Europe Economics

The Economic Case for Investing in Europe's Defence Industry

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1.1 Broad macroeconomic impacts of defence investment

The primary purposes of defence spending are the preservation of peace, the protection of security, the maintenance of safe trade and transport routes, the underpinning of international diplomacy, and the support of the projection of national political values. These primary purposes have profound macroeconomic implications — few countries can flourish economically without secure defence arrangements.

But defence expenditure, like other forms of public spending, has narrower short- to medium-term macroeconomic implications. Cuts to public spending can be vital to making government budgets and debt positions sustainable. But not all spending is the same in its short- to medium-term macroeconomic impacts. Cuts to some forms of government spending are likely to induce larger shifts (often, in the short-term, falls) in GDP than other forms of spending.

In this context, the EDA asked Europe Economics to consider a hypothetical investment of €100m in the EU defence industry and to compare the short- to medium-term impacts of this investment with an equivalent level of investment in other industries.

1.1.1 Multiplier effects

Economists distinguish between the short-term macroeconomic impacts of different forms of spending by estimating what are called "multipliers" — i.e. the multiple by which GDP changes for a given change in spending. Multipliers are defined such that if a GDP multiplier is 1, then for every €100m of spending cut in that area GDP will fall (in the short-term) by €100m; whilst if a GDP multiplier is 0.5, then for every €100m of spending cut in that area GDP will fall (in the short-term) by €50m; and so on.

Where some part of spending will be on imports, a nationally-estimated multiplier may be lower than a globally-estimated multiplier. So, for example, if the delivery of some defence contract in Germany requires the contractor to import an intermediate product from Sweden, the German multiplier will be lower than the EU multiplier.

Similar multipliers can be defined for other macroeconomic variables such as employment, taxation and capital intensity.

1.1.2 GDP impacts

The total impact of an investment in a particular sector is calculated as the sum of the direct and less direct impacts on various different sectors of the economy.

The following table compares multipliers for defence expenditure, for a selection of Member States with significant defence sectors – the Letter of Intent (LOI) countries – and for the EU as a whole, with multipliers for other key sectors of public spending: health; education; and transport.

At the EU level, the GDP multiplier is almost equal across the four sectors, lying between 1.5 and 1.6.

With respect to defence, these estimates show the combined impact of different types of expenditure. Defence expenditure is spread across a range of activities and sectors, such as computers, transport equipment, fabricated metal products, construction, and scientific research. Different forms of defence spending therefore have slightly different short-term macroeconomic implications. With respect to GDP, the largest impacts come from expenditure on Weapons and Ammunition.

In general, at the Member State level, there is a very clear ranking, with education having the highest multiplier, followed by health, transport and defence. When considering multipliers applying within Member States, the differences between sectors are substantial. However, as we can see from the final column on multipliers as they apply across the EU as a whole, not too much should be read into within-Member State multipliers, as sectors significantly vary in terms of their international 'leakages' (often referred to hereafter as "Rest of World" leakages), i.e. the proportion of value added domestically, as opposed to overall, varies substantially in each of these sectors. In general, defence has more linkages with the rest of the world and, since intra-EU trade is not captured in national multipliers, within-Member State multipliers are bound to be lower. By contrast, when we consider the impact on the EU as a whole we see that the multiplier for defence is almost identical to that for other sectors that experience significant public expenditure.

	GDP multipliers of public expenditure changes						
Sector	**DE**	**FR**	**ES**	**IT**	**SE**	**UK**	**EU**
Transport	1.1	1.9	1.3	1.8	1.0	1.8	**1.5**
Education	1.4	2.1	1.8	2.1	1.3	2.0	**1.6**
Health	1.3	2.0	1.6	1.9	1.3	1.9	**1.6**
Defence	0.8	1.3	0.8	1.3	0.7	1.2	**1.6**

Source: Europe Economics' calculations

1.1.3 Tax revenue impacts

At the EU level, the total tax receipts (excluding social contributions) multiplier is nearly identical across the four sectors. The results by LOI Member State are shown below.

	Tax revenue multipliers of public expenditure changes						
Sector	**DE**	**FR**	**ES**	**IT**	**SE**	**UK**	**EU**
Transport	0.3	0.5	0.3	0.5	0.4	0.5	**0.4**
Education	0.3	0.5	0.4	0.6	0.5	0.6	**0.4**
Health	0.3	0.5	0.4	0.5	0.5	0.5	**0.4**
Defence	0.2	0.3	0.2	0.4	0.2	0.3	**0.4**

Source: Europe Economics' calculations

1.1.4 Employment impacts

An investment in the defence sector has employment effects that are comparable to those in the transport and health sectors. It is unsurprising that education has the highest employment multiplier, given its intrinsically high-labour intensity.

At the Member State level, education typically has the highest multiplier. Moreover, in most cases the defence multiplier is the smallest by a fair margin. As with GDP multipliers this is due to the greater international 'leakages' associated with the defence sector at a Member State level.

	Employment multipliers of public expenditure changes						
Sector	**DE**	**FR**	**ES**	**IT**	**SE**	**UK**	**EU**
Transport	16.7	27.6	15.2	26.7	14.3	29.9	**28.5**
Education	28.9	32.4	18.0	40.2	29.3	39.8	**36.4**
Health	26.9	31.1	16.8	33.9	21.2	37.9	**30.9**
Defence	13.8	17.8	18.4	21.9	8.7	18.9	**28.7**

Source: Europe Economics' calculations

1.1.5 Skilled employment

At the EU level, defence has markedly the highest skilled employment multiplier. This is followed by transport, health and education. It is interesting to note that education has the lowest skilled employment multiplier despite having the highest employment multiplier.

The results by Member State are shown below. As above, the greater international 'leakages' associated with the defence sector at a Member State level lead the skilled employment multipliers of some of the other sectors to exceed that of the defence sector for individual countries.

	Skilled employment multipliers of public expenditure changes						
Sector	**DE**	**FR**	**ES**	**IT**	**SE**	**UK**	**EU**
Transport	4.3	6.0	4.2	5.6	2.0	6.6	**2.6**
Education	2.2	5.5	5.7	2.8	2.3	6.4	**3.9**
Health	2.5	5.5	5.1	2.9	2.1	6.2	**4.6**
Defence	2.4	5.7	4.6	2.7	1.5	5.4	**7.6**

Source: Europe Economics' calculations

1.1.6 R&D potential

R&D is classified as a sector in the tables we used to estimate the impacts of an investment in the defence sector. Therefore, the impact of an investment on R&D potential was calculated using exactly the same method as the impact on GDP. The key difference is that the multipliers presented in the table below focus on the R&D sector alone, rather than considering impacts on all sectors of the economy.

At the EU level, investment in defence has by far the largest R&D multiplier. The defence multiplier is between 12 and 20 times the multipliers for the comparison sectors.

	R&D multipliers of public expenditure changes						
Sector	**DE**	**FR**	**ES**	**IT**	**SE**	**UK**	**EU**
Transport	2.2	10.0	3.3	9.2	5.4	6.4	**5.7**
Education	4.6	10.8	3.7	9.0	5.6	7.9	**5.6**
Health	3.4	11.8	4.2	9.0	5.1	8.6	**8.7**
Defence	72.1	131.4	58.1	33.9	52.7	117.4	**111.4**

Source: Europe Economics' calculations

1.1.7 Exports

A statistical comparison of export intensity multipliers between sectors is not possible, because exports are an exogenous final use in the I-O framework and so are invariant to changes in other variables. Therefore, it is impossible to calculate the effects of the investment on exports.

Our approach to this issue is, therefore, qualitative in nature and uses information on the quantity of exports in each comparison sector in conjunction with heuristic arguments to infer the likely effect on exports following investments in these sectors. We then compared this to the estimated effect for the defence sector.

Overall, we find that an investment in the defence sector is likely to have a much greater impact on exports than would an equivalent investment in the transport, education or health sectors.

The transport, education and health sectors tend to export little to countries outside the EU. By contrast, EU defence companies sell arms and ammunition to several countries outside the EU. The EU is a major supplier of arms to many lesser-developed countries and so any investment which would result in a more competitive EU offering could lead to the potential capturing of markets from other major arms suppliers such as the US and Russia. By virtue of being a more geographically open industry, an investment in EU defence is likely to have a much more substantial effect on EU exports than is an equivalent investment in the transport, health or education sectors.

1.1.8 Capital intensity

At the EU level, defence investment would lead to a higher level of consumption of fixed capital than investments in the education and health sectors, but a lower level than investment in the transport sector.

Results for the Member State level analysis are shown below, although data are not available for four of the LOI countries.

	Capital multipliers of public expenditure changes						
Sector	**DE**	**FR**	**ES**	**IT**	**SE**	**UK**	**EU**
Transport	No data	No data	No data	163.7	187.1	No data	**254.1**
Education	No data	No data	No data	198.2	141.1	No data	**171.0**
Health	No data	No data	No data	179.8	137.4	No data	**193.1**
Defence	No data	No data	No data	218.8	89.5	No data	**223.9**

Source: Europe Economics' calculations

1.1.9 Summary of broad macroeconomic impacts

At the EU level, the impacts on GDP, tax and employment of investing €100m in the health, education, transport and defence sectors are extremely similar.

Taking these results alone shows that defence spending has a macroeconomic role alongside other forms of public spending. However, there are several reasons to believe that, in some key dimensions, the overall macroeconomic benefit of investing in the defence sector should exceed that of investing in other sectors.

First, while the employment impacts of investing in the defence sector are broadly equivalent to the impacts of investing in the health and transport sectors, defence investments have a far greater impact on skilled employment than do investments in the other sectors considered in this report. In an increasingly knowledge-based and skills-based European economy, our analysis suggests that investments in the defence sector are more likely to create jobs that will be sustainable in the long term and will add value to the European economy than would equivalent investments in other sectors.

Second, the importance of R&D to the past, current and future success of the European economy is widely acknowledged, and has a sound economic basis in R&D models of endogenous growth. Investments in the defence sector are likely to make a significant contribution to the future economic growth of the EU, due to the significant impact that such investments have on R&D.

The impact on R&D due to defence investments is between 12 and 20 times greater than the impact of investments in the other key components of public expenditure (transport, health and education). Defence R&D can create significant spin-offs and technology transfer to other civil and defence applications. Therefore, the economic impact of investing in the defence sector exceeds that which has been captured in the I-O analysis.

1.2 Unpacking the mechanisms by which defence spending affects the broader economy

To explore in more detail the mechanisms through which defence expenditure converts into broader impacts on GDP, employment, tax revenue, exports and technology transfers to civilian sectors, we set out a series of case studies of specific defence projects:

- Air:
  - JAS Gripen,
  - Dassault Rafale,
  - Eurofighter Typhoon;
- Land – Leopard 2 Main Battle Tank;
- Maritime – Compact naval guns;
- R&T Case Study: Intelligence, Surveillance and Reconnaissance Unmanned Air Systems; and
- Defence aerospace technology transfer and spin-offs.

1.2.1 Lessons

We draw a number of lessons from the case studies:

- Defence spending can take different forms, reflected in the acquisition of Gripen, Rafale and Typhoon (or other types of defence equipment). Studies based solely on the macroeconomic impacts of defence spending, by their blunt nature fail to identify the more detailed microeconomic impacts of such spending.
- There remain considerable opportunities for increasing the efficiency of European collaborative defence equipment programmes. For example, work-sharing for both development and production could be allocated on the basis of competition; a single prime contractor might manage the programme rather than an industrial consortium and committee arrangements; and the number of major-partner nations might be restricted to two partners so as to minimise transaction costs (bilateral collaboration).
- Investment in defence capabilities can sometime produce spectacular economic as well as defence benefits, when a Ministry of Defence identifies a military requirement that is shared by a number of nations, and then commissions a national supplier to develop a cost-effective solution. The resulting export sales, over several decades, far exceed the numbers required for that country's own defence requirements (in the case of Oto Melara's 76mm naval guns, by a factor of three).
- Investments in the EU defence sector can also lead to a significant cost saving relative to the next best alternative. For example, Germany's investment in the Leopard 2 enabled it to equip its cavalry regiments with a highly capable system for a cost that was 45 per cent lower than the next best alternative.

- There is some indicative support for the claim that arguments for defence spending might be based on wider economic and industrial benefits, including technology spin-offs. Further work is necessary to ascertain whether sufficient robust evidence exists to substantiate this.
- Economic spill-overs affect air, land and maritime industrial sectors. While detailed published evidence is lacking on spill-overs by the defence industry sector, some indications suggest that aerospace is a leading spill-over sector.
- EU defence companies appear to earn economic rent on their operations and, in some cases, this rent appears to be substantial.[1] For example, the economic rent earned on exports of Leopard 2s was equivalent to 18 per cent of the cost of the Leopard programme. The earning of economic rent indicates that the sector makes a net contribution to the economy, over and above the contribution that the same resources would make if employed elsewhere. Moreover, our analysis suggests that a significant proportion of this economic rent is earned outside the EU; and so the rent is more than simply a transfer between EU taxpayers and EU defence companies.
- Defence spending can re-purpose resources from the manufacturing sector in general, i.e. from occupations where labour productivity is probably around the sector average, to uses in areas within the defence sector in which productivity is exceptional. In 2010 and 2011, Oto Melara achieved a turnover per employee that was over one-third higher than both that of the industry to which it belongs, and the average for Italian manufacturing.
- Defence investment enables nations to discover solutions that are cost-effective for them. Purchasing defence systems "off-the-shelf" is often advocated as a way of avoiding the enormous development costs and risks of new systems. Whether or not this is the right choice, there is usually a good case for examining this option, as a default position. Sometimes, however, the "shelf" lacks systems that suit a nation's circumstances and defence philosophy. Compact naval guns are such a case. The relatively small ships deployed by European coastal navies require capable, compact and multi-purpose guns. Their absence may have made different types of ships necessary, resulting in a lower level of naval capability or significantly higher costs.
- Although there are clearly some advantages in purchasing non-EU "off-the-shelf" defence products and services in some areas (and such products and services are purchased at present), it should also be recognised that non-EU "off-the-shelf" solutions can have some potentially adverse consequences:
  - For example, the Typhoon was estimated to have created 100,000 high-wage / high-skill jobs, exports valued between €13.4bn and €17.8bn, and import-savings valued between €39.3bn and €67.1bn while maintaining European independence and security of supply. These benefits would be lost if non-EU off-the-shelf solutions were purchased.
  - Purchasing non-EU off-the-shelf solutions could create classic issues of security of future. Absent a sufficient mass of investment in the EU defence industry, skills and capacities could deteriorate; rebuilding these would potentially be slow and expensive. For example, even if the EU were to undertake some work on the Joint Strike Fighter (JSF), it is unlikely that this work alone would be sufficient to maintain the design skills necessary for developing a new European combat aircraft.

As regarding whether defence research is better funded by direct investment in research or by the sellers of defence equipment themselves, we have argued that because, in the defence sector:

- it will often be the case that (a) one buyer (or group of buyers agreeing amongst themselves to all purchase the same technology) will comprise the overwhelming majority of purchases — often the

[1] 'Economic rent' is a factor's earnings in excess of what they could use in the next-best use (their 'opportunity cost'). For example, if an industry's cost of capital is 10 per cent and it earns 20 per cent on capital employed of €1billion, it could be said to earn an annual economic rent of €100m.

national defence agency of the country of the defence supplier; and (b) more fundamentally, other buyers will not purchase a product that has not been endorsed by being purchased by the national defence agency of the country of the defence supplier; and

- the key buyer typically has specific known needs arising from its strategic plans;

it is unsurprising and natural that advanced technology equipment projects research is often buyer-funded in the defence sector.

2 Introduction

The primary purposes of defence spending are the preservation of peace, the protection of security, the underpinning of international diplomacy, and the support of the projection of national political values. These primary purposes have profound macroeconomic implications — few countries can flourish economically without secure defence arrangements.

However, defence expenditure, like other forms of public spending, has narrower short- to medium-term macroeconomic implications. Cuts to public spending can be vital to making government budgets and debt positions sustainable. But not all spending is the same in its short- to medium-term macroeconomic impacts. Cuts to some forms of government spending are likely to induce larger shifts (often, in the short-term, falls) in GDP than other forms of spending.

In this context, the European Defence Agency (EDA) asked Europe Economics to consider a hypothetical investment of €100m in the EU defence industry and to compare the short- to medium-term impacts of this investment with an equivalent level of investment in other industries.

We have employed a range of different methods in this project, so as to provide a rounded analysis of the impacts of investment in the defence sector. Each method is contained within a separate Chapter of this report and is summarised in the following paragraphs.

Estimating short-term macroeconomic effects

We have used Input-Output (I-O) analysis to assess the impacts of a €100m investment on the EU economy. Our approach assumes that the additional investment would be distributed in accordance with past expenditure, and so those activities that have proven to be in demand would receive proportionally more of the additional investment. Our analysis includes impacts on: GDP; tax revenue; employment; skilled employment; R&D; exports and capital intensity.

Our estimates of the impacts of a €100m investment in the defence sector are contained in Chapter 3 of this report, while comparisons with other sectors are in Chapter 4.

Case studies

I-O analysis identifies the macroeconomic impacts of increased defence spending in the European Union. The focus is on economic impacts in terms of GDP, employment, tax revenue, exports and technology transfers to civilian sectors.

We completed six case studies of specific investments, taking a microeconomic approach to identifying the impacts of defence expenditure. The case studies contained in Chapter 5 of this report show the economic impacts of increased defence spending where that spending is reflected in the acquisition of different types of new defence equipment.

Each case study focuses on the economic impacts of the project. Various performance indicators reflecting competitiveness are used including unit prices, delivery dates, output and exports. The defence aerospace case studies also provide an insight into technology transfer (spin-offs) by providing numerous examples of such spin-offs, although we consider that significant opportunities remain for further research in this area.

Defence R&D

One of the defining characteristics of the defence sector is its dynamism. R&D is continually undertaken with the aim of improving both the quality and range of defence equipment and production processes. Chapter 6 of this report considers a number of issues related to defence R&D, using both a theoretical and an empirical approach.

Using the theoretical approach, we explain why the typical funding mechanism for defence R&D is one of buyer-funding rather than the seller-funding model that exists in certain other sectors. We explain the implications of the funding mechanism for private-venture funding in the defence sector.

Using the empirical approach, we report the views of stakeholders on various aspects of defence R&D. The information that is contained within this section of the report was gathered during the course of this project through a stakeholder survey.

Conclusions

The final chapter of this report draws together the different strands of the analysis described above and identifies the key lessons that emerge from this study.

3 Macroeconomic Impacts

The EDA asked Europe Economics to consider a hypothetical investment of €100m in the EU defence industry and to compare the impacts of this investment with an equivalent level of investment in other sectors. We have used I-O analysis to assess the impacts of a €100m investment on the EU economy. I-O analysis is a very simple general-equilibrium model which links various sectors in the economy through fixed linear relationships between the output of a sector and the inputs it requires from other sectors.

The main attraction of I-O analysis is that fixed linear relationships make it possible to calculate the effects of an increase in final demand for one sector on every other sector of the economy and on various macroeconomic variables – GDP, employment, tax revenue, incomes and so on. Another interesting feature is that 'multipliers' may be easily calculated. These 'multipliers' indicate the percentage change in any macroeconomic quantity (GDP, tax revenue, income, employment, etc.) as a result of a unit increase in final demand for a particular sector.[2]

There are, however, two main drawbacks of I-O analysis.

- The reliance on fixed linear relationships assumes no change in production technologies. Consequently, I-O is not accurate when analysing long-run effects. The results of I-O analyses should always be viewed as rough approximations to true short-run effects.
- I-O analysis only produces close approximations when economies are not close to full employment. Close to full employment, the additional resources required to produce extra output would simply not be available.

In the case of the current research, we focus on the short-run impacts of a hypothetical investment and so technological change does not present any difficulties. Furthermore, given the current economic circumstances of the EU, for the purposes of this study we operate on the assumption that no EU economy is currently operating close to full employment.

In preparation for I-O analysis, we divided the €100m defence investment across I-O sectors for all Member States. Appendix 1 describes how we addressed a number of conceptual issues such as defining the defence activities that are covered by the investment, distributing the investment across the participating Member States of the EDA and distributing the expenditure between I-O sectors. A final distribution is also given.

For each macroeconomic variable included in our analysis, we have calculated three kinds of effects:

- Direct effects: These are the first round effects caused by an increase in output of a sector. Direct effects include the increases in output, value added, employment, tax and so on that occur in those sectors that increase their output in order to meet the additional demand.
- Indirect effects: These are caused by all sectors adjusting outputs to allow for an increase in demand for intermediate inputs that would accompany any increase in output by any sector.
- Induced effects: These are the higher order effects caused by the factors of production (including providers of labour, capital and entrepreneurship) spending the additional income arising from the direct and indirect increases in output. An important point to note is that the structure of the I-O

2 We calculate direct, indirect and induced effects. Direct effects occur in the defence I-O sectors that receive additional investment. Indirect effects occur as other sectors adjust to increased demand for intermediate inputs. Induced effects arise as the higher output boosts wages and employees spend their additional income.

tables available from Eurostat does not allow us to calculate induced effects using I-O analysis, and so we have used national income multipliers as the basis for these calculations.

In this section, we report results that include all of these effects. Results excluding induced effects are presented in Appendix 4.[3]

3.1 GDP

3.1.1 Approach

We used the linear relationships inherent in the I-O tables to calculate the impacts of the €100m defence investment on the GDP of each Member State and the EU as a whole. In particular we used the tables as follows.

- To estimate the extra output required of each sector in order to fulfil the direct additional demand due to the investment, we relied on the relationships between sectors inherent in the tables. We also estimated the indirect effects arising from the increase in demand for inputs by various sectors.[4] Given sectoral estimates we simply summed the additional output across all sectors to obtain the total additional output for the Member State.
- To calculate the additional GDP as a result of the investment, we first calculated the proportion of output of each sector that represents value creation.[5] We then used the same proportions to estimate the value added consistent with the increased outputs as a result of the investment.
- To calculate the GDP multiplier due to direct and indirect effects, we simply divided the additional GDP by the additional investment in that Member State.
- The induced effects of an increase in demand (i.e. the impacts of an increase in consumption due to the increase in household incomes associated with an increase in demand) cannot be calculated by using I-O tables because the household sector is regarded as extraneous. We have calculated these effects indirectly using data on income multipliers. To do this, we first estimated income multipliers based on savings and import rates.[6] We then multiplied the GDP effects (excluding induced effects) by the income multipliers to arrive at the total effects (including induced effects). It should be noted that this analysis was conducted only at the Member State and EU levels, not at the sectoral levels.
- The higher order effects of an increase in demand for products of other geographical regions (as represented by 'Rest of World Multipliers') could not be calculated in this study.[7]

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3 Appendix 2 contains a more detailed description of I-O models, and how each of the effects and multipliers are calculated.

4 Technically, the additional output vector was calculated according to the formula $(\boldsymbol{I}-\boldsymbol{A})^{-1} \cdot \boldsymbol{X_D}$, where $\boldsymbol{A}$ is the input coefficients matrix and $\boldsymbol{X_D}$ is the vector of additional demand. See Appendix 2.

5 This proportion was calculated as value added divided by sectoral output.

6 The formula used was $\frac{1}{s+m}$, where s is the gross savings rate (that part of GDP that is not consumed by either the government or the private sector) and m is the import rate (that part of GDP which is spent on imports). The denominator of any multiplier formula contains that part of GDP which does not immediately lead to new value addition in the economy. Savings lead to investment, which leads to capital formation in the future, whereas imports lead to immediate value creation in the rest of the world. The other components of GDP (domestic consumption and exports) lead to direct value creation in the home economy, and are thus not included.

7 'Rest of the world multipliers' operate as follows. An increase in demand in a geographical region increases demand for products from the rest of the world. In turn, this increases demand within countries outside the geographical region that experienced the increase in demand. Assuming that there is two-way trade between

3.1.2 Results

Our calculations suggest that EU GDP would rise in the short term by €156m after taking induced effects into account. This equates to a multiplier of 1.56 when direct, indirect and induced effects are accounted for.

The detailed results by Member State are shown in the table below.

