duty soldiers who retire or exit from military service generally enter the civilian work force for a second career (Asch et al., 2007; Eynde, 2016). 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 their 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 (Asch et al., 2007).

The breadth of knowledge acquired through military education contributes to the rate of production of the firms that employ veterans, 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 educational benefit to the firm is a boost in its output, a key benefit of education to laborers is higher income from their participation in the market (Jorgenson & Fraumeni, 1992). This utility of human capital accumulated through military education is demonstrated by the labor decisions of soldiers at the completion of their first service contract. Soldiers who received more military education are more likely to exit the defense sector after their first enlistment period and pursue employment in the market at higher wages (see Farrell & Von Ah, 2018). Competition, then, allows for individuals to maximize their income by working towards production in firms with the highest wages. Ultimately, the improved productivity of firms leads to increased economic growth (Lucas, 1988).

Considerable resources are also spent by the defense sector on skills necessary for national security that have little use in other industries. This specific, on-the-job training—referred to here as *military skills*—includes little of the systematic subject matter discussed in formal education, perhaps other than physical education and basic health care, but rather the details necessary for production. For instance, while basic flying skills learned by fighter pilots can be applied to serving as a commercial airline pilot, the aerial dog-fighting skills acquired do not. Other examples include accession training, defined as the basic soldering skills required for military service.

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, 1993, 2017; MacLean & Elder, 2007). 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 situation, 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. Evidence of the limited impact can be seen in post-service wages, as the lack of transferability to the market suggests that firms disregard the military-specific training when presented with the situation of determining wages for veterans (McDonald et al., 2016).

2. Model

To model the effect between the defense sector's human capital investments and economic performance of the United States, this paper 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 & Stengos, 2009) and is consistent with the theoretical relationship between human capital, the defense sector, and economic growth as discussed in the preceding section. 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 system's microeconomic relationships.[2]

Second, having established the theoretical foundation for the study, attention is turned towards the means and structure of the 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

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

The relative value that the household gives towards leisure over consumption is determined by the preference parameter $\eta > 0$. 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, where its choice to consume or save is restricted by the income it receives from laboring towards production of the economy's good. Letting k_t denote the per-capita stock of physical capital and δ as its depreciation rate, then $k_{t+1} - k_t \left(1 - \delta\right)$ 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

[2] A variety of modeling approaches to understanding the defense-growth relationship have been used over time. To learn more about the limitations of these approaches, particularly the Feder-Ram model, see Dunne et al. (2005) or McDonald (2012).

production. Also influencing production is the output elasticity, α, that measures the responsiveness of production to change in amount of 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

$$c_t + k_{t+1} - k_t\left(1-\delta\right) \le A\left[k_t^{e\alpha}\left(h_t N_t^e\right)^{1-\alpha}\right]^{1-\gamma} m_t^{\gamma} \tag{2}$$

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 requires, production of the military good requires a measure of 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. Structure of the military good is assumed to be given by a constant elasticity of substitution 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

$$m_t = B\left[\theta k_t^{m\tau} + \left(1-\theta\right)\left(h_t N_t^m\right)^{\tau}\right]^{\frac{1}{\tau}} \tag{3}$$

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

Of importance to this study is the accumulation 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. 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.

$$h_{t+1} = h_t\left(\omega^e S_t^e + \omega^m N_t^m\right) \tag{4}$$

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

$$k_t^e + k_t^m = k_t \tag{5}$$

Second is a constraint faced by the household on the allocation of its time. It is assumed that the household allocates its time between leisure, laboring towards production of the economy's good, laboring towards the production of the defense sector, and pursuing formal education:

$$N_t^e + N_t^m + S_t^e + l_t \le 1 \tag{6}$$

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

2.1. Characterizing the solution

To solve the maximization problem of the model economy, I form its Lagrangian function. Given that the solution can be obtained by considering just the long-run growth, the functional notation of time has been dropped. Prime notation is adopted to signify the forward time period.

