North Carolina State University

From the SelectedWorks of Bruce D. McDonald, III

2012

Reconsidering the Defense-Growth Relationship: Evidence from the Islamic Republic of Iran

Bruce D McDonald, III
Recent literature has failed to reach a consensus on how best to model the defense-growth relationship. Although several attempts have been made to solve the problem by the theoretical comparison of models, empirical attempts at comparison have been largely restricted to the United States. Given the recent criticism of the Feder-Ram model, this article uses Iranian data to compare the performance of the Feder-Ram and augmented Solow models in the context of a growing, yet heavily militarized, economy. The results indicate that the improved ability of the augmented Solow model to explain economic growth can better account for the effects of an increase in defense expenditures.

**Introduction**

Despite the significant attention paid within the literature to the relationship between defense spending and economic growth, commonly referred to as either the defense-growth relationship or the defense-growth nexus, a meaningful consensus has failed to be reached as to whether defense expenditures hinder growth or promote it (McDonald and Eger 2010; McDonald 2011). Further complicating the problem is the failure of a dominate framework to emerge by which to investigate the relationship (Atesoglu 2009; Heo 2010; de Groot 2011), leading many to believe that work on the relationship produces as many questions as it does answers (Atesoglu
2009; Chan 1985; McDonald and Eger 2010). Ultimately, this failure has led the mainstream growth literature to conclude that the defense sector is not a significant factor in the explanation of economic growth (Dunne et al. 2005).

Regardless of the problems facing the defense-growth relationship, the issue of how a nation’s defense expenditures affect its overall economic growth has been an area of concern and contention to both academics and politicians for some time (Aizenman and Glick 2006; Mintz and Huang 1990; Ali 2011). To explore the defense-growth relationship, two dominant approaches have been used: a Feder-Ram based approach and an augmented Solow approach. Although the Feder-Ram approach has been accepted with widespread use, the augmented Solow approach touts an unparalleled theoretical literature. Several recent works have attempted to solve the problem by theoretically comparing these models, but the empirical attempts of comparison have been largely restricted to the United States. Certainly an American-based comparison provides useful results for those wanting to understand and explain the defense-growth relationship in the United States, but is the comparison useful for understanding the relationship elsewhere? During 2007, world defense expenditures totaled $1.339 trillion, of which the United States accounted for $547 billion (about forty-five percent) (Stockholm International Peace Research Institute 2010). During the same time, world GDP was $53.352 trillion, of which the United State accounted for $13.794 trillion (about twenty-six percent) (International Monetary Fund 2008). Given the dominance of the United States in the world market, international inference from past comparisons is limited.

A clear understanding of the defense-growth relationship around the globe still holds some interest, given the uncertainty of the effects of the remaining $792 billion in global expenditures. More compelling for the need to understand the defense-growth relationship in
other countries is the rate at which defense expenditures are increasing. From 1998 to 2007, global defense expenditures increased forty-five percent, the fastest rate of increase since World War II. Given the War on Terrorism, regional instability, and the stand-off between the Islamic Republic of Iran and the United States, the defense-growth relationship in the Middle East is of particular interest. When excluding the United States from analysis, the Middle East witnessed the highest regional growth of defense expenditures, increasing sixty-two percent to $91.5 billion from 1998 to 2007 (Stockholm International Peace Research Institute 2010). In this article, the literature on modeling the defense-growth relationship is advanced through an empirical comparison of the Feder-Ram and augmented Solow models. Using Iranian data from 1960 to 2006, both approaches are employed to demonstrate their use in explaining how increases in defense expenditures influence economic growth in the context of a highly militarized, non-western economy.

As the article demonstrates, the reliance upon the Feder-Ram model to explain the defense-growth relationship is misguided. Though the dominant model of the past twenty years, this model suffers from several problems, including the inability to deal with the delayed effects of defense expenditures and the absence of a strong theoretical reasoning as to why the model should work. As a replacement model, this article recommends the augmented Solow model. While simple in design, a Solow-based approach to economic growth has been shown to successfully explain variations in the rate of economic growth across the globe (Barro 1990). When applied to the defense-growth relationship, not only is the model able to overcome the failings of the Feder-Ram approach, it is also able to make use of the extensive literature on neoclassical economics in clarifying the cause and direction of the relationship. In comparing the ability of both models to explain the economic growth of Iran, this article shows that the
augmented Solow model is clearly superior in terms of its ability to explain economic performance, but also in terms of the clarity in direction and significance of the defense-growth relationship. As the estimates of the augmented Solow model show, defense expenditures produce a positive effect on Iranian economic performance.