Table 3.1: GDP effects and multipliers by Member State (including induced effects)

Member State	Income multiplier	Increase in GDP (€m) (incl. induced effects)	GDP Multiplier (incl. induced effects)
AT	1.23	0.36	0.45
BE	1.00	0.29	0.35
BG	Not available	Table not available	Table not available
CY	Not available	Table not available	Table not available
CZ	1.32	0.57	0.67
EE	0.93	0.08	0.37
FI	1.78	1.64	0.88
FR	2.19	32.18	1.28
DE	1.49	13.55	0.79
EL	2.75	2.09	0.52
HU	1.02	0.13	0.38
IE	1.16	0.06	0.28
IT	2.18	8.72	1.27
LV	1.34	0.07	0.61
LT	1.23	0.06	0.48
LU	Not available	Table not usable	Table not usable
MT	Not available	Table not available	Table not available
NL	1.20	1.62	0.43
PL	1.79	2.74	0.87
PT	1.88	0.41	0.56
RO	1.58	0.32	0.66
SK	0.99	0.13	0.40
SI	1.14	0.11	0.54
ES	1.89	4.24	0.84
SE	1.45	1.49	0.65
UK	2.24	29.01	1.17
EU-27	**1.62**	**155.98**	**1.56**

Source: Europe Economics' calculations
Note: LU tables are too sparsely populated – several sectors are restricted

We have found that the multipliers for individual Member States are all below that for the EU-27. This is because the Member State level analysis does not take into account the spill-over effects of an increase in demand for products of other EU Member States, while the EU level analysis does.[8]

The income multipliers differ significantly between Member States due to differences in savings and import rates. For example, countries such as Greece and Portugal have high income multipliers because they have low savings rates, while the UK and France have high income multipliers because of relatively low import rates. It is interesting to note that the Member States with a substantially developed defence industry (France, UK, Germany, Spain, Italy and Sweden) have a similar dispersion of multipliers to the other Member States.

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the countries, this will create a feedback effect that results in a further increase in demand in the geographical region which experienced the original boost to demand.

8 More specifically, the input coefficients in the EU-27 table reflect inputs produced anywhere in the EU; whereas in the Member State level tables they reflect only inputs produced in that Member State. The structure of the I-O tables available from Eurostat makes it impossible to include spill-over effects arising from increases in imports at the Member State level. As such, the estimates for Member States in the above table should be regarded as lower bounds.

Countries with high income multipliers generally have high GDP multipliers. However, it should be noted that the positive impact of low savings rates on GDP would apply only in the short term. Countries with lower savings rates also have lower rates of capital formation and investment, and so might face growth constraints in the medium to long term. Therefore, it is possible that short-term increases in income come at the expense of long-term growth in countries with low savings rates. We cannot test this hypothesis here, however, as the estimation of medium- and long-term changes is beyond the scope of this study.

Moreover, it should be noted that this analysis assumes that the same proportion of each sector's output would be imported as at present. However, it would be possible to target the additional investment at domestic / European activities. If this were the case, multipliers would be larger. Such an effect cannot be captured in traditional I-O analysis and so the effects identified in Table 3.1 may be seen as underestimates.

3.2 Tax revenue

3.2.1 Approach

We combined the tax data contained in the I-O tables and supplementary tax data from Eurostat with our results on GDP effects to calculate the impact of the €100m investment on tax revenue.

Our analysis of production taxes proceeded as follows:

- We first divided total production taxes in each sector (including 'taxes less subsidies on production' and 'other net taxes on production') by sectoral output to obtain an estimate of the proportion of the value of output that was appropriated by tax.
- To calculate direct effects, we multiplied these tax rate estimates by the direct increase in sectoral output, i.e. the amount of investment in each sector.
- To calculate indirect effects, we multiplied the tax rate estimates by the direct and indirect increase in sectoral output.

The results of our analysis of production taxes are presented in Appendix 4.

We then moved to our analysis of the effect on total tax receipts. In order to incorporate taxes which do not appear in I-O tables (i.e. income taxes, capital taxes, etc.) we used data from Eurostat on tax receipts as a percentage of GDP. We conducted two sets of calculations, one for total tax receipts and another for total tax receipts plus social contributions.

- We obtained data from Eurostat on tax receipts as a percentage of GDP in the years corresponding to the various national and EU I-O tables.
- To calculate direct effects, we multiplied these percentages by the direct increases in GDP in each Member State and the EU.
- To include indirect effects, we multiplied these percentages by the direct plus indirect increases in GDP in each Member State and the EU.
- To include induced effects, we multiplied these percentages by the total increase in GDP (including induced effects) in each Member State and the EU.

This method is consistent with the assumption that the additional GDP (direct, indirect and induced) has the same composition in terms of tax liability as pre-existing GDP. This assumption is unlikely to be entirely accurate because the direct and indirect GDP increases have a different sectoral composition when compared to pre-existing GDP, which in turn may not have the same tax liability as each other. Therefore, estimates obtained using this method should be regarded as an approximation.[9]

3.2.2 Results (total tax receipts excluding social contributions)

Taking induced effects into account, a €100m investment in the EU defence sector would lead to an increase in total tax receipts (excluding social contributions) by €42m. This is consistent with a multiplier of 0.42, i.e. each euro of investment would add €0.42 to total tax receipts (excluding social contributions).

The detailed results by Member State are shown in the table below.

Table 3.2: Total tax effects (excluding social contributions) and multipliers by Member State (including induced effects)

Member State	Total tax rate (%)	Increase in total tax receipts (€m) (incl. induced effects)	Total tax multiplier (incl. induced effects)
AT	28.4	0.10	0.13
BE	31.1	0.09	0.11
BG	Table not available	Table not available	Table not available
CY	Table not available	Table not available	Table not available
CZ	18.5	0.11	0.12
EE	20.4	0.02	0.08
FI	30.1	0.49	0.26
FR	25.6	8.24	0.33
DE	23.7	3.21	0.19
EL	20.6	0.43	0.11
HU	26.6	0.04	0.10
IE	22.5	0.01	0.06
IT	27.7	2.41	0.35
LV	22.3	0.02	0.14
LT	20.3	0.01	0.10
LU	Table not usable	Table not usable	Table not usable
MT	Table not available	Table not available	Table not available
NL	24.4	0.39	0.10
PL	20.8	0.57	0.18
PT	24.0	0.10	0.13
RO	18.7	0.06	0.12
SK	18.6	0.03	0.08
SI	24.5	0.03	0.13
ES	24.2	1.03	0.20
SE	37.2	0.55	0.24
UK	29.1	8.44	0.34
EU-27	**26.8**	**41.80**	**0.42**

Source: Europe Economics' calculations
Note: LU tables are too sparsely populated – several sectors are restricted

We note that the Member State multipliers are lower than the EU multiplier. Of the Member States with major defence investment, the UK, Italy and France have high multipliers of between 0.33 and 0.35, while Spain and Germany have moderate multipliers of 0.20 and 0.19. The high multipliers for the UK, Italy and France are due to a combination of large GDP effects, high income multipliers and high tax rates. Slovakia has the lowest multiplier, due to a combination of a small GDP multiplier, a

9 A more exact way to calculate the impacts on tax revenue would be to calculate effects within an I-O model where households, capital and government are endogenous sectors. Here, payments by households and owners of capital to government would be regarded as tax, and the effects of income, production and capital taxes could be analysed. However, the structure of Eurostat I-O tables regard households and the government as exogenous, making such analysis infeasible.

low income multiplier and a low tax rate. The Netherlands, Lithuania and Hungary also have small multipliers.

These estimates can be regarded as more accurate in that the additional income generated by the direct and indirect effects is spent according to the same sectoral pattern as existing GDP. Thus, the sectoral composition of additional GDP including induced effects is likely to be closer to that of pre-existing GDP. This would reduce the errors coming from differential sectoral tax rates.

3.2.3 Results (total tax receipts including social contributions)

We have also calculated the effects for a definition of tax receipts that includes social contributions. These are shown in the table below.

Table 3.3: Total tax effects (including social contributions) and multipliers by Member State (including induced effects)

Member State	Total tax rate (%)	Increase in total tax receipts (€m) (incl. induced effects)	Total tax multiplier (incl. induced effects)
AT	44.2	0.16	0.20
BE	47.0	0.14	0.17
BG	Table not available	Table not available	Table not available
CY	Table not available	Table not available	Table not available
CZ	33.4	0.19	0.22
EE	30.7	0.02	0.11
FI	43.0	0.70	0.38
FR	44.1	14.19	0.57
DE	40.2	5.45	0.32
EL	34.0	0.71	0.18
HU	40.4	0.05	0.15
IE	29.9	0.02	0.08
IT	40.3	3.51	0.51
LV	32.9	0.02	0.20
LT	28.7	0.02	0.14
LU	Table not usable	Table not usable	Table not usable
MT	Table not available	Table not available	Table not available
NL	38.9	0.63	0.17
PL	32.8	0.90	0.29
PT	35.9	0.15	0.20
RO	28.8	0.09	0.19
SK	31.5	0.04	0.13
SI	38.9	0.04	0.21
ES	36.7	1.56	0.31
SE	45.9	0.68	0.30
UK	37.4	10.85	0.44
EU-27	**40.4**	**63.02**	**0.63**

Source: Europe Economics' calculations
Note: LU tables are too sparsely populated – several sectors are restricted

3.3 Employment

3.3.1 Approach

We used employment data in conjunction with I-O data and the results of our GDP impacts analysis to estimate the number of jobs created by sector and by Member State. In particular:

- We used Eurostat data on employment by NACE code to derive employment by I-O sector for the year corresponding to the latest available I-O tables for each Member State and the EU-27.

- We then divided total employment by sectoral output (in €m) to obtain the number of domestic workers per €m output.
- We multiplied the additional output (in €m, calculated during the GDP impacts analysis) in each sector and Member State by the number of domestic workers per €m output in order to estimate the number of jobs that would be created.[10] This was estimated for both direct effects (multiplying with direct increases in output) and indirect effects (multiplying with indirect increases in output).
- Induced effects on output were not calculated due to the absence of households from the Eurostat I-O tables. Therefore, a different methodology was required to calculate the induced employment effects:
  - Using national level employment data and data on GDP at current prices from Eurostat, we calculated the number of domestic workers per €m GDP for the year corresponding to the latest available I-O table.
  - We multiplied this figure by the additional GDP due to induced effects in €m to obtain an estimate of the number of additional jobs created due to induced effects.

3.3.2 Results

After accounting for induced effects we find that 2,870 new jobs would be created in the EU as a result of the €100m investment in the defence sector. This equates to a multiplier of 28.7, which means that each €1m invested would create 28.7 jobs.

The results of the Member State level analysis are shown in the table below.

[10] It is important to distinguish between additional employment and jobs created. An increase in employment opportunities would almost always be higher than the actual increase in employment, as those that fill the new jobs might leave another job to do so. Such 'displacement effects' depend on several factors, including the level of unemployment, the mix of skills and so on. Estimating these effects is beyond the scope of the project, and hence they are not taken into account here.

Table 3.4: Employment effects and multipliers by Member State (including induced effects)

Member State	No. of domestic workers per €m GDP	No. of jobs created (incl. induced effects)	Employment multiplier (no. of new jobs per €m investment) (incl. induced effects)
AT	14.5	5.5	7.0
BE	14.0	5.3	6.4
BG	Table not available	Table not available	Table not available
CY	Table not available	Table not available	Table not available
CZ	34.7	22.4	26.0
EE	54.3	4.9	23.1
FI	14.3	26.3	14.1
FR	13.6	447	17.8
DE	15.6	237	13.8
EL	19.8	49.6	12.5
HU	36.8	5.9	16.4
IE	12.0	1.0	5.1
IT	15.7	151	21.9
LV	160	Employment data insufficient	Employment data insufficient
LT	70.3	Employment data insufficient	Employment data insufficient
LU	Table not usable	Table not usable	Table not usable
MT	Table not available	Table not available	Table not available
NL	15.0	24.8	6.6
PL	57.8	16	51.2
PT	30.2	14.7	20.1
RO	67.0	21.8	44.6
SK	57.6	7.7	23.1
SI	33.0	4.3	20.6
ES	20.9	92.5	18.4
SE	13.0	20.0	8.7
UK	15.5	470.1	18.9
EU-27	17.7	2,870	28.7

Source: Europe Economics' calculations
Note: LV and LT employment data are missing for several key investment sectors
Note: LU tables are too sparsely populated – several sectors are restricted

Our results show that there is a wide spread of employment multipliers after induced effects have been accounted for, reflecting the spread in labour productivities and GDP effects. Somewhat unsurprisingly, most jobs would be created in the Member States that receive the highest investment, i.e. the UK, France, Germany and Italy. There would be a disproportionately high number of jobs created in Poland due to that country's relatively low labour productivity.

The fact that the EU level multiplier is relatively high does not mean that as a whole EU workers are unproductive. Rather, this reflects the relatively higher GDP impact at the EU level due to the incorporation of intra-EU trade. Moreover, the fact that the EU employment multiplier is smaller than that of some Member States, despite the EU GDP multiplier being higher than those of all Member States, is because some Member States have labour productivities that are so low relative to the EU average that even a relatively small GDP increase can only be achieved by a relatively large addition to the workforce.

3.4 Skilled employment

3.4.1 Approach

In estimating the impacts on skilled employment, we used data from the EU Labour Force Survey (LFS) on highest levels of education in conjunction with our results on total employment. Our methodology for direct and indirect effects was:

- define skilled employment;
- calculate the percentage of skilled workers in each sector; and
- apply these percentages to the total increases in employment calculated in the previous section.

For induced effects, a similar methodology was followed with percentages being calculated at the Member State and the EU level, and applied to our estimates of induced employment impacts.

Regarding the first step of our methodology, we defined skilled employment as employment that requires at least a tertiary qualification. This coincides with levels five and six in the ISCED 1997 classification.[11] We then assumed, for simplicity, that skilled jobs are filled by skilled workers only (i.e. those with tertiary education) and non-skilled jobs are filled by non-skilled workers only. Then, the proportion of skilled jobs would simply be the proportion of workers with education levels five or six.

The second step of our methodology was more problematic because data on education levels attained by sector are not readily available. Even for Member States with abundant data availability, such as the UK, a cross-tabulation of education levels and economic sectors is not available at a sufficiently granular level. Moreover, although organisations such as CEDEFOP regularly publish material regarding skill levels in Europe, they do so based on EU Labour Force Survey (EU-LFS) micro-data, and a skills level breakdown by I-O sector is not available from CEDEFOP publications. We are aware that the EU-LFS micro-data set contains, for each observation, the highest level of education according to the ISCED 1997 classification as well as the economic activity according to NACE codes. However, access to the EU-LFS micro-data is severely limited.[12]

Given these constraints, it was necessary to adopt the following (second-best) approach based on a simple economic model.[13] We assumed that (i) there are only two types of workers – skilled and unskilled – each with a given level of productivity; and (ii) workers earn wages in proportion to productivity. In such a setup, we can show that productivity at a national level is given by the average of productivities of skilled and unskilled workers, weighted by the proportion of skilled and unskilled workers.

To calibrate the model we gathered the following data:

- Eurostat data on value added per worker in the year of the latest I-O table.
- EU-LFS data on the proportion of workers with tertiary education in the economy, i.e. the proportion of skilled workers.

[11] The International Standard Classification of Education (ISCED) was designed by UNESCO in the early 1970s. For the 1997 classification of education levels, see http://www.unesco.org/education/information/nfsunesco/doc/isced_1997.htm .

[12] According to Eurostat, "Access is in principle restricted to universities, research institutes, national statistical institutes, central banks inside the EU and EEA countries, as well as to the European Central Bank". If an exception cannot be made, then a formal application procedure would take 6 months, which would mean that the data would not be available in time for the completion of the project. See http://epp.eurostat.ec.europa.eu/portal/page/portal/microdata/documents/EN-LFS-MICRODATA.pdf

[13] The model is described in technical detail in Appendix 3.

- Eurostat data on income distribution, which shows the average income earned by those with various levels of education. By assumption, in our model incomes are in proportion with value added per worker. Combined with data from the EU-LFS on the number of workers at each education level, this gave us the relative productivity level of skilled and unskilled workers.

Using these data, and the fact that national productivity is a weighted average of skilled and unskilled productivities in our model, we calculated the absolute levels of skilled and unskilled productivity for each Member State.

We estimated the proportions of highly skilled workers in each sector that are consistent with the sector level productivity (as calculated when analysing employment impacts) while keeping the absolute levels of skilled and unskilled productivity levels constant. The main drawback of this method is the assumption that there are two groups of homogeneous workers, implying two levels of productivity and two levels of income. In reality, we know that there is a wide spread of productivities across sectors, and even within sectors.

Moreover, the share of wages in total value added per worker in a capital-intensive industry might be smaller than that in a labour-intensive industry. It is therefore not surprising that our analysis resulted in numerous cases where actual sector productivity was below the calculated unskilled worker productivity, or above the calculated skilled worker productivity. In such cases, we assumed that the sector comprised entirely unskilled and skilled workers, respectively. Given the abundance of such cases, the estimates should be viewed with caution.[14]

Skilled and unskilled productivities derived from this model are shown in the table below.

[14] More precise estimates for direct and indirect effects could be obtained with access to the EU-LFS micro-data. This problem does not apply to our estimates of induced effects because the actual proportions of skilled workers are easily and reliably available at the national and EU level.

Table 3.5: Estimates of skilled and unskilled productivities

Member State	Proportion of skilled workers	National productivity (€ per worker)	Derived skilled productivity (€ per worker)	Derived unskilled productivity (€ per worker))
AT	18.2%	69,100	86,300	65,300
BE	36.8%	71,600	86,900	62,700
BG	Table not available	Table not available	Table not available	Table not available
CY	Table not available	Table not available	Table not available	Table not available
CZ	17.1%	28,800	38,800	26,800
EE	35.9%	18,400	23,000	15,900
FI	37.9%	70,100	86,100	60,400
FR	32.4%	73,500	92,500	64,500
DE	26.2%	64,200	79,000	58,900
EL	27.6%	50,600	71,500	42,700
HU	23.1%	27,200	36,600	24,400
IE	40.7%	83,600	102,000	71,100
IT	14.7%	63,700	95,500	58,200
LV	19.2%	6,260	1998 data not available	1998 data not available
LT	30.5%	14,200	20,600	11,400
LU	Table not usable	Table not usable	Table not usable	Table not usable
MT	Table not available	Table not available	Table not available	Table not available
NL	32.3%	66,700	81,800	59,500
PL	21.4%	17,300	27,000	14,700
PT	15.2%	33,100	60,700	28,100
RO	14.8%	14,900	27,800	12,700
SK	16.5%	17,400	21,900	16,500
SI	21.7%	30,300	42,700	26,800
ES	32.2%	47,900	63,000	40,800
SE	33.8%	77,000	87,600	71,600
UK	30.7%	64,400	82,300	56,500
EU-27	**26.9%**	**56,400**	**77,000**	**48,800**

Source: Europe Economics' calculations

Note: LV I-O table is for the year 1998, but productivity data are not available for that year

Note: LU tables are too sparsely populated – several sectors are restricted

3.4.2 Results

Including induced effects, 761 skilled jobs would be created across the EU, representing 26.5 per cent of all jobs. This is consistent with a multiplier of 7.61, i.e. each €1m investment in EU defence would create approximately eight skilled jobs. The results of the Member State level analysis are shown in the table below.[15]

[15] These estimates should be treated with some caution, given that we have followed a second-best methodology in absence of access to micro-data. The necessity for such caution is indicated by the fact that our model suggests that several sectors are composed only of skilled or unskilled labour, which is unlikely to be supported by evidence. While these are the best estimates that may be calculated given the data available, they are likely to be less accurate than, for instance, the results on total employment.

Table 3.6: Skilled employment effects and multipliers by Member State (including induced effects)

Member State	No. of skilled jobs created (incl. induced effects)	No. of skilled jobs created as a proportion of total jobs created	Skilled employment multiplier (no. of new skilled jobs per €m investment) (incl. induced effects)
AT	1.4	25.4%	1.8
BE	0.8	14.1%	0.9
BG	Table not available	Table not available	Table not available
CY	Table not available	Table not available	Table not available
CZ	2.9	12.9%	3.4
EE	0.7	14.1%	3.3
FI	6.6	25.1%	3.5
FR	144	32.1%	5.7
DE	42.0	17.8%	2.4
EL	9.9	20.0%	2.5
HU	0.7	12.2%	2.0
IE	0.2	15.6%	0.8
IT	18.4	12.2%	2.7
LV	Employment data insufficient	Employment data insufficient	Employment data insufficient
LT	Employment data insufficient	Employment data insufficient	Employment data insufficient
LU	Table not usable	Table not usable	Table not usable
MT	Table not available	Table not available	Table not available
NL	5.1	20.5%	1.4
PL	37.3	23.2%	11.9
PT	1.9	12.9%	2.6
RO	4.1	19.0%	8.5
SK	1.6	21.1%	4.9
SI	0.7	17.1%	3.5
ES	22.9	24.7%	4.6
SE	3.5	17.3%	1.5
UK	135	28.8%	5.4
EU-27	**761**	**26.5%**	**7.6**

Source: Europe Economics' calculations
Note: LV and LT employment data are missing for several key investment sectors
Note: LU tables are too sparsely populated – several sectors are restricted

Our results suggest that the greatest numbers of jobs are created in those Member States receiving the highest investment, and in Poland. Only Poland and Romania have higher multipliers than the EU-wide figure, owing to relatively low productivity rates.

3.5 R&D

3.5.1 Approach

The direct and indirect additions to value added in the R&D sector were calculated during the process of estimating GDP impacts (where the GDP impacts in each sector were estimated). In order to include induced effects, we first calculated the percentage of national value added accounted for by the R&D sector and then applied this percentage to the additional GDP due to induced effects in each Member State and the EU.

3.5.2 Results

Upon including induced effects, R&D value added would increase by €11.14m. Member State specific results are shown in the table below.

Table 3.7: R&D effects and multipliers by Member State (including induced effects)

Member State	Share of R&D in total value added (%)	Addition to R&D value added (€'000) (incl. induced effects)	R&D multiplier (addition to R&D value added in € per €1,000 investment) (incl. induced effects)
AT	0.5	4.6	5.8
BE	0.7	9.1	10.9
BG	Table not available	Table not available	Table not available
CY	Table not available	Table not available	Table not available
CZ	0.4	20.9	24.3
EE	0.4	1.3	6.2
FI	0.6	31.2	16.8
FR	0.9	3,300	131
DE	0.5	1,240	72.1
EL	0.1	6.0	1.5
HU	0.5	1.9	5.3
IE	0.3	0.1	0.5
IT	0.8	233	33.9
LV	0.3	0.2	2.0
LT	0.0	0.0	0.1
LU	Table not usable	Table not usable	Table not usable
MT	Table not available	Table not available	Table not available
NL	0.4	68.4	18.1
PL	0.4	123	39.1
PT	0.3	11.4	15.6
RO	0.3	4.3	8.7
SK	0.2	3.0	9.1
SI	0.7	15.1	72.3
ES	0.4	292	58.1
SE	1.1	121	52.7
UK	0.5	2,920	117
EU-27	**0.6**	**11,100**	**111**

Source: Europe Economics' calculations

Note: LU tables are too sparsely populated – several sectors are restricted

The bulk of the EU increase in R&D value added would be concentrated in three Member States – France, the UK and Germany. This is both because most R&D investment would take place in these States, and because these States have large and well-developed defence research establishments. This is confirmed by the fact that these three States have three of the four highest national multipliers.

The wide spread in national multipliers arises from the fact that several countries do not spend large portions of their defence spend on R&D.

3.6 Exports

3.6.1 Approach

Since exports are an exogenous final use in the I-O framework they are invariant to changes in other variables, and so it is impossible to calculate the effects of the investment on exports though I-O analysis. We have therefore employed an alternative approach involving econometric analysis of macroeconomic data to determine the relationship between defence exports and defence expenditure.

3.6.1.1 Data

We procured the following data for 81 countries for the years 2000-11.

- Defence export data in $m in 1990 prices from the Arms Trade database.[16] For some of these years, data were missing for several countries.
- Defence expenditure data in $m in 2010 prices from the SIPRI Military Expenditure Database 2011.[17] Again, data were missing for some countries for some of these years.
- GDP data in $ in 2005 prices from the National Accounts Estimates of Main Aggregates, United Nations Statistics Division.[18] Here, data were available for all countries in all years.

The 81 countries included in our master sample are shown in the table below.

