



Defence Output Measures

An Economics perspective

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Defence R&D Canada
Centre for Operational Research and Analysis

Defence Economics Team

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Abstract

This Contract Report examines the measurement of defence output from an economics perspective. Economic theory offers some policy guidelines for determining the optimal defence output for any society. As an optimising problem, the economics rule is to aim at the socially desirable or optimal defence output which is achieved by equating additional or marginal costs with additional or marginal benefits. While the economics approach is difficult to 'operationalise' into a set of clear unambiguous policy guidelines, it does provide a framework for designing valuations for defence outputs and activities. Experience of measuring defence outputs is reported for the UK, Australia, New Zealand, a group of European nations and the USA.

Résumé

Le présent rapport de contrat examine la mesure des extrants en matière de défense d'un point de vue économique. La théorie économique offre certaines lignes directrices stratégiques pour la détermination des extrants optimaux de défense pour toute société. En tant que problème relatif à l'optimisation, la règle d'économie consiste à viser un extrant de défense optimal ou souhaitable sur le plan social qui est réalisé en faisant concorder les coûts supplémentaires ou marginaux avec les avantages supplémentaires ou marginaux. Bien que l'approche économique soit difficile à « opérationnaliser » en une série de lignes directrices stratégiques claires et sans équivoque, elle offre toutefois un cadre pour la conception des évaluations pour les extrants et activités de défense. L'expérience de la mesure des extrants en matière de défense est rapportée pour le Royaume-Uni, l'Australie, la Nouvelle-Zélande, un groupe de nations européennes et les États-Unis.

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Executive summary

Defence Output Measures: An Economics Perspective

Keith Hartley; DRDC CORA CR 2011-178; Defence R&D Canada – CORA; November 2011.

Measuring output is not usually regarded as a policy problem. Market economies ‘solve’ the problem through market prices reflecting the choices of large numbers of buyers and willing sellers. But defence differs from private markets which is why there is a problem in measuring and valuing defence output.

Economic theory provides guidelines for measuring defence output. These guidelines are expressed as a set of rules for achieving the ideal or society’s preferred amount of defence. However, these rules cannot be operationalised and converted into clear guidance for policy-makers.

Defence markets lack the incentive and penalty structures of private markets. Defence markets are dominated by state-ownership and state funding of Armed Forces. There are not large numbers of private consumers, they lack competition, their top managers are not profit-seekers, and there is no capital market threatening take-overs and bankruptcy.

Defence markets have further distinguishing features. Both defence and peace are public goods where the lack of price signals lead to the under provision of the product. Also, in conflict, defence forces destroy markets, use military power to re-allocate resources and create chaos reflected in destructive power. In contrast, markets promote voluntary trade and exchange, prices are used to allocate resources and markets are about equilibrium and creative power.

Military production functions show the relationship between defence inputs and defence output. Measures of defence inputs can be obtained but output measures are more difficult to ‘operationalise.’ Defence budgets provide useful information on defence inputs reflected in military spending. Input, output, management and resource accounting budgets have been used as outcome measures but none have ‘solved’ the problem of measuring and valuing defence output.

Falling defence budgets and rising unit costs of equipment mean that defence policy-makers will not be able to avoid the need for difficult defence choices such as base infrastructure closure or divesting military capabilities. The benefits of defence spending are outlined and critically assessed. Both economic and non-economic benefits are presented.

Experience of measuring defence outputs is reported for the UK, Australia, New Zealand, a group of European nations and the USA. The published data do not improve on the measures of defence capability provided by some nations (e.g. UK). But capabilities are limited measures of defence output, lacking data on the value of benefits from the capabilities. Nor are the capabilities comprehensive measures of defence output, often omitting some outputs.

Overall, the study identifies key questions which have to be addressed in measuring defence output. These are what is defence output; how can it be valued; and is it a worthwhile investment?

Sommaire

Defence Output Measures: An Economics Perspective

Keith Hartley; DRDC CORA CR 2011-178; R & D pour la défense Canada – CARO; novembre 2011.

La mesure des extrants n'est habituellement pas perçue comme un problème en matière de politiques. Les économies de marché « règlent » le problème par des prix du marché reflétant les choix d'un très grand nombre d'acheteurs et de vendeurs consentants. Mais la défense diffère des marchés privés, ce qui explique pourquoi il y a un problème concernant la mesure et l'évaluation des extrants en matière de défense.

La théorie économique offre des lignes directrices pour la mesure des extrants en matière de défense. Celles-ci sont exprimées en une série de règles permettant de réaliser le volume de défense idéal ou privilégié par la société. Or, ces règles ne peuvent être opérationnalisées et converties en directives claires pour les décideurs.

Les marchés de la défense ne disposent pas des structures d'incitatifs et de sanctions des marchés privés. Les marchés de la défense sont dominés par les propriétés étatiques et le financement des Forces armées par l'État. Il n'existe pas un très grand nombre de consommateurs privés, ils manquent de concurrence, leurs cadres supérieurs ne sont pas à la recherche de profit et il n'existe pas de marché financier les menaçant de mainmises ou de faillites.

Les marchés de la défense ont d'autres particularités. La défense et la paix sont des biens publics où le manque de signaux des prix entraîne une offre sous-optimale du produit. De même, en conflit, les forces de la défense détruisent les marchés, usent de la puissance militaire pour réaffecter des ressources et créent un chaos qui se reflète dans un pouvoir destructeur. En revanche, les marchés font la promotion du commerce et des échanges volontaires, les prix sont utilisés pour affecter les ressources et les marchés reflètent l'équilibre et le pouvoir créateur.

Les fonctions de la production militaire montrent la relation entre les intrants et les extrants en matière de défense. Les mesures relatives aux intrants de défense peuvent être obtenues, mais les mesures relatives aux extrants sont plus difficiles à « opérationnaliser ». Les budgets de la défense offrent de l'information utile sur les intrants en matière de défense reflétés dans les dépenses militaires. Des budgets de la comptabilité des intrants, des extrants, de la gestion et des ressources ont été utilisés comme mesures relatives aux résultats, mais aucun n'a « réglé » le problème de la mesure et de l'évaluation des extrants de défense.

Les budgets de la défense en décroissance et l'augmentation des coûts unitaires d'équipement signifient que les décideurs dans le domaine de la défense ne seront pas en mesure d'éviter de devoir faire des choix difficiles en défense, comme la fermeture de bases militaires ou le retrait de capacités militaires. Les avantages relatifs aux dépenses en matière de défense sont présentés et évalués de manière critique. Tant les avantages économiques que non économiques sont présentés.

L'expérience de la mesure des extrants en matière de défense est rapportée pour le Royaume-Uni, l'Australie, la Nouvelle-Zélande, un groupe de nations européennes et les États-Unis. Les données publiées ne permettent pas d'améliorer les mesures relatives aux capacités en matière de défense fournies par certaines nations (p. ex. Royaume-Uni). Or les capacités constituent des mesures limitées en matière d'extrants de défense, manquant de données sur la valeur des avantages provenant des capacités. Les capacités ne sont pas non plus des mesures exhaustives d'extrants en matière de défense, omettant souvent certains extrants.

Dans l'ensemble, l'étude cerne les questions principales auxquelles on doit répondre dans la mesure des extrants en matière de défense. Ces questions sont : quel est l'extrant de défense? Comment peut-il être évalué? S'agit-il d'un bon investissement?

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1 Introduction

1.1 Terms of Reference

The Terms of Reference required research on defence outputs and the production of a background paper on the measurement of defence outputs from an economic perspective. The economic discussions and lessons learned from the UK experiences are expected to facilitate DND's own efforts to establish a workable output measure that can be aligned with CBP and other governmental management systems (Contract DND-10/23136, January 2011).

2 The Contribution of Economic Theory

2.1 What is the problem and why does it exist?

Defence sectors absorb substantial scarce resources with alternative uses (e.g. schools, hospitals). The costs of defence are well known within each country. However, there is no obvious single indicator of the value of defence output. This contrasts with the valuation of output in private sector market economies. In defence, the traditional solution to measuring output has been to assume that output equals inputs (a convention widely used in the public sector).

Market economies produce a wide variety of goods and services. These are exchanged in markets which facilitate beneficial trade and exchange. In competitive markets (as defined by economists) there are large numbers of willing buyers and large numbers of willing sellers resulting in a set of market prices for goods and services. These market prices show society's valuation of the various goods and services by reflecting consumer's willingness to pay and supplier's willingness to provide the various goods and services.

But not all markets resemble the economist's competitive model. Often, there are major departures from the competitive model leading to *market failures* where markets fail to fully and accurately satisfy consumer demands. There are three major sources of market failure. First, markets might be *imperfect* reflecting monopolies, oligopolies and entry barriers. Second, *externalities* mean that left to themselves, private markets will provide 'too much' of a socially undesirable good or activity (e.g. pollution) and 'too little' of a socially beneficial good (e.g. the spin-offs from R&D). Third, *public goods* with defence as a classic example of such goods lead to market failure as discussed in the next section (Tisdell and Hartley, 2008).

The policy problem for defence is now clearer. Private markets for, say, motor cars and TVs, are characterised by physical outputs of these goods (e.g. numbers of cars and TV sets produced per year) and a corresponding set of market prices which, show society's valuation of these goods (what they are worth to society based on consumers willingness to pay). There are no such market prices for defence. Why not?