The Defense-Growth Relationship

Beginning with the pioneering work of Hitch and McKean (1960), defense economics has been an area of interest and an issue of academic focus since the start of the 1960s. The escalation, and later the conclusion, of the Cold War brought greater interest to the issue, leading to a controversy of whether an expansion of the defense sector would lead to an increase in economic growth or whether such an expansion would impede growth. From this literature, there are at least three channels through which defense expenditures can influence the economic growth of a state.² The first channel is through the defense sector’s investment in technological research and development. In addition to being charged with overseeing issues of national security, the defense sector is charged with the development of new weapons technology, often including heavy industry (Gold 1990). Although the research interests of the defense sector are largely militarily related weapons, development and production have often led to technological innovations that have public uses (Adams and Gold 1987; Phillips 1983). Just as private sector innovations, the spillover effect from defense technology contributes to the total factor of productivity of the economy as a whole. Although not usable directly within the private sector, weapons development and production have often led to technological innovations that have public uses (Trebilcock 1969). The development of the atom bomb during World War II, for instance, led to the development and application of nuclear technology and energy production.
Other examples include innovations in transportation, nuclear power, and computers that have been adopted by the private sector as a means of maximizing employee and firm efficiency.

A second channel through which military expenditures can influence growth is through the tax burden created by increased defense expenditures (Chan 1987; Heo 2010). An increase in defense expenditures create a budgetary trade off because expenditures can only be financed by creating new taxes, increasing the budgetary deficit, or by issuing additional money (Chan 1985; Ward and Davis 1992; DeGrasse 1983). Following a Keynesian school of thought, Carroll (2006) argues that different modes of financing produce different economic effects, with defense expenditures funded through taxation restricting growth by lowering the expected after-tax return on capital and reducing the flow of savings available to finance capital formation. Conversely, expenditures funded through deficit financing produce a positive, accelerator effect by which government output is expanded, increasing employment and stimulating consumer demand, resulting in an encouragement of investment. Historically, nations have relied upon increased taxation to finance defense expenditures, leading Carroll (2006) to conclude that defense expenditures are more likely to restrain growth than promote it.

The third channel occurs by crowding out investment from areas that might be considered more productive (Heo and Eger 2005; Knight et al. 1996; Mintz and Huang 1990). Financial resources are limited, forcing the defense sector and private investors to compete for the available capital. According to Knight, Loayza, and Villanueva (1996), crowding-out occurs due to the lower return on fixed capital, reducing the investment available to finance capital formation in the private economy. As defense expenditures increase, the capital available for private investment declines, forcing the choice between investing in either the defense or private sector (Russett 1969). Defense expenditures may also effect growth through its influence on the
efficiency of resource allocation (Knight et al. 1996). While the private sector is guided by a market economy, the defense sector does not face the same dynamics. Demonstrating the inefficiency of resource allocation, Ward and Davis (1992) show that defense expenditures can limit growth by moving resources away from the private sector, which maintains a higher rate of productivity than either the public or defense sectors (see also Mintz and Huang 1990, 1991).

These channels suggest a trade-off between defense expenditures and economic growth. Although the first channel suggests that the net effect of military expenditures on economic growth is likely to be positive, it remains impossible to escape the latter two channels. It is therefore reasonable to hypothesize a negative effect on economic growth due to any increase in a state’s defense expenditures. It is also not surprising that many past studies have shown empirical results to support not only a positive association through technology (Heo and DeRouen 1998; Phillips 1983), but also a negative effect by crowding out investment (Heo and Eger 2005; Mintz and Huang 1991) and through a budgetary tradeoff (Carroll 2006; Ohanian 1997). Between the duality of theoretical groundings for the defense-growth paradigm and the mixed results displayed in the literature, some have suggested that the relationship may be an empirical issue rather than a theoretical one (Alexander 1990). Though the consensus seems to be that while a positive spillover may be possible, the majority of defense programs are not technologically related, suggesting that the spillover can have only a minor influence. Regardless of the size of the spillover, however, there is still a need to fund the programs, suggesting a relationship that is ultimately negative. Given the variety of approaches undertaken to measure the relationship, what remains to be determined is how we can best estimate the effect of an increase in a nation’s defense expenditures.
Models of the Defense-Growth Relationship

