THE VALUE OF MILITARY INTELLIGENCE

by

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Abstract

This study integrates military intelligence into the optimal allocation of the government budget. Intelligence activities, defined as including the process of data collection and knowledge analysis for decision making by the military and governmental hierarchies, are perceived as serving three goals: (a) evaluation of the rival's capabilities and intentions; (b) enhancing the capability of the military by increasing the effectiveness of its weapon systems and reducing the effectiveness of the rival's weapon systems; (c) intelligence superiority yields an advantage over the rival, particularly with respect to deterrence and preemption. We develop and analyze static (deterministic, one-period) models in which two rival countries are engaged in an arms race. Current results show that the optimal expenditure on intelligence by each rival is likely, but not necessarily, a monotone increasing function of: (a) the government budget; (b) the efficiency of the intelligence apparatus; (c) the decision makers' degree of conservatism. We also analyze scenarios in which the two rivals participate in a knowledge race in addition to the usual arms race. In such cases, the country with the higher intelligence effectiveness (due to high-quality human capital, say) may force its rival to spend significant resources on intelligence, thus, gaining a substantial advantage in security and welfare. Finally, we present an application of the model to the Israeli-Syrian arms race.

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I. Introduction

The technology and information revolution, along with globalization, have placed *intelligence* as a major factor in achieving appropriate national security in the face of current military and terror threats. Clearly, high-quality knowledge of the capabilities and intentions of rivals is a major factor in achieving a balanced military, meaningful deterrence capabilities, and success in warfare situations.

From time immemorial, intelligence has been a key factor in security planning, as shown notably by the biblical story of the twelve spies and Sun Tzu's treatise *The Art of War*.[3] More recent history also demonstrates the significant and increasing role of military intelligence and the importance of finding the appropriate structure of the country's intelligence apparatus.[4]

The development and organization of intelligence agencies dates back to the end of the 19th century, when they began to emerge as governmental advisory units or as integral components of the military. Military intelligence became very effective during World War II and the Cold War era, and is currently being employed in various regional conflicts and the globalized war against terror. In today's global context, military intelligence has become so central to the building and maintaining of balanced national security, that it is essential to define and assess its planning and expenditures within the context of an integrated arms and knowledge race.

The rapid development of military intelligence has been followed by rapidly increasing expenditure on intelligence operations, innovation and equipment. Though information on intelligence expenditures is highly confidential, some publicly available data suggest that investment in intelligence is about 5%-12% of the defense

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[3] Two instances of Sun Tzu's insights on the importance of intelligence and knowledge should be studied by all civil servants: "A hundred ounces of silver spent for intelligence may save ten thousand ounces spent on war" (cited by Hughes-Wilson, 1999); "If you know the enemy and know yourself, you need not fear a thousand battles. If you know yourself and not the enemy, for every victory you will suffer a defeat. But if you know neither yourself nor the enemy, then you are a fool and will meet defeat in every battle."

[4] The decisive role of information is demonstrated in the following two examples. (1) During World War II, the Allies gained strategic and tactical advantages when they were able to decipher the "Enigma" code and when they used feints as part of the Normandy invasion in June 1944; (2) High-quality intelligence helped Israel gain a significant military advantage during the 1967 Six-Day War. The three-hour long air strike on its enemies' air force bases at the beginning of the war was made possible, among other factors, by precise intelligence and out-of-the-box thinking.

budget in developed countries. The USA, for example, spent at least $75 billion directly on its intelligence community in the 2009 fiscal year (US, DNI, 2009). Moreover, much of the investment in *integrative technologies* is related to R&D for future intelligence systems. Setter and Tishler (2007) report that about 20% of the US defense R&D expenditures during 1996-2005 were dedicated to integrative technologies, and showed an increasing trend over this period. Thus, we conclude that the USA invests about 15% of its national defense budget in intelligence ($110 billion in the 2009 fiscal year).

The focus of this study is to determine the optimal value of military intelligence achieved by the process of allocating the government budget into civilian and military expenditures, assuming that governments endeavor to maximize national welfare. Defining intelligence as the process of data collection and knowledge analysis for decision making by the government and military hierarchies, we perceive it as serving three main goals: (1) to evaluate the rival's capabilities and intentions (denoted as the *evaluation effect*); (2) to increase the effectiveness of the country's own weapon systems and reduce the effectiveness of the rival's weapon systems (denoted as the *operational effect*); (3) intelligence superiority yields an advantage over the rival, particularly with respect to deterrence and preemption (denoted as the *relative effect*).

The paper is organized as follows. Section II provides an overview of the relevant literature. Intelligence characteristics are discussed in Section III. Our main model is developed in Section IV and the properties of special cases of the main model are described in Section V. Section VI characterizes the main model and Section VII presents an application of the model to the Israeli-Syrian arms race. Section VIII summarizes.

II. Literature Review

The main objective of this study is to evaluate and analyze the value of intelligence within a decision model of national social welfare maximization. The analysis is based on the defense economics literature, applied security studies and the literature on the value of information.

Much has been written on military intelligence from the defense, historical and political science points of view. The term *value of information* has been defined and assessed in many areas of scholarship, including engineering, mathematics and game theory; economics; information systems; strategy and marketing; information sciences; and military operations research.[5] However, academic work on the integration of military intelligence and defense economics is scarce.

There is a vast academic and popular literature on intelligence agencies, their characteristics, history, organizational structure, and main failures, as well as on national strategy, law, ethics, etc. Most definitions of military intelligence share three components: processed information, time relevancy and policy-making decisions. Scholars agree that military intelligence aims at ensuring national security during peace and war times and should be based on governmental (or military) agencies.[6]

The organizational structure of the intelligence community is commonly discussed in terms of efficiency, public policy, government agenda, bureaucratic processes and law (see, for example, Posner, 2006, Petrov, 2007, Gilboa and Lapid, 2008). Among the major issues of concern are: centralization vs. decentralization of intelligence agencies; advantages and disadvantages of inter- and outer-military intelligence efforts, and the level of redundancy among the various security agencies.[7]

The US intelligence community is believed to be the world's largest, with an annual budget of $75 billion (FY2009), with about 200,000 employees in 16 different agencies (USA, DNI, 2009). Figure 1 presents the share of the expenditure on intelligence in the total defense budget in Israel, Syria, the USA[8] and the UK[9]. Figure

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5 See, for example, the mathematical analysis by Blackwell (1951), the assessment of the value of information by Ahituv (1989), the analysis of the value of information within an economic model by Shapiro and Varian (1999), the game theoretic approach by Solan and Yariv (2004), and the review of the literature by Repo (1989).

6 A comprehensive bibliography of the intelligence literature can be found in Clark (2007).

7 We do not focus here on the optimal organizational structure of the intelligence community. Rather, we consider all the intelligence agencies as one entity,

8 Some of the official US military intelligence expenditures data are in US, DCI (1997, 1998) and US, DNI, (2007, 2008). Additional data are available or based on data from the final report of the 9/11 Commission and some unofficial estimates (see Global Security, 2009).

9 The UK data include only the direct expenses in its intelligence agency, MI5 (UK, MI5, 2009). The shares of the other countries are estimates of both direct and indirect investments in intelligence.

1 suggests that this share is about 10%-15% and, generally, increasing in the last few years.