$$\begin{aligned}\mathcal{L} = \sum_{t=0}^{\infty}\beta^t\{&\ln c + \eta l \\ &+\lambda_1\left[A\left[k^{e\alpha}(hN^e)^{1-\alpha}\right]^{1-\gamma}m^{\gamma} - c - (k^e{\prime} + k^m{\prime})\right. \\ &\left.+(k^e + k^m)\left(1-\delta\right)\right] \\ &+\lambda_2\left[B\left[\theta k^{m\tau} + \left(1-\theta\right)(hN^m)^{\tau}\right]^{\frac{1}{\tau}} - m\right] \\ &+\lambda_3\left[h\left(\omega^e S^e + \omega^m N^m\right) - h\prime\right] \\ &+\lambda_4\left[1 - N^e - N^m - S^e - l\right]\}\end{aligned} \tag{7}$$

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 conditions for the equilibrium growth path are given by the Euler's in Eqs. (8)–(12).

$$\eta = \frac{1}{c}A(1-\gamma)(1-\alpha)\left[\left(\frac{k^e}{hN^e}\right)^{\alpha}h\right]\left[k^{e\alpha}(hN^e)^{1-\alpha}\frac{1}{m}\right]^{-\gamma} \tag{8}$$

$$\begin{aligned}\eta = \frac{1}{c}&\left[\gamma A\left[k^{e\alpha}(hN^e)^{1-\alpha}\right]^{1-\gamma}m^{\gamma-1}\right]B\left[\left(1-\theta\right)(hN^m)^{\tau-1}h\right]\left[\theta k^{m\tau}\right. \\ &\left.+\left(1-\theta\right)(hN^m)^{\tau}\right]^{\frac{1-\tau}{\tau}} + \frac{\eta\omega^m}{\omega^e}\end{aligned} \tag{9}$$

$$\frac{1}{c} = \frac{1}{c\prime}\beta\left[A(1-\gamma)\alpha\left[\frac{k^e{\prime}}{h\prime N^e{\prime}}\right]^{\alpha-1}\left[k^e{\prime}^{\alpha}(h\prime N^e{\prime})^{1-\alpha}\frac{1}{m\prime}\right]^{-\gamma} + \left(1-\delta\right)\right] \tag{10}$$

$$\begin{aligned}\frac{1}{c} = &\frac{1}{c\prime}\beta\left(1-\delta\right) \\ &+\frac{1}{c\prime}\left[\gamma A\left[k^e{\prime}^{\alpha}(h\prime N^e{\prime})^{1-\alpha}\right]^{1-\gamma}m\prime^{\gamma-1}\right]\beta B\left[\theta(k^m{\prime})^{\tau-1}\right]\left[\theta k^m{\prime}^{\tau}\right. \\ &\left.+\left(1-\theta\right)(h\prime N^m{\prime})^{\tau}\right]^{\frac{1-\tau}{\tau}}\end{aligned} \tag{11}$$

$$\begin{aligned}\frac{\eta}{h\omega^e} = &\frac{1}{c\prime}\beta A(1-\gamma)(1-\alpha)\left[\left(\frac{k^e{\prime}}{h\prime N^e{\prime}}\right)^{\alpha}N^e{\prime}\right]\left[k^e{\prime}^{\alpha}(h\prime N^e{\prime})^{1-\alpha}\frac{1}{m\prime}\right]^{-\gamma} \\ &+\frac{1}{c\prime}\left[\gamma A\left[k^e{\prime}^{\alpha}(h\prime N^e{\prime})^{1-\alpha}\right]^{1-\gamma}m\prime^{\gamma-1}\right] \\ &\beta B\left[\left(1-\theta\right)(h\prime N^m{\prime})^{\tau-1}N^m{\prime}\right]\left[\theta k^m{\prime}^{\tau}\right. \\ &\left.+\left(1-\theta\right)(h\prime N^m{\prime})^{\tau}\right]^{\frac{1-\tau}{\tau}} + \frac{\eta}{h\prime\omega^e}\beta(\omega^e S^e{\prime} + \omega^m N^m{\prime})\end{aligned} \tag{12}$$

Eqs. (8) and (9) represent the optimal labor-leisure decisions. The left-hand side of the Euler equations represents 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 Eq. (12), which describes the household's choice between leisure in the current period and consumption in the future. Just as with the labor-leisure decisions, the marginal benefit from future consumption must be equal to the marginal cost of leisure in the present for the decision to be optimal.