The Feder-Ram Model

The most common model to explain the defense-growth relationship has been some variation of the Feder-Ram model (see Alexander 1990; Atesoglu and Mueller 1990; Mintz and Huang 1990; Ram 1986; Ward and Davis 1992). Derived from a neoclassical economic perspective, the Feder-Ram approach employs a supply-side explanation for aggregate output with changes in labor and capital. Following its development, a series of variations have been adopted within the literature, dependent upon the number of sectors included and the pattern of externalities (Sandler and Hartley 1995). According to Heo, the approach holds the potential for significant contribution to the literature on the defense-growth relationship because it is “developed from a consistent theoretical structure” (1998:39) or, at least, “fairly well grounded in the neoclassical production function framework” (Biswas and Ram 1986:367). As Dunne, Smith and Willenbockel note, however, the “popularity of the approach lies in the appearance of a direct link from theoretical model to econometric specification” (2005:453).

The basis for the approach was first developed by Feder, who wrote that “aggregate growth is related to changes in capital and labor through an underlying production function” (1983:60). From this, Feder divided the aggregate output of the economy into two sectors: exports and non-exports. Following Feder’s division of the economy, Ram (1986) proposed a two-sector model to explain growth as comprised of a government and a private sector. In a series of studies, Mintz and Huang (1990, 1991) and Huang and Mintz(1991) argued for a third sector, a defense sector, on the grounds that the effects of defense expenditures could also differ from that of non-defense related government spending due to a different set of incentives. While the literature has relied upon a variety of adjustments to the Feder-Ram approach (see Heo
the basic three-sector version of the model distinguishes between the effects of defense expenditures \((D)\), non-defense expenditures \((N)\), and the rest of the economy \((P)\). These sectors are demonstrated as follows:

\[
\begin{align*}
D &= D(L_d, K_d) \\
N &= N(L_n, K_n) \\
P &= P(L_p, K_p, D, N)
\end{align*}
\]

Where subscripts denote the allocation of inputs among sectors, such that the allocation of inputs among capital, \(K\), and labor, \(L\), is given as:

\[
\begin{align*}
K_d + K_n + K_p &= K \\
L_d + L_n + L_p &= L
\end{align*}
\]

Following Feder (1983) and Ram’s (1986) sector approach to the economy, total economic output \((Y)\) is described as:

\[
Y = D + N + P
\]

and the differential of the marginal factor productivity in the defense and nondefense sector can be captured, where \(\delta_i\) denotes the difference in productivity between the three sectors, within the relationships:

\[
\begin{align*}
\frac{D}{P} &= \frac{D}{D} = (1 + \delta_d) \\
\frac{N}{P} &= \frac{N}{N} = (1 + \delta_n)
\end{align*}
\]

Taking the proportional differential of economic output with the total differentials of sectors \(N, D,\) and \(P\) leads to the following equation:

\[
\frac{\dot{Y}}{Y} = \frac{P_L}{Y} + \frac{P_K}{Y} + \left(\frac{\delta_d}{1 + \delta_d} + P_d\right) \frac{D}{Y} \dot{D} + \left(\frac{\delta_n}{1 + \delta_n} + P_n\right) \frac{N}{Y} \dot{N}
\]
where $I$ is equal to the derivative of capital, $K$, and represents net investment. Using $\theta$ to denote the externality effects of the defense and nondefense sectors, and the constant elasticity of $P$ with respect to $D$, the equation can be rewritten as:

$$
\dot{Y} = \frac{P_L}{Y} \dot{L} + \frac{P_k}{Y} \dot{I} + \left(\frac{\delta_d}{1 + \delta_d} + P_d\right) \frac{D}{Y} \dot{D} + \theta \dot{D} + \left(\frac{\delta_n}{1 + \delta_n} + P_n\right) \frac{N}{Y} \dot{N} + \theta \dot{N}
$$

The popularity of the Feder-Ram approach has led to variations of this model being used to estimate the effects of the defense sector with data for individual countries (see Heo 2000; Mintz and Huang 1990; Ward and Davis 1992), cross-country data (see Heo 1998), and time-series, cross-sectional data (see McDonald and Eger 2010; Murdoch et al. 1997). Despite the preferences for the Feder-Ram model, however, the approach does draw some theoretical criticism (Alexander 1990; Dunne 1996; Dunne et al. 2005). First, there are criticisms centered on the notion that it is not possible, in reality, to divide the economy into a series of discrete sectors (Alexander 1990). While we can account for sectors individually, a Feder-Ram approach fails to account for the relationships between sectors. For example, it is expected that private sector growth would lead to increased tax revenue, which would lead to larger defense and nondefense government sectors. Despite the defense literature’s reliance upon the Feder-Ram model, the theoretical failings of a sectoral approach have led the mainstream growth literature to more advanced models of economic growth.