Table 3.8: Countries in master sample for export analysis

EU Member States		Others				
Austria	Lithuania	Albania	China	Jordan	Oman	Thailand
Belgium	Luxembourg	Angola	Colombia	Kazakhstan	Pakistan	Turkey
Bulgaria	Malta	Argentina	Costa Rica	Korea, South	Peru	UAE
Czech Rep.	Netherlands	Australia	Croatia	Kyrgyzstan	Philippines	Ukraine
Denmark	Poland	Bahrain	Eritrea	Lebanon	Qatar	Uruguay
Finland	Portugal	Belarus	Georgia	Libya	Russia	Uzbekistan
France	Romania	Bosnia-Herz.	Ghana	Malawi	Saudi Arabia	Venezuela
Germany	Slovakia	Brazil	India	Malaysia	Serbia	Viet Nam
Greece	Spain	Brunei	Indonesia	Moldova	Singapore	Zimbabwe
Hungary	Sweden	Cambodia	Iran	Montenegro	South Africa	USA
Ireland	UK	Canada	Israel	New Zealand	Switzerland	
Italy		Chile	Japan	Norway	Syria	

Data on defence exports were not available within the EU for Cyprus, Estonia, Latvia or Slovenia, hence it was impossible to include them within our sample.

3.6.1.2 Methodology

Our methodology centred on trying to establish a relationship between defence spending and defence exports, and then to use this relationship to determine the effect on exports of a €100m increase in defence expenditure. To do this, we used multiple regression analysis[19] to determine the effects of an increase in defence expenditure on defence exports, controlling for the effects of GDP on defence exports.

The first step in our approach was to convert the three data series (defence exports, defence expenditure and GDP) into a common unit with the same base year. To do this, we converted the GDP figures from $ to $m, and converted defence exports and defence expenditure figures into 2005 prices using price deflator data.

Given that our dataset was in the form of a panel,[20] we employed random effects panel data models. Panel data models exploit variations both across individual countries as well as within the same

[16] http://armstrade.sipri.org/armstrade/page/toplist.php

[17] http://milexdata.sipri.org.

[18] http://data.un.org/Data.aspx?q=gdp+at+constant+price&d=SNAAMA&f=grID%3a102%3bcurrID%3aUSD%3bpcFlag%3a0

[19] Multiple regression analysis is a statistical technique aimed at finding the effects of changes in independent or explanatory variables on dependent variables, controlling for changes in other variables that might affect the dependent variable. The goal is to discover underlying relationships between variables which are consistent with the observed data. For an overview of multiple regression analysis, see any textbook on econometric analysis (e.g. Greene, William H. (2003) *Econometric Analysis*, 5th Edition, New Jersey: Prentice Hall).

[20] In econometric terminology, a dataset is in panel form when there it involves both a cross-sectional as well as a time component. Here, the cross-sectional component was fulfilled by the 81 countries, and the time

country over time to uncover underlying relationships that would have given rise to the data. The use of panel data models specifically allows country-specific effects to be taken into account.

Choosing the correct sample is of the utmost importance, as an implicit assumption in running a regression is that the underlying relationships between variables are the same across the entire sample (unless specifically modelled otherwise). We constructed three samples, and all our regressions were run over these three samples.

- all 81 countries in the master sample;
- the 23 EU Member States in the master sample; and
- the 22 EDA participating Member States in the master sample.

It was impossible to conduct analysis at the individual Member State level due to the fact that the maximum number of data points for any one country was 12, which is not enough for reliable econometric analysis.

All our regressions had the following basic form:

Table 3.9: Basic form of regressions for export effect analysis

Dependent variable	Explanatory variables	Control variables
Defence exports	Defence expenditure Square of defence expenditure	GDP Square of GDP

The inclusion of squared terms aimed to allow for non-linearities in the relationships. While the basic form of the regressions remained the same, we investigated five different models, depending on how the terms were defined.

- Absolute levels: all the variables were defined as absolute levels.
- First differences: here all the variables were defined as the difference between the absolute levels of this period and the previous period. First differencing is beneficial in that it removes any systematic error that is constant within a country.
- Logarithms: all variables were defined as logarithms of absolute levels. This is consistent with a multiplicative relationship between variables rather than the additive relationship consistent with the absolute levels and first differences models.
- Growth rate: all variables were defined as growth rates of absolute levels over the previous period's absolute levels. This is almost exactly equal to first differencing logarithms, which is how the calculations were done in the modelling exercise. Due to first differencing, any country-specific systematic errors would be removed.
- Arellano-Bond: this is a more sophisticated model, where a lag of the dependent variable is also included as an explanatory variable. We applied the Arellano-Bond framework to the growth rate model, so that the growth rate of defence exports could potentially depend not only on the growth rates of defence expenditure and GDP (and their squares), but also on the growth rate of the previous year. This framework allows for the introduction of dynamism, i.e. causal links across time.

In order to evaluate which models were to be chosen for the final analysis, we relied on two main tests.

- Normality of residuals. An important assumption of all the models we used was that the random errors associated with each observation, i.e. the part of the variation in defence exports that

component was fulfilled by the fact that each country had data for up to 12 years. Random effects models allow for each country to have its own idiosyncratic effect on the dependent variable.

cannot be explained by variations in defence expenditure or GDP, are distributed according to the normal distribution.[21] In order to test whether the residual variations in defence exports (after accounting for the part consistent with the relationships uncovered through the regression) were normally distributed, we plotted the distribution of the residuals and visually compared this to the normal distribution.

- Specification of functional form. To test whether the functional form of the model was correct (i.e. multiplicative vs. linear, omission of non-linear terms), we relied on the Ramsey RESET test.[22]

3.6.2 Results

We found that the absolute levels, first differences and logarithms models were inconsistent with the normality of residuals assumption (though the residuals were closer to normal for the EU and pMS sub-samples), and so these were discarded outright. This left the growth rate and Arellano-Bond models. The growth rate model showed residuals close to normal for all three sub-samples, and the Ramsey RESET test indicated that the functional specification was also correct. The Arellano-Bond model also showed residuals close to normal, although the deviation from normal was higher than for the growth models. Moreover, the Arellano-Bond model passed the RESET test only for the EU and pMS sub-samples.[23] However, the additional explanatory variable, i.e. lagged export growth rate, turned out to be a strongly significant determinant of current export growth rate, and so this model was chosen as the central model for results.[24]

At the EU level, the Arellano-Bond model suggests that a one percentage point increase in the growth rate of defence expenditure is associated with a 4.07 percentage point increase in the growth rate of defence exports. Applied to 2005 growth rates (since this is the base year for the export analysis), a €100m increase in defence expenditure is associated with a €16.61m increase in defence exports. The magnitude of the increase in exports would be different when the relationship is applied to data for different years.

The results of the growth rate model at the EU level suggested that a one percentage point increase in the growth rate of defence expenditure is associated with a 2.67 percentage point increase in the growth rate of defence exports. This corresponds to a €10.87m increase in defence exports applied to 2005 figures. However, the result of the growth rate model was weaker, in that it was not

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[21] The normal distribution is a special distribution where a majority of observations are in the vicinity of the mean, and the frequency of observations deviating from the mean reduces as the deviations become larger. The normal distribution is very commonly used in statistics and econometrics because of its abundance in the real world, and the fact that it has several attractive statistical properties.

[22] Ramsey, J.B. (1969) 'Tests for Specification Errors in Classical Linear Least Squares Regression Analysis' *Journal of the Royal Statistical Society*, Series B., Vol 31, No 2, p350–371.

[23] These two would also not have passed if we chose a tighter significance level for the test.

[24] A few caveats to these results need to be outlined:

i) The analysis does not differentiate between intra-EU and extra-EU exports – it is impossible to do so without a breakdown of exports between intra- and extra-EU for each country in each time period.

ii) This analysis is unable to distinguish between the various types of defence expenditure, and as such the implicit assumption is that either (i) the relationship with defence exports holds true for all kinds of defence expenditure, and / or (ii) the investment occurs in the same pattern as defence expenditure in general (i.e. including operations and maintenance and other defence expenditure heads).

iii) Our results should be read as support for correlation, not causation. While it is possible to uncover the relationships between different sets of variables through multiple regression analysis, it is much more difficult to establish the direction of causation. In most cases, the direction of causation comes from economic theory or other logic.

significant at the five per cent level (but only at the 10 per cent level), whereas the result of the Arellano-Bond model was significant at the five per cent level.[25]

Results for the pMS sub-sample were very similar to those for the EU-sub sample.

3.7 Capital intensity

3.7.1 Approach

To estimate the impact on capital intensity, we derived the additional fixed capital that would be required to sustain output increases consistent with those derived in the GDP impacts section. To do this, we relied on data on the consumption of fixed capital (CFC) in the I-O tables.

To calculate direct and indirect effects, we first calculated, for each sector, the percentage of output that was accounted for by CFC by dividing the CFC figure by total output. We then multiplied this figure in each sector with the corresponding direct and indirect output increase as a result of the additional investment.

To calculate induced effects we calculated the proportion of national and EU GDP accounted for by CFC, and multiplied the increase in GDP as a result of induced effects with these percentages for each Member State and the EU.

3.7.2 Results

After including induced effects, the addition to consumption of fixed capital would be €22.39m. This is consistent with a multiplier of 223.88, i.e. a €1,000 investment in European defence would lead to an increase in the consumption of fixed capital by €223.88.

The results of the Member State level analysis are shown in the table below.

[25] The level of significance here refers to the probability incorrectly rejecting the hypothesis that there is no association between the growth rates of defence expenditure and defence export. A lower level of significance makes rejecting the hypothesis harder.

Table 3.10: Capital intensity effects and multipliers by Member State (including induced effects)

Member State	CFC as a proportion of national GDP	Addition to consumption of fixed capital (€000) (incl. induced effects)	Capital intensity multiplier (addition to consumption of fixed capital in € per €1,000 investment) (incl. induced effects)
AT	16.9%	48.5	61.2
BE	17.7%	46.4	55.8
BG	Table not available	Table not available	Table not available
CY	Table not available	Table not available	Table not available
CZ	21.1%	93.9	109
EE	13.9%	7.2	34.4
FI	19.5%	274	147
FR	CFC data not available	CFC data not available	CFC data not available
DE	CFC data not available	CFC data not available	CFC data not available
EL	18.3%	367.2	92.1
HU	17.4%	14.6	40.6
IE	11.6%	6.6	32.2
IT	17.2%	1,500	219
LV	14.9%	8.2	69.7
LT	13.0%	5.9	50.9
LU	Table not usable	Table not usable	Table not usable
MT	Table not available	Table not available	Table not available
NL	17.2%	200	53.1
PL	14.7%	380	121
PT	19.9%	69.3	94.6
RO	CFC data not available	CFC data not available	CFC data not available
SK	21.7%	22.6	67.8
SI	17.7%	16.5	78.8
ES	CFC data not available	CFC data not available	CFC data not available
SE	15.3%	205	89.5
UK	CFC data not available	CFC data not available	CFC data not available
EU-27	**15.6%**	**22,300**	**224**

Source: Europe Economics' calculations
Note: IT I-O table provides aggregate CFC figure; estimates constructed by applying percentage to total GDP effects
Note: LU tables are too sparsely populated – several sectors are restricted

Several Member States do not publish data on the consumption of fixed capital in their input-output tables, including the five biggest recipients of the hypothetical defence investment. Therefore, the value of a Member State level analysis is limited in this case.

However, Italy publishes aggregate consumption of fixed capital even as it does not publish sector-wise consumption of fixed capital. This allowed us to construct an estimate for Italy by first calculating the percentage of GDP attributable to the consumption of fixed capital, and then applying this percentage to the total increase in GDP (including induced effects) in Italy. The resultant estimate places Italy's multiplier a long way above the next best (Finland). The variation in multipliers in general has increased upon taking induced effects into account, due to the varying importance of the consumption of fixed capital in GDP and the varying magnitudes of induced GDP increases.

3.8 Impacts at a sectoral level

All the impacts presented in this section are at the Member State or EU level. The I-O framework allows us to calculate direct and indirect effects by I-O sector. The tables describing these results are extremely detailed and so are not included in this report. However, we would be pleased to provide these results on request.

3.9 Sensitivity analysis

We tested the sensitivity of our results to two kinds of variation – by countries of investment and by sectors of investment.

3.9.1 Geographic scenarios

We considered six scenarios in the geographic sensitivity analysis, each relating to a different set of Member States over which the €100m investment would be divided. These are:

- all Member States;
- UK and FR;
- LOI (DE, ES, FR, IT, SE, UK);
- LOI plus CZ, PL, NL;
- LOI plus Visegrad; and
- Visegrad (PL, CZ, HU, SK).

We followed the methodologies described above for calculating the effects in each scenario. The key point to note is that the distribution across sectors in each case was based on the actual relative defence spending of only the set of Member States receiving investment in each scenario.

The main EU-level multipliers for each scenario are given in the table below.

Table 3.11: Main multipliers in various geographic scenarios

Scenario	GDP	Employ-ment	Skilled employ-ment	Total tax	R&D	Capital intensity
All	1.6	28.7	7.6	0.4	111.4	223.9
UK and FR	1.6	28.2	8.1	0.4	158.6	221.6
LOI (DE, ES, FR, IT, SE, UK)	1.6	28.5	7.8	0.4	128.5	223.1
LOI plus CZ, PL, NL	1.6	28.6	7.7	0.4	121.4	223.5
LOI plus Visegrad	1.6	28.6	7.7	0.4	123.9	223.4
Visegrad (PL, CZ, HU, SK)	1.6	29.4	6.8	0.4	44.2	228.6

Source: Europe Economics' calculations

The main observations are as follows.

- GDP multipliers are similar across all scenarios.
- Employment multipliers are also fairly similar, but slightly higher in scenarios where investment is concentrated in geographic areas with relatively lower labour productivities.
- Skilled employment multipliers are higher in scenarios where investment is concentrated in areas with higher labour productivities.
- Total tax multipliers are similar across all scenarios.
- R&D multipliers are highest when investment is concentrated in areas with historically large investment in defence R&D. The multiplier for the Visegrad scenario is substantially lower than all other scenarios, highlighting the LOI countries' importance as centres for defence R&D.
- Capital intensity multipliers are similar, but show a small tendency to increase as investment is shifted to lesser-developed Member States.

3.9.2 Sectoral scenarios

We considered three scenarios in the sectoral sensitivity analysis where the scenarios differed in terms of the defence sectors to which the investment was allocated. These are

- all;
- weapons and ammunition; and
- construction.

Again, we followed the same methodology as earlier, but divided investment in proportion to historical defence spending of only the sectors receiving investment. For all these scenarios, we assumed that the geographic scenario 'all' applied, i.e. the geographic scope of investment was not restricted.

The main EU-level multipliers for each scenario are given in the table below.

Table 3.12: Main multipliers in various geographic scenarios

Scenario	GDP	Employ-ment	Skilled employ-ment	Total tax	R&D	Capital intensity
All	1.6	28.7	7.6	0.4	111	224
Weapons and ammunition	1.6	29.8	6.4	0.4	8.0	235
Construction	1.6	30.4	5.6	0.4	6.2	247

Source: Europe Economics' calculations

The main observations are as follows.

- GDP multipliers are slightly higher for weapons and ammunition and construction, but the difference is negligible.
- Employment multipliers are also higher when the two sectoral restrictions apply.
- However, skilled employment multipliers fall as employment multipliers rise.
- Total tax multipliers are similar across scenarios.
- R&D multipliers are a lot lower for the two sectoral restrictions. This is mainly due to the complete absence of direct effects in the scenarios with sectoral restrictions.
- Capital intensity multipliers are also higher for the two sectoral restrictions.

4 Comparison with Other Sectors

Comparisons across sectors were carried out by calculating the various multipliers for three other sectors with high levels of public spending, and comparing these to defence. The three sectors chosen were:

- transport services, particularly land transport, as public subsidies in the transport sector are focused mainly on bus and rail;
- public health services; and
- education services.

Each of these areas either corresponds directly, or is a subset of, a single I-O sector in both the NACE Rev. 1.1 and NACE Rev. 2 classification systems. The methodology used was as follows.

- For each type of impact, we calculated the increase that would result from a €1 investment in every sector.[26] This corresponds to the multiplier covering only direct and indirect effects.
- To incorporate induced effects, we employed the same methodology used to calculate induced effects for each type of macroeconomic effect.
- The comparisons were completed for each Member State and for the EU as a whole.

4.1 GDP

At the EU level, the GDP multiplier is almost equal across the four sectors, lying between 1.53 and 1.59. Defence has a slightly higher multiplier than transport, a slightly lower multiplier than education and the same as health. The results by Member State are shown below.

[26] For a technical account of how such multipliers are calculated, see Appendix 2.

Table 4.1: GDP multiplier comparison by Member State

Member State	Transport (land transport services)	Education	Health	Defence
AT	0.75	1.16	1.05	0.45
BE	0.58	0.96	0.83	0.35
BG	No tables available	No tables available	No tables available	No tables available
CY	No tables available	No tables available	No tables available	No tables available
CZ	1.02	1.23	1.06	0.67
EE	0.54	0.81	0.71	0.37
FI	1.41	1.59	1.54	0.88
FR	1.85	2.10	2.02	1.28
DE	1.07	1.39	1.34	0.79
EL	1.91	2.69	2.25	0.52
HU	0.67	0.92	0.80	0.38
IE	0.75	1.03	1.05	0.28
IT	1.76	2.13	1.93	1.27
LV	0.88	1.14	0.99	0.61
LT	1.01	1.13	1.02	0.48
LU	Tables unusable	Tables unusable	Tables unusable	Tables unusable
MT	No tables available	No tables available	No tables available	No tables available
NL	0.91	1.11	1.04	0.43
PL	1.23	1.67	1.55	0.87
PT	1.24	1.79	1.54	0.56
RO	1.29	1.40	1.18	0.66
SK	0.61	0.87	0.75	0.40
SI	0.70	1.03	0.94	0.54
ES	1.34	1.79	1.62	0.84
SE	0.97	1.29	1.26	0.65
UK	1.80	2.04	1.87	1.17
EU-27	**1.53**	**1.59**	**1.56**	**1.56**

Source: Europe Economics' calculations
Note: LU tables are too sparsely populated – several sectors are restricted

In general, there is a very clear ranking at Member State level, with education having the highest multiplier, followed by health, transport and defence. The differences between sectors are substantial. However, not too much should be read into this as the four sectors have varying degrees of 'rest of the world leakages', i.e. the proportion of value added in each of these sectors domestically varies substantially. In general, defence has more linkages with the rest of the world and, since intra-EU trade is not captured in national multipliers, these multipliers are bound to be lower.

It is also worth noting that the multipliers differ between Member States that are economically comparable (e.g. the Baltic states). As per the discussion of GDP effects in Chapter 3, the explanation for this is differences in savings and import rates. For example, Estonia has historically had both a higher saving rate and higher import rate than Latvia and Lithuania. Both of these factors mean that the income multiplier for Estonia is lower than that of the other Baltic states and hence its GDP multipliers are also lower.

4.2 Tax revenue

At the EU level, the total tax receipts (excluding social contributions) multiplier is nearly identical across the four sectors, lying between 0.41 and 0.43. Defence has a slightly higher multiplier than transport, a slightly lower multiplier than education and the same as health. The results by Member State are shown below.

Table 4.2: Total tax revenue (excluding social contributions) multiplier comparison by Member State

Member State	Transport (land transport services)	Education	Health	Defence
AT	0.21	0.33	0.30	0.13
BE	0.18	0.30	0.26	0.11
BG	No tables available	No tables available	No tables available	No tables available
CY	No tables available	No tables available	No tables available	No tables available
CZ	0.19	0.23	0.20	0.12
EE	0.11	0.16	0.15	0.08
FI	0.42	0.48	0.46	0.26
FR	0.47	0.54	0.52	0.33
DE	0.25	0.33	0.32	0.19
EL	0.39	0.55	0.46	0.11
HU	0.18	0.25	0.21	0.10
IE	0.17	0.23	0.24	0.06
IT	0.49	0.59	0.53	0.35
LV	0.20	0.26	0.22	0.14
LT	0.21	0.23	0.21	0.10
LU	Tables unusable	Tables unusable	Tables unusable	Tables unusable
MT	No tables available	No tables available	No tables available	No tables available
NL	0.22	0.27	0.25	0.10
PL	0.26	0.35	0.32	0.18
PT	0.30	0.43	0.37	0.13
RO	0.24	0.26	0.22	0.12
SK	0.11	0.16	0.14	0.08
SI	0.17	0.25	0.23	0.13
ES	0.32	0.43	0.39	0.20
SE	0.36	0.48	0.47	0.24
UK	0.52	0.59	0.54	0.34
EU-27	**0.41**	**0.43**	**0.42**	**0.42**

Source: Europe Economics' calculations
Note: LU tables are too sparsely populated – several sectors are restricted

Again, there is a very clear ranking at the Member State level, with education having the highest multiplier, followed by health, transport and defence. The differences between sectors are substantial. Again, not too much should be read into this, as these multipliers depend directly on the GDP effects, which are sensitive to the extent of 'rest of the world leakages'.

4.3 Employment

Investments in the defence sector have employment effects that are comparable to those in transport and health. The results by Member State are shown below.

Table 4.3: Employment multiplier comparison by Member State

Member State	Transport (land transport services)	Education	Health	Defence
AT	10.83	19.43	19.33	6.99
BE	11.11	21.64	20.23	6.42
BG	No tables available	No tables available	No tables available	No tables available
CY	No tables available	No tables available	No tables available	No tables available
CZ	40.74	57.27	46.34	26.00
EE	33.92	92.13	77.27	23.12
FI	23.38	27.58	27.68	14.13
FR	27.61	32.41	31.13	17.83
DE	16.65	28.86	26.85	13.75
EL	45.67	61.95	47.53	12.45
HU	34.08	59.73	44.97	16.41
IE	15.96	17.29	12.04	5.08
IT	26.67	40.18	33.88	21.92
LV	Employment data insufficient	Employment data insufficient	Employment data insufficient	Employment data insufficient
LT	Employment data insufficient	Employment data insufficient	Employment data insufficient	Employment data insufficient
LU	Tables unusable	Tables unusable	Tables unusable	Tables unusable
MT	No tables available	No tables available	No tables available	No tables available
NL	14.45	22.29	20.06	6.59
PL	73.12	125.69	117.06	51.17
PT	39.75	58.69	43.79	20.08
RO	67.86	103.22	91.45	44.60
SK	25.80	87.98	74.74	23.13
SI	27.15	50.04	36.69	20.62
ES	15.21	17.96	16.82	18.42
SE	14.30	29.33	21.21	8.72
UK	29.92	39.83	37.88	18.89
EU-27	**28.48**	**36.38**	**30.91**	**28.70**

Source: Europe Economics' calculations
Note: LV and LT employment data are missing for several key investment sectors
Note: LU tables are too sparsely populated – several sectors are restricted

At the Member State level, education almost universally has the highest multiplier. Moreover, in most cases the defence multiplier is the smallest by a fair margin; but this is, again, due more to the greater 'rest of the world leakages' associated with the sector at a Member State level.

4.4 Skilled employment

At the EU level, defence has the highest skilled employment multiplier. This is followed by transport, health and education. It is interesting to note that education has the lowest skilled employment multiplier despite having the highest employment multiplier. Again, due to the reliance on the second-best model for estimating skilled employment effects, skilled employment multiplier estimates should be viewed as less precise than other estimates.

The results by Member State are shown below.