Further, Eqs. (10) and (11) portray the optimal consumption-savings decisions of the household. 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 $\frac{c\prime}{c} > 0$, 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.

Through exploitation of the model and the Euler equations, it can be shown that c, m, k^e, k^m, and h all grow at the same rate, ϕ, along the balanced growth path. By normalizing the model around human capital, the steady-state form of the model is produced. This is shown as

$$\hat{c} + \phi\hat{k}^e + \phi\hat{k}^m - \left(\hat{k}^e + \hat{k}^m\right) \left(1-\delta\right) \leq A\left[\hat{k}^{e\alpha}\left(\overline{N}^e\right)^{1-\alpha}\right]^{1-\gamma}\hat{m}^{\gamma} \tag{13}$$

$$\hat{m} = B\left[\theta\hat{k}^{m\tau} + \left(1-\theta\right)\left(\overline{N}^m\right)^{\tau}\right]^{\frac{1}{\tau}} \tag{14}$$

$$\phi = \omega^e\overline{S}^e + \omega^m\overline{N}^m \tag{15}$$

$$\overline{N}^e + \overline{N}^m + \overline{S}^e + \bar{l} = 1 \tag{16}$$

$$\hat{c} = \zeta_1\hat{k}^{e\alpha(1-\gamma)}\overline{N}^{e-\alpha} - \gamma(1-\alpha)\hat{m}^{\gamma} \tag{17}$$

$$\hat{c} = \frac{\gamma}{\eta}AB\left(1-\theta\right)\hat{k}^{e\alpha(1-\gamma)}\overline{N}^{e(1-\alpha)(1-\gamma)}\overline{N}^{m\tau-1}\hat{m}^{\gamma-\tau} + \hat{c}\frac{\omega^m}{\omega^e} \tag{18}$$

$$\phi = \zeta_2\hat{k}^{e\prime(\alpha-1)-\gamma\alpha}\overline{N}^{e(1-\alpha)(1-\gamma)}\left(\hat{m}\prime\right)^{\gamma} + \zeta_3 \tag{19}$$

$$\phi = \zeta_3 + \beta\gamma\theta AB\hat{k}^{e\prime\,\alpha(1-\gamma)}\overline{N}^{e(1-\alpha)+(1-\gamma)}\hat{k}^{m\prime\,\tau-1}\hat{m}\prime^{(\gamma-\tau)} \tag{20}$$

$$\phi = \beta\omega^e\left(1-\bar{l}\right) \tag{21}$$

where

$$\zeta_1 = \frac{A(1-\gamma)(1-\alpha)}{\eta} \tag{22}$$

$$\zeta_2 = \beta A(1-\gamma)\alpha \tag{23}$$

$$\zeta_3 = \beta\left(1-\delta\right) \tag{24}$$

In the steady-state model, a bar is used to distinguish the optimal allocation of the household's time to the respective activity. A hat is used to signify the variable in per-unit-of-human-capital terms.

3. Model calibration

In the preceding section, 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, it is only a theoretical description of the household preferences and the constraints placed upon them. The model does, 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. Specifically, many of the parameters in the model are not identified in U.S. balanced growth observations. In choosing parameter values for the model, I follow the standard strategy of calibration as established by Kydland and Prescott (1982), and clarified by Cooley and Prescott (1995) and Heer and Maussner (2009). 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. 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.