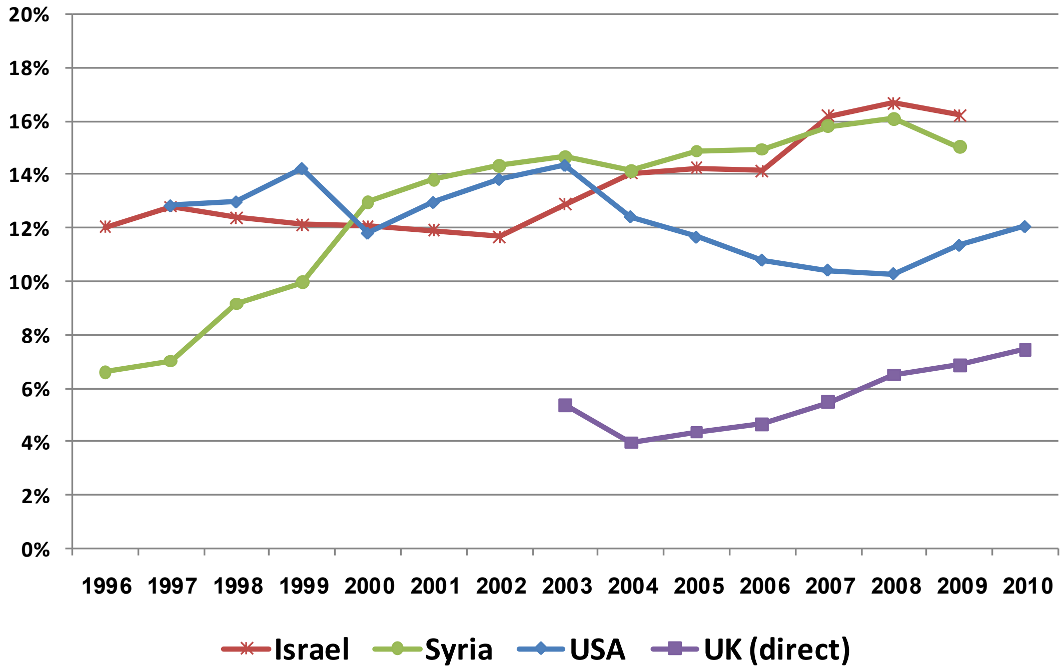

Figure 1: The share of intelligence in the defense budget in the USA, UK, Israel and Syria: 1996-2010
(Source of defense budgets: SIPRI, 2010)

The structure and logic of economic models of security derive from the experience that was acquired during World War II and the Cold War. Lanchester (1956) was the first to model an armed conflict between two rivals, based on a set of equations evaluating the security level of each side versus the other. Hitch and McKean (1963) present an economic model with qualitative and quantitative characteristics of security. Their focus is on efficient budget allocation and strategic deterrence between the two superpowers during the Cold War. A similar rationale led Intriligator (1975) to model security as a function of a nation's ability to use nuclear power, defeat the enemy and save (at least some of) its own assets. Darilek et al. (2001) extend Lanchester's model by incorporating command and control systems which provide better information about the position of enemy forces in the policy maker's objective function. Recent studies on the implications of arms races include, for example, Kagan, Tishler and Weiss (2005), Collier (2006) and Dunne and Smith (2007).

This study integrates intelligence into the arms race framework. We define a nation's security level as a function of the ratio of its own and its rival's military capabilities. Following the approach of Rogerson (1990), Hirao (1994) and Setter and Tishler (2007) we let military capability depend on the quantity and quality of weapon systems and intelligence. Clearly, intelligence is based on quality human capital, R&D and innovation. Recent trends in defense R&D expenditures are analyzed by Hartley (2006), and the effect of R&D on anti-terrorist government policy is discussed by Trajtenberg (2006). The studies of Setter and Tishler (2006, 2007) focus on integrative technologies and their implications for future planning; The influence of defense R&D on the quality of military equipment is assessed by Middleton et al. (2006), and Kirkpatrick (2004) discusses the consequences of the costs of sophisticated high-performance weapon systems.

Studies that assess the intelligence factor within economic models are scarce. In their most general arms race model Brito and Intriligator (1995) assume that countries use their stock of information to predict their rival's future investment in weapon systems. However, Brito and Intriligator (1995) used this process only to update each country's information in the next period, concluding that their model formulation "is too general for specific analysis".

Generally, the contribution of intelligence to military capability is analyzed in the context of the value of information and game theoretic frameworks (see Solan and Yariv, 2004 and Hendricks and McAfee, 2006 for the analysis of feints and espionage). Bracken and Darilek (1998) discuss tactical information superiority in the battlefield. Biran and Tauman (2008) analyze the impact of intelligence in a strategic environment in which one country seeks to develop strategic (nuclear) capabilities, while the objective of its opponent is to frustrate this intention by using information based on operating an intelligence system with a certain level of precision. Their results show that when the intelligence precision level is commonly known: (a) both countries benefit from a higher level of intelligence precision; (b) both rivals are better off with intelligence than without it, irrespective of its level of precision. Finally, direct linkages between economic analysis and military intelligence processes are assessed by Ho (2007, 2008), who discusses the impact of spying and double crossing using contract theory.

III. Intelligence Characteristics

The main characteristics of military intelligence are as follows:

- Intelligence itself has no direct effect on military capability. To be effective, military intelligence has to be integrated with weapon systems and personnel to create military capability.
- Intelligence consists of collecting and assessing knowledge which is relevant to all levels of the military and the government hierarchies – state leaders, policy makers, top military personnel and soldiers on the battlefield. Intelligence may be used for both tactical and strategic decision making.
- Gaining information superiority is based on high-quality *human capital* and *technology*. Human capital characteristics such as entrepreneurship, innovation and out-of-the-box thinking are the key factors to the success and effectiveness of the intelligence community. Moreover, most of the relevant intelligence cannot be bought. Rather, it has to be home made since it relates to the country's particular rivals and needs. Thus, each country has to invest its own resources to access the knowledge necessary for effective military operations and deterrence. That is, each country has to produce its own military R&D and internal sources and capabilities for collecting, analyzing and distributing the necessary data to the relevant agents at the relevant time.
- The intelligence mission is hampered by an inherent uncertainty, which may be reduced by good procedures and high-quality human capital, but cannot be eliminated.
- Intelligence gathered by the rival may have a significant negative influence on the country's military capability. Good intelligence gathering by the rival can reduce the relevance of the country's own intelligence as well as the potency of its weapon systems and, thus, its overall military capability. Strategically, a higher relative level of intelligence is likely to lead to military superiority and better deterrence.

The main benefits of military intelligence can be classified under three main headings: the evaluation effect, the operational effect, and the relative effect. First, a policy maker plans her national budget and military capability based on her evaluation of the capabilities and intentions of the rival, allowing for some confidence level margins (because of the possibly very high cost of making mistakes). More and better intelligence reduces the level of uncertainty in assessing the tactical and strategic capabilities and intentions of the rival. More accurate knowledge of the rival's capability and intentions is likely to lead to a more efficient process of planning and building the country's own capability and, thus, bring about a higher security level.[10]

Clearly, each country has some knowledge on its rival's military capabilities. Since this knowledge is limited and, normally, contains large uncertainties, the country's decision maker has to be prepared for several, possibly many, military configurations and potential war scenarios which the rival may be planning. Consequently, the value of the intelligence to the policy maker depends on two attributes: (a) the degree of uncertainty with which the decision maker is willing to live (the decision maker's *conservatism*), and (b) the efficiency of the intelligence process (denoted *intelligence efficiency*). These two attributes affect the country's perception of the level of the rival's military capability. We refer to this as the **evaluation effect**.

Second, the knowledge collected and analyzed enhances the capability of the country's military by increasing the effectiveness of its weapon systems and reducing the effectiveness of the rival's weapon systems. For example, executing an air strike is much more efficient when accurate and updated intelligence on the enemy targets is available. Technical intelligence on the rival's weapon systems may lead to the development of systems which will be able to reduce the rival's weapon systems' effectiveness in combat situations. Finally, more knowledge on the rival's intentions and capabilities can lead to the development of weapon systems and procedures that can surprise the rival in combat activities and, thus, achieve a significant advantage in the battlefield. We refer to this as an **operational effect**.

Third, having intelligence superiority over the rival has its own direct advantage. The country's investment in intelligence relative to its rival may be an important factor in defining the rival's beliefs on the scope of deterrence and preemption. For example,

[10] A similar interpretation is based on a scenario analysis. Government and military decision makers work with a set of assumptions on future (short-, mid- or long-term) potential war scenarios. It is a reasonable assumption that higher expenditure on intelligence narrows the set of potential future scenarios and, therefore, reduces the need for excessive expenditure on weapon systems, infrastructure and personnel.

the willingness of each country's leader to enter into a conflict or a full-scale war is, generally, based on her assumptions about the country's capabilities relative to those of its rival. These assumptions depend, to a large extent, on the country's advantage in intelligence over its rival. We refer to this as the **relative effect**.