2.1.1 Defence Markets: Public Goods

Defence markets are distinctive with some unique features. Defence is a classic example of a public good and its results or mirror image in the form of peace is also a public good. A public good is non-rival and non-excludable: my consumption of the air defence of Toronto does not affect your amount of protection and once defence is provided I cannot exclude you from its consumption. Private goods such as motor cars and TV sets are rival and excludable: my consumption of a motor car means that you cannot have it and I can exclude you from using (consuming) my motor car (where my purchase of a car conveys private property rights in the vehicle).

The public goods features of defence provide incentives for free riding both within a nation and between nations in a military alliance (e.g. NATO; US-Canadian security). Free riding results in a nation's citizens failing to reveal their true preferences for, and valuations of, defence. Here, the problem is that the state in providing and financing defence does not know the true preferences of the potential beneficiaries of defence: it cannot easily quantify the volume of the defence public good demanded by consumers and estimate the true price the beneficiaries are willing to pay (Engerer, 2011). There are some theoretical solutions to estimating the optimal amount of a public good but these are difficult to operationalise (Cornes and Sandler, 1996). Or, public opinion polls might be used but these are a limited mechanism for assessing accurately society's opinions on defence spending and defence policy and the willingness of citizens to pay for defence.

2.1.2 The Guidelines of Economic Theory

Economic theory offers some policy guidelines for determining the optimal defence output for any society. As an optimising problem, the economics rule is to aim at the socially desirable or optimal defence output which is achieved by equating additional or marginal costs with additional or marginal benefits. But this approach is difficult to 'operationalise' into a set of clear unambiguous policy guidelines.

Marginal costs and especially marginal benefits are not immediately obvious and identifiable. The economic model assumes a social welfare function showing society's preferences between defence (security) and civil goods: again, an attractive concept but not one which is readily operationalised and identifiable for any society. Furthermore, estimates of the benefits of defence are complicated by its public goods and free riding characteristics. In addition, voting systems are not reliable and accurate methods of identifying voter preferences for specific public goods and services. Typically, elections are general embracing choices between political parties offering various taxes and spending policies with defence budgets and policies as one element in the product mix. Problems can also arise in aggregating voter preferences into a ranking for society as a whole (the voting paradox: Tisdell and Hartley, 2008). Further problems arise since the economic model assumes maximising behaviour when agents might be satisficers settling for an acceptable solution short of the maximum.

2.2 Comparing Defence and Private Markets

There are major differences between private markets and defence markets. Private markets have market prices showing society's valuation of its outputs where these prices reflect a set of incentive and penalty mechanisms. Goods are 'private' rather than public goods with excludability and rivalry; there are large numbers of private consumers and buyers; there is rivalry between firms; firms are motivated and rewarded through profits; and a capital market imposes penalties on poor economic performance through take-overs and the ultimate sanction of bankruptcy (with managers losing their jobs).

The Armed Forces in defence markets lack such incentive and penalty mechanisms so that they are slow to adjust to change. Often, change in the Armed Forces results from budget pressures, new technology, defeat in war and occasionally by the views of a reforming Defence Secretary or Chief of the Defence Staff (Solomon, *et al*, 2008).

In contrast to private markets, defence markets have no market prices: for example, there are no market prices for submarine or tank forces. Nor are defence markets based on rivalry between suppliers; there is no profit motive for suppliers; nor are there capital market pressures corresponding to take-overs and bankruptcy in private markets. Defence markets have a further distinctive feature reflected in the state-funding and state provision (ownership) of its Armed Forces. Governments are monopsony buyers and monopoly providers of Armed Forces. This contrasts with private markets where there are large numbers of buyers and rivalry amongst suppliers. State-owned and funded defence markets are less likely to undertake worthwhile changes. There is also a unique military employment contract which differs drastically from private sector employment contracts. The military employment contract requires military personnel to obey commands which relate to type, duration and location of work (world-wide deployments) with the probability of injury and death.

Each of the Armed Forces is a monopoly supplier of air, land and sea systems with monopoly property rights in the air, land and sea domains. This has implications both affecting efficiency in defence markets. There are barriers to new entry which prevent rival Armed Forces from offering competing products. For example, armies often operate attack helicopters and UAVs which are rivals to close air support and surveillance provided by air forces; similarly, land-based aircraft are alternatives to carrier-borne aircraft. Efficiency requires that there be a mechanism for promoting such competition; instead, each Service guards its traditional property rights in the air, land and sea domains thereby creating barriers to new entry. There is a related impact on efficiency. As monopolies, each of the Armed Forces lacks any competing organisations and hence, any incentives for efficiency improvements and for innovation. Here, efficiency embraces both allocative and technical efficiency. Allocative efficiency requires the choice of the socially desirable output and technical efficiency requires the use of least-cost methods of production. Again, problems arise in determining allocative efficiency (see below on principal-agent models). However, technical efficiency can be assessed by allowing activities traditionally undertaken 'in-house' by the Armed Forces to be 'opened-up' to competition from private suppliers (military outsourcing). Indeed, the formulation of such competitions can offer improvements in allocative efficiency (e.g. by inviting competitions for different levels of service in order to identify marginal costs for different levels).

Defence markets lack other incentives of private markets. There are no profit incentives to stimulate and reward military commanders for searching for and introducing productivity improvements or for identifying new and profitable opportunities (for example, the role of entrepreneurs in private markets). The absence of a capital market also means that military managers are unlikely to lose their jobs for poor performance and that there are no capital market opportunities for promoting and rewarding mergers and take-overs. For example, a military commander of a regiment cannot merge with another regiment to achieve economies of scale and scope, nor can an army regiment acquire air force and naval transport units where such mergers might offer both cost savings and output improvements (such as horizontal, vertical and conglomerate mergers).

Uncertainty dominates defence policy. Defence policy has to respond to a range of future threats, some of which are unknown and unknowable. Assumptions are needed about likely future allies and their response to threats, the location of threats, new technologies and the time dimension of threats (e.g. today or in 10-15 years time or 30-50 years ahead where the uncertainties are greatest). These uncertainties mean that forces have to be capable of adapting to change, and today's weapons have to be capable of meeting threats up to 50 years ahead. Admittedly, the private sector faces considerable uncertainty about future markets and new technologies and these unknowns extend over lengthy time horizons. However, defence is different in that the uncertainties are dependent on and determined by governments and nation states rather than by the actions of large numbers of private individuals as consumers, workers and shareholders.

There is one further key difference between defence and private markets. Defence aims to avoid conflict but where conflict arises, it destroys markets, creates disequilibrium, it means resource re-allocation based on military forces and leads to chaos: the result is *destructive power*. War involves the destruction of labour and capital. In contrast, private markets are about equilibrium, voluntary trading and exchange, resource allocation based on prices, leading to *creative power* (a greater output of goods and services).

2.3 Public Choice and Principal-Agent Models

Defence choices are made in political markets which are a further reason why they depart from the economist's optimising solution. Political markets comprise voters, political parties, bureaucracies and interest groups each pursuing their self-interests. Voters as taxpayers are principals: they want something done and they appoint agents to perform their required tasks. For principals, the challenge is to design incentives to ensure that agents pursue the aims of the principals rather than their own objectives. For example, voters as principals will require peace, security and protection but their agents in Defence Ministries and the Armed Forces might prefer to buy British or Canadian goods and services because doing so offers jobs, technology and export benefits which contribute to the re-election of the governing party.

Expressing and enforcing the aims of principals is affected by the limitations of the voting system as a means of expressing voter preferences for defence spending and policies. Free riding further affects the willingness of voters to accurately reveal their preferences for defence. Principals also lack the necessary information for making informed and rational defence choices. The result is that agents have opportunities for determining national defence policy and pursuing their own interests when doing so. For example, a nation's international peace-keeping contributions might provide considerable satisfaction to the country's Prime Minister, senior Ministers and civil servants from attending international meetings at the UN and participating in regional meetings. The principal-agent and public choice analysis raises the general question of who gains and who pays for these defence policies (e.g. international peace-keeping; national procurement of defence equipment, including offsets)? Ultimately, taxpayers pay and receive some defence benefits whilst agents consume some benefits which have not been chosen by voters and taxpayers.

The principal-agent model has implications for choices, resource-use and efficiency in defence markets. It also has implications for measuring defence outputs where these will reflect a combination of principal and agent choices. The model can also be linked to the political market where defence choices are made.

In political markets:

1. Voters and taxpayers as principals will seek to maximise the benefits (satisfaction) from their votes.
2. Political parties are vote-maximisers; governments seek re-election and will become agents of voters.
3. Bureaucracies can be modelled as budget-maximisers acting as agents of the government.
4. Producer groups will be profit-seekers (rent-seekers) acting as agents of the procurement agency or bureaucracy.

The principal-agent and public choice models provide an analytical framework for understanding the military-industrial-political complex and its influence on defence choices and outputs. As principals, voters are generally poorly informed about defence policy so they will allow defence choices to be made by various agents, namely, governments, civil servants in Defence Ministries and procurement agencies, and by the Armed Forces. These agents will be further influenced by powerful producer groups in the form of large defence contractors (e.g. via lobbying) seeking to be awarded lucrative defence contracts.