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. Throughout both steps of the calibration process, some variables and parameters may be able to be measured based on observable data and others may be measured based on past research. When a measurable or preexisting data does not exist, calibration follows the principles of algebra to solve for the missing information using the system of equations derived in the model. Once these steps are accomplished, the model is ready for use in studying the analytical behavior of prospective policy decisions on economic performance.

Based on per-capita U.S. data from 1949 to 2014, I begin with the establishment of the steady-state time allocations. Households typically allocate about a third of their discretionary time to market activity (Aguiar & Hurst, 2007; Ghez & Becker, 1975; Juster & Stafford, 1991), providing a value for l of 0.642. Data on the allocation of the labor force are from the Bureau of Labor Statistics' *National Income and Product Accounts* (NIPA) and the Department of Defense's *Military Personnel Programs* (M-1) documents. Due to the time constraint in the model, the time variables S^e, represents 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.

Next, I fix the values for the parameters that have been established by the previous literature. According to Jones (2002), the value for α, an output elasticity that measures the responsiveness of production to changes in the levels of the resources used, is set at 0.337. The discount factor on lifetime utility, β, is selected by Cooley and Prescott (1995) as 0.960. Finally, δ, the rate of capital depreciation, has been shown to be fixed at 0.048 (Barro & Sala-i-Martin, 2004; Cooley & Prescott, 1995).

According to the properties of the model, all variables in the balanced-growth path grow at a constant rate over time, denoted as ϕ. For the model economy, Eq. (15) provides the basis for establishing the growth rate, which is seen to depend on the determinants of human capital. Accordingly, in the model economy ϕ is fixed as the average growth rate of personal income, as reported in the NIPA, at 1.021. Using Eq. (21), ω^e is established as 21.271. Eq. (15) can then be used to fix ω^m as 17.364. Since all growth in the economy is the result of human capital, the technology available for use in private good production, A, is constant. Because A does not influence the production of the military good, the sector's human capital investments, or the growth rate, it can be arbitrarily set to 1.

Attention is now directed at deriving the output-capital ratio and consumption-capital ratio of the benchmark economy. The balanced growth properties of the model require that the ratios 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 budget constraint, Eq. (13) can be rewritten and simplified to

$$\frac{y}{k^e+k^m}=\frac{c}{k^e+k^m}+\left[\phi-\left(1-\delta\right)\right] \tag{25}$$

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. Data on total economic output, y, and total physical capital, k^e+k^m, are from the NIPA and the Federal Reserve's economic database.[3]

To establish a value for ζ_1, I begin by dividing Eq. (13) by (17). Through simplification, the division can be shown to equal

$$\zeta_1=\frac{N^e}{1+\left[\phi-\left(1-\delta\right)\right]\left(\frac{k^e+k^m}{c}\right)} \tag{26}$$

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 then be established with Eq. (24) and the parameters β and δ, producing a value of 0.923.

Next, I turn to the parameters relating to the production of the military good. As a government program, the defense sector is subject to restrictions on its ability to make a profit. Applying a zero-profit condition to Eq. (14), the production of the military good, produces

$$\frac{\hat{k}^m}{N^m}=\frac{\theta}{1-\theta} \tag{27}$$

where the defense sector's capital-labor ratio 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 U.S. Department of Defense's *National Defense Budget Estimates*. Based on data from sample period, the long-term average of the sector's capital-labor ratio is 0.869. Using this ratio, Eq. (27) can be used to derive a value for θ of 0.465.

The defense parameters γ, which represents the rate at which the sector 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 publicly 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 Eqs. (13), (14), (17), (19), and (20) 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 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 Eq. (25)), and the previously determined parameter and variable values.

4. Results

The results produced from the process of calibration come in several parts. The first of these parts is the param-

[3] Total economic output is measured as the sum of gross national production and the flow of services from consumer durables. Total physical capital is measured as the sum of business equipment and structures, residential structures, government structures and equipment, and the stock of consumer durables.