IV. Model Setup

This section presents an integrated model accounting for the three intelligence effects discussed in the previous section. To better understand the model, we analyze in Section V two special cases of the integrated model. The properties of the integrated model are assessed in Section VI. Formally, we consider a one-period arms race between two rivals (denoted *x* and *y*). The decision maker in country *x* allocates an exogenously given budget (B_x) to civilian government consumption (C_x), a quantity of weapon systems (*x*), intelligence (k_x) and, possibly, R&D to improve the integration between weapon systems and intelligence (q_x), in order to maximize her country's utility (welfare) function $U_x = C_x^{w_x} S_x^{1-w_x}$. S_x denotes the security level of country *x*. The known constant parameters w_x and $(1-w_x)$ are the civilian consumption and security elasticities, respectively. The notation for country *y* is similar. The security level of each country is defined to be the *ratio* between its own military capability and its perception of the military capability of its rival. Formally, Problem 1, the decision problem of country *x*, is as follows:

$$\underset{C_x, x_1, q_x, k_x}{Max}\ U_x = C_x^{w_x}\left(\frac{x^{\alpha}\left(q_x\left(1+\frac{k_x}{k_y}\right)\right)^{\beta}}{y^{\gamma}\left(q_y\left(1+\frac{k_y}{k_x}\right)\right)^{\delta}\left[1+\lambda_x\frac{\sigma_x}{\sigma_x+k_x}\right]}\right)^{1-w_x} \qquad (1)$$

$s.t.:$

$$z_x C_x + p_x x + r_x q_x + h_x k_x \le B_x \qquad (1.1)$$

$$C_x, x, q_x \ge 0 \qquad (1.2)$$

$$k_x > 0 \qquad (1.3)$$

$$z_x, p_x, r_x, h_x > 0 \qquad (1.4)$$

$$0 \le w_z \le 1 \qquad (1.5)$$

$$\alpha, \beta, \gamma, \delta, \lambda_x, \sigma_x \ge 0 \qquad (1.6)$$

where z_x, p_x, r_x and h_x denote the unit prices of civilian consumption, weapon systems, R&D and intelligence, respectively. α, β and γ are constant parameters. λ_x is a constant parameter measuring the decision maker's degree of conservatism regarding her perception of the military capability of the rival. The constant parameter σ_x is the efficiency level of country x's intelligence process (efficiency is higher when σ_x is smaller).[11] The higher the policy maker's conservatism (or her required confidence margin level) the larger is λ_X, which, in turn, implies a higher level of expenditure on intelligence (or other defense assets) for country x to reach a given security level. Similarly, a higher level of σ_X can be interpreted as a lower level of the country's intelligence efficiency since it requires a lower value of intelligence to reach a given level security.

Inequality (1.1) represents the linear budget constraint, constraints (1.2)-(1.3) ensure that all decision variables obtain non-negative values, constraint (1.4) ensures that unit prices are positive and (1.5)-(1.6) state the required conditions on the model parameters. Note that Problem 1 specifies, similarly to Darilek et al. (2001), that military capability is affected by the *relative* investment in intelligence by the two rivals (e.g., k_x/k_y).

V. The Properties of Two Special Cases of the Integrated Model

The Evaluation Effect

Focusing on the intelligence evaluation effect, we assume that all non-intelligence defense assets of country x (weapon systems, personnel, training) are aggregated into one variable, X, which we call, for simplicity, weapon systems. The real investment in intelligence, k_x, is dedicated only to evaluating the rival's military capability. The notation for country y is similar. Therefore, this formulation is focused on the trade-off between direct investments in military capabilities and the intelligence evaluation effort. Thus, Problem 2, the decision problem of country x under the *evaluation effect*, is:

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[11] The formulation of the rival's perceived military capability is similar to that of Johnson (2000).

$$\underset{C_x, X, k_x}{Max} \quad U_x = C_x^{w_x} \left(\frac{X}{Y\left(1+\lambda_x \dfrac{\sigma_x}{\sigma_x + k_x}\right)} \right)^{1-w_x} \tag{2}$$

$s.t.$:

$$C_x \cdot z_x + X \cdot p_x + k_x \cdot h_x \leq B_x \tag{2.1}$$

$$C_x, X, k_x \geq 0 \tag{2.2}$$

$$z_x, p_x, h_x > 0 \tag{2.3}$$

$$0 \leq w_x \leq 1 \tag{2.4}$$

$$\lambda_x, \sigma_x \geq 0 \tag{2.5}$$

The evaluation effect, $g(k_X) = 1 + \lambda_X \dfrac{\sigma_X}{\sigma_X + k_X}$ depends on σ_x and λ_X, the measures of the country's intelligence efficiency and the degree of conservatism of its decision maker, respectively. The solution of the country *x* decision problem and its characterization are given in **Propositions 1** and **2** below.

Proposition 1: The analytical solution of the evaluation effect model

a) The optimal intelligence expenditure of country *x* is given by:

$$k_x^* = \max\left(\frac{1}{2}\left(\sqrt{\lambda_x \sigma_{xy}\left((2-w_x)^2 \lambda_x \sigma_{xy} + 4(1-w_x)\left(\sigma_{xy} + \frac{B_x}{h_x} \right) \right)} - \left(\sigma_x \left((2-w_x)\lambda_x + 2 \right) \right) \right), 0 \right)$$

This expression includes the internal or corner solution (in which $k_x = 0$). Obtaining the optimal solution for civilian and weapon systems expenditures is straightforward.

b) The sufficient and necessary condition for positive expenditure on intelligence is:

$$k_x^* > 0 \ iff: \frac{(1-w_x)}{\sigma_x} \cdot \left(\frac{\lambda_x}{1+\lambda_x} \right) \frac{B_x}{h_x} > 1.$$

The inequality in part (b) of Proposition 1 implies that when the weight given by the government to security level is large (*w* is small) or the intelligence efficiency is high or the policy maker is highly conservative or the cost of intelligence is relatively small, it is more likely that country *x* will invest a positive amount in intelligence.

Proposition 2: Characteristics of the evaluation effect model

a) The investment in intelligence is an increasing function of the level of conservatism of the decision maker. That is,

$$sign\left[\frac{\partial k_x}{\partial \lambda_x}\right] = sign\left[\sigma_x{}^2 + \left(\frac{(1-w)}{(2-w)}\left(\sigma_x + \frac{B_x}{h_x}\right)\right)^2\right] > 0$$

b) The investment in intelligence first increases and then decreases as a function of the efficiency of the intelligence process. That is,

$$sign\left[\frac{\partial k_x}{\partial \sigma_x}\right] = sign\left[\underbrace{\left\{\left(4(1+\lambda_x) - ((2-w)\lambda_x + 2)^2\right)(1+\lambda_x)\right\}}_{=-(2-w)^2\lambda_x{}^2 - 4(1-w)\lambda_x \le 0}\sigma_x{}^2 - \underbrace{\left\{4\lambda_x(1+\lambda_x)(1-w)\frac{B_x}{h_x}\right\}}_{\le 0}\sigma_x + \underbrace{\left((1-w)\frac{B_x}{h_x}\lambda_x\right)^2}_{\ge 0}\right]$$

c) The investment in intelligence is a decreasing function of the decision maker's preference for civilian consumption, w_x. That is,

$$sign\left[\frac{\partial k_x}{\partial w_x}\right] = sign\left[-(\lambda_x\sigma_x)^2\sigma_x{}^2(1+\lambda_x) - (\lambda_x\sigma_x)^3 - 2\lambda_x{}^2\sigma_x{}^3\frac{B_x}{h_x} - \left(\frac{B_x}{h_x}\lambda_x\sigma_x\right)^2\right] < 0$$

Finally, it is straightforward to show that the optimal solution of country *x* (*y*) is not affected by the optimal decision variables of country *y* (*x*). That is, Problem 2 does not yield an arms race.

Problem 2 can be modified in several ways to yield an arms race. For example, letting $\sigma_x = f(Y) = a_o + a_1 Y$, where a_o and a_1 are known (non-negative) constants yields an arms race. This formulation implies that efficient intelligence is positively dependent on the rival's military capability. The analytical solution of a general simultaneous game is complicated (a fourth-order polynomial in k_x). However, the optimal solution can be obtained analytically for a symmetric game in which the exogenous parameters of country *x* and country *y* are identical.