Examples abound of the influence of the military-industrial-political complex on defence choices. Government Ministers will be aware of the vote-consequences of defence choices (e.g. impacts of base and plant closures; the benefits of awarding defence contracts to firms in marginal constituencies). Defence Ministries and the Armed Forces aiming at budget-maximisation will over-estimate the threat and under-estimate the costs of their preferred policies and projects. Exaggerating the threat from terrorism enables the Armed Forces to obtain larger defence budgets; under-estimating the costs of a new weapon system allows the project to start and once started, projects attract interest groups and become difficult to stop (a factor in 'optimism bias'). Defence contractors will also use persuasive language to be awarded valuable defence contracts. For example, it will be claimed that the contract will contribute valuable jobs, technology, spin-offs and exports and will be 'vital' to the future of the national defence industrial base. Rarely is attention given to the opportunity cost question, namely, whether the resources used in the defence project would provide even greater net economic benefits if used in alternative sectors of the economy. Overall, the public choice and principal-agent models show how these groups are likely to influence defence choices and defence outputs.

3 The Military Production Function

There is a further contribution from economic theory to output measurement in the form of the military production function. This is an input-output relationship relating all defence inputs to defence output. Inputs comprise technology, capital (bases, equipment) and labour (military personnel in the form of conscripts and/or volunteers). A formal expression of the function is:

$$Q = f(A, K, L) \tag{1}$$

where Q is defence output and A, K and L are inputs of technology (A), capital (K) and labour (L).

While the model appears attractive, there are at least four major problems. First, it is assumed that the factor inputs are arranged to minimise costs. This assumption is unrealistic in view of the lack of efficiency incentives in defence markets: there are no incentives and penalties to achieve least-cost production. Second, all defence inputs have to be identified and correctly valued. Third, defence output is simply asserted without recognising the problems of identifying and valuing defence output, including the multi-product nature of defence output. Fourth, the model simply identifies defence outputs resulting from various inputs: there are no criteria for determining society's preferred defence output (the best or optimal defence output)¹.

The two central problems with military production functions arise over inputs and outputs. Consider the problem of identifying and valuing all relevant inputs. These comprise technology, capital and labour and include the following items:

1. Technical progress as reflected in inputs embracing new equipment and new military facilities, including communications. For example, compare today's space satellite communications systems with the military communications facilities in 1914 (e.g. observation balloons).
2. Physical capital comprises equipment, military bases, land and logistics (repair and maintenance).
3. Human capital comprising military personnel reflected in numbers and in their human capital reflected in the skills of the military labour force. Skills and productivity will differ between regular forces, conscript and reserve forces. Other co-operating and

¹ There are various forms of production function. A Cobb-Douglas production function is widely used. This makes two assumptions. First, short-run diminishing returns as a variable factor is varied against a fixed factor; and second, constant returns to scale over the long-run when all factors are variable. With constant returns to scale, the exponents of capital and labour sum to one and each exponent shows that factor's share in total income or output (e.g. an exponent of 0.75 for labour suggests that labour incomes account for 75% of total income, with capital accounting for the remaining 25%).

substitute labour inputs comprise civilian labour inputs, including military outsourcing and police forces (e.g. police forces substituted for British Army troops in policing Northern Ireland: Ridge and Smith (1991)).

Identifying, measuring and valuing defence output is even more challenging. Economic theory simply asserts the concept of defence output without exploring its definition and multi-product nature which is the focus of this study.

There are few published studies which have estimated military production functions. Typically, such studies have estimated for readily identified measures of effectiveness, such as providing an air defence capability or the numbers of aircraft destroyed or the number of aircraft sorties per day. This approach is used in *cost-effectiveness* studies but such studies focus on only a limited measure of defence output (Hildebrandt, 1990; 1999). For example, a cost-effectiveness study of air defence would compare the costs and effectiveness of alternatives such as land-based air defence missiles versus manned fighter aircraft; or anti-submarine capability would compare land-based maritime patrol aircraft versus naval frigates; or anti-tank capability would compare missiles and attack helicopters. A different approach was used in a more recent study which estimated a military production function where various defence inputs were used to estimate the probability of winning in various conflict scenarios (Middleton, *et al*, 2011).

There is a variant of the military production function, namely, a defence R&D production function. This shows that *current* defence R&D determines *future* military equipment quality with its impact on defence output. The relationship between defence R&D and equipment quality is positive but subject to diminishing returns and substantial lags: for example, today's military equipment quality was determined by defence R&D spending some 10-15 years ago. Equipment quality can be 'converted' into time advantage. Thus, over the period 1991-2001, US military equipment was six years ahead of that of the UK, seven years ahead of France and twelve years ahead of Sweden (Middleton, *et al*, 2006). The defence R&D production function can be expressed as:

$$E_q = f(RD_d, Z) \tag{2}$$

where E_q is military equipment quality (e.g. British versus US tanks); RD_d defence R&D and Z represents all other factors.

The defence R&D production function needs more theoretical and empirical work. For example, 'other factors' might contribute to equipment quality and these need to be identified in the model. Furthermore, the links between equipment quality and military capability need identifying including the role of variables such as military skills which will also contribute to final defence output. Similarly, the model focuses on the broad aggregate of defence R&D spending without any analysis of the most effective mix of research and development spending. More empirical work is needed to determine the most cost-effective ratio of research to development work within total defence R&D budgets and the impact of that R&D on equipment quality.

Traditionally, defence outputs were measured on an input basis where inputs were assumed to equal outputs. Table 1 presents some input data of the type used for measuring some of the inputs to a military production function.

Table 1 Defence Inputs for a Group of Nations (2009)

Country	Defence spending (US\$ millions, 2009 prices)	Defence share of GDP (%)	Armed Forces Personnel (Numbers, 000s)	Defence R&D (US\$, millions, 2000 prices)
Australia	20109	1.8	58	242.7
Canada	19869	1.5	67	201.6
France	54446	2.1	243	3643.5
Germany	47466	1.4	254	1103.2
Italy	30489	1.4	197	64.9
Spain	16944	1.2	134	1666.5
Sweden	6135	1.3	13	218.7
UK	59131	2.7	197	2559.9
USA	574070	4.0	1368	65896.0
China	98800	2.0	2285	NA
India	36600	2.6	1325	NA
New Zealand	1358	1.2	9.8	NA

Notes:

Defence spending data for Australia, China, India and Sweden are in 2008 prices: source SIPRI (2011).

Data for NATO nations is provided from one source and is on a consistent basis.

Defence R&D data are in US\$ millions 2000 prices and PPP rates.

NA is not available. Sources: NATO (2010); OECD (2010).; SIPRI (2011).

3.1 Technical Spin-Offs

Defence R&D can also contribute to wider economic benefits in the form of technical spin-offs and spill-overs (external benefits or external economies). There are numerous examples such as the jet engine, avionics, radar, composite materials, the internet and the application of helicopter rotor blade technology to wind turbines. These externalities might be regarded as part of defence output but such views need to be assessed critically. Technology spin-offs are not the main aim of defence spending which seeks to provide peace, protection and security. Any technical spin-offs can be regarded as a windfall gain from defence spending. Moreover, a list of spin-off examples fails to address the central question of the market value of such spin-offs and whether there are

better alternative uses of defence R&D resources. Consideration also needs to be given to the wider economic impacts of defence spending.

3.2 Defence-Growth Relationships

A considerable literature has developed on the relationship between defence spending and a nation's economic growth. There are two alternative hypotheses. First, the view that defence spending *favourably* affects an economy's growth rate (a positive impact: Benoit, 1973). Second, the contrasting hypothesis that military expenditure *adversely* affects a nation's growth rate: Deger and Smith, 1983). Some of the literature has widened the possible relationship to include the impact of defence spending on other macro-economic variables such as employment, unemployment, inflation, exports and R&D (Hartley, 2010a).

Both hypotheses are dominated by myths, emotion and special pleading. Plausible explanations can be provided for a positive or negative impact of defence spending on growth and there is evidence supporting both impacts! The divergent results reflect the need for a properly-specified model of economic growth showing the causal relationships, including the integration of defence spending in such a model. Typically, defence spending is simply added to a conventional growth model without careful consideration of its causal impact on growth. The varied results in this field reflect different economic and econometric models, different combinations of variables, different time-periods, cross-section and time-series studies, an heterogeneous set of countries and the use of data of varying degrees of reliability and scope of coverage.

A considerable literature has used Granger causality tests to examine the relationship between military spending and the economy. A critique of this literature concluded that parameters may not be stable over different time periods or different countries and that "... Granger causality test statistics are uninformative about the size and direction of the predicted effects and Granger causality measures incremental predictability and not economic causality" (Dunne and Smith, 2010, p440). The critique concludes with the need to provide "measures of the political and strategic determinants of military expenditures, such as threats" (Dunne and Smith, 2010, p440).

4 Assessing Defence Outputs: Problems and Challenges

4.1 The Problem

Defence differs from private markets in that there are no output measures such as the numbers and values of motor cars produced and sold. Private markets provide a set of performance and efficiency measures such as sales, labour productivity and profitability. Traditionally, defence outputs were measured on an input basis where inputs were assumed to equal outputs. In fact, defence outputs are a complex set of variables concerned with security, protection, and risk management, including risks avoided, safety, peace and stability.

There is a further complication. Austrian economists assert that defence policy-makers cannot measure human values and their valuation of foregone alternatives when making choices. People's valuations are subjective; they differ between individuals, and they cannot be measured, compared and weighted (Butler, 2010, p83). In contrast, defence inputs are more easily identified, measured and valued with the results reflected in a nation's annual defence budget. For economists, questions then arise as to whether annual defence budget information provides data to assess the efficiency of its military expenditure: how much is spent and what are the resulting outputs? Do defence budgets provide policy-makers and politicians with the sort of data needed to assess the benefits and costs of different defence forces? For example, a larger army or navy or air force; the impacts of substituting equipment for military personnel; or the impact of substituting reserves for regular force personnel? Various types of defence budgets are available and have been used comprising input budgets, output budgets, management budgets and resource accounting budgets.