Second, there are criticisms that a Feder-Ram approach is subject to severe misspecification (Alexander and Hansen 2004). Central to these criticisms are issues over what sectors should be distinguished from other residual sectors within the growth equation. The difficulty of what to include can be seen early in the literature with Ram (1986, 1987) and Biswas and Ram (1986), all of which included two sector models, but chose different sectors on
which to focus. For Ram (1986, 1987), the sectors included government expenditures and exports, respectively. For Biswas and Ram (1986), the included sectors were the defense expenditures and exports. Given the variations of the models and the possibility of bias, Ram (1995) concluded that a minimum of four sectors is necessary. As Alexander and Hansen (2004) note, however, about ninety percent of the Feder-Ram based studies of the defense-growth relationship include only two or three sectors. Despite advances in understanding the defense-growth relationship, the misspecification of the Feder-Ram approach continues as recent work has continued to vary the model significantly across applications, calling into question the validity of recent contributions.

**The Augmented Solow Model**

While the literature on the defense-growth relationship has relied heavily on the Feder-Ram model, Dunne, Smith and Willenbockel (2005) criticized the model, arguing that the approach ignores the mainstream growth literature. As an alternative approach to estimating the relationship, they recommend an augmented Solow model (see Dunne et al. 2002; Knight et al. 1996; Yakovlev 2007). This approach, based on the work of Solow (1956) and Swan (1956), employs a supply-side description of changes to aggregate output, which, in turn, explains the growth of the resulting changes in labor and capital. Mankiw, Romer, and Weil (1992) expanded this approach by providing an augmented Solow model, whereby the accumulation of economy-wide human and physical capital provides a description for growth. Although a simple explanation of economic growth, of particular interest in the augmented Solow model is ability to provide a realistic description of economic growth. According to Mankiw, Romer and Weil (1992), the model can explain eighty percent of cross-country variation in growth, compared to
the Feder-Ram model, which can explain only sixty-six percent of variation (Mintz and Huang 1990).

Estimation of the augmented Solow model relies on two assumptions. First, the causality of defense expenditures effecting growth within the literature of the Feder-Ram approach hold across other economic growth models. Second, rather than relying on a sectoral approach to measure the effects of defense expenditures, the augmented Solow model follows the first channel of influence and assumes that defense expenditures’ share of growth will affect a nation’s total factor productivity. This influence on productivity occurs through a leveling effect on the efficiency parameter that directs labor-augmenting technological change.

Following the neoclassical tradition, the augmented Solow model begins with a neoclassical production function that features labor-augmenting technological change demonstrated as:

\[ Y_t = K_{t}^{\alpha} [A_{t}L_{t}]^{1-\alpha} \]

where the notation \( Y \) is aggregate real income, \( K \) is real capital output, \( L \) is labor, and \( A \) is the level of technology. It is then assumed that labor and technology grow exogenously at the rates \( n \) and \( g \), respectively. This relation is given as:

\[ L_t = L_0 e^{nt} \]

\[ A_t = A_0 e^{gt} d_t^{\theta} \]

Included in the assumptions of technology is \( d \), the share of defense expenditures in GDP, which grows at rate \( \theta \). This creates a specification of technology that suggests a permanent change in \( d \) will not affect the long-term steady state growth. However, it does have the possibility of producing a level effect on the per-capita income along the growth path. It could also affect the transitory growth rate as it moves toward a new equilibrium.
With the traditional assumptions of the Solow model, a constant rate of savings, \( s \), is invested. Witnessed are a constant growth rate of the labor force, represented by \( n \), an advancement of knowledge, represented by \( g \), and a given rate of depreciation, represented by \( \delta \). Further, \( y \) is defined as output per laborer, \( y = Y/AL \), and \( k \) as capital stock per laborer, \( k = K/AL \).