The Operational Effect

This model is focused on the intelligence operational (quality) and relative effects. That is, we assume that $\lambda_x = 0$. Thus, the country *x* decision problem under the operational effect is defined in Problem 3:

$$\underset{C_x,x_1,q_x,k_x}{Max}\ U_x = C_x^{\ w_x}\left(\frac{x^{\alpha}\left(q_x\left(1+\frac{k_x}{k_y}\right)\right)^{\beta}}{y^{\gamma}\left(q_y\left(1+\frac{k_y}{k_x}\right)\right)^{\delta}}\right)^{1-w_x} \qquad (3)$$

$s.t.$:

$$z_x C_x + p_x x + r_x q_x + h_x k_x \le B_x \qquad (3.1)$$

$$C_x, x, q_x \ge 0 \qquad (3.2)$$

$$k_x > 0 \qquad (3.3)$$

$$z_x, p_x, r_x, h_x > 0 \qquad (3.4)$$

$$0 \le w_x \le 1 \qquad (3.5)$$

$$\alpha, \beta, \gamma, \delta \ge 0 \qquad (3.6)$$

The solution of a general (non-symmetric) arms race between country *x* and country *y* is given by Proposition 3 below.

Proposition 3: Solution of the operational effect

a) There is a unique equilibrium solution to Problem 3.
b) The ratio of the two rivals' optimal intelligence is given by:

$$\frac{k_x^{\ *}}{k_y^{\ *}} = \frac{\theta_x \frac{B_x}{h_x}}{\theta_y \frac{B_y}{h_y}} \qquad (4.1)$$

Hence, when $\theta_x = \theta_y$, the ratio between the rivals' investments in intelligence depends only on the unit prices of intelligence and the government budgets. Specifically:

$$\theta_x = \theta_y \Rightarrow \frac{k_x^{\ *}}{k_y^{\ *}} = \frac{B_x}{B_y} \cdot \frac{h_y}{h_x} \qquad (4.2)$$

VI. The Solution of the Integrated Model

There is no analytical solution to Problem 1. However, the reaction function of country *x* and some of its characteristics are given in Proposition 4 below.

Proposition 4: Characteristics of the model solution

a) The reaction function of Problem 1 (presented for country *y*) is given by:

$$k_y = -\frac{\left[\begin{array}{l}(1+\theta_x\beta)k_x^{\,3} + \left(\sigma_x(2+\lambda_x)(1+\theta_x\beta) - \theta_x\left(\frac{B_x}{h_x}\beta - \lambda_x\sigma_x\right)\right)k_x^{\,2} \\ + \left(\sigma_x^{\,2}(1+\lambda_x)(1+\theta_x\beta) - \theta_x\frac{B_x}{h_x}\beta\sigma_x(2+\lambda_x) - \theta_x\lambda_x\sigma_x\frac{B_x}{h_x}\right)k_x - \left(\theta_x\frac{B_x}{h_x}\beta\sigma_x^{\,2}(1+\lambda_x)\right)\end{array}\right]}{\left[\begin{array}{l}(1+\theta_x\delta)k_x^{\,3} + \left(\sigma_x(2+\lambda_x)(1+\theta_x\delta) + \theta_x\lambda_x\sigma_x - \theta_x\frac{B_x}{h_x}\delta\right)k_x^{\,2} \\ + \left((1+\theta_x\delta)\sigma_x^{\,2}(1+\lambda_x) - \theta_x\frac{B_x}{h_x}\sigma_x(\lambda_x + \delta(2+\lambda_x))\right)k_x - \left(\theta_x\frac{B_x}{h_x}\delta\sigma_x^{\,2}(1+\lambda_x)\right)\end{array}\right]} k_x \quad (5.1)$$

where $\theta_x \equiv \frac{1}{\left(\frac{w_x}{1-w_x} + \alpha + \beta\right)}$

b) The optimal solution is obtained for a relatively small interval (denoted the optimal solution interval) which can be characterized as follows:
   i) The optimal solution interval is an increasing function of the absolute difference in the rivals' effectiveness of intelligence $(|\beta - \delta|)$.
   ii) The optimal solution interval is an increasing function of each rival's ratio of the government budget and the unit price of intelligence $\left(\frac{B_x}{h_x}, \frac{B_y}{h_y}\right)$.
   iii) The optimal solution interval is a decreasing function of the decision makers' degrees of conservatism (λ_x, λ_y).

In the rest of this section we present numerical examples that characterize the properties of the integrated model (given by Problem 1) in an arms race between two rivals. For simplicity, we assume that the parameters that represent country *x* are identical to those of country *y*, except that $\beta \neq \delta$. That is, $w_x = w_y = 0.6,\ \alpha = \gamma = \delta = 0.5,\ \beta = 0.6$. The values of the exogenous variables are: $B_x = B_y = 50$; $z_x = p_x = r_x = h_x = z_y = p_y = r_y = h_y = 1$.

In Figures 2-5 we show how the optimal solution changes in response to a change in only one of the exogenous variables or parameters of country *x* (shown on the x-axis of each figure).

a) Investment in intelligence is an increasing function of the country *x* budget. Clearly, the investment in intelligence (and civilian consumption) of country *x* increases when *x*'s government budget increases. In response, country *y* slowly increases its investment in intelligence. As expected, country *x* (*y*) welfare increases (decreases) in response to the increase in the budget of *x*.

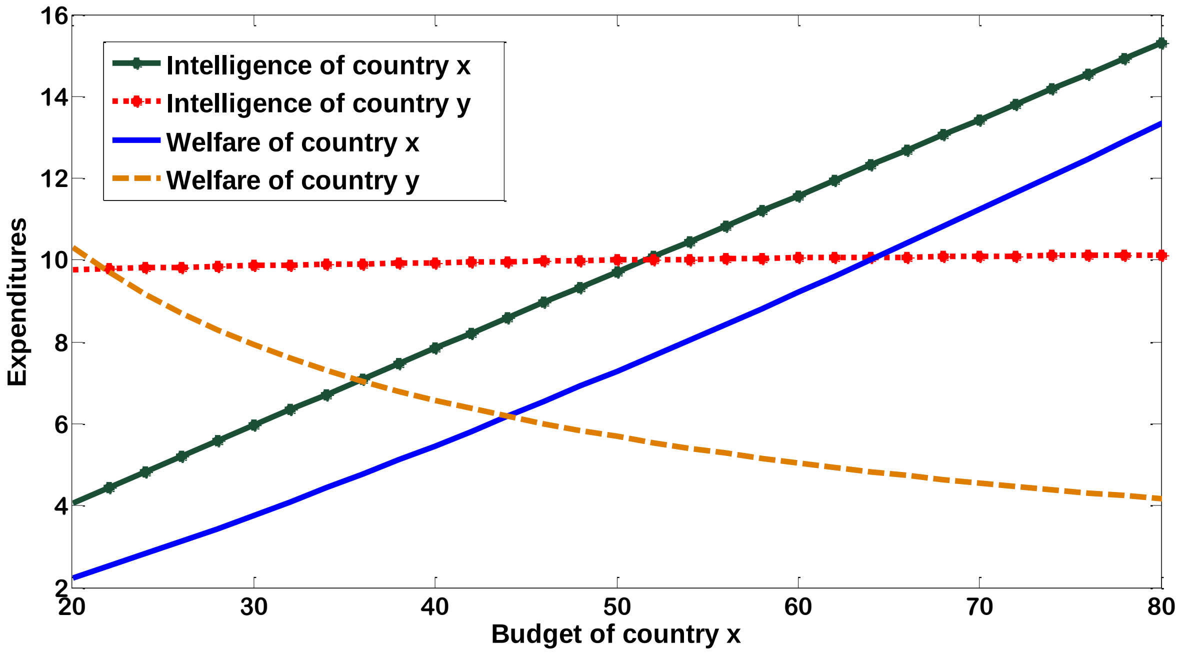

Figure 2: Integrated model: Equilibrium expenditures and welfare as a function of country *x* government budget

b) The investment in intelligence by country *x* increases in response to an increase in its intelligence quality and effectiveness. Consequently, country *y* increases its own investment in intelligence. Note that the response of *y* is larger than the increase in investment in intelligence by country *x* that prompted the response of country y since country *y*'s intelligence effectiveness is smaller than that of country *x*. Consequently, the welfare of *x* increases and the welfare of *y* declines. It is straightforward to show that country *x*'s civilian expenditure increases and its quantity of weapon systems decreases in this case.