4.1.1 Defence Budgeting

4.1.1.1 Input Budgets

Input budgets provide some limited information on defence inputs such as the pay of military and civilian personnel, supplies, production and research and movements (Hartley, 2011, chp 4). However, such budgets have major limitations for assessing efficiency. First, the budget fails to show any defence outputs other than the vague heading of 'defence.' Second, it does not relate inputs to specific outputs (e.g. air defence; anti-submarine defences). Third, inputs focus on the current year only and do not reflect the life-cycle costs of current procurement decisions. Fourth, inputs are not always valued in terms of market values reflecting scarcity of resources (e.g. some resources, such as military bases and land for training, might not be priced and are available at zero price; other resources such as conscripts are not priced at their labour market values). These limitations led to the development of output budgeting.

4.1.1.2 Output Budgets

Output budgets also known as programme budgets are in complete contrast to input budgets and are much closer to the economist's model of defence budgets. They provide information on some of the outputs of defence such as nuclear strategic forces, air defence, aircraft carriers, infantry regiments and reserve forces together with their costs. Output budgets also provide information on the possibilities for substitution (e.g. between nuclear and conventional forces; between reserves and regulars). With output budgets, a distinction needs to be made between the budget available to the Defence Ministry and the budget released to Parliament and the public. The published version of the budget does not reveal all the information available to the Defence Ministry and the basis for the choices which are reflected in the published version (Davies, *et al*, 2011, chp 17).

There are at least two major limitations with output budgets. First, the expenditure figures used in output budgets are unlikely to be least-cost solutions due to lack of competition and proper market structures. Second, whilst they are known as output budgets, there remain problems in identifying the outputs of defence. Often, outputs are defined in terms of the numbers of military personnel, aircraft squadrons, warships and infantry regiments. But the published data are usually measures of intermediate, rather than, final outputs in the form of protection, security, safety and peace. For example, the numbers of military personnel are misleading if their training, productivity and readiness for operations are ignored. Similarly, the numbers of aircraft, tanks and warships are misleading without data on their average age and their operational availability both currently and in the future. Then, the combinations of military personnel and equipment need to be assessed as effective forces with their ability to be deployed and sustained to different overseas locations for long periods.

4.1.1.3 Management Budgets

Management budgets focus on efficiency. Top level and lower level budget holders are identified and awarded cash budgets where delegated financial powers allow military commanders and managers to switch resources to achieve agreed objectives. But, inevitably, there are problems with management budgets. Budget holders (e.g. commanders of bases and units) often face constraints on their freedom to vary the mix of inputs of capital and labour (equipment and personnel). It is not unknown for large items of expenditure to be pre-committed leaving base and unit commanders with choices about relatively small items of expenditure (e.g. window cleaning; catering; transport). And efficiency incentives are reduced if some of the benefits accrue to the Defence Ministry or the national Treasury. Nor can efficiency be achieved without clearly-specified defence output targets. Cost savings can easily be realised if output targets are not specified!

4.1.1.4 Resource Accounting and Budgeting (RAB)

The UK adopted RAB in 2002 in order to bring public sector accounting practices into line with those in the private sector. RAB represents a shift from cash-based budgets to resource accounting which includes depreciation and cost of capital charges. There is an annual balance sheet for the Ministry of Defence (MoD) showing fixed and current assets, provisions and liabilities. Data on the value of MoD's fixed assets includes valuations for fighting equipment and

the defence estate (e.g. military bases and land for training). By identifying the costs of holding assets, RAB provides incentives for disposal (e.g. of surplus land, bases and estates). However, the adoption of private sector management and accounting practices alone will not lead to efficiency in MoD. The private sector has a range of mechanisms and incentives for achieving efficiency including competition, the profit motive and the capital market with the threat of take-over and bankruptcy. Such mechanisms and incentives are absent from MoD (and the public sector). All parts of the public and private sectors consist of individuals and groups with incentives to pursue their self-interest (people will adjust and play any games: principal-agent models): the task for MoD is to provide efficiency incentives equivalent to those in the private sector. Here, the continued absence of an acceptable measure of defence output remains a serious obstacle to assessing efficiency in the defence sector.

4.2 Challenges

Two pressures will make it essential to focus on the size of a nation's defence budget and the efficiency with which defence resources are used. First, continued pressure to reduce defence budgets and re-allocate resources to other public spending programmes, especially education, health and welfare (including care for the increasing elderly populations). Second, the additional pressure on defence budgets from rising equipment costs. A simple example shows the importance of rising unit equipment costs which will affect all nations (all figures are for unit production costs in 2010 prices):

- Spitfire unit costs (1940): £154,850
- Typhoon unit costs (2010): £73.2 million
- Typhoon replacement in 2050: £1+ billion

Norman Augustine famously forecast that with continued rising unit costs, by 2054, the entire US defence budget will purchase just one aircraft which would have to be shared between the Air Force and Navy (the Marines would have it for one day in leap years). He also forecast that the UK and France would reach this position two years earlier (Augustine, 1987, p143). Rising unit costs and constant or falling defence budgets (in real terms) means that difficult defence choices cannot be avoided: something has to go and the question is, what? The challenge in answering such questions requires reliable measures of defence output or in the absence of such measures, the development of improved proxies. This study contributes to knowledge by identifying the issues involved in developing better output measures and by reviewing the experience of other nations.

5 Defining Defence Outputs: The Benefits of Defence

In principle, defence provides an output in the form of goods and services which provide a stream of current and future benefits to a nation's citizens and to the citizens of other nations who might also receive such benefits. The benefits are both economic and non-economic although such a distinction can be problematic. The economic benefits of defence usually take the form of services which contribute to national output. The non-economic benefits of defence include its foreign policy benefits, peace-keeping and its contribution to a nation's 'feel good' factor, including its involvement in being a responsible international citizen and member of the international community.

Typically, defence economists rarely address the concept of defence output apart from vague references to security. Government statisticians and the National Accounts have traditionally measured defence output on the convention that output equals input (ONS, 2008). Improving this limited measure requires that the concept of defence output be developed and explored.

5.1 Security

Security can be defined as the feeling of being secure and safe. In principle, defence provides security which is a multi-product output embracing protection, safety, insurance, peace, economic stability and risk avoidance or reduction (Solomon, *et al*, 2008). Further dimensions include prosperity, individual and national freedoms, liberty and the 'way of life.' These are all difficult to measure and might be influenced by factors other than defence. Also, these aspects of security are public goods which are not marketed and non-marketable services involving no tangible and physical products. Such difficulties of measurement do not remove the need for exploring concepts as a means of understanding the challenges of measuring defence output.

Security is sometimes defined as the absence of threats or risks (Baldwin, 1997; Engerer, 2011). But a world of no threats or risks does not and cannot exist: real worlds are characterised by threats and risks. Questions then arise about which threats and risks can be reduced, by whom and at what cost? New developments have led to security referring to issues other than military security (creating fuzzy boundaries). Individuals are faced with threats to their lives, health, property, other assets and their prosperity (e.g. from criminals and terrorists; disease/pandemics and ill health; natural or man-made disasters; economic recessions). Individual threats are additional to threats to nation states (e.g. military threats from other nations; environmental problems originating from other nations) which raises questions about which threats should be handled privately and which publicly. And where threats are handled publicly, which is the most appropriate and least-cost solution? For example, military solutions are appropriate for external military threats whilst internal policing is most appropriate for internal threats from criminals (e.g. physical violence to individuals involving injury and death; robbery). Threats to an individual's state of health require dietary, medical and care solutions (e.g. from doctors and nurses; care homes). Threats to prosperity require government macro- and micro-policies to promote full employment and economic growth (e.g. opportunities for education, training and labour mobility although some of these activities can be funded privately). Technical progress and changing consumer preferences have resulted in shifts from the public provision of security to private protection measures provided and financed by individuals (e.g. private security

guarding; camera surveillance of property; creation of neighbourhood watch schemes providing local club goods).

Security has a geographical dimension. For example, defence can be viewed as a means of protecting a nation's property rights over its land, sea and air space. But a nation's defence forces might also be used to protect other nations' citizens so that the public good becomes international which further increases the problem of obtaining and financing the optimal amount of the international public good (including peace). Overall, security measures can be analysed as national or international public goods, club goods and private goods each with different solutions and each embracing different industries (e.g. security industries; defence industries: Engerer, 2011). These different industries have different customers, products and technologies (Sempere, 2011).

5.2 The Economic Benefits of Defence

Defence contributes to individual and collective security and protection, both of which are valuable commodities. It protects households and their assets, firms and their assets, the national infrastructure, national institutions and national freedoms (e.g. democracy; freedom of speech and movement, etc). It also protects national interests, including independence and 'appropriate sovereignty' (e.g. protecting a nation's interests in a globalised world, including leverage and status in world politics and diplomacy: see below). How can these commodities be valued? There are at least three approaches.