Within the model, capital accumulation is described as:

\[
\dot{k}_i = sy_i - (n + g + \delta)k_i = sk^\alpha_i - (n + g + \delta)k_i
\]

This implies a steady state of \( k \) as:

\[
k^*_i = \left[ \frac{s}{n + g + \delta} \right]^{1/(1-\alpha)}
\]

After linearly adjusting around the steady state and approximating the transition dynamic of output per laborer as it approaches the steady state, the model relates \( y_e \) to the observed output per laborer through:

\[
\ln y_i = e^\psi \ln y_{i-1} + \left(1 - e^\psi\right)\left[\ln A_o + \frac{\alpha}{1-\alpha}\left(\ln s - \ln(n + g + \delta)\right)\right] + \theta \ln d_i - e^\psi \theta \ln d_{i-1} + \left[e^\psi_i - e^\psi_{i-1}\right]g
\]

Using \( \theta \) to represent the elasticity of income with respect to the long-run defense expenditure share of GDP, the final effects of defense expenditures on economic growth within the augmented growth model can be written as (see Knight et al. [1996] for a full derivation of the model):

\[
\Delta \ln y_i = \beta_0 + \beta_1 \ln y_{i-1} + \beta_2 \ln s_i + \beta_3 \ln(n_i + g_i + \delta_i) + \beta_4 \ln d_i + \beta_5 \ln d_{i-1} + \varepsilon
\]

According to Dunne, Smith and Willenbockel (2005), there are three advantages to using an augmented Solow model. First, the augmented Solow model is dynamic, allowing for an understanding of the effects of defense expenditures over time. Second, the exclusion of
nondefense government expenditures and various externality effects reduces the likelihood of multicollinearity present in other approaches. Third, the measure of human capital includes both capital depreciation and total factor productivity, suggesting it is more theoretically specified than Feder-Ram’s inclusion of the growth rate of the labor force. Notwithstanding these advantages, the augmented Solow model has failed to be adopted by most defense-growth proponents.

Data and Method

In order to compare the Feder-Ram and augmented Solow models as developed in the previous section, data from the Islamic Republic of Iran was collected for the years 1960 to 2007. These data are outlaid in calendar years and are expressed in 1998 constant rials. Data on total government consumption, defense expenditures, GDP, and gross domestic private investment are obtained from the Central Bank of the Islamic Republic of Iran. Following Alexander (1990), total government consumption is used as the government sector output. Non-defense government expenditures are obtained by subtracting defense expenditures from total government consumption, whereas private sector output is obtained by subtracting total government consumption from GDP. For labor data, I follow the previous defense-growth literature and use the population growth rate as a proxy (Alexander 1990; Heo 1998; Ram 1986). As noted by Lebovic and Ishaq, “because labor participation rates show little volatility in the short run, the population growth rate may be used instead” (1987:118). For data specific to the augmented Solow model I follow the previous growth literature and fix the sum of $g$ and $\delta$ at 0.05, assuming that any reasonable change in this assumption will have a minimal effect on the estimate (Mankiw et al. 1992). A summary of key data are given in Table 1.
Before providing the findings of the empirical analysis, there are several methodological issues that must be addressed. First, to estimate the models, I employ an ordinary least squares approach to explain variation in the economic growth of Iran over time. The second methodological issue to be addressed is the determination of the appropriate lag for variables included within the augmented Solow model. According to Gujarati (1988), the inclusion of a distributed lag allows for the capturing of dynamic effects by including changes in variables over time. Since the specification of the growth model contains distributed lags and there is no *a priori* information on the lag structure, an objective criterion is needed to determine the proper number of lags. To accomplish this task, I rely on a standard information criterion (SIC), as suggested by Schwarz (1978) and Geweke and Meese (1981). As noted in Table 2, the SIC results suggest a lag structure of $t-2$ as appropriate.

Last are the econometric issues that are inherent to the models and longitudinal nature of the study. As noted by Dunne, Smith and Willenbockel (2005) and Sandler and Hartley (1995), there is a possibility of simultaneity between economic growth and defense expenditures and between investment and nondefense government expenditures within the Feder-Ram model. To address this potential problem, I employ a Granger causality analysis to test for exogeneity. The results of the Granger causality analysis show no statistically significant causal effect for both relationships, suggesting the absence of simultaneity within the model.\(^5\)

The third econometric issue to be discussed is the issue of stationarity. According to Granger and Newbold (1974), the results of a time series regression may be spurious if any variable within the analysis is not stationary. For the augmented Solow model, the issue of stationarity is not a problem, given the use of log changes in the model. Given the design of the
Feder-Ram model, however, stationarity does remain a potential issue. Following Granger and Newbold, each variable within the Feder-Ram model was tested for the presence of a unit root based on the Dickey-Fuller test. The results of the Dickey-Fuller test show the absence of a unit root, suggesting that stationarity is not a problem within the model.