Sub-sections (a) and (b) above present examples of scenarios in which the two rivals participate in a knowledge race in addition to the usual arms race. In such cases, the country with the higher intelligence effectiveness (e.g., $\beta > \delta$) may force its rival to spend significant additional resources on intelligence. Thus, the country with the higher intelligence effectiveness gains a substantial advantage in security and welfare. Figure 4 presents the optimal investment in intelligence by both rivals in response to an increase in country *x*'s intelligence efficiency, σ_x. Following the analytical result in Section IV we find that the optimal investment in *x*'s intelligence increases until the advantage of the intelligence efficiency of *x* over *y* is sufficiently large, at which point country *x* starts to reduce its investment in intelligence. Country *y*'s investment in intelligence is (very) slowly increasing as the intelligence efficiency of *x* increases.

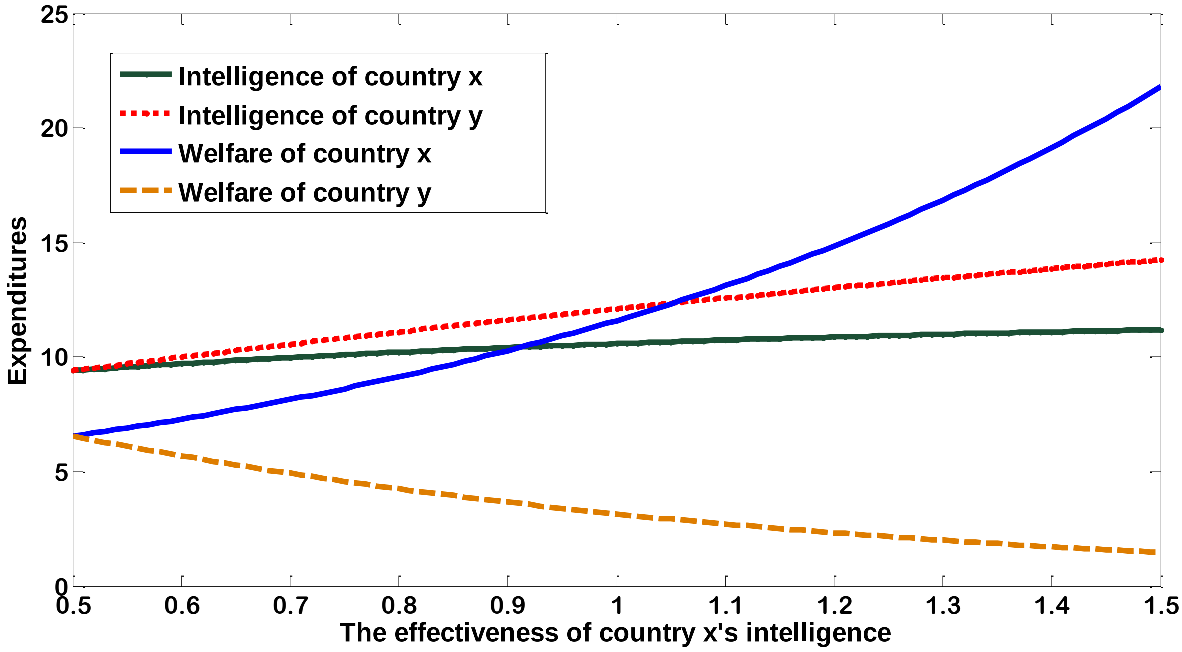

Figure 3: Integrated model: Equilibrium expenditures and welfare
as a function of the quality and effectiveness of country *x*'s intelligence, β

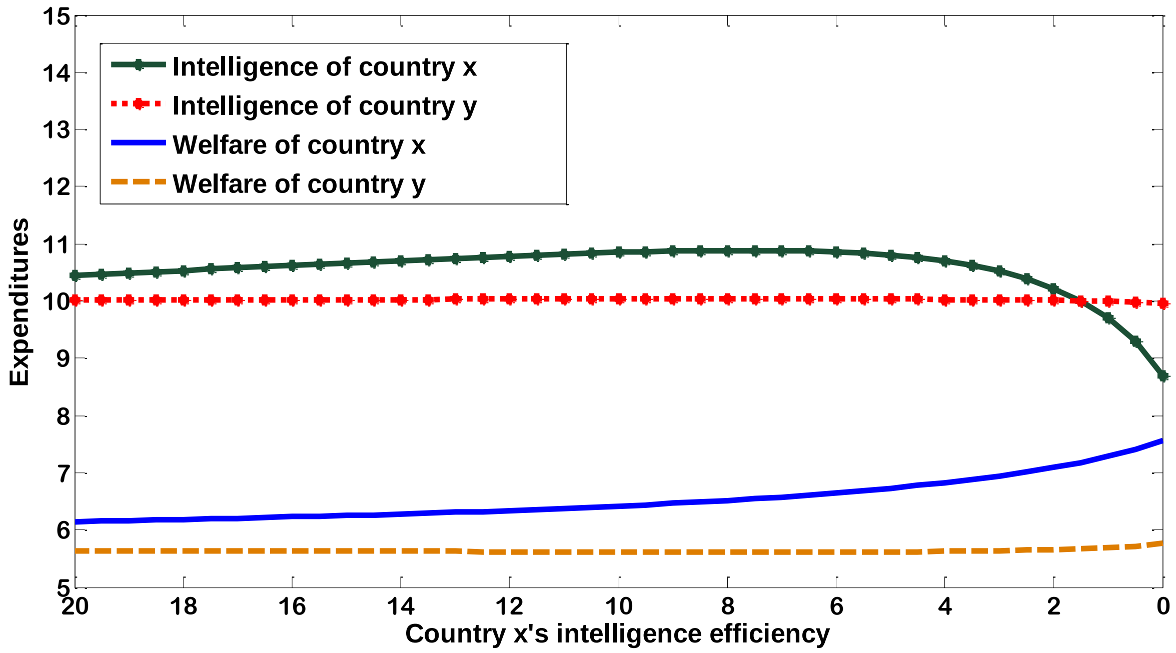

Figure 4: Integrated model: Equilibrium expenditures as a function
of the efficiency of country *x*'s intelligence process, σ_x

c) Figure 5 exhibits the effect of an increase in the level of conservatism of country *x*'s decision makers. The investment in intelligence by both rivals is an *increasing* function of the degree of conservatism of *x*. Clearly, this increase is much more pronounced in country *x* (country *y* responds to country *x*'s increase in the degree of conservatism). Clearly, both countries reduce their civilian consumption in this case, which yields a reduction in their welfare, as long as war does not break out.

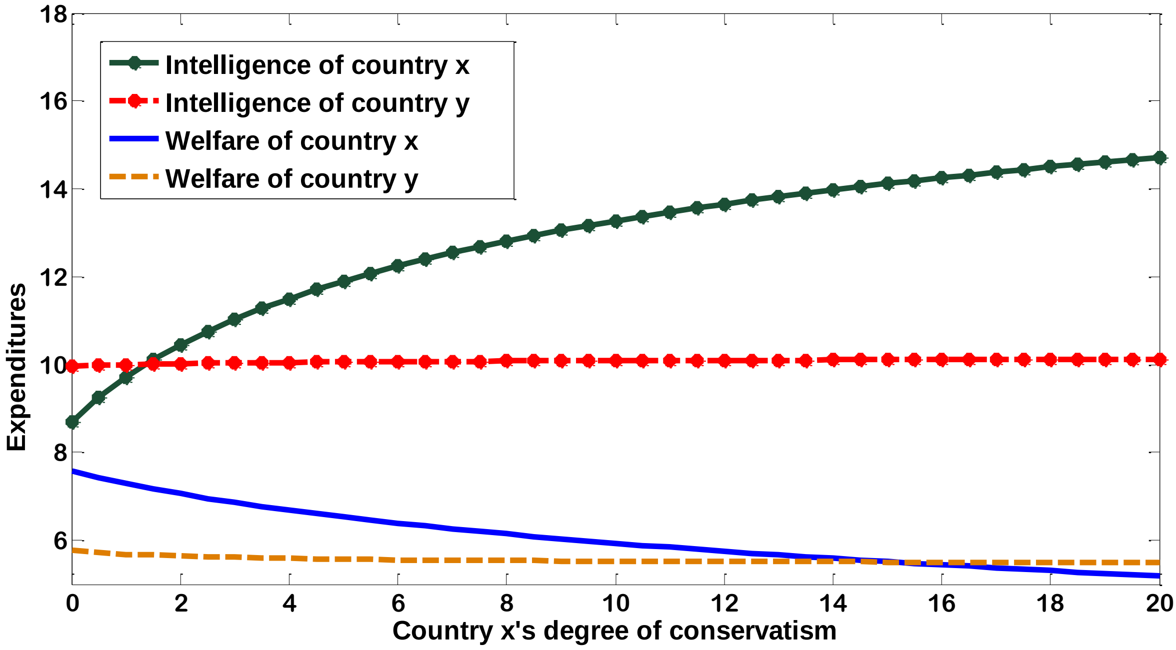

Figure 5: Integrated model: Equilibrium expenditures and welfare as a function of country *x*'s degree of conservatism, λ_x

To sum up, the main characteristics of the optimal solution of the integrated model, including both the evaluation effect and the operational effect are as follows:

- The investment in intelligence is much less beneficial for small values of the government budget, low intelligence efficiency and low degree of conservatism. This result is due to the fact that intelligence alone is not valuable; rather, intelligence becomes valuable when it is combined with other factors of military capability (weapon systems, for example). The expenditure on intelligence is a concave function of the level of intelligence efficiency: it increases when intelligence efficiency effectiveness is small and rising, and decreases when intelligence efficiency effectiveness is sufficiently large.