First, estimate a nation's per capita defence spending and then ask whether its citizens are willing to pay at least such a sum for the annual protection offered by its Armed Forces. Comparisons can be made with other public spending programmes, such as health and police forces. Second, value-of-life studies can be used to estimate the valuation of lives saved and injuries avoided resulting from the provision of Armed Forces (Jones-Lee, 1990). Health economists have developed measures of health output in the form of quality adjusted life years or QALYS (but these are not valued). The defence equivalent of QALYS would be protection adjusted life years (PALYS: Hartley, 2010b). In addition to estimating the value of lives saved from defence, there are further gains from valuing the property saved by avoiding damage and destruction (i.e. estimating both human and physical capital saved). Third, consider defence as insurance in response to various current and future known and unknown threats and contingencies. These contingencies involve time-periods of some 25-50 years into the future: the result is lags in the relationship between inputs and defence outputs meaning that defence productivity cannot be based on the standard relationship between inputs and outputs within a calendar year. The insurance approach has private market comparators. Individuals and firms pay for a variety of insurance policies and other forms of protection. Examples include households buying insurance for homes, motor cars, driving, health care, international travel and retirement. In addition, households buy further protection in the form of household security (e.g. alarms; guard dogs), purchasing safer motor cars, locating in a safe neighbourhood and joining neighbourhood watch schemes (through payments-in-kind). Similarly, firms make various insurance payments for protecting their assets; they employ security guards and introduce measures to protect their staffs and assets from terrorist attacks. Admittedly, these are private rather than public goods but nonetheless, the payments in cash and kind provide some indication of the willingness of households and firms to pay for protection: such willingness to pay might then be applied to

estimating the minimum level of a nation's defence spending. Further spending on protection is reflected in expenditure on a nation's police forces and internal security. The result is a substantial expenditure on private and public spending on internal security: again, such sums provide an estimate of the lower bound of national defence spending.

By providing security and protection for a nation's citizens, defence spending and the Armed Forces create the conditions allowing and promoting beneficial voluntary trade and exchange within and between nations. Protection of national property rights over land, sea and air space promotes *national* market exchanges whilst protection of international trade routes promotes beneficial *international* trade and exchange. For example, a nation's navy protects its international shipping and trade routes, including protection from piracy. National and international market exchange contributes to improving society's welfare (e.g. compare a society which lacks well-developed national markets). In the context of national markets, the Armed Forces provide a capability to respond to national emergencies and provide aid to the civil community. Without Armed Forces, the civil powers would have to provide more resources for emergencies (at a cost for providing such capabilities which will only be required infrequently) or ignore such contingencies.

Defence spending and a nation's Armed Forces prevent and avoid conflict and where conflict occurs they seek to minimise its duration and effects on citizens as well as contribute to a rapid post-conflict recovery. In this context, defence provides a deterrent aiming to persuade potential adversaries that conflict is not worthwhile. Where deterrence fails, defence spending aims to provide a war fighting capability to achieve a 'successful' conclusion by minimising the costs of conflict. These features are economic benefits reflected in the cost savings from avoiding conflict or in minimising its duration and contributing to post-conflict recovery and restoration of market activity. Again, it is difficult to measure cost savings for events which do not occur. Indeed, such problems raise the general methodological issue of the counter-factual: what would have happened without a nation's defence spending?

Defence spending provides some direct national economic benefits comprising jobs, technology, spin-offs, exports and import-savings. The Armed Forces are a source of employment, their spending in local areas adds further to employment, and they provide a source of trained and skilled labour for the rest of the economy. In addition, spending on national defence industries further contributes to jobs, advancing technology, spin-offs and the balance of payments. However, these economic benefits need to be assessed critically: there are serious doubts about many of these claimed economic benefits. For economists, a major concern arises over the alternative-use value of the resources employed in the Armed Forces and national defence industries. It needs to be asked whether the resources used in the military-industrial complex would make a greater contribution to jobs, technology, spin-offs and exports if these resources were used elsewhere in the economy (Hartley, 2010b).

Bilateral military alliances might provide additional economic benefits. For example, the US-UK special relationship provides the UK with access to US technology for its nuclear-powered submarines and missiles for its nuclear deterrent; it provides the UK with a leading role in the F-35 programme; and enables major UK defence firms' access to the US defence market (e.g. BAE; Rolls-Royce). Also, the USA provides security and protection for the UK which might otherwise require a larger defence budget. Similarly, Canada benefits from US defence spending and protection leading to lower Canadian defence spending.

5.3 The Non-Economic Benefits of Defence

Defence spending also contributes major non-economic benefits to a nation and it might be that the non-economic benefits are valued more highly than the economic benefits. Non-economic benefits are those which do not contribute to national output. They comprise political, military-strategic and international benefits.

These non-economic benefits include the ability to pursue national interests and foreign policy objectives; adding to a country's international reputation, standing and status in the world (the feel good factor); and its position in the world power hierarchy. These non-economic benefits might be reflected in a nation's position in the United Nations (e.g. membership of the Security Council), its membership of world economic organisations (e.g. OECD; IMF; G-8 and G-20 groups of nations), its leadership positions in international military alliances (e.g. NATO) and its ability to influence the behaviour of other nations. There are military-strategic benefits from bilateral or multilateral military alliances (e.g. benefits from standardisation of equipment and tactics: some of these benefits are economic in the form of cost-savings).

A nation can obtain further non-economic benefits in the form of prestige and international reputation by providing military forces for international peace-keeping and peace enforcement leading to world peace. But such peace-keeping contributions are not costless. Further non-economic benefits arise where a nation's Armed Forces contribute to international efforts on humanitarian aid and disaster relief. These contributions provide a 'feel good' factor for the contributing nation's citizens (e.g. national spending on child protection and social services: Hartley, 2010b).

6 The Evidence: International Experience with Measuring Defence Output

6.1 UK Experience

Before 1998, the UK published traditional input and intermediate measures of its defence output. Typically, these comprised numbers of Armed Forces military personnel and their formations embracing numbers of aircraft squadrons, infantry regiments, tank units and warships. The published data on unit numbers were available in varying degrees of detail (e.g. aircraft squadrons by types of aircraft; types of warships, etc). The amount of published data and its detail has improved over time. Data were also published on the numbers of regular and reserve forces and the numbers of civilian personnel employed by the Ministry of Defence (MoD). During the Cold War, the Armed Forces focused on preparing for and deterring a direct military attack on the UK or Western Europe. After the Cold War, there was no longer a direct military threat to the UK. In 1998 the publication of the Strategic Defence Review (SDR) marked a significant change in published defence output measures.

The 1998 SDR represented a pioneering contribution to UK published data on defence output measures. For the first time, the UK published data on its *defence capabilities* which are a more meaningful indicator of defence output. These defence capabilities are viewed as planning commitments. The 1998 SDR committed the UK to be a ‘force for good’ in the world with an associated world military expeditionary capability. On this basis, the UK Armed Forces were able to support continuing commitments (e.g. Northern Ireland at that time) and be able to:

- i. Respond to a major international crisis of a similar scale and duration to the Gulf War (an armoured division; 26 warships; over 80 combat aircraft); or,
- ii. Undertake a more extended overseas deployment on a lesser scale (e.g. Bosnia) while retaining the ability to mount a second substantial deployment if this were made necessary by a second crisis (e.g. combat brigade and supporting air and naval units). It was not expected that both deployments would involve warfighting or that they would be maintained for longer than six months. One might be a short warfighting deployment; the other an enduring non-warfighting operation (SDR, 1998, p23).

These defence capabilities were subject to various constraints of readiness, location, duration and concurrency. Different levels of readiness involve different cost levels: continued high readiness is costly. Similarly, location and duration affect force requirements: regional conflicts outside the NATO area and for an indefinite duration require different sizes and structures of Armed Forces compared with short-term deployments to, say, Bosnia or Kosovo. SDR identified the core regions of Europe, the Gulf and the Mediterranean. Concurrency is a further issue involving the number of operations which can be conducted at any time involving their scale, location and duration. The UK was committed to conducting two medium scale operations concurrently (SDR, 1998).

Following the 9/11 terrorist attacks on the USA, the 1998 SDR was modified. A modified policy was announced in 2003/04 which comprised Cmnd 6041, 2003; Cmnd 6269, 2004):

- The ability to support three simultaneous small to medium scale operations where at least one is an enduring peace-keeping mission (e.g. Kosovo)². Small scale is defined as the UK's deployment to Macedonia in 2001; medium-scale is Afghanistan (2001); and large scale was operation TELIC (Iraq); or,
- The ability at longer notice to deploy forces for large-scale operations while running a concurrent small scale peace support operation or,
- Ability to project military force to sub-Saharan Africa and South Asia as well as a capability to respond to international terrorism.

The most demanding operations will be conducted as part of a coalition, usually involving the USA. This requires the UK's Armed Forces to be interoperable with US Forces. An announcement that the optimum ratio for prolonged commitments was 3-4 ships and 5 Army and RAF crews/units for each one deployed (Cmnd 6269, 2004). Further changes occurred with the Strategic Defence and Security Review of 2010 (Cmnd 7498, 2010). Following planned budget cuts, the UK's Defence Planning Assumptions and its defence capabilities were reduced to:

- An enduring stabilisation operation around brigade level (up to 6500 personnel) with air and naval support; and,
- One non-enduring complex intervention (up to 2000 personnel) and,
- One non-enduring simple intervention (up to 1000 personnel) or,
 - Alternatively, three non-enduring operations if not already engaged in an enduring operation or,
 - For a limited time, and with sufficient warning, committing all the UK's effort to a one-off intervention with up to three brigades with air and naval support (about 30,000 personnel). This would be about two-thirds of the force deployed to Iraq in 2003.
- Maintaining a 'residual defence capability' for unforeseen emergencies or to reinforce existing operations or to respond to scenarios where the UK acts alone (HCP 992, 2011, p20).