Table 4.4: Employment multiplier comparison by Member State

Member State	Transport (land transport services)	Education	Health	Defence
AT	1.22	0.91	1.42	1.78
BE	1.08	0.22	0.92	0.90
BG	No tables available	No tables available	No tables available	No tables available
CY	No tables available	No tables available	No tables available	No tables available
CZ	4.22	2.73	3.27	3.35
EE	3.36	1.45	1.61	3.26
FI	3.93	4.41	4.38	3.54
FR	5.98	5.54	5.52	5.73
DE	4.34	2.23	2.48	2.44
EL	7.89	9.53	9.25	2.48
HU	3.05	1.02	1.95	2.00
IE	1.44	1.05	6.03	0.79
IT	5.57	2.83	2.87	2.68
LV	Employment data insufficient	Employment data insufficient	Employment data insufficient	Employment data insufficient
LT	Employment data insufficient	Employment data insufficient	Employment data insufficient	Employment data insufficient
LU	Tables unusable	Tables unusable	Tables unusable	Tables unusable
MT	No tables available	No tables available	No tables available	No tables available
NL	1.58	1.47	1.47	1.35
PL	13.12	11.35	11.64	11.85
PT	3.78	4.34	9.39	2.59
RO	25.80	9.20	10.81	8.49
SK	22.35	1.23	2.95	4.88
SI	2.45	1.91	2.51	3.52
ES	4.24	5.65	5.10	4.55
SE	1.96	2.28	2.13	1.51
UK	6.61	6.36	6.24	5.43
EU-27	**5.62**	**3.85**	**4.61**	**7.61**

Source: Europe Economics' calculations

Note: LV and LT employment data are missing for several key investment sectors

Note: LU tables are too sparsely populated – several sectors are restricted

Among the comparison sectors, the general ranking of transport, health and education is not universal. This could be due to different employment patterns regarding the proportions of skilled workers in each sector across Member States, but the imprecision introduced by using the second-best model in the absence of micro-data would also probably be an important factor.

4.5 R&D

At the EU level, investment in defence has by far the largest R&D multiplier. The defence multiplier is between 12 and 20 times the multipliers for the comparison sectors. This result is not surprising because a significant portion of investment in defence is channelled directly into the R&D sector leading to the presence of direct effects, whereas investment in the comparison sectors would only generate indirect and induced effects.

Table 4.5: R&D multiplier comparison by Member State

Member State	Transport (land transport services)	Education	Health	Defence
AT	1.46	1.50	1.44	5.76
BE	0.25	0.16	0.86	10.93
BG	No tables available	No tables available	No tables available	No tables available
CY	No tables available	No tables available	No tables available	No tables available
CZ	1.41	1.21	1.47	24.33
EE	-0.04	1.40	0.38	6.19
FI	3.96	4.73	4.37	16.76
FR	10.00	10.83	11.83	131.40
DE	2.16	4.62	3.35	72.06
EL	1.42	4.40	1.92	1.50
HU	1.61	0.64	1.19	5.27
IE	0.55	0.70	1.47	0.52
IT	9.19	9.02	9.02	33.86
LV	1.20	1.21	1.28	2.01
LT	0.18	1.49	1.10	0.11
LU	Tables unusable	Tables unusable	Tables unusable	Tables unusable
MT	No tables available	No tables available	No tables available	No tables available
NL	0.82	1.60	1.01	18.14
PL	3.36	4.01	3.86	39.14
PT	3.03	3.20	5.74	15.23
RO	3.05	5.20	4.71	8.72
SK	0.25	0.14	0.57	9.07
SI	0.99	1.47	1.56	72.28
ES	3.26	3.71	4.21	58.13
SE	5.37	5.63	5.10	52.71
UK	6.44	7.93	8.55	117.35
EU-27	**5.65**	**5.58**	**8.73**	**111.38**

Source: Europe Economics' calculations
Note: LU tables are too sparsely populated – several sectors are restricted

The EU level result is replicated in magnitude at the Member State level, except for countries which invest little or nothing in defence R&D (including Greece, Ireland, Latvia, Lithuania and Romania). The difference between defence and the other sectors is amplified for Slovenia, perhaps indicating that it invests significantly in defence R&D but does not have a strong indigenous R&D sectors otherwise.

4.6 Exports

A statistical comparison of export intensity multipliers between sectors is not possible because of the fact that exports are an exogenous final use in the I-O framework and so are invariant to changes in other variables. Therefore, it is impossible to calculate the effects of the investment on exports though I-O analysis.

While we conducted a separate econometric analysis to estimate the export intensity of the defence industry, similar exercises for the comparison sectors were beyond the scope of this study. We therefore offer a more qualitative comparison, using information on the quantity of exports in each comparison sector in conjunction with heuristic arguments to infer the likely effect on exports following investments in these sectors. We then compare this to the estimated effect for the defence sector.

At the EU level, 3.04 per cent of the output of the land transport sector is exported. The corresponding numbers for the education and health sectors are much lower at 0.31 and 0.05 per cent. We discuss each of these in turn.

- By their very nature, land transport services may only be exported at borders – transport within the EU cannot be exported. Thus, in this sense, the sector is largely 'domestic' when we consider regions rather than individual countries. Any investment in land transport would increase exports from the EU only to the extent that, on the land borders of the EU, EU-based transport services would become better alternatives than non-EU-based transport services. The vast majority of the effect would be felt within the EU, so the export effect of an investment in the land transport sector is likely to be small.

- The education sector is highly domestic and the small amount of exports is, presumably, due to students from outside the EU coming to study within the EU, or due to EU institutions conducting distance-learning programmes. Both of these are most likely to be significant in only the higher education sub-sector. Therefore, any investment in EU education is mostly likely to benefit EU consumers of education services.
- The health sector is almost entirely domestic. Exports could be due to instances of 'medical tourism', i.e. patients from other countries coming to the EU for medical treatment. However, medical tourism is much more prevalent in developing countries that are able to offer significantly cheaper treatments while boasting a reasonably high level of expertise. While medical equipment might have significant exports this is not included in the health services sector, which is the recipient of most public funding. The effects of an investment in the health sector are most likely, therefore, to be felt domestically. While the costs of treatment might be lowered, it is unlikely that they would be lowered enough to attract a significant amount of medical tourism, as €100m is negligible when compared to the size of the health sector.[27]

It is not possible to directly compare these effects to the defence sector export intensity effect estimated in the previous chapter, as that number did not distinguish between intra- and extra-EU trade. However, we understand that the EU defence sector exports a lot more than any of the three comparison sectors. EU defence companies sell arms and ammunition to several countries outside the EU. According to the European Council's Fourteenth Annual Report on the Control of Exports of Military Technology and Equipment,[28] the EU exported arms worth €37.52bn worldwide in 2011.[29] The EU is a major supplier of arms to many lesser-developed countries, and so any investment that would lead to a more competitive EU offering could lead to the potential capturing of markets from other major arms suppliers such as the US and Russia. By virtue of being a more geographically open industry, an investment in EU defence is likely to have a much more substantial effect on EU exports than is an equivalent investment in the transport, health or education sectors.

Looking at country level effects, the picture is more ambiguous than that for the EU as a whole. Table 4.6 shows the percentage of output for each of the comparison sectors that is accounted for by exports.

27 The output of the human health services sector in the EU in 2005 was €881.94bn.

28 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:C:2012:386:0001:0431:EN:

29 This included €7.98bn to the Middle East, €1.2bn to North Africa, €3.59bn to North America, €0.85bn to North East Asia, €0.95bn to Oceania, €1.84bn to other European countries, €0.71bn to South America, €2.46bn to South Asia, €1.78bn to South East Asia and €0.49bn to Sub-Saharan Africa.

Table 4.6: Exports as percentage of total output by Member State

Member State	Transport (land transport services)	Education	Health
AT	31.21%	0.10%	1.08%
BE	10.42%	0.20%	0.09%
BG	No tables available	No tables available	No tables available
CY	No tables available	No tables available	No tables available
CZ	26.81%	0.04%	0.00%
EE	26.06%	0.10%	0.05%
FI	7.85%	0.08%	0.11%
FR	11.80%	0.00%	0.60%
DE	3.19%	0.00%	0.00%
EL	2.94%	0.20%	0.29%
HU	27.02%	0.08%	0.16%
IE	5.00%	0.00%	0.00%
IT	2.38%	0.00%	0.00%
LV	44.41%	1.27%	1.07%
LT	54.73%	0.00%	0.64%
LU	Tables unusable	Tables unusable	Tables unusable
MT	No tables available	No tables available	No tables available
NL	34.61%	3.42%	0.53%
PL	14.13%	0.05%	0.18%
PT	22.07%	0.02%	0.02%
RO	24.39%	0.00%	0.00%
SK	32.14%	0.58%	3.43%
SI	40.71%	0.07%	0.06%
ES	14.10%	0.00%	0.00%
SE	1.38%	0.68%	0.25%
UK	4.10%	1.94%	0.10%
EU-27	**3.04%**	**0.31%**	**0.05%**

Source: Europe Economics' calculations

Note: LU tables are too sparsely populated – several sectors are restricted

The table shows that the shares of exports in the transport sector are sometimes very high, especially for small countries on mainland Europe. This is presumably because the consideration of individual countries rather than the EU as a whole means that the total length of borders has increased, making more transport cross-border in nature. The effect on the exports of individual Member States of an investment in EU transport is extremely ambiguous, as in most cases an increase in exports by one Member State would be at the expense of exports by neighbouring Member States. This is because transport is mostly an undifferentiated commodity on any given route. One could take either a French or a Belgian bus to travel from Lille to Brussels. If the French offering becomes more competitive, then there will be a shift of traffic from Belgian to French buses. This differs from the impacts on a sector such as defence, where more differentiated offerings are available and competition does not occur at such a narrow level.

Education and health services are still predominantly domestic at the Member State level and therefore any investment will generally benefit domestic consumers.

Investments in the defence sector are likely to have a greater impact on the exports of individual Member States than are the comparison sectors. The pattern of EU defence production is generally complementary at the Member State level. For instance, there are very few Member States that can produce sophisticated warships, and so the remaining EU Member States must buy from either these suppliers or from other international suppliers. In 2009, France won export orders worth €8.2bn.[30] In

[30] Annuaire Statistique de la Défense, 2010-11, Secrétariat Général pour l'Administration, Chapitre 4, page 82.

2009 and 2010, Britain won export orders worth £7.3bn and £5.8bn, respectively.[31] In 2010, Germany's total exports of defence equipment to EU countries amounted to €1,528m.[32]

The main difference between the export patterns in the transport and defence sectors are that transport exports are more likely to be to neighbouring countries, and are more likely to exist in equal measure in both directions while defence exports are less balanced and are made irrespective of geographical distance. This, along with imports from the US, is indicative of global rather than regional markets for defence products. Therefore, any investment that makes European firms more competitive would be likely to lead to increased exports, as business would be captured from international competitors rather than just other EU firms.

In conclusion, it seems that both at the EU and Member State level, investment in defence is likely to have a much greater export impact than in any of the three comparison sectors.

4.7 Capital intensity

At the EU level, defence investment would lead to a higher level of consumption of fixed capital than investments in the education and health sectors, but a lower level than investment in the transport sector.

Results for the Member State level analysis are shown below.

31 United Kingdom Defence Statistics 2011, Table 1.13. The Air sector accounted for 68 per cent of 2010 exports.

32 Bericht der Bundesregierung über ihre Exportpolitik für konventionelle Rüstungsgüter im Jahre 2010: Rüstungsexportbericht 2010, seite 38 ("sämtliche Kriegswaffenausfuhren 2010 (kommerziell und BMVg)". Exports by the Bundesministerium für Verteigigung (BMVg) accounted for 2 per cent of total exports in 2010 (page 38).

Table 4.7: Capital intensity multiplier comparison by Member State

Member State	Transport (land transport services)	Education	Health	Defence
AT	225.62	105.64	120.23	61.24
BE	118.75	50.58	102.93	55.82
BG	No tables available	No tables available	No tables available	No tables available
CY	No tables available	No tables available	No tables available	No tables available
CZ	266.65	259.83	143.26	109.24
EE	100.15	65.44	55.28	34.37
FI	246.42	242.31	207.53	146.86
FR	CFC data not available	CFC data not available	CFC data not available	CFC data not available
DE	CFC data not available	CFC data not available	CFC data not available	CFC data not available
EL	441.16	378.74	324.72	92.11
HU	126.47	103.74	64.88	40.64
IE	121.31	58.27	52.07	32.22
IT	163.72	198.19	179.80	218.77
LV	198.06	111.40	139.93	69.70
LT	147.65	122.35	136.19	50.94
LU	Tables unusable	Tables unusable	Tables unusable	Tables unusable
MT	No tables available	No tables available	No tables available	No tables available
NL	143.32	141.26	80.29	53.08
PL	220.54	168.80	171.85	120.69
PT	284.45	228.68	215.17	94.49
RO	CFC data not available	CFC data not available	CFC data not available	CFC data not available
SK	182.29	71.88	134.21	67.76
SI	147.99	79.62	92.58	78.76
ES	CFC data not available	CFC data not available	CFC data not available	CFC data not available
SE	187.12	141.14	137.38	89.45
UK	CFC data not available	CFC data not available	CFC data not available	CFC data not available
EU-27	**254.08**	**170.97**	**193.10**	**223.88**

Source: Europe Economics' calculations
Note: LU tables are too sparsely populated – several sectors are restricted

The transport sector has the highest multiplier among the comparison sectors almost universally. Moreover, the defence multipliers are generally the smallest, but not too much should be read into this considering the high level of 'rest of the world leakages' in the sector.

5 Case Studies - Unpacking how defence spending affects the broader economy

5.1 The contribution of these case studies

In this section we explore in more detail the mechanisms through which defence expenditure converts into broader impacts on GDP, employment, tax revenue, exports and technology transfers to civilian sectors, by setting out a series of case studies of specific defence projects.

Various performance indicators reflecting competitiveness are used including unit prices, delivery dates, output and exports. Only published data are available some of which might be unreliable, especially data on prices and the military-operational performance of the various combat aircraft.

Project case studies are also valuable in providing insights to technology transfer (spin-offs) arising from aircraft programmes. Numerous examples are presented of such spin-offs, although there remain major opportunities for further research in this area.

The case studies also identify the major prime contractors whose financial performance can be assessed. Firm performance indicators include labour productivity and profitability, and comparisons can be made between the military aerospace firms and non-defence firms.

An economic evaluation of specific cases will consider their costs and benefits, as well as the costs and benefits of competitor products. Costs include acquisition and operational costs over the project's life-cycle. Benefits include the contribution of the equipment to national defence as reflected in security, protection, deterrence and peace.

A challenge for our analysis lies in the fact that defence output is difficult to measure, and typically it is assumed that output equals inputs. Since that approach ignores entirely the impact of productivity, it is not a satisfactory way to measure defence output. In addition to national defence output, military aircraft contribute to wider economic and industrial benefits reflected in jobs, technology and exports. Ideally, these wider economic benefits need to be included in any economic evaluation of new defence equipment and we attempt to reflect at least a significant portion of such wider benefits for each case considered in this section.

5.2 Cases Studied

The cases studied in this section are as follows:

- Air:
  - JAS Gripen;
  - Dassault Rafale; and
  - Eurofighter Typhoon.
- Land – Leopard 2 Main Battle Tank;
- Maritime – Compact naval guns;

- R&T Case Study: Intelligence, Surveillance and Reconnaissance Unmanned Air Systems; and
- Defence aerospace technology transfer and spin-offs.

5.3 Air – JAS Gripen

The JAS 39 Gripen is a Swedish multi-role affordable lightweight fighter aircraft. Gripen was designed to replace the Swedish Saab Draken and Saab Viggen. It is a single-seat and single-engine multi-purpose combat aircraft for which initial development work started in June 1980. The initial Swedish air force contract was awarded in June 1982 for five prototypes and 30 production aircraft with options for the next 110 aircraft. Gripen was designed to be a small and relatively cheap multipurpose aircraft, with half the weight of the previous third generation Viggen and greater operational capability at only 60-65 per cent of the life-time cost of the Viggen.[33]

The contract for the Gripen specified its performance characteristics, costs and delivery schedules with the consortium partners guaranteeing the contract. The contract was for a fixed price with variation of price clauses (with the Swedish procurement agency accepting the foreign exchange risk). Previously, Swedish defence contracts were cost-plus contracts with separately negotiated charges for modifications. Saab was the prime contractor and systems integrator for the Gripen which involved the company in substantial risk-taking: some of these technical and financial risks were shifted to its sub-contractors. The major sub-contractors included Volvo Aero for the engine; Ericsson for the radar and flight control system; BAE Systems for the fuselage and wing; Martin Baker (UK) for the ejector seat; and other French, UK and US firms also acted as sub-contractors (note the absence of Swedish sub-contractors who were reluctant to accept the risks of the project: Eliasson, 2010, Supplement I).

Sweden ordered a total of 204 Gripen aircraft with the final aircraft delivered in late November 2008.[34] In relation to the contract, Gripen was delivered ahead of time and at a lower cost than estimated. Such a performance is unusual for major defence projects which are usually characterised by substantial cost overruns and delays in delivery. In addition to sales to Sweden, Gripen has been exported to South Africa, the Czech Republic, Hungary, Thailand and Switzerland (see Table 5.1).

5.3.1 Costs and sales of Gripen

Published data on development and production costs for combat aircraft are often unreliable and Gripen is no exception. Various estimates suggest its development costs ranged from €2.3bn to €10bn, with unit production costs varying between €35.5m and €67.5m at 2012 prices. In terms of opportunity costs, Gripen at the peak of the programme employed 6,000 engineers; but Eliasson (2010) claims that its spill-overs were so large that there was no net cost to society of the project: in fact, it is claimed that in net terms society benefited from the Gripen development (even setting aside the security gains).

Table 5.1 presents some of the features of the Gripen programme, including its contractors, performance, timescales, output and exports.

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33 Eliasson, G (2010). *Advanced Public Procurement as Industrial Policy: Aircraft Industry as a Technical University*, Springer Sciences and Business Media, New York.

34 In 2004, Sweden operated 200+ Gripen. After 2008, the Swedish Air Force operated 100 Gripen and reports suggest that in future, it will equip with some 60 Gripen Next Generation (NG).

Table 5.1: Major features of Gripen multi-role fighter aircraft

Contractors	**Aircraft performance**
Prime: Saab	Speed: Mach 2
Major suppliers:	Combat radius: 497 miles
Volvo Aero	Single seat
Ericsson	Single engine
Timescales	**Dates**
Start of funded development work	June 1980
Programme approved	6 May 1982
Initial contract for 5 prototypes	June 1982
First flight	9[t]December 1988
Initial operating capability (IOC)	September 1997
Development timescales	**Total months**
Total time from start to first flight	102
Time from programme approval to first flight	79
Time from start to IOC	207
Time from approval to IOC	184
Output	**Number of units**
Sweden	204
South Africa	26
Switzerland	22
Thailand	6
Hungary (lease)	14
Czech Republic (lease)	14
TOTAL (excluding leases)	**258**

Notes: Next Generation Gripen was ordered in early 2013. It involves the modification of existing Gripen aircraft operated by the Swedish Air Force. Leased aircraft were leased from Sweden: hence, their numbers are deducted from the Sweden total and reflected in the aggregate total. Output figures include orders and are at March 2013. The order for Switzerland awaits confirmation at April 2013. Where no exact dates are available, it was assumed that the relevant date was the middle of the month.

5.3.2 An Economic Evaluation of the Gripen

Gripen was developed as a relatively cheap multi-role combat aircraft. It was designed for the specific operational requirements of the Swedish Air Force (e.g. short take-off and landing; simple maintenance requirements; rapid turn-around between missions; multi-role, etc). At the time of the original procurement choice for Gripen, how did its unit costs compare with the next-best alternative combat aircraft? Table 5.2 shows some comparators.

Table 5.2: Gripen and rival aircraft unit prices, 2011-12

Aircraft	**Unit production cost (€m, 2011 prices)**	**Operational costs (€ per flying hour, 2012 prices)**
Gripen	60.1	3,620
Rafale	62.0	12,705
Typhoon	85.0	13,860
F-16	26.4	5,390
F-18E/F	60.0	8,470 to 18,480
F-35	144.4	23,870

Sources: Hartley, *White Elephants?* New Directions, Brussels, 2012; Janes, *All the World's Aircraft*, 2012; and StratPost, July, 2012.

The US F-16 is considerably cheaper than the Gripen on unit acquisition costs but more expensive on operational costs, and it is not suited to Sweden's operational requirements. Also, the F-16 was introduced in 1978 whereas Gripen was introduced in 1997, so the F-16 is probably not a valid comparator.

More suitable comparators include the US F-18E/F and the French Rafale which had similar unit production costs but both were costlier to operate. On a purely cost basis, the Swedish Gripen was a least-cost purchase.[35]

Gripen also provided Sweden and other European countries with wider benefits such as jobs, exports, technology and spin-offs, tax revenue, independence, security of supply and so on. Such benefits would have been 'lost' with the acquisition of a foreign aircraft. Additional economic benefits have been derived from the 82 export sales of Gripen (including leased aircraft).

5.3.3 The Technology Contribution of Gripen

The technology contribution of Gripen is well-documented.[36] Three findings are relevant to an economic analysis of the Gripen project.

First, Sweden views its aircraft industry as an advanced technical university that provides research, education and training services free of charge to other firms and related industries.

Second, Eliasson argues that the capacity to develop a complete military aircraft combat system or a large commercial airliner and the associated systems is an extremely scarce industrial competence. This skill is only available in possibly six nations, namely, France; the UK; Russia; the USA; and possibly China and Sweden.

Third, Gripen has generated numerous spill-overs, including:

- general engineering technologies;
- critical software engineering;
- systems integration;
- development of lightweight structure technologies;
- medical spin-offs;
- unmanned aircraft;
- space –e.g. cheap satellites;
- technology transfer to industrialising economies (e.g. as part of the sale of Gripen to South Africa, Saab agreed that South African engineers would work at Saab for periods of 6 months to 2 years);
- maintenance of advanced Swedish producers of civilian aircraft and aircraft engine subsystems for international markets (Saab and Volvo); and
- further examples of Gripen's spill-overs include telephone systems, civil security, heavy trucks, engines and automobiles.

Estimates have been made of Gripen's spill-over effects. Spill-over multipliers are additional returns to society of a particular military investment over and above the value of the product being developed as a multiple of the original investment (in constant prices and present value terms). The spill-overs from Gripen are estimated at 188bn to 344bn SEK based on a total programme cost for Gripen of 124bn SEK (2007 prices).[37] Eliasson concludes that it is "difficult, probably impossible, to find another industry in the markets for public goods and services that rivals military aircraft in generating spillovers".[38]

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[35] The issue of operational performance in relation to military requirements is not considered here.

[36] See Eliasson, G (2010), *Advanced Public Procurement as Industrial Policy: Aircraft Industry as a Technical University*, Springer Science and Business Media, New York. Eliasson provides the basis for this section.

[37] Eliasson, 2010

[38] Eliasson, 2010, p36

5.3.4 Performance of Saab Company

The annual Company Reports for Saab allow a comparative assessment of its performance on aerospace and other divisions of the Company. Two performance indicators are used, namely, productivity and profitability. The key question for our purposes is whether Saab's defence business is more successful than alternative uses of its resources. In the event, this apparently simple exercise shows the problems of testing such a hypothesis.

Table 5.3 presents the performance results for all Saab Company divisions.

Table 5.3: Saab company performance, 2012

Company division	Sales (€m)	Employment (full-time equivalent)	Labour productivity (€000s)	Profitability (%)	Defence sales (% of total sales)	Export sales (%)
Aeronautics	728	2,932	248	5.9	83	39
Dynamics	572	1,568	365	13.0	92	88
Electronic defence systems	512	2,578	199	2.7	98	76
Security and defence solutions	716	3,105	231	7.0	71	76
Support and services	409	1,805	226	12.0	78	29
Combitech	169	1,245	136	8.7	51	3
Whole company	2,876	13,900	207	8.5 (14.2)	Not available	Not available

Source: Saab Company Report, 2012

Notes: Labour productivity is sales divided by employment. Profitability is operating margin which is operating income as a percentage of sales. Under profitability, figure in brackets is return on capital employed for the Company as a group.

Aeronautics comprises sales of Gripen, UAVs and components for Saab and other aircraft (Airbus; Boeing). Dynamics comprises missiles, torpedoes, etc. Electronic Defence Systems comprises radar, electronic warfare and data links. Security and Defence Solutions comprises C4R, AEW and civil security. Support and Services is for markets where Saab is active. Combitech is a consulting firm.

Compared with the Company average, the Aeronautics division has a higher labour productivity but lower profitability. The Dynamics and Electronics divisions are more defence-intensive, with almost 100 per cent defence sales. The productivity and profitability results for these two divisions differed markedly, with the Dynamics division substantially above and Electronics substantially below the Company averages for productivity and profitability. Various rank correlations were estimated between productivity, profitability, the defence/civil split and export shares, but none was statistically significant.[39] The absence of reliable correlations probably reflects the small sample size (six observations). Overall, the evidence from Saab is suggestive rather than conclusive.