- The expenditure on intelligence is an increasing function of the decision maker's degree of conservatism (or her required confidence margin level). The national welfare of both rivals during peace time is lower the higher is the decision makers' degree of conservatism. Clearly, to assess the long-term effect of the degree of conservatism on welfare one needs to account for the expected damage of a possible war between the rivals.
- The rivals' levels of intelligence effectiveness have a strong effect on the model solution. Intuitively, these parameters express the in-house quality of the country's human capital and R&D. Thus, it seems that a higher quality of human capital and, hence, higher quality defense R&D, are likely to substantially improve the country's security and increase its civilian consumption and utility level.
- It is straightforward to show that the two rivals participate in a knowledge race in addition to the usual arms race, in which they compete on weapon systems quantity and quality. In such scenarios, the country with the higher intelligence effectiveness may force its rival to spend significant (though less effective) resources on intelligence. Thus, the country with the higher intelligence effectiveness gains a substantial advantage in security and welfare.

VII. Application to the Israeli-Syrian Arms Race

Data

a) The annual government budget and military expenditures were obtained from official Israeli and Syrian sources (Israel Budget, 2011, Syria CBS, 2011; Military expenditure is the sum of "defense" or "national security" expenditure and "other expenditures" in both countries). Civilian consumption is evaluated as the difference between the government budget and military expenditure.

b) We assume that a significant share of the annual "extra expenditure" item in the Israeli government budget is dedicated to intelligence efforts. This decision follows Wolfson (2009) who claims that 60%-90% of this item, which amounts to $1-1.25 billion, includes the budget of the secret services. During the last several years we observe a significant increase in Syria's "other expenditures" (see Syria CBS, 2011). Thus, we assume that the "extra security expenditure" item comprises 20% to 40% of Syria's annual intelligence budget.

c) The share of the Israeli intelligence in the defense budget was approximately 7% in 2003 (Nevo and Shur-Shmueli, 2004). We assume that the Israeli expenditure on intelligence during 1996-2002 follows the trend of the German intelligence agencies (specifically, the BND), which is reported to be divided as follows: “personnel costs account for almost 70 percent of the BND budget, with investment accounting for another 10 percent” (Intelligence Agencies, 2000). There are clear indications that the Israeli expenditure on intelligence increased significantly after 2003 (see Melman, 2008). A similar trend is observed in the USA (Karim, 2009). Consequently, we assume that the share of the Israeli intelligence expenditure in the defense budget was 6%, 7% and 9% during 1996-2000, 2001-2004, and 2005-2009, respectively.

No official data on Syrian expenditure on intelligence are available. Thus, we use a similar set of assumptions for Syria and conclude that intelligence expenditures in Syria accounted for 4%, 5% and 7% of the Syrian defense budget during 1996-1999, 2000-2006, and 2007-2009, respectively (see also Karakaş, 2010).[12] Figure 6 shows the share of intelligence expenditure in the defense budget that we used for calibration.

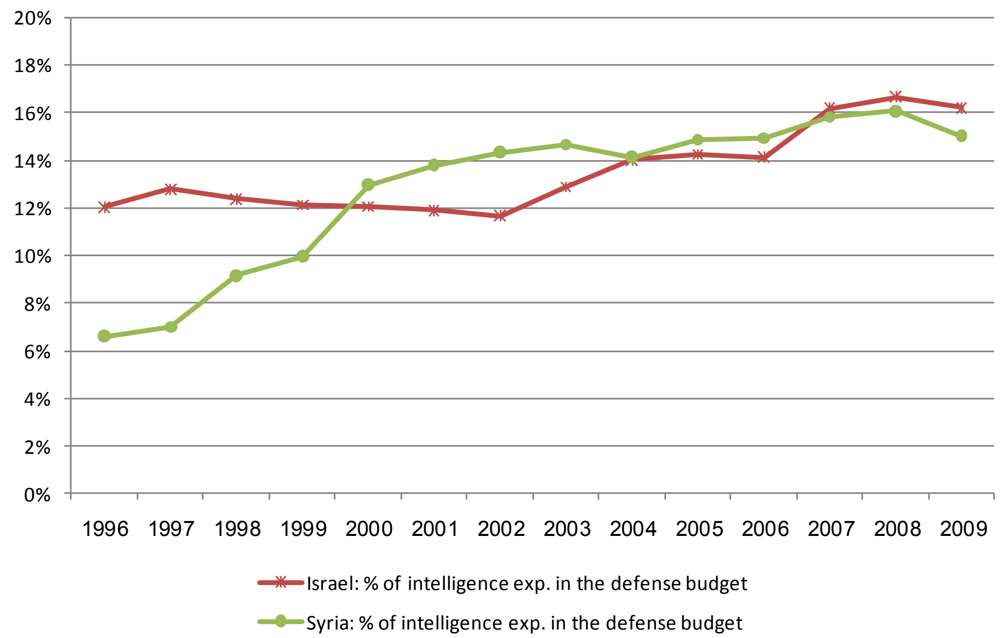

Figure 6: The share of intelligence expenditures in the defense budget in Israel and Syria during 1996-2009

[12] Our assumptions about the shares of intelligence expenditures in Syria’s defense expenditures are for different intervals (sets of years) than for Israel. In the case of Syria, significant changes in the item “other expenditures” took place in the government budget during the three sets of years.

d) The unit price indices in our data were obtained from the data on consumer price indices and average wages in Israel and Syria during 1996-2009 (Israel CBS, 2011; Syria CBS, 2011). The sources of the price indices are listed in Table 1.

Table 1: Sources of price indices for Problem 1

	variables	Israel	Syria
		Average per employee job	
Civilian consumption prices	z_x, z_y	Consumer price index	Consumer price index
Military capability prices	p_x, p_y	Price index of the public administration, of the state and the national institutions	Manufacturing industries price index
Intelligence prices	h_x, h_y	Research and development wages	Electric equipment and machines

Finally, using the nominal data of the defense and military budgets together with the price indices based on 2008 constant US$, we obtain the real data for the total defense budget and its components (see Figures 7 and 8).

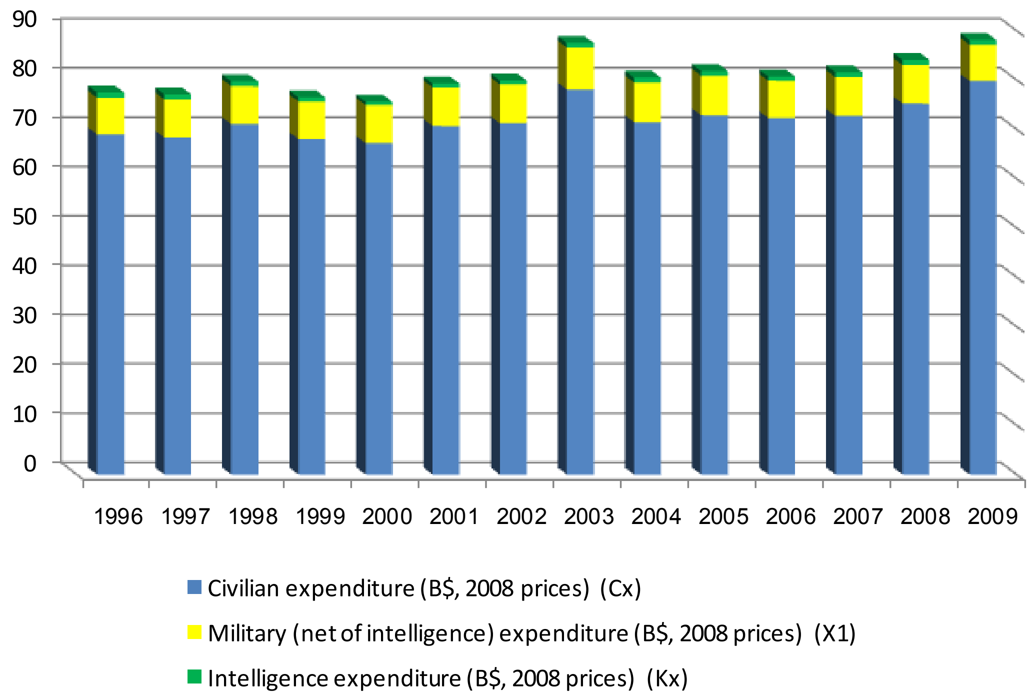

Figure 7: Israel's defense, military and intelligence expenditures: 1996-2009 (billion US$; 2008 prices)