MoD budgets pay for the UK force elements to be ready for operations as outlined in the Defence Planning Assumptions. However, the costs of these missions are funded from the Government's Contingency Reserves. Over time, the rising unit costs of defence equipment and of volunteer military personnel will result in smaller Armed Forces and reduced defence capabilities (as defined by the UK MoD). More important would be an assessment of the costs of achieving these defence capabilities compared with other nations providing similar capabilities (i.e. is the UK providing its capabilities at least-cost?). Within MoD, measures of defence training activities are used to assess performance. These include flying hours, days spent at sea and Army personnel data on gains to trained strength and data on military exercises (ONS, 2008).

² Interestingly, the 2003/04 policy increased the UK's defence capabilities and commitments.

The MoD publishes an annual performance report which offers some further insight into its defence capabilities (HCP 992, 2011). For example, its 2011 Report focused on success in Afghanistan reflected in the costs of operations; the costs of its force elements (e.g. a ship at an annual cost of £28 million; a fixed wing combat aircraft at £6.5 million per year); and the direct costs of Service personnel (£49000 per Service personnel per year: HCP 992, 2011). Useful though such information might be, it is both qualitative and vague (success in Afghanistan) and focuses on input costs which are unhelpful data by themselves. On force readiness, the MoD's Performance Report admits that "Measuring and aggregating readiness is complex, not least because it is based on judgements of what is required to enable the Armed Forces to respond to a wide range of potential challenges"(HCP 992, 2011, p21). MoD reports on where there are 'critical and serious weaknesses' in UK Forces. For 2010/11, the main focus was on the capabilities and force elements used in Afghanistan. Interestingly, MoD's Performance Report included a section on Defence Exports where one aim is to support British industry and jobs (HCP 992, 2011). Defence exports are not an obvious output indicator for the MoD.

The MoD's Performance Report also included a section on implementing the 2010 Strategic Defence and Security Review which provided further information on the interpretation of the UK's defence capabilities. There is a NATO commitment to spend at least 2% of GDP on defence; there is an aim of achieving savings from contract renegotiations with the defence industry; to retain a surface fleet of 19 warships; to reduce the force of main battle tanks by 40%; and to scrap the Nimrod MRA4 fleet (at a saving of some £200 million per aircraft: HCP 992, 2011).

The UK's defence capabilities output measures are an improvement on the traditional input approach but there remain deficiencies at least in terms of publicly available information. For example, the National Audit Office has reported that the UK MoD has a good system for defining, measuring and reporting the readiness of its Armed Forces which compares well with other countries (e.g. Australia; Denmark; USA: NAO, 2005). It is recognised that perfect readiness is too costly. But, the published data on readiness refers to whether there are serious or major weaknesses which are useful but not very illuminating (e.g. without knowing what and where such weaknesses arise and their impact on force effectiveness). A statement that 50% of UK Forces had no serious or critical weaknesses suggests that the remaining 50% of the Forces demonstrated such serious weakness which is a source of concern! Moreover, these performance assessments are undertaken by MoD personnel which could raise questions of objectivity.

A National Audit Office Report on the performance of MoD in 2009-10 presented and reviewed performance indicators (NAO, 2010). This Report focused on financial management information (e.g. management of stocks and assets)) and made no mention of defence output measures. At most, there was a mention of broad defence output indicators. These included qualitative evaluations such as 'success on operations;' whether there were serious and critical weaknesses in readiness; manning levels in relation to manning balance by Service (with no data); and flying hours achieved against targets (again, without any data). In relation to the MoD aim of global and regional reduction in conflict, no output measure was reported by the National Audit Office (NAO, 2010).

The National Audit Office also publishes value for money reports (e.g. on multi-role tanker aircraft capability) and annual reports on MoD's major projects. The project reports assess major defence projects against their contractual commitments on cost, delivery and performance usually

identifying cost overruns, delays and a failure to meet all performance requirements. Such value for money reports are a useful addition to knowledge but they do not include wider industrial and economic benefits of major projects, nor do they provide any assessment of the ‘battle-winning’ performance of defence equipment (e.g. as demonstrated in Afghanistan and Iraq).

Overall, the UK’s defence capabilities are useful measures of defence output but deficiencies remain. Some of the indicators of force readiness are qualitative; readiness is a variable measure depending on circumstances (readiness for what, when and where?); no valuation is placed on each of the capabilities; not all capabilities are identified; and the capabilities cannot be aggregated into a single measure of defence output. None of the output measures address the contribution of defence to conflict prevention and its contribution to minimising the costs of conflict including the saving of lives. In fact, MoD economists have examined the different approaches to capturing output used in various parts of MoD. “These include a number of partial aggregations and a balanced scorecard approach covering the three main areas of activity: success in military tasks, readiness to respond and preparing for the future... and... it was confirmed that no existing technique offered a solution. Although it is hoped that in the longer term progress will be made on the direct measurement of defence outputs and productivity, this remains an elusive goal” (Davies, *et al*, 2011, p399).

6.2 UK Experience in Other Parts of the Public Sector and the Private Sector

Other parts of the UK public sector have addressed the issue of measuring their outputs. Examples include health, education, public order and safety, transport and social protection. The problems of measuring UK public sector outputs were reviewed by Atkinson (2005). This Review started by recognising that government output is generally non-marketed output and it is the absence of market transactions which underlie many of the problems of measuring public sector outputs. The traditional approach used in National Accounts statistics is the output equals input convention (Atkinson, 2005). The Review recognised that in the case of defence it is hard to identify the exact nature of the output (Atkinson, 2005, p12). Some principles were suggested: can we borrow from private sector experience (where the focus is on value-added); and government output should be adjusted for quality changes (which is a problem for defence).

The Atkinson Review reported on experience of output measurement in public sectors such as health, education, public order and safety and social protection. In *health*, it reported on the use of an aggregate output index constructed from separate series such as total numbers of in-patient and day cases. It recognised quality issues where health care embraces saving lives and extending the life span and preventing illness. Here, it reported on the possibilities of using quality measures of health care based on Quality Adjusted Life Years (QALYS). *Education* output was measured by such indicators as examination results and the numbers of full-time school pupils (but numbers fail to reflect attendance). *Public order and safety* embraced police, fire, law courts and prisons. Outputs were measured by such indicators as number of nights spent in prison; fighting fires; and the number of crime-related incidents. *Social protection* includes the residential care of children and adults and output is measured by the numbers in residential care (Atkinson, 2005). Experiences of measuring outputs in these parts of the UK public sector provide some guidance for measuring defence outputs. Measuring health outputs involving saving lives and preventing illness have parallels in defence. The development of QALYS for

health might be extended to defence in the form of Protection Adjusted Life Years (PALYS). Since the Atkinson Review, the Office for National Statistics has continued to develop and improve output measures for various parts of the UK public sector. For example, education output measures are now adjusted for attendance and for quality changes (e.g. annual changes in examination points scores: ONS, 2010). But often the output measures are aggregate indices with no valuation of outputs.

Experience of measuring output in the UK transport sector has addressed a key issue raised in defence, namely, the value of life and the value of lives saved by transport improvements. The value of life is based on a person's willingness to pay (e.g. for good health care; for road safety improvements). On this basis, the UK Department of Transport valued a life at £1.57 millions and a non-fatal serious injury at £176,215 per person (2009/10 prices).

Experience in the UK private sector might provide guidance on the possible valuations to be placed on defence output. In the private sector, individuals and households allocate resources to protection and safety. Examples include insurance policies for protecting property; household security measures (e.g. cameras; fencing; alarms; dogs); car insurance and purchase of safer cars; location of homes in 'safe' areas; and the purchase of private medical and life insurance. In addition, there are public expenditures on protection, including police, fire and rescue services, prisons as well as health care. Expenditures on these 'comparator sectors' provide an indication of society's willingness to pay for various measures of protection.

6.3 Australian Experience

The Defence White Paper of 2009 outlined Australia's defence policy and force structure to 2030 (DoD, 2009). It specified Australia's strategic interests to comprise (ranked in order of priority):

- The defence of Australia against armed attack with the capability to act independently so as not to be reliant on foreign military forces. This principal task requires the Australian Defence Force (ADF) to control the air and sea approaches to Australia.
- The security, stability and cohesion of Australia's immediate neighbourhood which is shared with Indonesia, Papua New Guinea, East Timor, New Zealand and the South Pacific Island states.
- An enduring strategic interest in the stability of the wider Asia-Pacific region;
- A strategic interest in preserving the world international order which restrains aggression and manages other risks and threats and addresses the security impacts of climate change and resource scarcity.

These objectives are to be achieved by Australia acting independently, by leading military coalitions and by making tailored contributions to military coalitions. As a result of these priorities, the ADF of 2030 will need to improve especially its maritime capabilities as well as enhancing its air capabilities. Part of the funding for these capability improvements are to be achieved by efficiencies and savings of AUD \$20 billion which it is claimed will not compromise effectiveness (DoD, 2009, p14). Also, to fund ADF of 2030, the Government has committed to

real growth in the defence budget of 3% to 2017-18 and then 2.2% real growth to 2030 (DoD, 2009, p137). The 2009 White Paper recognises that defence planning is about managing strategic risks, that uncertainties remain and that it is not possible to eliminate all risks (an ideal warning time of 10 years is reported: DoD, 2009, chp3, p28).