Lastly, there is also the potential problem of autocorrelation, given that the models are longitudinal in design. To test for the presence of autocorrelation, I use the Durbin-Watson (D-W) statistic. The D-W statistic indicates that there is an autocorrelation problem for the Feder-Ram model but not for the augmented Solow model (D-W = 1.59 and 1.73, respectively). To correct the serial correlation of the error terms, I used generalized least squares (GLS) estimates of the parameters in the Feder-Ram model.

**Empirical Analysis**

The results of the empirical analyses are reported in Tables 2 and 3. Turning first to the comparison of the overall performance of both models, the results show that, despite the preference of the Feder-Ram model, within the Iranian experience the model failed to perform, with a R^2 of 0.34 and an F-test of 2.74. Contrary to the failure of the Feder-Ram model, the augmented Solow model performed exceptionally well at explaining Iranian economic growth, with an R^2 of 0.89 and an F-test of 965.53. While the performance of both models is consistent with the previous literature, in which the Feder-Ram model has been shown to explain about sixty-six percent of variation (see Mintz and Huang 1990) and the augmented Solow model about eighty percent (see Mankiw et al. 1992), performance of the models is tied not to the means of estimation, but rather to the theoretical foundation on which the models are based. As noted by Dunne, Smith and Willenbockel (2005), the Feder-Ram model lacks a strong
foundation. Thus, there is no theoretical reason as to why the model should work, which is clearly demonstrated here. Alternatively, much of the high explanatory ability of the augmented Solow model can be tied to the inclusion of capital investment and labor, both of which have historically shown a significant effect on economic growth.

Next, turning to the Feder-Ram model of the defense-growth relationship, the individual estimates reflect the failed performance of the overall model. Although this article had previously hypothesized a negative association between defense expenditures and economic growth, based on the Feder-Ram analysis, any change in the defense expenditures’ share of GDP and its externality effect have an insignificant impact. The results appear to reflect those of both Heo and Eger (2005) and Mintz and Haung (1990, 1991). Similarly, the results follow Carroll (2006), suggesting that an increase in the nondefense expenditures share of GDP and the subsequent externality effect also showed an insignificant effect on economic growth. Turning to the control variables, both capital investment and labor showed a negative, but insignificant, effect on economic growth.

[Table 2 about here]

Last, turning to the results of the augmented Solow model, we find a starkly different relationship. In addition to the model’s improved overall performance, the relationship between defense expenditures and economic growth is different than that of the Feder-Ram model. The results of the estimates reveal that an increase in defense expenditures has a significant and positive effect on economic growth in the short-term, and continues to do so in the following two years. Further explained, a one percent increase in the defense expenditures of the Islamic Republic of Iran is expected to lead to 0.05 percent increase of economic growth in the current year. In total, the increase of expenditures is expected to produce an increase of growth of 0.09
percent. Although this contradicts both the findings of the Feder-Ram model and the proposed hypothesis, it is consistent with Atesoglu (2002), Cuaresma and Reitschuler (2004), and Mueller and Atesoglu (1993). As to the other control variables, as expected, the previous year’s national income has a significant and positive effect on economic growth. Capital investment \((ln s)\) and labor [represented as \(ln(g+n+\delta)\)], however, have a significant and negative impact. Though a negative finding is contrary to traditional macroeconomic theory, recent work on the Iranian economy suggests that a negative relationship should be expected due to the governmental restrictions on the private sector (McDonald 2009).

[Table 3 about here]

**Analysis and Conclusion**

Dramatic increases in defense expenditures around the globe in recent years are likely to continue as United States involvement the Middle East and the war on terrorism continue. Although this trend, coupled with global economic instability, has renewed public interest in the defense-growth relationship, the relationship has been an issue of interest to both academics and politicians for some time. The importance of the implications behind the defense-growth relationship has even led many researchers to dedicate their careers to finding an answer. Such dedication, however, has proved futile as neither the direction of the relationship, nor the means of expressing the relationship have been agreed upon. While some progress has been made in recent years through comparison of defense-growth models (see Dunne et al. 2005; Heo 2010; Sandler and Hartley 1995), these comparisons have been limited in inferential ability due to their American focus. To assist in furthering the literature, this article has sought to investigate the relationship through the comparison of the two leading models: a Feder-Ram model and an
augmented Solow model. To complete the comparison, both models are estimated using data from the Islamic Republic of Iran from 1960 to 2007.