5.4 Air – Dassault Rafale

The Rafale is a French twin-engine, delta-wing, multi-role combat aircraft manufactured by Dassault Aviation. There are single-seat and two-seat variants for the French Air Force (Rafale A and B models) and a carrier-based variant for the French Navy (Rafale M and N models).

It is claimed to differ from other current European combat aircraft in that it is built almost entirely by one country, involving most of France's major defence contractors such as Dassault, Thales and Safran. There is a network of 500 sub-contractors. Estimates suggest that the programme employs 7,000

[39] The following Spearman rank correlations were estimated: productivity and profitability gave r= +0.31; profitability and defence/civil split r= --0.26; productivity and defence/civil split gave r= +0.37; for productivity and export shares, r= +0.57; and for profitability and export shares, r= --0.11.

workers although this appears a low figure and might apply to employment at Dassault only.[40] There is an annual production rate of 11 aircraft; each aircraft takes 24 months to build.

Rafale was planned to replace the Jaguar, Crusader, Mirage, Entendard and Super Entard operated by the French Armed Forces. Initially, in 1979, Dassault joined the UK-German European Combat Aircraft project which developed into the 5-nation Future European Fighter Aircraft project (with Italy and Spain). By 1985, France had withdrawn from the project to pursue its own national programme. The French withdrawal was due to differences in operational requirements, including its requirement for a carrier-capable version and its demand for a leading role in project management. Next, in October 1982, Dassault was awarded a contract to build a technology demonstrator which became the Rafale A which first flew in July 1986. In April 1988, the French government awarded Dassault a contract for four Rafale prototypes. At the time, there was a planned requirement for 330 Rafales and the aircraft was expected to enter service in 1996. The end of the Cold War and reductions in the French defence budget, together with political and economic uncertainties, resulted in considerable delays to the Rafale's development time. The prototype Rafale C model flew in May 1991 and the first squadron of Rafale M for the Navy was formed in May 2001 (Rafales for the French Air Force were delivered several years later in 2006). At December 2011, a total of 180 Rafale aircraft had been ordered for the French Air Force and Navy.

5.4.1 Costs and sales of Rafale

Various estimates of unit procurement costs in 2012 prices range from €57.1m (Rafale C version) to €62.4m (Rafale M version) to €105.25m (Rafale F3 version). In 2012, Rafale was awarded an export contract to India for 126 aircraft comprising 18 aircraft supplied by Dassault with the remaining 108 aircraft manufactured in India. The total value of the Indian contract was €8bn, giving a unit cost of €63.5m (2012 prices).

Table 5.4: Major features of Rafale multi-role combat aircraft

Contractors	**Aircraft performance**
***Prime*: Dassault Aviation**	Speed: Mach 1.8
Major Suppliers:	Combat radius: 655-1,093 mls
Safran/SNECMA	Single/two seat
Thales	Twin engine
Timescales	**Dates**
Start of technology demonstrator	October 1982
Contract for 4 prototypes	April 1988
First flight Rafale C	May 1991
Entry to service (IOC: Navy version)	June 2001
Development timescales	**Total months**
Total time from start to first flight	103
Time from contract to first flight	37
Time from start to service entry	224
Time from contract to service entry	158
Output	**Numbers**
France	180
India	126
Total	**306**

Note: Output and export data at April 2013. The Indian order awaits confirmation.

5.4.2 An Economic Evaluation of Rafale

Both Rafale and Gripen demonstrate that France and Sweden were capable of the independent national development of a modern combat aircraft. Compared with the Swedish Gripen, the French

[40] This employment estimate is low compared with Typhoon employment. Also, total employment at Dassault in 2012 was 11.472 employees comprising all activities (Rafale and civil aircraft production).

Rafale started later and was in service much later. Rafale achieved shorter development times to its first flight but required longer from start to service entry. Development timescales based on specific points in the development cycle obviously need to be interpreted with caution, since aircraft can differ in their operational status at first flight and at service entry (e.g. at first flight, the aircraft might lack its avionics and its design engine).

Compared with Gripen, the Rafale had a higher unit cost and operational cost (see Table 5.2). However, in terms of international competitiveness, Rafale has achieved higher total exports and a higher proportion of its output has been exported (41 per cent for Rafale compared with 32 per cent for Gripen).

5.4.3 The Technology Contribution of Rafale

A French study has considered spin-offs from the Rafale project.[41] The study separated the Rafale programme into eleven building blocks ("briques") and then mapped them into the eight broadly-defined technologies that were judged by the Ministry of Industry (in 2008) to be key to the French economy in 2010. Like many other studies in this field, there is an impressive list of technologies and spin-offs from Rafale, but any money valuation is lacking for the economic benefits of the technologies and their transfers.

The study assessed the contribution of each of the technologies stimulated by the Rafale programme to each of the eight key technologies, according to the degree of correlation between them. These correlations were qualitative and were characterised as:

- very strong: when the contribution is decisive and relatively direct, or when the corresponding technology would not have attained the same level of performance (or would not have existed) without the Rafale programme;
- strong: when Rafale's contribution is indirect, or when the contribution of other programmes or national policies are equally important; and
- related: when the Rafale programme contributed to the technology only in an indirect way.

The results of this exercise are reported in Table 5.5.

[41] This section summarises a non-attributed paper: '*Quelles retombees du Rafale pour la France?'*(June 2008).

Table 5.5: Rafale's technologies and the technologies judged to be key to the French economy

	Technologies judged to be key to the French economy in 2010							
Rafale's Building Blocks	Information technology	Materials & chemicals	Construction	Energy & environment	Health & safety	Transport	Distribution & consumption	Production technology
Complex software	S			R	R	S	S	S
Real-time critical software	VS			R	R	S	S	S
Data fusion	S			R	R	S	S	S
Cryptology	S			R	R	R	VS	R
Man-machine interfaces	S			R	R	R	R	R
Tools for conceptualising virtual reality	R	R		R	R	S		S
Materials	R	R		R		S		R
Sensor technology	R	R		R		R		R
Motorisation		R		R		R		R
Tools for engineering	R	R		R	R	S		R
Modelling aerodynamics	R			R		S		R

Note: VS is very strong; S is strong; and R is Related. A fourth correlation classed as 'marginal or non-existent' is disregarded and shown as an empty cell.

Looking first *across* the table, the Rafale technologies that seem most likely to generate spin-offs widely through the economy concern software and information technology. Among the major gains from the programme are:

- engineering tools developed by Dassault Systems (described as one of the rare French industrial 'start-ups' in the style of Google or Microsoft);
- developments in encrypting data, which is a tool of sovereignty in the fight against terrorism;
- tools for conceiving, modelling and simulating that are indispensable for designing modern civil aircraft; and
- man-machine interfaces – one of the "keys" for future competitiveness.

Looking *down* the table, the sectors that seem most likely to benefit from these spin-offs are information technology and transport.[42]

In parallel, each of Rafale's eleven technological categories was evaluated according to:

- their strategic importance for France, in terms of its national defence, and ability to export civil or military systems; and
- their potential for economic and technological development.

Six of Rafale's technological categories were judged to be exceptionally important (rated six or higher on a scale of zero to 10) on both these criteria: real-time critical software; data fusion; man-machine interfaces; modelling and simulating aerodynamics; sensors; and materials. Cryptology was judged to be the most important technology strategically.

[42] There is an alternative, less impressive, interpretation of the data in Table 6. The Table shows 88 cells. Of these 88 cells, only 2 showed 'very strong' (2%); 18 showed 'strong' (20%); 40 were 'related' (45%); and 28 were 'marginal or non-existent' (32%: mainly in materials and chemicals and construction).

Complex software and tools for engineering were judged to have exceptional economic and technological potential.

One of these engineering tools is what is known as 'simultaneous engineering' – the technique of establishing interfaces between parts of a programme that permit the partners in the programme to have visibility of it as a whole, and to share responsibilities and risks. 'Simultaneous engineering' is made possible by communication networks that permit exchanges of data and virtual platforms. Predictive models can be applied to these platforms to simulate their performance and maintenance requirements. These techniques have reduced the time required to develop new models.

The aerospace sector has pioneered these techniques because it faces the most demanding constraints and requirements. The techniques tend then to spread to all those complex industrial sectors in which the development phase is a decisive one.

The automobile industry is a major user because of its desire to reduce development times and to generate multiple versions of the same product. Engineering and, notably, the petroleum industry, are also intensive users, seeking to optimise the use of its facilities. Shipbuilding and steel are following the automobile industry.

The aerodynamics sector, which forms the basis of the aerospace industry, also has wider applications. Aerodynamic flows need to be predicted whenever objects move at high speed, as in transport. These technologies can address the effects of vibration and noise induced within aircraft and vehicles, both for those on board and for those nearby. Such simulations are also relevant to wind generators, the effects of turbulence between high buildings, sport, and estimating the behaviour of pollutants in the atmosphere. A programme such as Rafale requires particularly sophisticated means of investigating such topics, theoretically and experimentally, and contributes to both.

There were also spin-offs from Rafale within the aerospace industry. The development of Rafale's engine permitted Safran (Snecma) to propose a civil version to power the Russian regional jet (the RRJ or Superjet 100), thus permitting Safran to "enter the top rank of global engine integrators". Dassault also transferred some of its military technology to the development of its Falcon business jet.

5.4.4 Conclusion

Rafale supports the general finding that the aerospace industry is a source of high technology knowledge and associated spin-offs. However, the findings reported above are simply a list of examples with two key weaknesses. First, there are no monetary valuations for these technical benefits and, second, little is known about whether other industries generate similar or 'better' technology benefits and spin-offs.

5.5 Air – Eurofighter Typhoon

Eurofighter Typhoon is a single-seat, twin-engine, delta-wing, multi-role combat aircraft. Unlike Gripen and Rafale which are national projects, Typhoon is an international collaboration involving four European nations: Germany; Italy; Spain; and the UK.

In 1979, France, Germany and the UK began exploring the possibility of jointly developing a European Combat Aircraft. This project collapsed in 1981 over different operational requirements, a French insistence on design leadership, and British preference for a Rolls-Royce engine and French preference for their Snecma engine. By August 1985, after further collaboration plans, West Germany, Italy and the UK announced their decision to proceed with the Eurofighter programme. Spain joined the programme in September 1985 but France withdrew to pursue a national project which became the Dassault Rafale.

At the start, the planned Eurofighter procurement was for the UK and Germany to acquire 250 aircraft each, Italy 165 aircraft and Spain 100 aircraft. Delays to the programme occurred in 1991 due to the costs of German reunification and a German desire to cancel the project. However, the cancellation costs were unacceptable to Germany and the project continued. First flight was achieved in March 1994 and the first production contract was signed in January 1998. At this stage, the four partners planned to buy a reduced total of 620 aircraft with the UK planning to buy 232 aircraft, Germany 180 aircraft, Italy 121 aircraft and Spain 87 aircraft.

5.5.1 Costs and sales of Typhoon

Typhoon entered operational service in August 2003. Typhoon work shares are based on specialisation for parts of the aircraft, with each nation building the same parts for all the aircraft but with each nation assembling its own aircraft - resulting in four final assembly lines. On this basis, EADS Germany builds the main centre fuselage; BAE Systems builds the front fuselage, canopy and the rear fuselage section; EADS CASA builds the right wing and Alenia the left wing. Work shares are also designed so that no money crosses national borders.

At March 2013, the planned purchase of Typhoon by the four partner nations was 160 aircraft for the UK, 143 aircraft for Germany, 96 aircraft for Italy and 73 aircraft for Spain giving a total buy for the four nations of 472 aircraft. The economic and financial crisis in Europe and the UK might lead to further reductions in these orders. At March 2013, a total of 99 Typhoons had been exported to Saudi Arabia, Austria and Oman (see Table 5.6). Further delays to the programme occurred in 2010 when the partners agreed to slow down production rates to retain industrial capability.

The UK National Audit Office has published detailed costs for the UK component of the Typhoon programme and these are reported in this section.[43]

The UK costs are 37 per cent of Typhoon total costs for all four partner nations. The contracts for the UK airframe and engine were non-competitive. For the UK Typhoon, total development costs are estimated at €8.2bn and total production costs at €16.6bn, giving total programme costs of €24.85bn and unit production costs at €90m (UK costs only: 2012 prices and exchange rates).

Total life-cycle costs for the UK Typhoons are estimated at €46bn with equipment acquisition accounting for 61 per cent of this total. UK employment on Typhoon at BAE Systems, Rolls-Royce and Selex Galileo is estimated at 8,600 jobs but this number excludes other UK firms and their supply chain employment. Broadly, some 40 per cent of Typhoon production costs are allocated to the airframe, 40 per cent for equipment and 20 per cent for the engine.

The UK costs can be 'grossed-up' to provide an estimate of Typhoon's total development and production costs for all four partner nations, assuming UK costs are typical of costs for all four partner nations. On this basis, total development costs for Typhoon are estimated at €22.2bn, total production costs at €44.9bn and aggregate acquisition costs at €67.1bn (2012 prices).

For the UK, total programme costs are estimated to have increased by +20 per cent (over fewer aircraft). Of the €4.3bn cost increase, some €2.7bn (63 per cent) was due to inefficient collaboration arrangements, obligations to international partners and to project technical complexity. Delays on the UK Typhoon totalled 54 months, with 32 months of this delay due to technical factors and 22 months (41 per cent) due to international collaboration. At 2011, the National Audit Office concluded that the UK had not achieved value for money from its investment in Typhoon (National Audit Office, Management of Typhoon Project, 2011, p9).

[43] See, for example, National Audit Office: Major Projects Report 2012; and Management of Typhoon Project, 2011

Table 5.6: Major features of Typhoon multi-national combat aircraft

Contractors	Aircraft performance
***Prime:* Eurofighter**	Speed: Mach 2
Major suppliers:	Combat radius: 860 mls
Eurojet	Single seat
Euroradar	Twin engine
Timescales	**Dates**
Start of funded development work	May 1983
Programme approved	August 1985
First flight	March 1994
Entry to service	August 2003
Development timescales	**Total months**
Total time from start to first flight	130
Time from programme approval to first flight	103
Time from start to service entry	243
Time from approval to service entry	216
Output	**Units**
UK	160
Germany	143
Italy	96
Spain	73
Saudi Arabia	72
Austria	15
Oman	12
Total	**571**

Notes:
Funded development work led to the BAe Experimental Aircraft programme (EAP).
Output is based on orders at end-2012.

5.5.2 An Economic Evaluation of Typhoon

5.5.2.1 The costs of collaboration

Compared with Gripen and Rafale, Eurofighter Typhoon had much longer development times for each phase of development and entered operational service much later (August 2003 compared to June 2001 for Rafale and September 1997 for Gripen).

Collaboration tends to lead to cost penalties and delays in development and production. Typical 'rules of thumb' suggest that, compared with a national project, collaboration development costs can be represented by the 'square root' of the number of partner nations and programme delays are likely to be represented by cube root of the number of partner nations. On this basis, a four-nation project such as Typhoon can be expected to have development costs which are twice those of a similar national programme; and its development timescale might be some 60 per cent longer than a similar national project. Similar cost inefficiencies on collaborative production mean that unit cost reductions are about half those on national programmes.

There is evidence to support these 'rules of thumb.' A UK study compared the estimated development costs of Typhoon with a national alternative, finding that Typhoon development costs were 1.96 times the costs of developing a national alternative which is consistent with the square root rule. On timescales and compared with both Gripen and Rafale, the Typhoon took some 10-40 per cent longer to develop, which is less than suggested by the cube root rule.

Collaboration inefficiencies often reflect work-sharing rules which are based on political-equity criteria rather than competitiveness and comparative advantage. Similarly, programme delays reflect the administrative, organisational and industrial arrangements of international collaboration. Each partner nation involves its government, defence ministries, armed forces and key defence firms in the project:

reaching decisions with large numbers of participants takes much longer than where only one nation is involved. However, whilst collaboration leads to higher development costs compared with a national project, such costs are shared between all the partner nations. As a result, each partner nation can achieve substantial savings in development costs compared with a similar national programme. For example, even if the square root rule applies, for a four-nation collaboration such as Typhoon, each partner saves 50 per cent of the development costs compared with a national project.[44] Similarly, a comparison of the total development costs for the four-nation Typhoon compared with the national Rafale project suggests that whilst Typhoon was costlier, it was less than 10 per cent more costly than Rafale (i.e. less than predicted by the square root rule).

Output levels indicate the achievement of scale and learning economies while exports are an indicator of international competitiveness. Compared with Gripen and Rafale, the Typhoon has achieved the greatest scale of output but inefficiencies in collaborative production mean that its scale economies are only 50 per cent of those for a national project. This means that it needs to produce twice the national volume to be equally competitive. For exports, Typhoon has sold less than Rafale but more than Gripen (99 units for Typhoon; 126 units for Rafale and 82 units for Gripen) but Typhoon has only exported 17 per cent of its output compared with 32 per cent for Gripen and 40 per cent for Rafale.

In terms of unit procurement prices and operational costs, Typhoon is costlier than Rafale and Gripen (see Table 5.2). On this basis, European national projects such as Gripen and Rafale are competitive with multi-national programmes such as Typhoon. All defence equipment projects obviously create wider economic and industrial benefits and these need to be included in any economic evaluation of Typhoon.

5.5.2.2 Wider economic benefits of Typhoon

Wider economic and industrial benefits include employment, technology and spin-offs, exports and other contributions to retaining a defence industrial base, security of supply and re-supply and equipment standardisation. A simple identification and listing of the wider economic benefits of projects such as Typhoon is useful but not sufficient for a comprehensive economic evaluation. The potential benefits have to be identified, quantified and expressed in monetary terms. Some broad estimates are available of the wider economic benefits from Typhoon.[45]

5.5.2.3 Employment

Typhoon supports large numbers of highly-skilled, highly-paid and high value-added jobs in the four partner nations. Estimates show that, in 2006, development and production work on the Typhoon project supported some 100,000 to 105,000 personnel employed both directly and indirectly in over 400 companies throughout Europe (indirect employment comprises jobs in the supply chain). These jobs were distributed between the partner nations, with 20,000 personnel in each of Germany and Italy, 25,000 personnel in Spain and 40,000 personnel in the UK.

Learning curves for Typhoon production are estimated at 85 per cent, with a 90 per cent learning curve for combined labour and other operations. Breaks in production lead to the loss of learning experience: for example, a break of one year in Typhoon production is equivalent to returning to unit one in production (i.e. learning has to re-start).

[44] Consider a project costing €100bn for development on a national basis. A four-nation collaboration might cost twice that sum, namely, €200bn in development (the square root rule); but each nation will pay €50bn, so saving €50bn in development compared with a similar national project. However, in the ideal case involving no collaboration inefficiencies, each nation would only pay €25bn for development.

[45] Data on Typhoon are based on a published study: Hartley, K (2008), *The Industrial and Economic Benefits of Eurofighter Typhoon*, Eurofighter, Munich.

5.5.2.4 Technology contribution of Typhoon

Typhoon is an advanced, high-technology combat aircraft which has contributed to technical knowledge, some of which has provided technical spin-offs to other sectors. Typhoon requires special skills in aerodynamics, flight-control systems, structures, avionics and systems integration. Typhoon has resulted in an impressive list of examples of technology benefits. Some of these technology benefits have created and supported world-class firms. The following examples of technology benefits and spin-offs have been identified for Typhoon:

- carbon-fibre technology with further applications to civil aircraft and Formula 1 racing cars;
- super-plastic forming and fusion-bonding;
- aero-engine technology based on the EJ200 engine for Typhoon with possible applications to other military aircraft as well as civil aircraft (there are further spin-offs to power generation engines for civil work and applications to the health sector);
- spin-offs to civil aircraft, to motor car industries and to firms in the supply chains. In some cases, technology transfer has resulted from labour mobility where the labour skills on Typhoon have been highly transferable; and
- impacts on supply chains. Typhoon has resulted in the introduction of new technology and a whole range of modern business practices throughout the supply chain (e.g. application of IT; modern management and commercial practices; procurement and contracting skills, etc).

The market value of Typhoon technology spin-offs can be estimated by using other studies. Eliasson estimated that Gripen resulted in spill-overs valued at 1.8 to 2.3 times the value of the investment in Gripen. Assuming that this multiplier applies to Typhoon development costs only, the value of spin-offs from Typhoon might be some €40bn to €51bn. Another study of the Netherlands' planned purchase of US F-35 aircraft, estimated technology spin-offs valued at 13.2 per cent of the total Netherlands' development and production expenditure on its purchase of F-35 aircraft.[46] Applied to Typhoon such a percentage share would lead to spin-offs valued at €8.9bn.

Overall, these two studies suggest spin-offs on Typhoon valued within a range of €9-51bn. These estimates of the market value of Typhoon spin-offs are based on other aircraft and show considerable variation. There remains scope for a proper economic study of the market value of Typhoon spin-offs.

It is not possible to assess and compare the technology benefits and spin-offs for Typhoon with those for Gripen and Rafale. However, some broad generalisations can be made. All three aircraft are likely to have resulted in similar technology benefits but Typhoon and Rafale are more advanced combat aircraft than Gripen and used a new engine. This means that their technology benefits are likely to be greater per unit of expenditure compared to Gripen. Similarly, Typhoon and Rafale are more likely to have resulted in greater national technology spin-offs since they involved greater spending within their national economies than Gripen (hence fewer leakages of spending).

5.5.2.5 Tax revenues

Some analysts argue that tax revenues need to be included in any economic evaluation of Typhoon (and other combat aircraft). National treasuries often take a different view, and do not include tax revenues since they are transfer payments and all economic activity generates tax revenues (similarly for induced employment estimates). Nevertheless, estimates for Typhoon show that, for Germany, 60-70 per cent of its costs accrued to the national treasury through taxes and similar dues, giving a net cost of some 30-40 per cent of the total cost. In comparison, for Germany, a similar purchase of US

[46] See Vijver, M.V D and Vos, B (2006). The F-35 Joint Strike Fighter as a source of innovation and employment: some interim results, *Defence and Peace Economics*, 17,2, 155-159.

F-18 aircraft provided a return to the national treasury of 14 per cent, therefore raising its net cost to 86 per cent of the total. The licensed production in Germany of US F-18 aircraft led to taxes and dues of 35 per cent and a net cost of 65 per cent of the total cost.

Exports and import-savings

Exports provide additional employment, maintain a national defence industrial base without major additional costs to the national economy and provide a future stream of economic benefits from the sales of spares, training and mid-life updates. Estimates suggest that the value of this life-cycle business might be an extra 50-100 per cent of the initial price over 35 years. However, not all exports represent net gains since there might be offset requirements (e.g. 200 per cent offsets for sale of Typhoons to Austria), the waiving of any R&D levy and generous financial terms on foreign sales.

Typhoon's contribution to the balance of payments of the partner nations can be estimated. By April 2013, total Typhoon exports were 99 units. Assuming each aircraft sold at the UK unit production price of €90m, this suggests total revenue of €8.9bn which might support some 16,000 jobs. There is additional sales revenue over the aircraft life-cycle estimated at 50-100 per cent of the initial acquisition price over 35 years. On this basis, aggregate sales revenue from Typhoon exports might total €13.4-17.8bn which might support an aggregate total of some 24,000 to 32,000 jobs (based on export sales at April 2013).

In addition, Typhoon contributes to import-savings: these are the savings on imports of combat aircraft which would be needed in the absence of Typhoon. Here, various estimates are possible, each sensitive to the assumptions made about the costs of Typhoon and its possible rival aircraft. First, it might be assumed that Typhoon represents the least-cost solution so that all its costs can be counted as import-savings (i.e. both development and production). On this 'optimistic, best case' scenario, the import-savings from Typhoon totalled €67.1bn (total development and production costs for all partner nations, excluding support costs). Second, the unit costs of alternative and rival combat aircraft can be compared with Typhoon costs to determine whether there are lower-cost alternatives. Identifying such lower-cost alternatives is complicated by the need to obtain reliable and accurate unit price data, and by the need to compare differences in the operational capabilities of rival aircraft. For example, assuming that the four partner nations would have purchased 620 aircraft comprising a mix of US F-15 and F-18 aircraft, Typhoon created import-savings of €39.3bn.[47] On these assumptions, the total balance of payments contribution of Typhoon is some €52.7bn to €84.9bn (2012 prices).[48]

5.5.2.6 Industrial benefits

Industrial benefits arise in the form of the contribution of Typhoon to maintaining an independent European aerospace industry as an internationally-competitive industry and a rival to the US industry. It also ensures independence and security of supply and re-supply in conflict. Further industrial benefits take the form of demonstrating the ability to develop a modern complex combat aircraft and to manage a four-nation multi-national collaboration. Society has to reach some judgement of the valuation it places on these industrial benefits.