The 2009 White Paper deals with preparedness embracing readiness, sustainability and concurrency. It recognises that preparedness comes at a cost (but provides no data on the costs of different levels of preparedness). Sustainability refers to the ability to undertake tasks and operations over time, whilst concurrency deals with the ability to conduct a number of operations in separate locations simultaneously. The White Paper provided an extensive list of the required capabilities of the ADF including:

- the capabilities needed for sea and air control around Australia
- deploy a brigade group for combat operations for a prolonged period of time in the primary operational environment (for shorter period beyond that area)
- deploy a battalion group to a different area of operations in the primary operational environment
- maintain other forces in reserve for short-notice, limited warning missions
- provide tailored contributions to operations in support of Australia's wider strategic interests (e.g. special task forces group)
- provide assistance to civil authorities (e.g. fisheries protection; terrorist incidents; support for major events; emergency responses; humanitarian and disaster relief in Australia and its neighbours; provision of search and rescue support, etc).

The list of capabilities is extensive with no ranking and little indication of the military resources available for each capability. Some of the capabilities are clearly military; others, including aid to civil authorities, are a general 'catch-all' which might be used to justify public support for defence spending. Further data on capabilities is provided by the annual defence budget.

Australian defence budgets show published data on expenditure on various overseas operations, the sources of planned cost savings and capital investment programmes. There are data on the extra costs of overseas operations and on the numbers of military personnel by service (permanent; reserves; numbers of high readiness reserves). Further budget data are presented on planned performance and outcomes for each of three defence outcomes comprising the protection and advancement of Australia's national and strategic interests and support for the Australian community and civil authorities (including expenditure by military base area). Some limited performance indicators are published such as the number of unit ready days for the navy and flying hours for each of the services (DoD,2011).

A review of defence accountability was published in 2011 with the aim of improving accountability across defence (Black, 2011). The review recommended the introduction of specific, measurable and achievable outcomes with individuals given ownership and made accountable for their outcomes. The review recognised that there was a lack of specific outcome-

based language in defence and an insufficient use of measurable outcomes. Particular focus was placed on performance measures for shortfalls in equipment delivery to time, budget and quality (e.g. average delays of 28% or 2+ years; cost overruns of 52%: Black, 2011, p60-61). However, the review focused on management-organisational issues (e.g. too many committees) and not on the development of defence output measures and their consequences.

In June 2011, the Australian Minister for Defence announced a Defence Force Posture Review designed to assess whether the Australian Defence Force (ADF) is correctly positioned geographically to meet Australia's modern and future strategic and security challenges. These include:

- The rise of the Asia-Pacific and the Indian Ocean rim as regions of global strategic significance.
- The growth of military power projection capabilities of the Asia Pacific countries.
- The growing need for the provision of humanitarian assistance and disaster relief following extreme events in the Asia Pacific events; and
- Energy security and security issues associated with expanding offshore resource exploitation in Australia's North West and Northern approaches.

The ADF Force Posture Review will consider how the ADF will support Australia's ability to respond to a range of activities including deployments on overseas missions and operations; support of operations in Australia's wider region; and engagement with the countries of the Asia Pacific and Indian Ocean rim in ways which will help to shape security and strategic circumstances in Australia's interest. The Force Posture Review will also make recommendations on basing options for Force 2030. There is also a Submarine Sustainment Review which will review the sustainment of Australia's Collins Class submarines. Both Reviews are due to be completed by April 2012 (ADF, 2011).

6.4 New Zealand Experience

New Zealand has a considerably smaller defence effort compared with the UK (see Table 1; Hartley 2010b). Nonetheless, it has devoted substantial resources to measuring its defence output. This section describes and assesses the development of its output indicators as published in 1991, 1993 and 2011.

In 1991, the New Zealand Defence Force (NZDF) published defence output measures in its Annual Plan (NZDF, 1991). At this time, the output of the NZDF was grouped into two main categories, namely, retained outputs and current outputs. Retained outputs are the military groupings of operational forces which are retained to provide the Government with a basis of military power from which force may be applied. Current outputs reflect the range of current activities undertaken by the NZDF which reinforce foreign policy goals and contribute to the well-being of the nation. Current outputs were further divided into core (military activities which contribute to military outcomes) and non-core (services provided to the community). Published output data were provided for each of these various outputs. For example, retained outputs

consisted of eleven outputs, namely, naval combat forces; mine countermeasure forces; naval control and protection of shipping organization; strategic assets (force troops); ready reaction forces; infantry brigade group and force maintenance; long-range maritime patrol force; offensive air support force; long and medium-range air transport force; medium and short-range air transport force; and the utility helicopter force. Each output presented performance targets and performance achievements. For example, the performance target for the infantry brigade group required deployment for operations within 90 days and the performance achieved was for such a force to be available for sustained low-level operations at 90 days notice. Offensive air support required 3760 flying hours by Skyhawks but there was a shortfall of over 400 hours against this target.

Changes were made and announced in 1993 (NZDF, 1993). Seven output classes were identified, comprising protection of New Zealand's territorial integrity and sovereignty; the provision of military advice; the provision of intelligence; the provision of ancillary services; the contribution to regional security; mechanisms for participation in defence alliances; and contributions to collective security. Each output class was divided into sub-groups each with performance targets and achievements. For example, the sub-group of countering terrorism had a performance target of two counter-terrorist exercises but only one such exercise was conducted. Similarly, for the sub-group deterring intrusions, there was a performance target of sustaining a naval presence for up to 30 days in the New Zealand area and it was reported that this capability was demonstrated and achieved. Whilst an impressive amount of detail was published, there are serious deficiencies with the outputs reported and performance indicators used. First, the outputs and performance indicators reported are mainly inputs and intermediate measures of output. Second, some of the outputs are strange elements for defence outputs, namely, the provision of advice, intelligence and ancillary services which includes civil defence assistance, support services to the community and ceremonial support for the state. Third, the published data provide no weighting to indicate the relative importance of the various defence outputs. Is the provision of advice and intelligence ranked as highly as protection of New Zealand's territorial integrity and sovereignty? Fourth, some defence outputs might more appropriately be the responsibility of other government departments. Inevitably, defence outputs are refined and developed with time and experience and the New Zealand position at 2011 is summarised in the next section.

The NZDF Statement of Intent (NZDF, 2011) outlines the country's defence policy over the next 25 years. It specifies the primary mission of the NZDF as securing New Zealand against external threat, protection of its sovereign interests and the ability to take action to meet likely contingencies in the country's strategic area of interest. This primary mission recognises that the country's national interests affect both the security and prosperity of the nation. New Zealand must trade to survive which requires that New Zealand has unfettered access throughout the Asia-Pacific region to go about its business. "Instability, conflict and war, even far from New Zealand's shores, can therefore directly affect New Zealand's social and economic well-being" (NZDF, 2011, p9). Recognizing that the primary mission of the NZDF is so broad, a number of subsidiary or intermediate outcomes have been developed.

The NZDF main and intermediate outcomes are currently not linked to a formal set of measures, mainly due to the complexity of measuring outcomes which deliver security and protection: there is no single measure of success in delivering protection. "There is no definitive way of knowing what might have happened, but did not happen, because of the activities of the NZDF" (NZDF, 2011, p34).

The NZDF has 37 outputs within 16 output/expenses classes. Its output expenses classes include naval combat and support forces; mine countermeasures; land combat and support forces; naval helicopter forces; airborne surveillance; and fixed wing and rotary transport forces. Other output categories are strange components to be regarded as defence outputs, including military hydrography, military advice and multi-class output appropriations (e.g. support to youth development; support to military museums: NZDF, 2011). The NZDF also stresses its links with the community reflected in the provision of skills to society, promotion of a 'healthy' defence industry and a "buy New Zealand" procurement policy (NZDF, 2011, p11). However, it is now explained that these links to the community arise as by-products of the NZDF (NZDF, 2011, p11).

The NZDF uses a measure of military capability which shows the combined effect that inputs have on operational effectiveness. Military capability is assessed using two elements, namely, preparedness and force components described by the acronym PRICIE which comprises Personnel; R&D; Infrastructure; Concepts of operations and training; Information/technology; Equipment and logistics (NZDF, 2011, p48).

The NZDF recognises that its output measures appear as inputs rather than outputs. Inputs are used as proxies for military capabilities (e.g. that 500 flying hours of a specific type of aircraft will provide a certain military capability); but the measurement systems and capabilities are classified. However, following the New Zealand Defence Review, concerns were expressed that the current system is input focused and that there is a desire to measure military impacts and outcomes and cross-sector security outcomes. Where complex relationships are involved, it might not be possible to easily identify and measure cause and effect (CAG, 2011). No valuations of output are provided.

6.5 European Experience

The focus is on the major European defence spending nations using English language published data. The nations comprise France, Germany, Italy, Spain and Sweden.

6.5.1 France

A new French defence policy was announced in 2008 with the aim of making French armed forces more flexible for rapid deployment from the Atlantic to the Indian Ocean. France aims to provide the necessary resources to ensure the security of its citizens, to safeguard national independence and consolidate the nation's military and diplomatic power. Under the new policy, France will be able to project 30,000 personnel with 70 combat aircraft, one carrier group and two naval battle groups within a six month period for up to a year (a force capable of dealing with one major war or crisis at a time). Nuclear deterrence remains a key military mission but terrorism is the most immediate threat; and there are public service missions. There will be reductions in the numbers of military personnel and investment in new equipment. Some equipment is of poor quality: for example, only 50% of Leclerc tanks are mission ready; its refuelling aircraft are 45 years old; and some Puma helicopters are 30 years old (Independent, 2008). In 2010, the UK and France agreed an Anglo-French Defence Treaty with the potential for greater bilateral co-operation between their armed forces and defence industries.