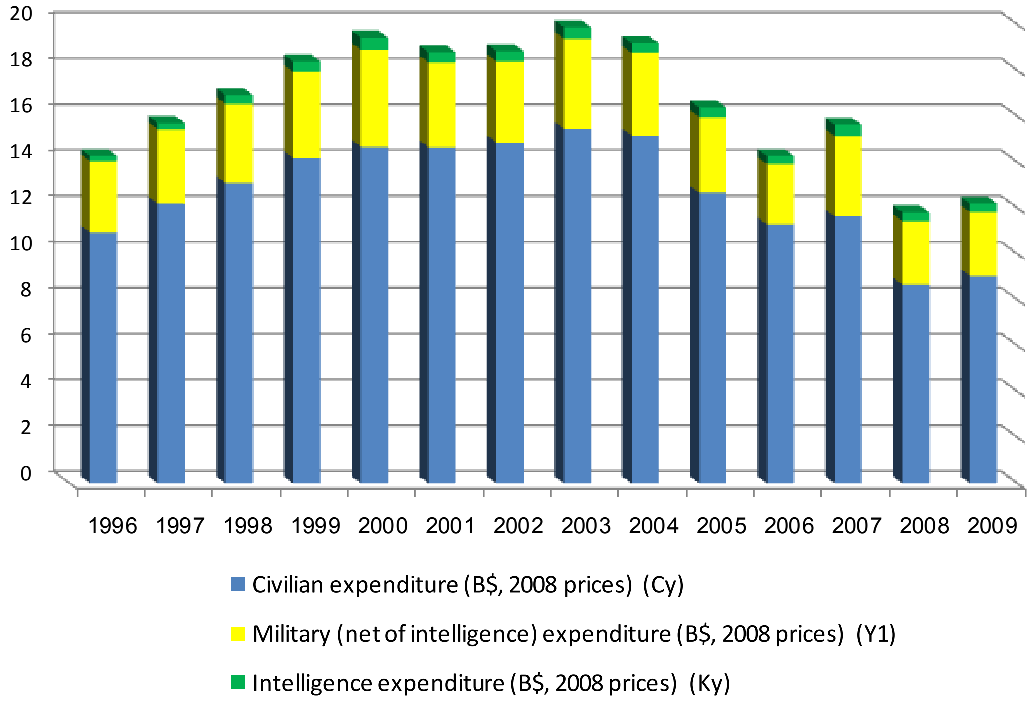

Figure 8: Syria's defense, military and intelligence expenditures: 1996-2009 (billion US$; 2008 prices)

Methodology

We now apply the theoretical model of Sections IV and VI to the Syrian-Israeli arms race, which is a long-term, non-symmetric, regional conflict that has been ongoing since the foundation of the state of Israel in 1948, though the last major war between the two rivals occurred long ago (the Yom Kippur War in 1973).

A detailed description of the economic characteristics of the conflict and the relevant military and other data are available in Kagan, Tishler and Weiss (2005) and in Ringel and Tishler (2011). Generally, reliable data on military expenditures are scarce, particularly on intelligence spending over time. Therefore, we use data from official national sources as well as other public sources (such as Nevo and Shur-Shmueli, 2004, Wolfson, 2009 and Ringel and Tishler, 2011), open media quotes and various other published information on intelligence agencies in our analysis.

The lack of reliable time series data prompted us to employ calibration rather than econometric methods for the evaluation of the model parameters. Israel is denoted as country x and Syria as country y. Calibration of the parameters of a simplified form of the integrated model given by (1) was carried out with annual data, for 1996-2009. For simplicity we do not account for the quality of weapon systems and denote $\tilde{x}^{\tilde{\alpha}} = x_1^{\alpha} q_x^{\beta}$ and $\tilde{y}^{\tilde{\gamma}} = y_1^{\gamma} q_y^{\delta}$, which does not affect the main theoretical conclusions or the empirical results.

We assume that w_x and w_y in (1) are constant over time and set them equal, separately in each country, to the average share of the military expenditure in the total government annual budget.[13] This assumption implies that $w_x = 0.82$ and $w_y = 0.80$. All the other model parameters are calibrated from the data. These parameters are:

α, γ - The elasticity of the military capability of country *x* (*y*) with respect to weapon systems.

β, δ - The elasticity of the military capability of country *x* (*y*) with respect to intelligence.

λ_x, λ_y - The degree of conservatism of country *x* (*y*)'s decision maker.

σ_x, σ_y - The measure of efficiency of country *x* (*y*)'s intelligence process.

We calibrate these parameters based on 1996-2009 annual data by using nonlinear regression for the first-order conditions of each country's decision Problem 1. That is, we minimize the sum of squared errors of the first-order conditions of Problem 1 for country *x* and country *y*. Specifically,

$$\underset{\substack{\alpha,\beta,\lambda_x\sigma_x \\ \gamma,\delta,\lambda_y\sigma_y}}{Min} \sum_t \left(\varepsilon_{\tilde{x}(t)}{}^2 + \varepsilon_{k_x(t)}{}^2 + \varepsilon_{\tilde{y}(t)}{}^2 + \varepsilon_{k_y(t)}{}^2 \right) \qquad \forall t = 1996,...,2009 \qquad (6.1)$$

where

$$\varepsilon_{\tilde{x}(t)} = \left[(1-w_x)\alpha \frac{(B_{xt} - (p_{xt}\tilde{x}_t + h_{xt}k_{xt}))}{\tilde{x}_t} - w_x p_{1t} \right] \qquad \forall t = 1996,...,2009 \qquad (6.1.1)$$

$$\varepsilon_{k_x(t)} = \left[(1-w_x)(B_{xt} - p_{xt}\tilde{x}_t - h_{xt}k_{xt}) \left(\frac{\delta}{k_{xt}} + \frac{(\beta-\delta)}{k_{xt}+k_{yt}} + \frac{\lambda_x\sigma_x}{(\sigma_x + k_{xt})(k_{xt} + \sigma_x(1+\lambda_x))} \right) - w_x h_{xt} \right]$$
$$\forall t = 1996,...,2009 \qquad (6.1..2)$$

with similar first-order conditions for country *y*.

[13] The robustness of our assumptions is assessed later on in this section.

Results

The calibrated parameters for Israel and Syria are given in Table 2.

Table 2: The calibrated parameters for Israel and Syria

Calibrated parameters	Security elasticity	Intelligence effectiveness (elasticity)	Decision maker's degree of conservatism	efficiency of intelligence
	α, γ	β, δ	λ_x, λ_y	σ_x, σ_y
Israel (Country *x*)	**0.83**	**0.16**	**0.22**	**0.22**
Syria (Country *y*)	**1.12**	**0.07**	**0.53**	**8.53**
Intelligence effectiveness: Israel/Syria	$\frac{\alpha}{\gamma}$	$\frac{\beta}{\delta}$	$\frac{\lambda_x}{\lambda_y}$	$\frac{\sigma_x}{\sigma_y}$
	0.74	2.29	0.41	0.03
Sum of residual errors	1.21			

The main insights that can be gleaned from Table 2 are as follows. The parameter values reflecting the effectiveness of the weapon systems (α, γ) are around 1 for both countries. The parameter values reflecting intelligence effectiveness (β, δ) are positive but much closer to 0 than to 1, suggesting that the marginal contribution of intelligence efforts to military capability is diminishing. The decision makers' degrees of conservatism (λ_x, λ_y) are also positive and closer to 0 than to 1. As expected, the value of the intelligence effectiveness in Israel is much larger than that in Syria (Israel's level of human capital is higher). At the same time we observe that Syria's decision makers are more conservative in their assessments than those in Israel. The marginal contribution of weapon systems to military capability in Syria is somewhat higher than that in Israel.