5.5.2.7 Summary

The wider economic and industrial benefits of Typhoon are summarised in Table 5.7.

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47 It was assumed that the 620 aircraft would comprise 200 F-15s and 420 F-18s at unit prices of $99.6m and $68.7m, respectively.

48 The estimates are based on the lower-bound of export sales (including support sales) of €13.4bn plus the costs of the US purchases of €39.3bn and the upper-bound estimates of exports sales of €17.8bn and the 'optimistic' scenario of Typhoon import-savings of €67.1bn.

Table 5.7: Wider economic and industrial benefits of Typhoon

Employment	Technology and spin-offs	Exports and Import-savings	Others
100,000 jobs. High wage/ high skill jobs	*Examples:* Carbon fibre technology; aero-engine technology. Possibly valued at €9bn to €51bn.	Exports valued at €13.4bn to €17.8 bn. Import-savings valued at €39.3bn to €67.1bn. Total balance of payments contribution of €52.7bn to €84.9bn	European independence and security of supply. Demonstration of ability to integrate complex systems and manage a multi-national collaboration

The net economic benefit of Typhoon for the four partner nations can be estimated by considering its income from exports minus the costs of developing and producing Typhoon minus the costs of creating exports plus the costs of importing from overseas. The figures reported in this section show that export values might be as much as €17.8bn (which might increase with future exports); Typhoon costs are €67.1bn (these are acquisition costs only); and the costs of importing alternative aircraft are estimated at €39.3bn (there are no data on the costs of creating Typhoon exports). Using these estimates, the net economic benefits of Typhoon are minus €10bn for the four partner nations (i.e. a net economic cost). However, Typhoon is designed to meet European military requirements compared with imported equipment; it has also provided technology spin-offs; and there are other industrial and military benefits. If these wider economic and industrial benefits are valued at €10bn or more by the partner nations then Typhoon produces a net economic benefit.

5.6 Air – Comparative analysis

5.6.1 Domestic production and exports

The three European case studies show that developing combat aircraft for national purposes also generates exports. Table 5.8 shows domestic and export sales and proportions for the three European combat aircraft. At April 2013, the nationally-developed Rafale has the best export performance of the three European combat aircraft.

Table 5.8: National production and exports

Aircraft	Domestic sales (number)	Export sales (number)	Export/domestic sales (%)
Gripen	204	82	40
Rafale	180	126	70
Typhoon	472	99	21

Note: this table assumes that the Rafale sale to India will be formally concluded.

5.6.2 Competitiveness

Prices and delivery dates are an indicator of international competitiveness. Table 5.9 shows data on unit production costs and unit total costs (i.e. including development and production costs). Data are also shown on the date of first flight and the date of service entry. These data suggest two conclusions. First, Typhoon is costlier than its European rivals and some of its US rivals but the three European aircraft are cheaper than the US F-22 and F-35 aircraft. Second, the time between first flight and service entry of the US F-15, F-16 and F-18E/F aircraft was shorter than that of the three European aircraft. This suggests that the US has a competitive advantage in development timescales.

Table 5.9: Unit prices and delivery dates

Aircraft type	Unit production cost (€m, 2012 prices)	Unit total cost (€m, 2012 prices)	Date of first flight	Date of service entry
Gripen JAS-39C	60.1	66.4	December 1988	September 1997
Rafale C	54.0	118.0	May 1991	June 2001
Typhoon	90.5	124.9	March 1994	August 2003
F-15 Eagle	96.6	Na	July 1972	January 1976
F-16	33.1	Na	February 1974	August 1978
F-18E/F Super Hornet	69.9	85.1	November 1995	November 1999
F-22 Raptor	158.5	302.4	September 1997	December 2005
F-35 JSF	105.4	123.8	December 2006	After 2016

Notes: Data for all aircraft except F-35 Joint Strike Fighter from Estimating the Real Cost of Modern Fighter Aircraft, Defense-Aerospace.com, 2006. Data based on standard definitions and methodology except for JSF which is based on GAO Report, 2012.
All prices adjusted to 2012 prices using national inflation rates and exchange rates.

5.6.3 Life-cycle costs

Table 5.10 shows estimates of life-cycle costs for European and US combat aircraft. The US F-16 and Swedish Gripen are the least costly aircraft in the sample. Both Gripen and Rafale are competitive with the US F-18E/F. In contrast, the US F-35 is the costliest aircraft in the sample.

Table 5.10: Life-cycle costs

Aircraft	Annual acquisition costs (€m, 2012 prices)	Annual operational costs (€m, 2012 prices)	Annual unit costs (€m, 2012 prices)	Total unit costs index (Gripen = 100)
Gripen	4.57	0.72	5.29	100
Rafale	4.71	2.54	7.25	137
Typhoon	6.46	2.77	9.23	174
F-16	2.01	1.08	3.09	58
F-18E/F	4.56	2.70	7.26	137
F-35	10.97	4.77	15.74	298

Note: Annual costs are annualised based on aircraft life of 20 years, 200 operational hours per year and a discount rate of 5%. Annual acquisition costs are production costs only. Unfortunately, the data reported in this table are not available for the F-22.

5.6.4 Combat effectiveness

Unit prices, life-cycle costs and delivery dates are indicators of competitiveness, but they need to be adjusted for aircraft quality in terms of operational performance to ensure that we compare like with like. While attempts have been made, the results from such adjustments have proven contradictory and so we consider that there is not yet a sufficiently robust basis on which to compare the combat effectiveness of different aircraft.

5.6.5 Output levels

Levels of output are a further indicator of competitiveness as they may suggest the achievement of scale and learning economies. Table 5.11 shows output levels for European and US combat aircraft. Typical national output levels for US combat aircraft exceed 1,000 units which is considerably greater than European output levels. For the European nations to achieve US scales of output requires either export sales and/or international collaboration.

Table 5.11: Output levels

Aircraft	Output levels (including exports)
Gripen	258
Rafale	306
Typhoon	571
F-15A-D	1,198
F-15 E (Eagle)	415
F-16	4,500+
F-18 Hornet	1,480
F-18E/F Super Hornet	628
F-22	195
F-35	2,457

Note: Outputs at end 2012 and including export sales.

5.6.6 Collaboration for the three European aircraft

International collaboration remains a procurement policy option for European nations (and for the USA, e.g. the F-35). Consider the output implications if the European nations currently producing three different types of combat aircraft had chosen to collaborate. The result would have been one type of combat aircraft produced for the air forces of six European nations. Total orders for the nations' air forces would have been some 856 units (national orders only excluding exports) and so the achievement of scale and learning economies would have been more likely. In addition, there would have been savings in R&D costs since only one R&D bill would have been incurred.

For illustrative purposes only, assume that Rafale is selected by all six European nations. Compared with the current three types, the selection of Rafale would lead to possible savings in development costs of €32.2bn (for Gripen and Typhoon) and possible savings in unit production costs of over 20 per cent. However, some of these cost savings might be reduced if the six-nation programme is characterised by inefficient work-sharing arrangements.

5.6.7 Comparative firm performance

Data are available which allow a comparative assessment of firm performance for the major firms involved in the three air case studies. These firms are Saab for Gripen, Dassault Aviation for the Rafale and BAE Systems, and EADS and Finmeccanica for Typhoon. There are also data for the major European aero-engine companies, for the major US aerospace companies and for a composite of All Companies which can be used to reflect the alternative use value of resources. These data are shown in Table 5.12. The data are subject to limitations because: firms have different combinations of defence and civil sales; the data are for one year only so do not show trends over time; and the R&D data do not reflect government-funded R&D spending which will be a major component of defence R&D expenditure. Value added productivity figures more accurately reflect a firm's economic performance since the alternative labour productivity data include bought-in parts and equipment (i.e. purchases from other firms).

Table 5.12: Comparative firm performance

Company	Sales (€m)	R&D (%)	Profits (%)	Labour productivity (€000s)	Value added productivity (€000s)	R&D per employee (€000s)
All Companies	416	3.6	8.0	299.1	103.9	10.9
Aerospace	474	4.1	6.7	250.7	101.8	10.2
EADS	46,037	6.7	--1.1	385.2	111.6	25.9
BAE	24,652	1.1	4.4	262.2	85.4	3.0
Finmeccanica	17,740	11.7	7.0	244.5	109.6	28.6
Dassault	3,678	7.1	9.6	301.2	153.7	21.3
Saab	2,587	4.8	5.6	198.3	96.9	9.6
SAFRAN	11,395	5.9	4.3	206.3	93.9	12.2
Rolls-Royce	12,600	4.5	11.3	327.3	89.3	14.8
Boeing	51,161	5.1	3.1	325.6	Na	16.6
Lockheed Martin	33,860	1.7	10.2	241.9	Na	3.9
UK Automobiles	1,335	4.5	--1.1	302.7	54.8	13.6

Notes:
Sales are in Euros millions; RD is R&D as percentage of sales; Profits are profits as share of sales; Labour productivity is sales per employee in Euros 000s; VA productivity is value added per employee in Euros 000s; RD per employee is R&D per employee in Euros 000s.
Value added is the difference between sales revenue and the cost of bought-in goods and services. Value added data are for 2007/08 and for the top 750 European companies only. All other data in Table are for 2009/10 and are based on the top 1,000 global companies. The All Companies data are a composite based on the top 1,000 global companies which provides a benchmark for assessing the performance of the Aerospace group. The Aerospace group is also based on the top 1,000 global companies. Na is Not available: the UK database only published value added data for the major European companies.
The Aerospace group comprises the major aerospace and defence companies in the UK, Europe and the world.
Automobiles and parts are for the top 1,000 UK companies; but for value added data are for the top 800 UK companies.
Data are from the 2010 R&D Scoreboard and the 2009 Value Added Scoreboard, Department for Business Innovation and Skills, UK. These were the final years for each of these publications.

Table 5.12 allows comparisons between the Aerospace and Defence sector and the All Companies group as well as comparisons between the major aerospace companies (all based on global companies). Compared with the Aerospace and Defence group, the All Companies group achieved higher performance for all indicators except for R&D shares, suggesting that there were more attractive alternatives for use of resources.

Interestingly, there were significant variations and differences between the major aerospace firms. BAE Systems, which is one of the most defence-intensive companies, recorded the lowest value-added productivity and one of the lowest profitability figures amongst the major European aerospace firms. In contrast, Dassault Aviation 'outperformed' the All Companies group on all the indicators shown in Table 5.12.

Amongst the Aerospace firms, the two with a large civil aircraft business, Boeing and EADS, were distinctive. Each had better labour productivity record compared with the All Companies group and EADS had better value added productivity. The contrasting examples are BAE Systems and Lockheed Martin, which are defence-intensive companies with lower labour productivity compared with Boeing and EADS and lower value added productivity for BAE. However, both these defence-intensive companies achieved higher profitability than Boeing and EADS.

Data are also shown for the UK Automobiles sector which is one alternative use of resources in the UK economy. BAE Systems and Rolls-Royce each achieved higher profitability and higher value added productivity figures than the UK Automobile industry. Rolls-Royce also achieved higher figures for labour productivity and R&D per employee.

Overall, the firm level data show mixed results. Some Aerospace and Defence companies show a better performance than for the alternative uses of resources but other firms show an inferior performance, raising serious questions as to why such firms remain in the Aerospace and Defence industry. One answer to this question might be that they view the industry as still offering their best prospects of profitability with the perceived alternatives remaining less attractive.

5.6.8 Implications / lessons

We learn a number of lessons from the case studies in this section.

First, these cases illustrate that defence spending can take different forms, reflected in the acquisition of Gripen, Rafale and Typhoon (or other types of defence equipment). Studies based solely on the macroeconomic impacts of defence spending, by their blunt nature fail to identify the more detailed microeconomic impacts of such spending.

Second, these cases suggest that considerable opportunities remain for increasing the efficiency of European collaborative defence equipment programmes. For example, work-sharing for both development and production could be allocated on the basis of competition: a single prime contractor might manage the programme rather than an industrial consortium and committee arrangements; and the number of major partner nations might be restricted to two partners so as to minimise transaction costs (bilateral collaboration). The A400M highlights the problems for seven-partner nation collaborations (major cost overruns and delays) whilst Airbus civil aircraft demonstrate the success of international collaboration based on a smaller number of major partners. Similarly, the US Joint Strike Fighter (F-35) example is based on a business model with a prime contractor (Lockheed Martin) which selected its partner companies (BAE Systems and Northrop Grumman) and which has varying levels of international partnerships (e.g. UK as level 1 partner; other nations as junior/minor partners).

Third, the case studies provide indicative support for the view that the arguments for defence spending might be based on wider economic and industrial benefits, including technology spin-offs.

5.7 Land – Leopard 2 Main Battle Tank

5.7.1 Background

Main battle tanks (MBTs) are the modern cavalry. They serve three principal functions on the battlefield – mobility, firepower and protection. For example, the mission of the M1A2 Abrams Tank is to "close with and destroy enemy forces using firepower, manoeuvre, and shock effect".

The Leopard 2 was the result of an unsuccessful agreement between the USA and Germany in 1963 to develop a common tank known as the "Main Battle Tank/ Kampfpanzer – 70" (MBT/ KPz-70). Both countries needed an improved MBT to counter the Soviet T-72s that were deployed in the 1970s, as well as the anticipated T-80s.

In 1969, when vehicles became available for trials, it became obvious that they were too heavy. No agreement could be reached on how this should be addressed. The programme was terminated in 1970, following the expenditure of DM 830m. However, in 1969, the German Office for Defence Technology and Procurement (Bundesamt für Wehrtechnik und Beschaffung, BWB) initiated a study to save the majority of the MBT/ KPz-70 development programme.

The outcome was Leopard 2. Krauss-Maffei was selected as the main contractor and systems manager, production was shared between Krauss-Maffei and Maschinenfabrik Kiel (MaK) on a 55:45 basis, and Wegmann was appointed the turret integrator. The main 120mm smooth bore gun was to be supplied by Rheinmetall, with the turret.

In 1977, the BWB decided to order 1,800 Leopard 2s, in five batches. By 1992, three more batches had been delivered, bringing the total to 2,125. Thereafter, the German army's fleet of Leopards was upgraded, using the existing chassis.

The purpose of this case study is to consider two economic impacts of this programme:

- whether the programme enabled the BWB to meet the German Army's requirements for the 2,125 MBTs delivered between 1980 and 1992 at a lower cost than that of the best alternative; and
- whether the programme generated additional exports, and if so, whether they generated revenues in excess of their estimated cost of production.

5.7.2 Would Germany (and Europe) have had to pay more for their main battle tanks in the absence of the Leopard 2?

5.7.2.1 The cost of Leopard 2

The first step in our analysis of whether the Leopard 2 was cheaper than the next-best alternative is to establish the cost of the Leopard 2 programme to BWB. As shown in Table 5.13, we estimate that the average unit price of the Leopard in this period was DM 5.24m and the total cost of the programme was DM 11,100m, measured at 1992 prices.[49]

Table 5.13: Estimated cost of the domestic Leopard deliveries

	Number produced 1980-1990	German producer price index*	Years in which an upgrade was made**	Estimated unit price, at current prices (DM m)	Estimated unit price, at 1992 prices (DM m)	Estimated programme cost, at current prices (DM m)	Estimated programme cost, at 1992 prices (DM m)
1980	106	69.4		3.61	4.60	383	488
1981	229	73.6		3.83	4.60	877	1,054
1982	45	77.1		4.01	4.60	181	207
1983	450	78.2	1	4.41	4.98	1,982	2,241
1984	300	80.4		4.53	4.98	1,359	1,494
1985	300	82.1	1	5.00	5.39	1,501	1,616
1986	0	80.2		4.89	5.39	0	0
1987	370	79.9	1	5.26	5.83	1,947	2,156
1988	0	81.2		5.35	5.83	0	0
1989	150	83.9		5.53	5.83	829	874
1990	100	85.1		5.61	5.83	561	583
1991	0	87.0		5.73	5.83	0	0
1992	75	88.4		5.83	5.83	437	437
Total	**2,125**					**10,100**	**11,100**

*OECD, 2005 = 100

**It was assumed that the unit price of the 1980 deliveries was in line with the original 1977 budget provision (DM 6,500m for 1,800 Leopards), and that the cost of the seventh batch of 100 Leopards completed in 1990 was DM 561m, as reported by Global Security.org (www.globalsecurity.org/military/world/europe/leopard2.htm). The unit prices for other years were interpolated between 1980 and 1990, using the German PPI and estimating an uplift factor (of about 8 per cent) for each of the three Leopard upgrades.

5.7.2.2 The next-best alternative to Leopard 2

In the absence of the Leopard, which tank would have been selected by the BWB?

It seems probable that in the absence of the Leopard 2 the German army would have adopted the Abrams M1. As already noted, both the Leopard 2 and the Abrams M1 grew out of the collaborative

[49] This is very close to the DM 5.3m figure reported by Global Security.org. However, it is not clear whether this figure is an average of prices in different years or is a costing at prices in a particular year. It may have included the upgrade of the Leopard 2 (to become 2A3s), whereas our estimate does not.

German-US programme. They were then developed in parallel and were introduced into their respective armies from about 1980.

The general consensus among the defence community (those, at least, who write knowledgably on this subject) is that these were, and remain, the two best tanks in the world. They have both been widely adopted. Although the British FV4030/4 Challenger (later designated Challenger 1) and the French AMX-56 Leclerc were both considered to be highly capable tanks, they were commercial disappointments. Each won orders in just one country – Jordan and the United Arab Emirates, respectively. Differences in national replacement cycles also played a part. Challenger 1 and the French AMX-56 Leclerc did not enter service until 1983 and 1990, respectively.[50]

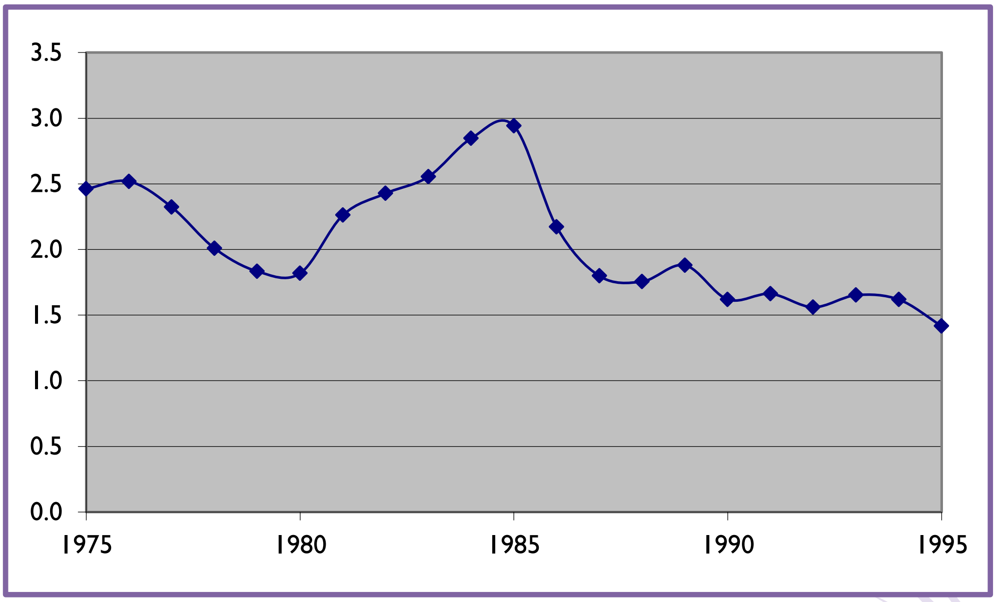
For these reasons, it seems likely that in the absence of the Leopard 2, the German Army would have been equipped with the Abrams M1.

5.7.2.3 The cost of the next-best alternative to Leopard 2

A counterfactual of this kind is necessarily a thought-experiment. There are few reliable data in the public domain with which to construct it: neither Ministries of Defence nor defence companies are in the habit of revealing details of their negotiations, so a number of assumptions have to be made.[51]

The same is true about the way the German government would have handled the DM/US$ exchange rate. As shown in Figure 5.1, the DM/US$ exchange rate was quite volatile in the relevant period. The values of defence export contracts are often reported in US$ (by SIPRI, for example) but it is not clear which exchange rate was used to calculate these values – was it the rate prevailing at the time the contract was concluded, or the rate at the time of delivery, several years later?

Figure 5.1: The DM/$ exchange rate 1975-1995



[50] The fact that the German Army needed a MBT replacement several years earlier than the British Army was one of the factors that led to the cancellation of an Anglo-German Future Main Battle Tank programme in the 1970s (FMBT/KPz3). The Challenger 1's availability as early as 1983 could not have been anticipated when the Leopard was being developed. It was the result of the cancellation by Iran, following the 1979 revolution, of an order for a modified Chieftain, which was then taken over by the UK MoD.

[51] The average price of 1,155 Abrams M1A2 ordered by the US Department of Defense between 1980 and 1999 was reported in 1999 to be $6.2m, but it is not clear whether this was the total cost divided by the number of tanks or whether it is expressed at 1999 prices; and whether it includes the cost of the development programme.

For our purposes, the relevant price comparator to the Leopard 2 is the price at which new Abrams tanks were exported. Table 5.14 reports five such contracts and, for comparison, the corresponding export prices for the Leopard. These comparisons are necessarily approximate. Contracts may contain differing provisions for spares, peripheral equipment and training, and would also have been subject to different offset obligations.

Table 5.14: Unit prices at which Abrams and Leopard tanks were exported (current prices)

	Abrams M1 ($m)	Leopard 2 ($m)	Number	Purchaser	Source of price/value data
1980	-	1.76	445	Netherlands	Jerchel and Schnellbacher, p.36.
1984	-	3.68	380	Switzerland	SIPRI
1988	5.15	-	524	Egypt	SIPRI
1990	4.76	-	315	Saudi Arabia	SIPRI
1999	5.64	-	100	Egypt	SIPRI
2001	5.90	-	100	Egypt	SIPRI
2003	-	5.88	170	Greece	Army Guide
2004	6.85	-	59	Australia(1)	SIPRI
2007	-	5.70	20	Canada	SIPRI

Source: SIPRI Arms Transfer Database.
(1) This $420-475m deal also included seven M88A2 armoured recovery vehicles (ARVs). We adjusted for this on the basis of the unit prices for the order for 13 of these vehicles by Egypt in 2001, adjusted for inflation.

To take account of the fact that these unit prices tend to increase over time, partly as a result of inflation and partly as a result of periodic upgrades, we regressed these prices against the year in which the contracts were awarded. To test whether the export prices of the two tanks differed significantly we included a dummy variable that took the value unity for Abrams M1 contracts and zero for Leopard 2 contracts.[52]

This analysis suggests that the unit export price for an Abrams M1 tended to be 38 per cent higher than that of a Leopard.[53]

According to the SIPRI Arms Transfer Database, the Abrams did not win an export contract before 1988, i.e. during most of the period when German was building up its Leopard fleet. This may have been due to security concerns, but even if these had been absent an economic factor would probably have ruled out such contracts. The economic fact that the US$ appreciated significantly against the DM after 1980, by over 60 per cent between 1980 and 1985 (see Figure 5.1) meant that it would have been relatively expensive to purchase American tanks. Only when the US$ depreciated did Abrams win export orders (to Egypt in 1988 and Saudi Arabia in 1990).

5.7.2.4 Definition of a 'no Leopard' counterfactual

As shown in Table 5.15, the counterfactual suggests that if the investment in the Leopard had not been undertaken, Germany would have had to pay 79 per cent more for the 2,125 tanks that it purchased between 1980 and 1992.

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52 We also tested whether unit prices reflected the size of the order: they did not appear to do so.

53 We used a semi-log function in which the log of the unit price was regressed against the year and the Abrams dummy variable, with the following result:

Log (unit price) = - 66.8 + 0.034*Year + 0.321*Abrams dummy
(5.21) (2.65)
Adjusted R^2 = 0.82
The t ratios are in parentheses. The Abrams dummy is statistically significant at the five per cent level.
The percentage impact of the dummy variable on unit price in this particular functional form is $e^{0.287} – 1$, or 38 per cent.