6.5.2 Germany

NATO remains the centrepiece of Germany's defence policy. The new defence policy announced in 2011 involves some major changes for Germany's armed forces. There will be reductions in the defence budget; conscription will be abolished to be replaced by an all-volunteer force; Germany's expeditionary capabilities will be improved; and there will be closer military co-operation in Europe, especially in procurement and training (GMOD, 2011). Under the new policy, Germany plans to increase the deployment of the Bundeswehr outside Germany from the current 7,000 to some 10,000 soldiers (but there is no statement of the geographical coverage of these expeditionary forces). There are also plans to reduce the numbers of equipment (aircraft; helicopters; ships).

6.5.3 Italy

Despite possible cuts in defence spending due to Italy's austerity programme, Italy retains an expeditionary capability. Reports suggest that the air force has been particularly affected by defence cuts. There are also reports that Italy is planning to reduce its involvement in peacekeeping missions in the Balkans and possibly in Lebanon, concentrating instead on Afghanistan where force levels peaked at 4000 soldiers (Nativi, 2010).

6.5.4 Spain

Reductions in defence spending were part of the austerity programme. The 2011 budget reflected four objectives: the safety of the troops (via operating and logistics expenditure); operational readiness; the maintenance of weapons systems; and international operations and the fulfilment of Spain's international commitments. New tools were announced for improved oversight and management of defence expenditure.

6.5.5 Sweden

A new defence policy was announced in 2009 with an emphasis on mobility and flexibility of Sweden's armed forces. It plans that an entire operational organisation of some 50,000 people will be used within one week after a decision on heightened alert. In contrast, today only one-third of the national operational organisation is equipped and prepared for an operation within one year. Some defence capabilities were listed in terms of numbers of military personnel (e.g. deployment of 1,700 people for continuous international peace-support operations) and in numbers of Gripen aircraft (100 of the C/D model). The voluntary principle will replace compulsory military service and there will be substantial reserve forces (e.g. four mechanised battalions). Sweden specified its area of national interest, namely, the Baltic Sea or the northern area (SMOD, 2009).

6.5.6 The European Defence Agency

The EDA publishes defence data for its Member States. These include various annual financial data such as levels of defence spending and its share of GDP for Member States; equipment procurement and R&D expenditure; spending on infrastructure and construction; defence

expenditure outsourced; and expenditure on collaborative equipment programmes. There are also data on numbers of military, civilian and internal security personnel and expenditure on personnel, as well as data on numbers of different types of equipment (combat aircraft; tanks; warships). Most of these data are for inputs rather than defence outputs although some EDA officials regard such indicators as number of military personnel as output measures. There are, however, some data which are measures of intermediate output and proxies for defence output, namely, operation and maintenance expenditure, operational costs, average numbers of troops deployed and the average numbers of sustainable (land) forces (EDA, 2011). Comparative analysis of such data for Member States might indicate substantial variations in internal efficiency.

6.5.7 The USA

The USA is different with its global power commitments and large-scale defence spending. US national security strategy requires a ‘comprehensive global engagement aimed at supporting a just and sustainable international order’ (USDOD, 2011, p2-1). The USA remains the only nation able to project and sustain large-scale military operations over extended distances. Its main objectives are to prevail in today’s wars; prevent and deter conflicts; prepare for a wide range of contingencies; and preserve and enhance the all-volunteer force(AVF). Three of these objectives refer to actual and potential threats, but the commitment to the AVF is an input and not a threat! Funding for these objectives is partly from efficiency savings including cancellation of unwanted and poorly performing equipment programmes.

The US DoD publishes a massive amount of data of varying degrees of usefulness. For example, it states its aim of sustaining military capabilities to fight two wars, confront global terrorism and provide humanitarian assistance and disaster relief (but no valuations are given to each of these objectives). It also presents extensive data on performance results relating to its primary warfighting goals and its supporting goals (e.g. preserving the AVF; implementing the defense agenda). It is claimed that 75% of DoD performance goals were met in 2010 with 25% not met: winning our nation’s wars was apparently 100% met even though the final outcomes in Afghanistan and Iraq remain unknown! Similarly, for defence of homeland security, it was reported that 67% of goals were not met which seems a surprisingly high failure rate for such a core defence function (i.e. protecting US citizens: USDOD, 2011, p7-11). Performance results are made by DoD staff who have an obvious interest in the outcomes. Nor does published US defence budget data enhance understanding of its defence outputs in terms of capabilities and their valuations. Budget data show annual expenditure on military personnel, operations and maintenance, R&D and procurement, family housing and military construction, published by totals and by service.

6.6 Evaluating International Experience

None of the nations reviewed in this study addressed the challenges of measuring and valuing defence output. The nearest to an output measure consisted of the identification of various defence capabilities; but these were not always comprehensive. For example, the UK did not identify all its capabilities, including defence of the UK homeland and the nuclear deterrent and no valuations were provided for the various capabilities. Nonetheless, defence capability measures are an improvement on the traditional input measures of numbers of personnel and

equipment. The next challenge is whether various capabilities can be weighted and aggregated into a single index.

7 Conclusion and Policy Recommendations

This study has identified a set of questions arising in efforts to measure defence outputs. Indeed, it has raised more questions than answers; but the process of identifying questions contributes to further understanding needed to address **the central research questions of what is defence output; how can it be valued; and is defence spending a worthwhile investment?**

In its published form, international experience of measuring defence output has found some useful output measures, usually in the form of specific defence capabilities. These are improvements on the traditional emphasis on inputs in the form of numbers of military personnel and equipments (e.g. numbers of combat aircraft, tanks and warships). However, they provide no indication of the value of these defence capabilities nor the value of other capabilities such as peace, protection, deterring conflicts and insurance against future threats. Non-economic benefits rather than measurable economic benefits might dominate the overall benefits of defence spending. Nor should it be assumed that there exists a single 'best' indicator: performance indicators can often give unexpected and perverse results (e.g. the operation was a success but the patient died).

A starting point in answering the central research questions is to **identify the costs of defence and then ask whether defence provides at least a similar level of benefits.** For example, if defence spending costs \$X bn, does it provide benefits of a similar value? Similar questions need to be asked about the costs and benefits of conflict and peacekeeping operations: was the Iraq conflict a worthwhile investment for the USA?

Next, analysis needs to **evaluate the costs and benefits of small (marginal) changes.** If defence spending is increased or decreased by 10% what are the effects on defence outputs (benefits)? Such marginal changes need to be assessed by total and by each military service (e.g. what would be the impacts of a 10% increase or decrease in the size of the Army?).

Specifying the questions is the first stage in any evaluation; **but who raises and answers the questions?** In a democracy, elected politicians are ultimately responsible for determining the size of military expenditure and its allocation between each of the services. Typically, unelected agents dominate these choices. Governments might use representative samples of voters to form **focus groups** which would offer views on the size of alternative defence budgets and force structures. Such groups would be advised by officials and military personnel. Focus groups are not an ideal solution (e.g. free rider problems remain; groups have to be selected and they will have their internal momentum and dynamics) but they provide politicians with an additional mechanism for identifying voter preferences on defence spending and policy.

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List of symbols/abbreviations/acronyms/initialisms

ADF	Australian Defence Force
CAG	Comptroller and Auditor General, New Zealand
CF	Canadian Forces
Cmnd	Command Paper (British Government)
CORA	Centre for Operational Research and Analysis
DND	Department of National Defence
DoD	Department of Defense (United States and/or Australia)
DRDC	Defence Research & Development Canada
EDA	European Defence Agency
FY	Fiscal Year
GMOD	German Ministry of Defence
GDP	Gross Domestic Product
IT	Information Technology
NAO	National Audit Office (United Kingdom)
NZDF	New Zealand Defence Force
OECD	Organization for Economic Cooperation and Development
ONS	Office of National Statistics (United kingdom)
PPP	Purchasing Power Parity
R&D	Research & Development
SMOD	Swedish Ministry of Defence
SIPRI	Stockholm International Peace Research Institute
TCE	Transaction Costs Economics
US	United States

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This Contract Report examines the measurement of defence output from an economics perspective. Economic theory offers some policy guidelines for determining the optimal defence output for any society. As an optimising problem, the economics rule is to aim at the socially desirable or optimal defence output which is achieved by equating additional or marginal costs with additional or marginal benefits. While the economics approach is difficult to 'operationalise' into a set of clear unambiguous policy guidelines, it does provide a framework for designing valuations for defence outputs and activities. Experience of measuring defence outputs is reported for the UK, Australia, New Zealand, a group of European nations and the USA.

Le présent rapport de contrat examine la mesure des extrants en matière de défense d'un point de vue économique. La théorie économique offre certaines lignes directrices stratégiques pour la détermination des extrants optimaux de défense pour toute société. En tant que problème relatif à l'optimisation, la règle d'économie consiste à viser un extrant de défense optimal ou souhaitable sur le plan social qui est réalisé en faisant concorder les coûts supplémentaires ou marginaux avec les avantages supplémentaires ou marginaux. Bien que l'approche économique soit difficile à « opérationnaliser » en une série de lignes directrices stratégiques claires et sans équivoque, elle offre toutefois un cadre pour la conception des évaluations pour les extrants et activités de défense. L'expérience de la mesure des extrants en matière de défense est rapportée pour le Royaume-Uni, l'Australie, la Nouvelle-Zélande, un groupe de nations européennes et les États-Unis.

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Defence Economics, Output Measures, Strategic Planning, Production Functions