The calibration results, particularly the values of α/γ and β/δ were checked for reliability in a variety of ways. First, we created data sets for several different assumptions about the share of intelligence expenditure in the defense budget data and for several measures of the defense budget. Second, we created data sets in which each observation is the average of two or three consecutive years. Then, we repeated the calibration process for each data set. The summary of these analyses shows that our basic results are robust (see Table 3).

Table 3: Summary of robustness analysis for the main parameters

Robustness analysis results	$\frac{\alpha}{\gamma}$	$\frac{\beta}{\delta}$	λ_x, λ_y	σ_x, σ_y	Sum of squared residuals (SSR)
Basic	**0.74**	**2.29**	$\boldsymbol{\lambda_x \leq \lambda_y}$	$\boldsymbol{\sigma_x \leq \sigma_y}$	**1.21**
Min - Max	0.44 - 1.26	1.17 - 7.21	Significant variance and some corner results		0.84 - 1.84
Average (St. Dev,)	0.75 (0.14)	2.80 (1.59)			1.21 (0.24)
Insights	$0.71 \leq \frac{\alpha}{\gamma} \leq 0.77$ in 22/27 cases		$\lambda_x \leq \lambda_y$ in 25/27 cases		$0.97 \leq SSR \leq 1.32$ in 22/27 cases
	$1.38 \leq \frac{\beta}{\delta} \leq 2.85$ in 23/27 cases		$\sigma_x \leq \sigma_y$ in 23/27 cases		

Future trends of the Israeli-Syrian arms race: An example

Using the calibrated parameters one can forecast and assess the development of the arms race under various assumptions on the exogenous variables of the model. Figure 9 presents the predicted evolution of the Israeli-Syrian arms race during the next 20 years under the assumptions that real unit prices of weapon systems and intelligence remain constant and for two scenarios of government budget annual growth rate: (a) 5% per annum in Israel and Syria; (b) 5% in Israel and only 2% in Syria. The computations employed the actual 2010 data as the starting point and the "basic" parameter values (see Table 2).

The numerical results emphasize the initial (current) gap between the Israeli and the Syrian economic conditions and military capabilities. In both scenarios the Israeli advantage in security, civilian consumption and welfare is predicted to be very significant throughout the next 20 years. This advantage is due to the current gap in the countries' GDP (and, consequently, in their government budgets) and the higher effectiveness of the Israeli intelligence. The Israeli advantage in military capability (S_x) decreases slightly when the annual rate of change of the GDP in both countries is set at 5%, and increases by a noticeable amount under the more realistic assumption that Israel's government budget annual growth rate (5%) is set higher than that of Syria (2%).

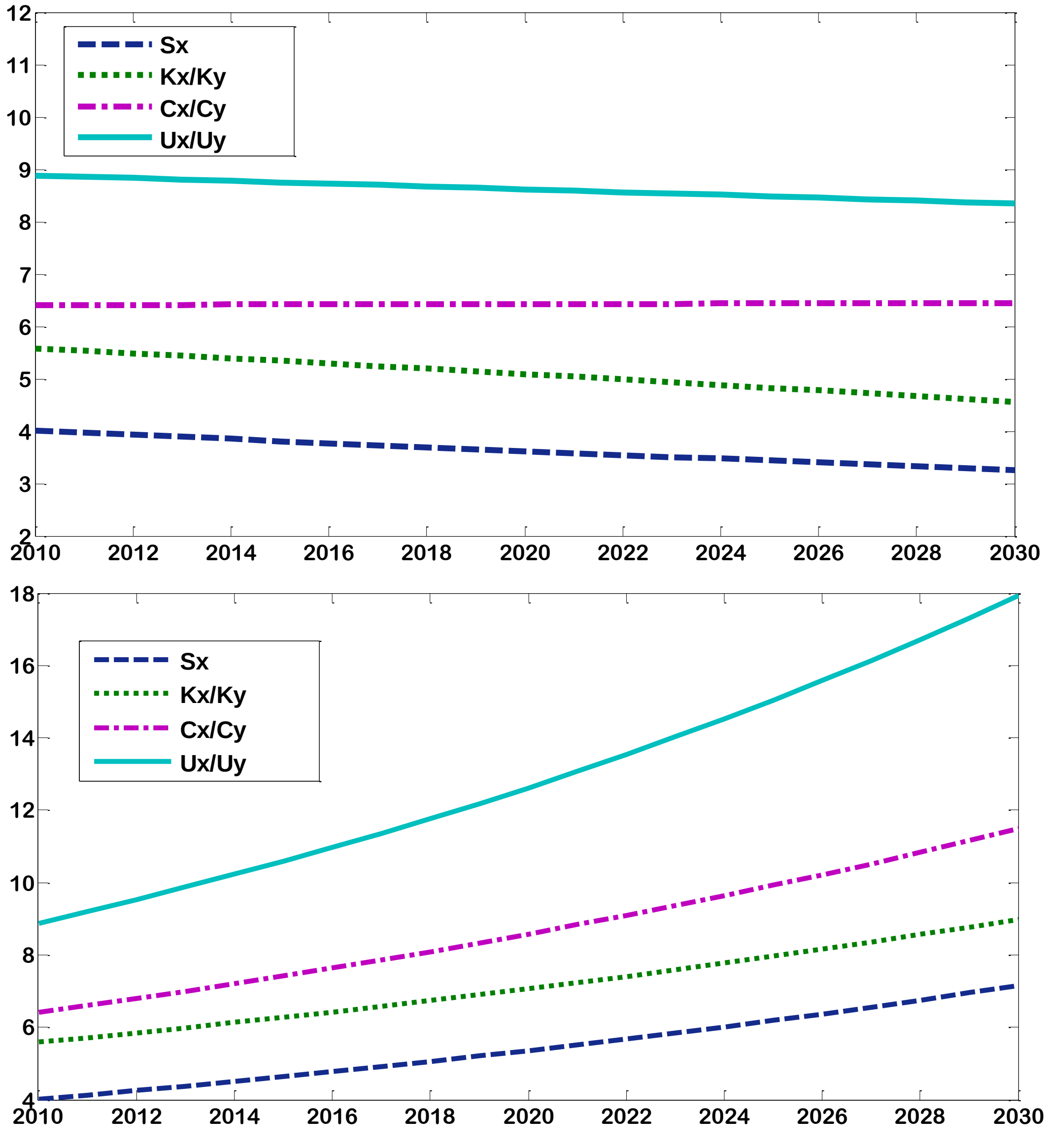

Figure 9: Future trends in the Israeli-Syrian arms race under two scenarios:
<u>Upper chart</u>: Annual government budget growth rate is 5% for Israel and Syria
<u>Lower chart</u>: Annual government budget growth rate is 5% for Israel and 2% for Syria

VIII. Summary

The current technology and information revolution, along with globalization, have positioned intelligence as a major factor in achieving appropriate national security in the face of military and terror threats. High-quality knowledge of the capabilities and intentions of rivals is a major factor in achieving a balanced military, meaningful deterrence capabilities, and success in warfare situations.

This study integrates military intelligence into the optimal allocation of the government budget and characterizes the ensuing implications. It presents scenarios in which the two rivals participate in a knowledge race in addition to the usual arms race. In such cases, the country with the higher intelligence effectiveness (due to a higher quality of human capital) may force its rival to spend significant resources on intelligence and, thus, gain substantial advantage in security and welfare. We also show that in some situations one or both rivals may not invest any resources in intelligence. Finally, we use publicly available data to assess some of the features of the Israeli-Syrian arms race.

In the future we plan to develop and analyze models that integrate additional properties of the intelligence process and the quality of human capital into the government budget allocation process. In particular, we intend to better express the inherent uncertainty of intelligence, employ convex R&D costs (similarly to many studies in the industrial organization literature), and solve a multiple-period dynamic model which will allow more realistic integration of the quality of a country's human capital into the analysis.

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