Does this estimate overstate the probable cost penalty? For example, if the Abrams tank would have given Germany a superior capability, the BWB might have ordered fewer Abrams than the 2,125 Leopards that they ordered.

It is true that, in a physical sense, an Abrams M1 offered 'more tank' than a Leopard 2: the Abrams was significantly heavier (61.3 tonnes compared to the Leopard 2's 55 tonne combat weight, 52 tonnes empty) and had superior frontal armour. On the other hand, the Leopard 2 was equipped with a Rheinmetall 130 mm gun with which the Abrams was not equipped until 1986.

The Abrams' Avro-Lycoming 1,500 hp turbine engine gave it a higher acceleration and 'burst' speed, but this involved significantly higher fuel consumption rates, required correspondingly more tankers in support and additional training for the crews that operate them. Other armed forces that have considered the Abrams have been deterred by these factors.

In addition, the Leopard 2's lower weight and greater manoeuvrability and 'fightability' corresponded more closely to the German concept of operations.

Taking these and other factors into account it would be hard to claim that the Abrams M1 would have provided a superior all-round capability that would justify ordering fewer of them.

If anything, the financial penalty may have been understated. These two tanks are widely regarded as the two best tanks in the world. Hence, they are close competitors. The unit prices that we can observe are conditioned by the competition between them. In the absence of the Leopard, the export price of the Abrams might well have been higher than it was.

Table 5.15: Costing a no-Leopard counterfactual

	Deliveries of Leopards to the German Army	Estimated unit price	Estimated Cost of Leopards	Assumed unit price of exported Abrams	Assumed unit price of exported Abrams	Abrams' price premium	Implied cost of the Abrams' alternative
		DM m	DM m	$ m	DM m		DM m
				(1)	(2)		
1980	106	3.6	380	3.6	6.5	81%	690
1981	229	3.8	880	4.0	7.2	88%	1,650
1982	45	4.0	180	4.2	7.6	90%	340
1983	450	4.4	1,970	4.3	7.9	79%	3,550
1984	300	4.5	1,360	4.5	8.2	82%	2,470
1985	300	5.0	1,510	4.7	8.5	70%	2,560
1986	0	4.9	0	4.8	8.7	78%	0
1987	370	5.3	1,910	4.9	9.0	71%	3,330
1988	0	5.3	0	5.2	9.4	75%	0
1989	150	5.5	830	5.4	9.8	78%	1,470
1990	100	5.6	560	5.7	10.3	85%	1,030
1991	0	5.7	0	5.9	10.8	88%	0
1992	75	5.8	440	6.1	11.1	91%	830
Total	**2,125**		**10,010**			**79%**	**17,900**
At 1992 prices			**11,100**			**79%**	**19,900**
Cost difference							**8,800**

(1)Assuming that the BWB would have been required to pay the same unit price in 1988 as Egypt is reported to have paid then for their 524 Abrams. The unit $ price for Abrams in other years is estimated from this 1988 figure, on the basis of the US Consumer price Index.
(2)Assuming that the BWB would have bought US$ in 1980 to cover the cost of an Abrams programme, at the 1980 exchange rate of 1.82 DM/$.

5.7.3 Exports

The Netherlands was the first country to import Leopard 2s – a total of 465 were ordered by 1980. After extensive comparisons with the Abrams M1A2, Switzerland ordered 380 Leopard 2s in 1984, most of which were built in Switzerland under licence. Table 5.16 reports the exports of Leopards to date. We estimate that the value of exports of new Leopards was $3,880m at 1992 prices.

Table 5.16: Export sales of Leopard 2 (US$ m)

Recipient	Type	Number	Of which new	Year of order	Years of deliveries	Value $m	Value €m	Unit price $m
Netherlands	A4	465	465	1979	1981-1986	812		1.7
Switzerland	A4	380	380	1984	1987-1993	1,194		3.1
Sweden*	A4**	160	0	1994	1994	770		
Sweden	A5	120	120	1994	1996-2002	450		3.8
Spain*	A4**	108	0	1995	1995-1996	33		
Denmark*	A4**	51	0	1997	2002-2005	91		2.9
Finland*	A4**	124	0	2002	2003	66		0.5
Poland*	A4**	128	0	2002	2002-2003			
Greece	A6	170	170	2003	2006-2009	1,000	1,700	5.9
Greece*	A4**	183	0	2005	2007		420	1.8
Turkey*	A4**	298	0	2005	2006-2010		365	1.4
Chile*	A4**	172		2006	2007-2009	125		1.4
Canada	A6**	20	20	2007	2007	114		5.7
Singapore*	A4**	99		2007	2007-2011			
Total		**2,478**						
Of which new		**1,155**				**3,570**		
At 1992 prices						**3,880**		

Sources: SIPRI, Arms Transfer Database, Army Guide and Forum Europa websites.
*Built under licence; ** Second-hand;

Many more new Leopard 2s would have been exported had the Cold War continued. Its termination left Germany with a large stock of surplus Leopard 2s. A decision in 2007 to adopt "Structure 2010" involved reducing the German fleet of Leopard 2s from 2,528 to only 350. This explains the large number of second-hand Leopard 2s that were exported (and re-exported) in the table above. A number of nations were able to acquire Leopard 2s at bargain prices.

The Leopard 2 soon became the European tank of choice. Other capable European tanks, such as the Leclerc AMX-56 and the Challenger 1, were not able to compete on price and effectiveness with second-hand Leopard 2s. Conversely, the sales revenues from these second-hand Leopard 2s enabled the German Army to upgrade its Leopard 2 fleet at lower cost than would otherwise have been the case.

We focus here on the five reported export orders for new Leopards, shown in Table 5.16. These orders involved a total of 1,155 Leopards, with an estimated value of DM 7,220m. These exports were equivalent to 54 per cent of the number of domestic deliveries of new Leopards between 1980 and 1992, and 72 per cent of their value (see Table 5.13).

It does not seem likely that these exports would have occurred had the BWB not invested in Leopard 2's development and then ordered Leopards.

5.7.3.1 Economic rents earned on Leopard exports

It would be tempting to count the entire value of these sales (DM 7,220 m) as a benefit from the Leopard programme; as indeed they are, in a gross sense. We need to recognise, however, that those who have been employed on Leopard 2 production – highly-skilled and employable for the most part – would have found alternative employment if Germany had opted to import Abrams tanks. Many would probably have been employed producing Abrams under licence, with a value added per employee not dissimilar to that which was achieved producing the Leopard.

Krauss-Maffei Wegmann's turnover per employee in 2005 was €753,000, according to Statista. This was 3.3 times the average for German manufacturing and 4.2 times the average for EU manufacturing (Eurostat). This is why the exports were important: they allowed this exceptionally productive company to expand.

The concept of 'economic rent' is relevant here. The economic rent earned by an activity is the difference between the value of its output and cost of producing it, including a normal commercial rate of return on the capital employed. It measures any 'super-normal' incomes (profits, wages and salaries) that are earned from exceptional and product-specific skills and intellectual property.

It is not easy to estimate whether these rents were earned on the sales of Leopards to the German Government, or whether they would have been greater or lower if Abrams had been ordered and then manufactured in Germany. What is clear, however, is that in such a scenario the German economy would have lost any economic rents that were earned on its exports of Leopards.

In estimating the economic rents earned on exports we have assumed that the unit price cost paid by the BWB for its Leopard 2s was equal to the unit cost of production, including a commercial rate of return on capital. On this basis we estimate that the economic rents earned on the five export contracts in Table 5.17 amounted to DM 1,990m at 1992 prices, i.e. equivalent to 18 per cent of the cost to the BWB of the Leopard programme.

Table 5.17: Economic rents earned on exports of new Leopard 2

Year	No. exported	Purchaser	Reported / estimated unit price	Estimated value	Assumed unit cost production	Assumed cost of production	Economic rent
			DM m	DM m	DM m	DM m	DM m
			(1)		(2)		(3)
1980	445	Netherlands	3.2	1,420	3.6	1,610	-180
1984	380	Switzerland	8.0	3,030	4.5	1,720	1,320
1994	120	Sweden	6.1	730	5.9	700	20
2003	170	Greece	11.0	1,860	6.3	1,080	790
2007	20	Canada	8.5	170	6.9	140	30
Total	**1,135**	**-**	**-**	**7,210**	**-**	**5,250**	**1,980**
At 1992 prices				**7,720**			**1,990**

(1)The unit cost of the Leopards for the Netherlands was reported to be DM 3.2m by Jerchel and Schnellbacher, op. cit., page 36. For Switzerland we have used the unit price of 6.6m Swiss francs, equivalent then to DM 8.0m. The huge and unexplained difference between this figure and the unit cost agreed in 1978 by the Netherlands for their Leopard 2s provoked a lively debate, analysed later in a seminar at the University of Bern, 30 April 1999 (Das "Kesseltreiben" um die Leopard-2 Beschaffung von 1984: Ein politischer Skandal oder landesubliche Perteipolitik?").
(2)Assumed to be equal to the unit cost paid by the BWB in those years.
(3)The value of the exports less their estimated cost.

5.7.4 Summary and Conclusions

To conclude this case study, it seems probable that the investment in Leopard 2 made a significant economic contribution to the German economy by enabling the German Army to equip its cavalry regiments with a highly capable system at a much lower cost than the best alternative. We estimate that the BWB spent DM 11,100m at 1992 prices between 1980 and 1992 acquiring 2,125 Leopard tanks.

In the absence of the Leopard 2, the BWB would have needed to spend an additional DM 8.8bn (at 1992 prices) – 79 per cent more – in order to acquire an equivalent armoured capability.

In addition, this investment generated additional exports of 1,135 new tanks worth DM 7,730m at 1992 prices – equivalent to 69 per cent of the investment in the Leopard programme. The German economy derived an estimated 'economic rent' on these exports of DM 1,990m, i.e. revenue in excess of the full cost of producing these 1,135 tanks.

We estimate that the sum of these two benefits – the savings and the economic rent on exports – was in the region of DM 10,790m, equivalent to 97 per cent of the value of the BWB's DM 11,100m investment in Leopard 2s between 1980 and 1992.

Table 5.18 summarises the economic benefits that are estimated to have flowed from the Leopard programme.

Table 5.18: Economic benefits from the Leopard 2 programme (at 1992 prices)

	Number of Leopards	Cost	Savings, compared to best alternative	Economic rent on exports of new Leopards	Total resource benefits
		DM m	DM m	DM m	DM m
Investment in Leopard 2s by the German government, 1980-1992	2,125	11,100			
Abrams alternative	2,125	19,900	8,800		
Exports of new Leopards				7,720	
Economic rents earned on exports sales of new Leopard 2s	1,135			1,990	
Savings compared to buying Abrams M1 plus the economic rent earned on exports of new Leopard 2s					**10,790**
As proportion of Leopard investment					**97%**

5.8 Maritime – Compact naval guns[54]

Europe's two main producers of compact naval guns are the Italian company, Oto Melara, located in La Spezia, and now part of the Finmeccanica Group; and the Swedish company, Bofors, located in

54 The technical material for this case is drawn largely from a website http://www.navweaps.com/Weapons/WNUS_3-62_mk75.htm compiled from a number of authoritative sources, "Jane's Pocket Book 9: Naval Armament" edited by Denis Archer, "The Naval Institute Guide to World Naval Weapon Systems 1991/92" by Norman Friedman, "Jane's Ammunition Handbook: Ninth Edition 2000-2001" edited by Terry J. Gander and Charles Q. Cutshaw, updated 8 January 2013.

Karlskoga. Bofors was acquired by BAE Systems in 2005 and became known as Bofors Defence AB. It is now a subsidiary of BAE Systems Land and Armaments, based in the USA.

This case mainly concerns Oto Melara. With sales revenues of €416m in 2011, the company is relatively modest in comparison with Europe's major defence companies: naval guns are not a major item of defence expenditure. However, the case is of interest because it illustrates how a nation can:

- identify a military requirement that is shared by many nations;
- commission one of its companies to develop a cost-effective solution, and
- thereby generate defence exports that far exceed its own military requirements.

5.8.1 Background

In the mid-1950s the Italian Navy began planning to modernise. At that time, Italian warships were equipped for the most part with US-built 5-inch guns and the Bofors 40mm/L60. The view was taken that 5-inch guns were too heavy for many warships, whereas 40mm/L60 guns were too light for use as a corvette's main weapon.

The Italian Navy concluded that the best compromise was a dual purpose, medium-calibre cannon, capable of engaging both ships and aircraft. This weapon would be the primary armament on smaller warships, like corvettes, and the secondary armament on larger-class warships, e.g. frigates, destroyers and primary cannon armament of the planned helicopter cruisers. The Italian government contracted Oto Melara to design and manufacture it.

The result was the Compact 76 mm naval gun (the 76 mm Compatto). It was designed in 1963 and entered service with the Italian Navy in 1964. The gun's high rate of fire of 80-85 rounds per minute (rpm) makes it suitable for short-range anti-missile point defence, and its calibre also allows it to function in anti-aircraft, anti-surface, and ground support roles.

The Super Rapid ("Super Rapido") began to be produced in 1988 and is the current production version of the standard gun. It has selectable firing rates of 1, 10, or 120 rpm. The increased rate of fire was achieved by a cooling system which reduces the time required to transfer ammunition from magazine to barrel and fire. The Italian Navy is thought to be currently equipped with up to forty 76mm guns. [55]

Many others of both types have been produced under license, in Australia, India, Japan, Spain and the USA. They are manufactured in the United States by United Defense (now part of BAE Systems), in Japan by Japan Steel Works and in Spain by FABA (formerly IZAR, formerly Bazán).

For forty years the Oto Melara company has been an outstandingly successful manufacturer of naval guns. Forecast International commented that:

"The Oto Melara 76mm L62 has become an iconic naval weapon. It has been used on virtually every type of warship – from AEGIS-equipped destroyers to small, offshore patrol vessels. It fills almost every imaginable naval role – from air and missile defense to anti-piracy and maritime law enforcement. Indeed, the question is not why this gun should be selected for any specific program, but why anyone would want to install anything else." [56]

To convey an idea of what is claimed the latest standard version (the Super Rapid) can do, Oto Melara estimate that the Super Rapid can begin engaging missiles at about 6,000 metres, with the first rounds arriving on target at 5,500 metres. With these ranges, a single gun can deal with up to four subsonic sea-skimmer missiles, arriving simultaneously 90 degrees apart, before any reaches 1,000 metres.

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[55] Forecast International, *"The Market for Naval Surface Warfare Systems"*, 2011.
[56] Forecast International, *"The Market for Naval Surface Warfare Systems"*, 2011.

5.8.2 Economic significance

Two ways of thinking about the economic contribution of this programme, and about compact naval guns in general, involve the questions:

- How important were the exports that flowed from the Italian investment in these systems, and what was their value to the Italian economy?
- What is the counterfactual, for Italy and other European users of such systems, in the absence of these compact guns?

It is easier to be specific about the first of these questions. According to data published by the Stockholm International Peace Research Institute (SIPRI), the company has exported 877 such naval guns over the past four decades. An indicator of Oto Melara' pre-eminence in compact naval guns is that in this period its closest rival in this field, Bofors, exported 92 such systems. In contrast to the Leopard case, there is/was no obvious non-European alternative. It is a question, then, of how the Italian and other European navies would have armed themselves in the absence of such guns, and what would have been the operational and financial costs involved.

Table 5.19: Export deliveries of compact naval guns[57]

Oto Melara	1970s	1980s	1990s	2000s	2010s	Total
Compact 76mm	137	189	121	83		530
Super rapid 76mm		28	51	37		116
Compact 127mm	4	1	7	9		21
Compact 40L70		118	64	25	3	210
Total	**141**	**336**	**243**	**154**	**3**	**877**
Bofors						
SAK-70 Mk-1 57mm	38	9	1	0	0	48
SAK-70 Mk-2 57mm	0	5	14	18	7	44
Total	**38**	**14**	**15**	**18**	**7**	**92**

Source: SIPRI Arms Transfer Database, generated 1 March 2013.

According to Forecast International, Oto Melara had produced 854 76mm guns by the end of 2010.[58] Table 2 indicates that 646 such guns had been exported up to that point. This suggests that 208 such guns had been produced for the Italian Navy. In other words, for every 76mm gun that was produced for the Italian Navy, more than three had been exported.

On the basis that the unit price of the Super Rapid lay between $1.5m and $2m in 2011, depending on the number of units ordered and the customer,[59] the value of these exports was perhaps $970 – 1,290m (€700 – 930m) at 2011 prices.

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[57] Table notes: Some arbitrary allocations were made across two or more periods involving major orders of Compact 76mm guns (49 to Japan, 68 to South Korea and 81 to the USA) and Compact 40L70 guns (55 to South Korea).
The Compact weighed 7.5 tonnes (empty) and was capable of firing at the rate of 80-85 rounds per minute (rpm), each round weighing 12 kilograms. The "Super Rapid" (SR) is an improved, faster-firing (120 rounds per minute) version designed to counter anti-ship missiles. The magazine for the SR is independent of the turret, which means that the feed can be interrupted to insert different kinds of ammunition, making the gun more flexible against multiple targets.
The Oto-Melara/Otobreda twin 40L70 compact / "fast forty" gun system is a high-performance anti-missile, anti-aircraft and ship-to-ship close-in weapon system (CIWS), with a rate of fire of 600 rounds per minute (compact) / 900 rounds per minute (fast forty).

[58] This is less than the number reported by Oto Melara reported in December 2002: that about 1,000 Compact and Super Rapid guns were in service in 51 navies.

[59] Forecast International, "The Market for Naval Surface Warfare Systems", 2011.

The economic significance of an achievement of this kind is that it brings about a transfer of employees (and other resources) from the manufacturing sector in general, i.e. from occupations where their productivity is probably around the sector average, to one where their productivity is exceptional. In 2010 and 2011, Oto Melara achieved a turnover per employee that was over one-third higher than both that of the industry to which it belongs, and the average for Italian manufacturing.

Table 5.20: Turnover per employee comparisons, 2011 (€000)

	2010	2011
Oto Melara[1]	294	342
Italian weapons & ammunition industry[2]	239	252
Italian manufacturing sector[2]	218	252
Premium over manufacturing sector	**35%**	**36%**

(1) Company website
(2) 2010, Eurostat, Annual detailed enterprise statistics for industry; 2011, estimated on basis of 2009 and 2010 data. Value added per employee would be a better measure of productivity but company accounts do not enable this to be estimated.

5.8.3 Counterfactuals

The counterfactuals are more conceptual and speculative, but important to consider. One could think of them in any of a number of ways, but the two that seem to us to be the most plausible are:

- that Oto Melara had not developed their compact naval guns, but other European producers had done so; or
- that Europe had not developed compact naval guns, so that its navies would have had to rely on more traditional gun designs, adopted by the UK and the US.

Regarding the first possibility, the 10 European navies that adopted the Oto Melara Compact or its Super Rapid successor would probably have adopted the Bofors 57mm L70 - its closest rival and substitute - also favoured by a number of navies, including three European navies (Finland, Ireland and Sweden) the US Coastguard.[60]

Another alternative would have been the Creusot-Loire 100mm naval gun which, although not as successful commercially as the Oto Melara or the Bofors systems, has been used by four European navies (those of Bulgaria, Belgium, Germany and Portugal), and has been exported to China, Malaysia, Portugal and Saudi Arabia. However, apart from a 1957 deal to supply Germany with 57 Medele-1953 100mm guns, Creusot-Loire is reported to have exported only 26 naval guns and to have manufactured another eight in China.

The following comparison was made between the Oto Melara 76mm Mk3 and the Bofors 57mm L70.[61] "Both guns are similar in terms of installation weight, ship impact and throw weight (the 57mm throws a shell half the weight of that thrown by the 76mm but at twice the rate of fire). The 76mm has met and matched the challenge mounted by the smaller gun. The deciding factor was that, while the 76mm shell is twice the weight of the 57mm, it is much more than twice as destructive; the explosive content of the bigger round is proportionally much greater, demonstrated in a Canadian Navy Sinkex (navy exercise to practice sinking ships). This used a decommissioned destroyer to demonstrate a variety of weapons' effects. The ship was sent down by an Oto Melara 76mm in short order after a 57mm had failed to achieve the same result."

[60] The company was founded in 1944 and is based in Karlskoga, Sweden. It was formerly known as Bofors Defence AB. It was acquired by BAE Systems in August 2005, and is now known as BAE Systems Bofors AB, operating as a subsidiary of BAE Systems Land and Armaments.

[61] Forecast International, "57mm vs. 76mm".

Despite this, the Bofors 57mm is now catching up with Oto Melara, particularly in the USA (a previous 76mm user) where the Bofors has been selected for all three of the Coast Guard Cutter, DDG1000 and Littoral Combat Ship programmes.

To conclude on this aspect, the revealed preferences of European navies have been strongly in favour of the Oto Melara systems. [62] In their absence, several European navies would have had to adopt what they regard as a second-best alternative.

The second counterfactual – that Europe producers had not developed compact naval guns - would have had more far-reaching consequences. The guns adopted by the US Navy - the Mk45 5-inch gun produced by United Defense (now part of BAE Systems Land & Armaments) - weigh about four times as much as the Oto Melara Super Rapid gun (21-28 tonnes compared to 7.5 tonnes), and fire a much heavier shell (32.75 kg compared to 7.5kg), at a lower rate of fire (16-20 rounds per minute compared to 120).

The US gun would probably have been too heavy for the smaller of the European vessels. It would have been necessary to deploy fewer, larger vessels, or to deploy less capable smaller vessels.

In any case, ships that are armed in this way would not have met the requirements of most European navies. As Anthony Williams explains,[63] navies hold differing views about the role of gunnery. During the 1960s two completely different schools of thought developed among the world's navies. The Americans and the British believed that missiles or carrier aircraft would be the primary armament in dealing with both aircraft and enemy warships. This meant that medium-calibre guns would mainly be used for shore bombardment with a backup role in dealing with smaller-ship targets not worth a missile. In fact both navies went through a period when they assumed that certain classes of warships did not need a medium calibre gun at all.

“Other navies, including most of those in Western Europe, decided that the gun still had an important general purpose role and would need to deal with targets such as fast missile boats, and even anti-ship missiles as well as aircraft.

These philosophies led to different approaches in gun design. The British and American requirement did not call for a high rate of fire, so their mountings, the 4.5" Mk.8 and the 5" Mark 45, respectively, achieve only 20-25 rpm but have the benefit of being simple and relatively light at around 25 tons, as well as low on manpower demands.” The Europeans prefer high rates of fire (the Super Rapid’s 120 rpm and Creusot-Loire’s 90 rpm).[64]

In short, in the absence of the three rapid-fire compact guns that we have mentioned here, it is difficult to see how the majority of European navies could have equipped themselves in the way that they obviously prefer. They would have faced the prospect of either a lesser capability, or greater expense (more ships, or heavier ships armed with US or UK guns).

5.8.4 Conclusions

There are three main conclusions that can be drawn from this case study.

The first is that investment in defence capabilities can sometimes produce spectacular economic as well as defence benefits, when a Ministry of Defence identifies a military requirement that is shared by a number of nations, and then commissions a national supplier to develop a cost-effective solution.

[62] Oto Melara’s 76mm gun was preferred to the French 100mm naval gun both for the joint French/Italian Horizon frigate and the FREMM frigate.

[63] Anthony G Williams, “Naval Armament: the MCG (medium calibre gun) Problem”, blog posted on 23 October 2011.

[64] Anthony G Williams, “Naval Armament: the MCG (medium calibre gun) Problem”, blog posted on 23 October 2011.

The resulting export sales, over several decades, far exceed the numbers required for that country's own defence requirements (in the case of Oto Melara's 76mm naval guns, by a factor of three).

The second conclusion concerns the economic significance of an achievement of this kind. It involves a transfer of resources from the manufacturing sector in general, i.e. from occupations where labour productivity is probably around the sector average, to one in which productivity is exceptional. In 2010 and 2011, Oto Melara achieved a turnover per employee that was over one-third higher than both that of the industry to which it belongs, and the average for Italian manufacturing.

The third conclusion concerns the way defence investment enables nations to discover solutions that are cost-effective for them. Purchasing defence systems "off-the-shelf" is often advocated as a way of avoiding the enormous development costs and risks of new systems. Whether or not this is the right choice, there is usually a good case for examining this option, as a default position. But sometimes the "shelf" lacks systems that suit a nation's circumstances and defence philosophy. Compact naval guns are such a case. The relatively small ships deployed by European coastal navies require capable, compact and multi-purpose guns. Their absence would probably have required different types of ships, resulting in a lower level of naval capability, or significantly higher costs.