Table 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

Table 2
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
$\hat{m}$	0.021
l	0.642
S^e	0.039
N^e	0.307
N^m	0.011
ϕ	1.021

eter values. I start with annualized economic data for the United States over a 66 year period from 1949 to 2014, which is presented in constant 2009 dollars. A cutoff of 2014 is used due to the availability of data at the time of collection on the U.S. Department of Defense's enlistments and investments. Next, I aligned the model such that the properties of the model mimic the properties of the real economy.[4] Included in this process was the attainment of 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. Results of the model calibration are shown in Table 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.

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. 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.

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 parameter θ, which represents the share of factor inputs utilized in the production of the military good, is valued at 0.465. Because production relies on physical capital and labor, θ determines how much of the production comes from each resource. While this represents nearly equal reliance upon both physical and human capital, the factor share allocated towards the sector's human capital investments, 0.535 (measured as $1 - \theta$), demonstrates the sector's 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. 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.

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.

With the deep parameters of the economy fixed by calibration, the variable values for the balanced growth path of the U.S. economy are then determined. The results of this allocation are reported in Table 2 and can be interpreted as follows: The per-capita steady state value of the private

[4] As 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.

economy's physical capital is $10.01 per unit 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.

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 investment's effect can best be understood through the application to economic output. Using the output from 2014 as established in the previous section, along with the steady state growth rate, we can estimate the 2019 output of the United States. The result of this calculation shows that a growth rate of 2.1% is roughly equal to $475.5 billion in 2019. Using the defense sector's share of economic growth, approximately $89.8 billion of the output is related to the sector's human capital investments.

5. 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 (Aizenman & Glick, 2003; Compton & Paterson, 2016; Dunne & Tian, 2016; Heo & Ye, 2016). 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 exists, its directionality, and how it should be modeled (Dunne et al., 2005; Heo & Eger, 2005; McDonald, 2012). One reason for the failure of the literature is that it has primarily focused on the relationship in terms of a country's total defense expenditures (for example, see Dunne & Tian, 2015; Zhao et al., 2017). While the defense sector may exhibit consistent growth in its spending overtime, how the sector uses its funding may vary from year to year (Office of Management and Budget, 2019). As a result, spending on the functions of the sector that promote or hinder economic growth may also fluctuate, making the defense-growth effect nearly impossible to capture in the sector's aggregate spending.

This study has sought to contribute to the discussion on the defense-growth relationship by moving past the impact of total defense spending. Given the sector's dependency on human capital, and the size of the investments in the area made by the sector, I focused on the relationship in a programmatic context of the defense sector's human capital investments. It was hypothesized that the effect is determined by how the sector allocates its resources rather than its total expenditures. As one of the first programmatic approaches 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. Not only does the sector provide training to soldiers in the form of vocational and technical skills, but soldiers also receive on-the-job training during their military service. On-the-job training contributes to increased productivity within the defense sector and can be utilized by soldiers after the completion of their service.

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). From the derived model, it is seen that 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. 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 institutional stability on the production of the economy's general good, the increase in 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.

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. The first implications relate to the conversion costs of defense reduction and the initiatives needed to compensate for any potentially adverse effects. As the involvement of the United States in military action overseas has begun to wane, increased discussion has taken place on the reduction of military troops (Johns & Davies, 2019). The number of troops needed for action is different than the number needed to maintain the defense sector during peacetime. Furthermore, as the United States continues to struggle with its political environment and budgetary process, many of these discussions have alluded to the drain that military employment has had on skilled labor.

Reduction policies, however, 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 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

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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 (McDonald, 2013). 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 & 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 publicly 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.

Despite the relative size of the defense sector's human capital investments, this study has some limitations that should be noted. The primary limitation of the study is 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 may 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 may lead 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.

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 (Bernauer, Koubi, & Ernst, 2009; Knight, 1996). 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 the 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.

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