Although some research has compared the Feder-Ram and augmented Solow models, a core argument has been that, regardless of the approach used, the findings on the defense-growth relationship will remain consistent (Heo 2010). Within the Iranian economy, however, the empirical results of both models are clearly in disagreement. For the Feder-Ram model, defense expenditures showed a statistically insignificant effect on economic growth. Following defense expenditures, the Feder-Ram model shows itself incapable of explaining any economic growth, whether through nondefense expenditures, capital investment, or labor. Alternatively, within the estimates of the augmented Solow model, defense expenditures appear to improve economic growth.

One key distinction between the two approaches is the ability of the models to account for the economic performance of Iran. Based on the F-tests for the models, the augmented Solow model is more statistically significant than the Feder-Ram model (965.53 and 3.74, respectively). That is, the augmented Solow approach achieves a better fit to the Iranian experience by explaining a larger ratio of variance, as compared to the unexplained variance. A possible explanation is the likelihood of misspecification in the Feder-Ram model, which suffers from criticism on what sectors should be distinguished. The consequence of misspecification can be seen in previous work on the relationship with the Feder-Ram model, leaving researchers to consider only the direction of the relationship rather than the size (Heo 1998). Given the superior performance of the augmented Solow model, it is possible that these issues are diminished, once again allowing researchers to consider the effect size.
A second distinction is the ability of the approaches to account for the influence of defense expenditures over time. Past literature on the defense-growth relationship in the United States has argued for a delayed effect of up to five years (Heo and Eger 2005). Turning to the Iranian estimates in this article, standard information criteria show an effect from defense expenditures that can be felt up to two years later. Although some uses of the Feder-Ram model do involve lagged measures, the model itself is theoretically incapable of accounting for a delayed effect. It is unreasonable, however, to assume only an immediate effect, for which an augmented Solow model can easily account. This ability to account for a lingering effect clearly distinguishes the augmented Solow model as a time series approach.

Despite the reliance upon the Feder-Ram model and the growing popularity of the augmented Solow model, recent advances in macroeconomic theory have suggested more sophisticated ways of accounting for economic growth (Aghion and Howitt 1998). Though this article supports the augmented Solow model, work on the defense-growth relationship should continue to advance in looking for new and improved ways of accounting for the effects of the defense sector. This includes the comparison and adoption of newer models of economic growth, such as Atesolgu’s (2002) Keynesian-based model and Aizenman and Glick’s (2003) adaptation of Barro’s growth model. As noted by Mintz and Huang (1991) and Heo and Eger (2005), the real effects of defense expenditures on economic growth may come through indirect channels, such as employment, exportation, and investment (see also McDonald 2009). Further developments in the defense-growth relationship should strive to better address these indirect effects through multi-equation modeling techniques.
REFERENCES


Table 1. Statistical Summary of Variables, 1998 rials

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP*</td>
<td>214463.2</td>
<td>111066.9</td>
<td>43910.9</td>
<td>499071.1</td>
</tr>
<tr>
<td>Defense Expenditures*</td>
<td>10692.5</td>
<td>7248.5</td>
<td>1040.4</td>
<td>25948.6</td>
</tr>
<tr>
<td>Non-Defense Expenditures*</td>
<td>22402.8</td>
<td>11182.8</td>
<td>2876.8</td>
<td>41339.5</td>
</tr>
<tr>
<td>Investment*</td>
<td>17581.8</td>
<td>8743.8</td>
<td>2539.0</td>
<td>35546.4</td>
</tr>
<tr>
<td>Population**</td>
<td>44768</td>
<td>16069</td>
<td>21204</td>
<td>71532</td>
</tr>
</tbody>
</table>

*expressed in billions, **expressed in thousands
Table 2. Impact of Defense Expenditures on Economic Growth, Feder-Ram Model

<table>
<thead>
<tr>
<th>Dependent Variable:</th>
<th>Coefficient (Standard Error)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic Growth Rate, $\hat{Y}$</td>
<td>0.0943*** (0.0370)</td>
</tr>
<tr>
<td>Capital Investment, $\frac{I}{Y}$</td>
<td>-0.4819 (0.5383)</td>
</tr>
<tr>
<td>Labor, $\hat{L}$</td>
<td>-0.6440 (1.5681)</td>
</tr>
<tr>
<td>Defense Expenditures, $\frac{D}{Y}$</td>
<td>-0.3953 (1.1003)</td>
</tr>
<tr>
<td>Defense Sector Externality, $\hat{D}$</td>
<td>0.1109 (0.0896)</td>
</tr>
<tr>
<td>Nondefense Expenditures, $\frac{N}{Y}$</td>
<td>2.1297 (1.8635)</td>
</tr>
<tr>
<td>Nondefense Externality, $\hat{N}$</td>
<td>-0.0325 (0.2174)</td>
</tr>
</tbody>
</table>

R² = 0.34  
F-Test = 3.74  
Durbin-Watson = 1.84  

* p < 0.10, ** p < 0.05, *** p < 0.01
Table 3. Impact of Defense Expenditures on Economic Growth, Augmented Solow Model

<table>
<thead>
<tr>
<th>Dependent Variable:</th>
<th>Coefficient (Standard Error)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic Growth Rate, $\Delta \ln y_t$</td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>1.9513*** (0.5391)</td>
</tr>
<tr>
<td>GDP$<em>{t-1}$, $\ln y</em>{t-1}$</td>
<td>0.8297*** (0.0473)</td>
</tr>
<tr>
<td>Capital Investment, $\ln s_t$</td>
<td>-0.1789*** (0.0558)</td>
</tr>
<tr>
<td>Labor, $\ln (n+g+\delta)$</td>
<td>-0.1861* (0.1371)</td>
</tr>
<tr>
<td>Defense Expenditures, $\ln d_t$</td>
<td>0.0507*** (0.0323)</td>
</tr>
<tr>
<td>Defense Expenditures$<em>{t-1}$, $\ln d</em>{t-1}$</td>
<td>0.0282* (0.0471)</td>
</tr>
<tr>
<td>Defense Expenditures$<em>{t-2}$, $\ln d</em>{t-2}$</td>
<td>0.0137* (0.0399)</td>
</tr>
</tbody>
</table>

$R^2 = 0.89$
F-Test = 965.53
Durbin-Watson = 1.73

* p < 0.10, ** p < 0.05, *** p < 0.01
1 Although the Feder-Ram and augmented Solow models are the dominant frameworks, a number of other approaches have been used throughout the literature, including a Harold-Dumar growth model, Granger causal analysis, and Keynesian based demand-side models. Although each of these approaches has made a contribution to the understanding of the defense-growth relationship, they have been excluded from the comparison here due to their failure to obtain prominent status within the defense literature.

2 The theoretical linkage between defense expenditures and economic growth has been discussed at length in the literature, thus only a brief encounter is provided here. For a more detailed overview of the theoretical relationship between defense expenditures and economic growth, see Dunne (1996), Dunne et al. (2002), and Sandler and Hartley (1995).

3 The definition of defense expenditures utilized in this study is from the International Monetary Fund (IMF). Expenditures are characterized as

all expenditure, whether by defense or other departments, for the maintenance of military forces, including the purchase of military supplies and equipment (including the stockpiling of finished items but not the industrial raw materials required for their production), military construction, recruiting, training, equipping, moving, feeding, clothing and housing members of armed forces, and providing remuneration, medical care, and other services for them (quoted in Sen 1992:3).

4 There is some concern about the validity of data from the Central Bank of Iran. Data provided by the bank show a trend for defense expenditure that is similar to the trends seen in data from the Stockholm International Peace Research Institute and the World Bank. Central Bank data
are used in this study due to the duration of time for which data is made available. Readers should be aware of the validity concerns and the potential effect this may have on this study’s results.

5 The results of the Granger causal analysis are:

Defense spending growth $\rightarrow$ Economic growth, $Ch^2 = 0.4496$ (probability $> Ch^2 = 0.799$)

Economic growth $\rightarrow$ Defense spending growth, $Ch^2 = 2.1477$ (probability $> Ch^2 = 0.542$)

Investment $\rightarrow$ Non-military public expenditures, $Ch^2 = 4.2651$ (probability $> Ch^2 = 0.119$)

Non-military public expenditures $\rightarrow$ Investment, $Ch^2 = 1.1095$ (probability $> Ch^2 = 0.574$)

6 Dunne et al (2005) and Heo(2010) have also expressed concerns about the potential for multicollinearity. To address these concerns, a bivariate correlation was conducted. The results are:

<table>
<thead>
<tr>
<th></th>
<th>GDP</th>
<th>Defense</th>
<th>Non-Defense</th>
<th>Governmental</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Defense</td>
<td>0.6371</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Defense</td>
<td>0.7536</td>
<td>0.5898</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Governmental</td>
<td>0.7892</td>
<td>0.8376</td>
<td>0.9352</td>
<td>1</td>
</tr>
</tbody>
</table>

7 The root mean squared errors for the Feder-Ram and augmented Solow models are 0.0510 and 0.0508, respectively.