5.9 R&T Case Study: Intelligence, Surveillance and Reconnaissance Unmanned Air Systems

Intelligence, Surveillance and Reconnaissance Unmanned Air Systems (ISR UAS) are a sub-group of Unmanned Air Vehicles (UAV) that focus on intelligence, surveillance and reconnaissance roles.

To date, the focus of research and development with respect to UAVs has been in the USA and Israel. Indeed, research into the modern UAV began in earnest in the late 1970s, heavily influenced by an Israeli aerospace engineer named Abe Karem.[65] Karem, a former chief designer for the Israeli Air Force, developed the Albatross, which could remain airborne for 56 hours compared to just a few minutes for previous UAVs.

Comparatively fewer resources have, in the past, been devoted to UAV research within Europe. However, European countries such as Belgium, France, Germany, Italy, the Netherlands, and the UK are also increasingly active in UAV research, design and production.[66]

5.9.1 Development of ISR UAS

ISR systems include reconnaissance satellites, manned aircraft and UAS. They provide 'top-level' policy-makers with information and knowledge about the military capabilities of foreign nations, the location of their key defence plants and industrial sites, the presence of weapons of mass destruction and the plans of foreign countries and terrorist groups. Military commanders rely on intelligence for information on the location and activities of enemy forces ranging from conventional forces to terrorist units.

UAS are a relatively new technology that was developed in response to military demands, especially in the USA.

They were first used in the Vietnam conflict but their use was limited until 1990-1991 when they supplied location data for targeting precision guided munitions during the first Gulf War (Operation Desert Storm).

[65] This paragraph draws on "The dronefather" (The Economist, 1 Dec 2012) and an internal EDA summary of UAV developments

[66] Hatzigeorgopoulos, M. (2012), "European Perspectives on Unmanned Aerial Vehicles", European Security Review

UAS have now become an essential part of US military operations and have expanded with the conflicts in Iraq and Afghanistan. Indeed, US Forces have increased the number of UAS deployed from 167 in 2002 to more than 6,000 in 2008. There was a corresponding increase in US defence investment in UAS from $284m in 2000 to $2.5bn in 2008. There was also a $4.1bn budget request in 2011.[67] The Armed Forces of other advanced nations are similarly adopting UAS.

UAS can provide data at a much lower cost than satellites and have emerged as substitutes for them. UAS vary in size, complexity and range from small systems which can be launched by a single soldier for short-range tactical missions ('seeing over the hill') to the high-altitude Global Hawk which can acquire much the same information as reconnaissance satellites.

The development of UAS has been subject to substantial cost escalation. For example, there was a development cost escalation of 284 per cent on the Global Hawk, 97 per cent on the Reaper, 80 per cent on the Shadow and 60 per cent on the Predator. The average cost escalation of 10 American programmes was 37 per cent.[68]

Cost escalation has been just one argument posed by critics of the American UAS programmes. Concerns have also been expressed about lengthy delays, wasteful duplication (as each Armed Force has purchased its own UAS) and the difficulty of anticipating the rapid technical changes associated with UAS and UAV.[69]

5.9.2 A new and emerging industry

UAS and UAV are an example of rapid technical change which has created a new industry with some new entrants. The situation bears some resemblance to the early development of aircraft between 1903 and 1918 when a variety of new firms were created, each developing and testing different types of aircraft. That industry expanded with major military orders during World War I.

Overall, the United States UAS and UAV industry has not been dominated by the traditional and established aerospace companies. The industry has seen numerous new entrants, some of which are new small firms while others are new divisions of established companies from other industries.

In the US market, new entrants include independent small firms such as ShadowAir, ISR and Arcturus UAV. Other small firms specialising in UAS/UAV have been acquired by established aerospace firms. For example, Insitu Inc – which built the successful ScanEagle – was acquired by Boeing in 2008.

IT companies such as the Computer Science Corporation and DRS Technologies have entered the market. The latter of these supplies the Sentry and was acquired by the Italian defence company, Finmeccanica in 2008. Similarly, research and engineering companies such as Applied Research Associates and Altavian have entered the market.

5.9.3 The industry's technology

There is an absence of well-documented studies on the technologies required to produce UAS. However, some indications can be deduced from the firms involved in the industry and the missions of their UAS.

Some companies are IT, defence electronics, and research and engineering firms (CSC; ARA); others are established aerospace companies (Northrop Grumman). UAS technologies for ISR services

[67] CRS (2013) "Intelligence, Surveillance and Reconnaissance (ISR) Acquisition: Issues for Congress", Congressional Research Services, US Congress, Washington DC, April.

[68] CRS (2013) "Intelligence, Surveillance and Reconnaissance (ISR) Acquisition: Issues for Congress", Congressional Research Services, US Congress, Washington DC, April, pages 11-12

[69] CRS (2013) "Intelligence, Surveillance and Reconnaissance (ISR) Acquisition: Issues for Congress", Congressional Research Services, US Congress, Washington DC, April.

include miniaturisation, guidance systems, the development of small and long-endurance engines, small and accurate cameras, sensor technology, data collection and analysis, communication links and simulation technologies.

5.9.4 Civil applications

The military applications of unmanned systems for ISR missions will continue to expand as the technology develops. Unmanned systems will substitute for manned aircraft, especially for 'dangerous, dirty and dull tasks'.

There are also extensive civil applications of unmanned ISR systems. Known examples include: homeland security; search and rescue; border and coastal patrol and surveillance; domestic policing; agricultural, forestry, fisheries and ocean management; pipeline security; weather information; strategic infrastructure and sensitive facilities; and the policing and management of remote locations.

Unmanned aerial ISR systems provide new and valuable information and can replace costly labour-intensive operations. For example, unmanned aerial ISR systems can access forests in remote locations and can fly through forest fires (a task which would be too dangerous for manned aircraft) and so can provide support to fire-fighting services. They can also perform long-range inspections of power lines, pipelines, roads, hydro-electric facilities and off-shore wind farms. Further applications include transferring some of the aerial technology to unmanned ground and unmanned marine systems (e.g. underwater inspection).

5.9.5 Future prospects

The military demand for unmanned aerial ISR systems will decline following the end of the Afghanistan conflict in 2014. The reduced demand will be especially significant in the USA with specific economic impacts on its UAS/UAV industry, together with the general reduction in US military expenditure following the economic and fiscal crisis.

For the industry, reduced demand will mean job losses, plant closures, the exit of some firms and mergers between firms. The industry will also respond by seeking new market opportunities including export markets and new civilian markets for UAS and UAV.

5.10 Defence aerospace technology transfer and spin-offs

5.10.1 Background

There is no shortage of examples of spin-offs from the defence sector of the aerospace industry. Technical advances in military aircraft have been transferred and applied to civil aircraft; and the US space agency, NASA, has identified an impressive list of spin-offs from the US space programme. Examples of spin-offs from military aircraft include radar, the jet engine, flight control systems and composite materials. Spin-offs from the US space programme include light-emitting diodes (LEDs), by-pass operations and a range of applications in health and medicine, transportation, public safety and computer technology.

Some of these technologies have been applied to markets outside the aerospace industry. For example, aerospace technology has been applied to motor cars, including Formula 1 racing cars (lightweight materials; anti-skid braking; Global Positioning Systems). Helicopter blade technology has been applied to the turbine blades used for wind farms; jet engine technology has led to the development of new materials able to withstand high temperatures; and jet engines have been used for marine propulsion.

Given the substantial number of spin-offs from defence aerospace, it is not possible to provide a comprehensive review within this report. Therefore, this section reviews technology transfer and spin-offs from Unmanned Air Vehicles and satellite navigation (including Global Positioning Systems and other Global Navigation Satellite Systems).

5.10.2 Unmanned Air Vehicles (UAVs)

UAVs, also known as unmanned aircraft systems (UAS) or drones, are a new aerospace technology which offers opportunities for replacing manned aircraft. UAVs comprise an unmanned aircraft, a control system usually with a ground control station, a control link and other support equipment. Whilst they lack a human pilot, UAVs require substantial inputs of human and physical capital (e.g. to operate the ground control stations). They have been used extensively by all branches of the armed forces and by state intelligence agencies.

The military role of UAVs is expanding rapidly, especially as rapid technical change is leading to greater capability being installed in smaller airframes. The military role of UAVs includes intelligence, surveillance and reconnaissance (ISR) missions, strike missions, destruction of enemy air defences, communications, and search and rescue roles. Some UAVs are small enough to be hand-launched and used by ground troops to obtain intelligence about towns and villages. Unit costs of UAVs range from a few thousand Euros for small hand-launched models to millions of Euros for larger and more advanced versions (e.g. Global Hawk). Some UAVs are capable of long endurance: for example, the Predator UAV has achieved flights of some 40 hours.

As an example of technology transfer, UAVs are developing new civilian uses. These include land management; remote inspection of road and rail earthworks; monitoring coastal erosion; forest fire detection and monitoring; disaster relief; pipeline monitoring; traffic congestion; conservation of wildlife regions; and oil, gas and mineral exploration. In their civilian use, UAVs are involved in scientific research (e.g. of hurricanes) as well as domestic policing and homeland security, and in search and rescue operations.

5.10.2.1 Applications of UAV technology

UAV technology has extensive applications, both in spin-offs and dual-use applications. The following examples are just a small number of the technologies which have resulted from UAV developments:

- the development of simulator training;
- composite materials;
- cameras and imaging systems (e.g. the development of smaller infrared cameras);
- data and communications;
- ground control systems and equipment;
- navigation and guidance systems;
- robotics;
- the delivery of electric power over long distances via lasers;
- cloud-cap technology;
- rapid communications and intelligence, surveillance and reconnaissance capabilities;
- measurement systems (e.g. for inspecting complex parts such as aero-engine blades, automotive blocks and gears);
- the development of autonomous technology; and

- applications to the aerospace and medical equipment sectors.

5.10.3 Satellite Navigation

Satellite navigation comprises Global Positioning Systems (GPS) and Global Navigation Satellite Systems (GNSS) where there is global coverage. These systems comprise a set of satellites and ground-based stations. They require a rocket launcher to place the satellite into its space orbit.

The USA and Russia operate global GNSSs and Europe is developing its alternative Galileo system. Galileo will allow free access to basic services, but high precision capabilities will only be accessible to paying commercial customers and to military users. Other nations such as China, India and Japan are developing regional satellite navigation systems under national control and for their national region.

Originally, satellite navigation was developed for military uses (e.g. precision delivery of weapons; direction of military forces and location of enemy forces; disabling enemy satellite navigation systems). Over time, however, the technology has come to be used in many civilian applications.

5.10.3.1 Spin-offs from Satellite Navigation

Not surprisingly, some of the spin-off technologies from satellite navigation are similar to those from UAVs. They include a complete range of navigation uses in the land, sea, air and space domains. Spin-off technologies from satellite navigation include:

- surveying, mapping and exploration (e.g. oil exploration);
- precision tracking: examples include GNSS equipment for the visually-impaired and the tracking of criminal offenders on parole;
- weather forecasting;
- scientific research and experiments. For example, the greater understanding and observation of natural disaster events (e.g. earthquakes);
- road safety, traffic management and road pricing systems;
- robotics;
- improving the efficiency of agriculture (e.g. precision agriculture and driverless tractors);
- marketing;
- removal of unexploded ordnance;
- satellite phone networks; and
- improved aircraft safety through better navigation and landing aids.

5.10.4 Facilitating spin-offs

The European Space Agency (ESA) publishes a list of technologies transferred from its space activities. It suggests that space technologies are being used to enhance the life and wellbeing of citizens through, for example, healthcare products, improved waste management, water recovery, safety improvements and new sports equipment in motor racing, sailing, skiing and cycling.

The ESA has created a specialist agency, the Technology Transfer Programme Office, which has responsibility for technology transfer. This Office facilitates technology transfer through technology brokers, national initiatives and competitions. For example, the Office organises an annual competition to promote the wider business application of satellite navigation technology. The competition (known as the Galileo Masters Competition) invites individuals and teams to submit ideas for the creation of new businesses in the emerging satellite navigation market. Previous winners of the competition included a novel application to guide visitors around indoor exhibition centres, a system for the accurate positioning of offshore ships and a system to locate water pollution. Other previous winners included a navigation device for blind and visually-impaired persons, entertainment and tracking devices, and a management system for automotive accidents with hazardous cargo. The 2013 Satellite Navigation Competition invites bids in six areas concerned with high precision, smart moving, safety and security, public and social services, mobile location-based services and industry applications.

The US space agency, NASA, has also identified a list of spin-off technologies from its activities. These include health and medicine, transportation, public safety, consumer goods, energy and the environment, information technology and industrial productivity. NASA estimated that by 2012, space spin-offs had generated $5bn in revenues and saved $6.2bn in costs.[70] Other US studies of the economic benefits of NASA spending have estimated discounted rates of return from 33 per cent to 43 per cent; multiplier effects of 7 to 23.4; and employment multiplier effects of about 8 to 19 (these are jobs created for every $1m (2009 dollars) invested in NASA).[71]

5.10.5 Conclusion

A list of examples of spin-offs from UAVs and space and satellite navigation are useful, but not sufficient for developing a convincing economic case for state investment in these activities. There is a general absence of independent published economic studies of spin-offs in defence aerospace markets.

Economic analysis suggests that spin-offs are external economic benefits. In the presence of external benefits, private markets are likely to 'under-invest' in such socially-desirable activities and so there is a case for state intervention in such activities. However, this only represents a general case for state intervention in R&D markets. The case for state intervention in such specific markets as defence aerospace and space markets needs more supporting analysis and data.

Economic studies of spin-offs need an underlying economic model together with an accurate and reliable database using a common methodology and assumptions. An economic model is required to identify the various causal determinants of economic benefits. Next, there is a need to identify the economic benefits of spin-offs and how they are to be measured. For example, the economic benefits of spin-offs might comprise revenue generated, jobs created by numbers and skills, productivity improvements, lives saved and life improvements. A mere listing of such economic benefits would produce a list of non-comparable benefits (e.g. numbers of jobs and revenue generated) whereas a proper benefit analysis requires that all the economic benefits be valued in monetary terms so that they are comparable. Finally, there is a need to identify the contribution of a specific R&D programme to the creation of economic benefits, and whether such benefits would have emerged without the specific R&D programme.

5.11 Section Appendix: Economic Rents

Earlier sections of this report focused on estimating the impact of a one-off €100m investment in the EU defence sector and comparing these impacts with those that would arise if an equivalent investment were to be made in alternative sectors, whilst certain case studies suggested that there are rents in some parts of the defence sector. In this appendix, we build on that analysis by how defence investments can create economic rent for the EU as a whole, rather than (as is more normally the case) such rents constituting an inefficient transfer from consumers to producers.

70 NASA, Spin-Off, 2012.

71 Comstock, D, *et al* (2010), "A structure for capturing quantitative benefits from the transfer of space and aeronautics technology", International Astronautical Congress, Cape Town South Africa.

'Economic rent' is a factor's earnings in excess of what they could use in the next-best use (their 'opportunity cost'). For example, if an industry's cost of capital is 10 per cent and it earns 20 per cent on capital employed of €1bn, it could be said to earn an annual economic rent of €100m.[72]

Economic rent is an indication – provided that markets reallocate resources fairly smoothly – of an industry's net contribution to the economy. If this industry ceased to exist this is what the economy would lose, once it had adjusted to its disappearance. The industry's assets would be redeployed and could be expected to earn a return which is typical of the economy (10 per cent, the cost of capital). GDP would then be lower by €100m a year (the economic rent that the industry had earned before it ceased to exist).

While it has not been possible to make meaningful comparisons of rates of return on capital employed within this study – in part because definitions of 'capital employed' differ both between and within countries – we have sought to draw lessons from the limited data on profit margins that are available.

First, we obtained data on the profit margins of the 17 largest European defence companies in 2009. These data are shown in Table 5.21.

Table 5.21: Profit margins of major European defence companies (2009)

Company	Country	Arms sales ($m)	Total sales ($m)	Arms sales as % of total sales	Total profit ($m)	Profit/ total sales
BAE Systems	UK	33,250	34,914	95	-70	0%
Finmeccanica	Italy	13,280	25,244	53	997	4%
Thales	France	10,200	17,890	57	178	1%
DCNS	France	3,340	3,342	100	179	5%
Saab	Sweden	2,640	3,220	82	91	3%
Rheinmetall	Germany	2,640	4,750	55	-72	-2%
Cobham	UK	2,260	2,929	77	290	10%
Babcock	UK	2,010	2,952	68	169	6%
Navantia	Spain	1,980	2,197	90	-115	-5%
QinetiQ	UK	1,770	2,532	70	-99	-4%
Krauss-Maffei-Wegmann	Germany	1,630	1,715	95	211	12%
Groupe Dassault	France	1,360	4,751	67	438	9%
VT Group	UK	1,240	1,950	64	328	17%
Nexter	France	1,230	1,232	100	196	16%
Ultra Electronics	UK	810	1,014	80	122	12%
Chemring Group	UK	750	785	96	109	14%
Patria	Finland	660	749	88	24	3%
Total		**81,050**	**112,166**	**72**	**2,976**	**3%**

Source: SIPRI. Considers the largest companies for whom defence accounted for more than 50 per cent of sales.

The two most interesting insights that can be drawn from this table are:

- the largest of these companies traded on very modest margins in the year 2009 (although it is worth noting that BAE Systems' profit margins had recovered by 2010 – see Table 5.22); and
- six specialists (Cobham, VT, Nexter, Krauss-Maffei-Wegmann, Ultra Electronics and Chemring) were highly profitable, with margins in excess of 10 per cent, even in what was a bad year for the industry.

These figures suggest that the economic rent earned by defence companies can be substantial.

[72] Calculated as GDP loss = (20%-10%)*€100bn = €100m

We have also considered the potential of company accounts for assessing the economic rent earned by the defence sector. A limitation of company accounts is that they do not typically segment the company's activities in ways that we would wish, so that it may be difficult to assess the profitability of the defence-related activities of companies such as EADS that supply both defence and civil markets.

Another consideration is that if EU defence companies do succeed in earning economic rent, do they do so in their respective domestic market, in the EU market, or in non-EU markets? It could be argued that any rents that are earned within the EU do not add to the EU's economic welfare. They are simply transfers within the EU, from its taxpayers to the defence companies. Therefore, the economic rent that is of primary interest in the context of this study is that which is earned in non-EU markets.

The accounts published by BAE Systems are helpful in this context. BAE Systems is both a specialised defence company and it provides an exceptional amount of segmental detail in its accounts.

Table 5.22 shows the profit margins of BAE systems by market segment. The figures show that BAE Systems' margins on sales on its international Platforms & services operations in 2010 and 2011 were more than double those on their combined US and UK Platforms and Services operations.

These figures suggest that BAE systems earned some economic rent from its international operations. Given the figures reported in Table 5.21, it would not be surprising if many other defence companies also earned economic rent on their overseas operations.

Table 5.22: BAE Systems' profit margins by market segment

Market segment	Revenue from external customers	Reported profits	Margin on sales
	2011	2010	2011
	£m	£m	£m
Electronic systems	2,527	2,850	371
Cyber & intelligence	1,377	1,173	72
Platforms & services (US)	5,176	7,497	256
Platforms & services (UK)	5,942	6,154	592
Platforms & services (US & UK)	11,118	13,651	848
Platforms & services (International)*	2,748	3,306	439
Total	**17,770**	**20,980**	**1,730**

Source: BAE Systems Annual Report 2011, pages 120-122.

* The Group's business in Saudi Arabia, Australia, India, and Oman, together with its 37.5 % interest in MBDA

6 R&D in the Defence Sector

Previous chapters in this report have presented a quantitative assessment of the macroeconomic benefits of investing in the defence sector relative to equivalent investments in other sectors that are heavily funded by the public sector.

In this chapter, we build on that analysis by explaining when and why it is appropriate for defence to receive R&D funding from the public sector and how this funding acts as a spur to private sector investment. In particular, we first examine the scale of R&D expenditure in the defence sector. We then describe two stylised models of R&D funding and explain how the features of the defence sector influence the choice of funding model. We then complement that discussion with evidence from a survey of stakeholders on the importance of R&D to the performance of defence sector and the funding models that are used to support R&D activities.

We intentionally focus on research that is conducted by individual companies as this is the most likely to be affected by an investment of €100m in the defence sector. However, we acknowledge that the range of defence research is far broader than that considered here and can involve collaboration both between companies and across countries / Member States.

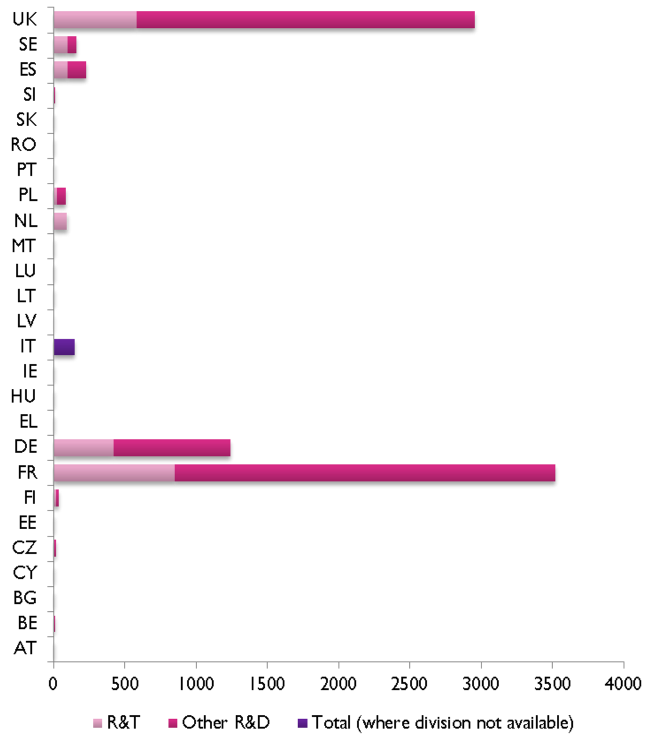
The discussion in this chapter is significantly more qualitative in nature than that of preceding chapters because it seeks to explain the rationale for a €100m public investment in the defence sector rather than simply assuming that such funding would be available.

6.1 Defence R&D

R&D is a key component of defence expenditure due to its many short-term and long-term impacts on a nation's defence capabilities and its economy. Figure 6.1 shows average defence R&D expenditure, by category, for each participating Member State between 2008 and 2010.

As indicated in the Figure, R&D spending is concentrated in three Member States – France, the UK and Germany. Taken together, these account for more than 90 per cent of total R&D spending by the participating Member States. Germany devotes a third of its R&D spend to R&T – the proportions for France and the UK are a quarter and a fifth. Other Member States spending material amounts on defence R&D include Spain, Italy, Sweden, Poland and the Netherlands.

Figure 6.1: Average defence R&D spend by participating Member States, 2008-2010 (€m)



6.2 R&D Funding

6.2.1 Two Models of R&D Funding

It is useful to distinguish between two broad models of research and development funding.[73] In the most common model, companies or individuals have ideas, research them, prove the concepts involved, and develop them into final products, and it is only once a final product is available that it is sold to customers. This is the model, for example, in the mobile phone sector. Apple conceived of the iPhone, developed working iPhones, all funded from their own internal research budgets, then sold them to customers. Let us refer to this as the "seller-funded research model".

In an alternative model, the potential customer for a product or idea commissions research into the feasibility of the product's development, and may then go on to commission and fund testing and the production of final products. This model is common for many forms of analytical, as opposed to product, research — e.g. much economics research is specifically commissioned by one buyer, rather than the researchers producing a report that they then attempt to sell to multiple interested parties. It is also the model used sometimes in response to specific disease outbreaks — e.g. government health agencies funding research into cures for a specific strain of bird 'flu. Let us refer to this as the "buyer-funded research model".

In the defence sector the buyer-funded research model is much more common than the seller-funded model. Governments usually specifically commission and fund the research and development of

[73] We note that other models of funding exist, including mixed models, third-party funding models, government funding without foreseen purchase etc. For the purpose of this report we have chosen to focus on the two most extreme cases – complete buyer funding and complete seller funding. This approach makes it easier both to highlight the key differences between models and to highlight the circumstances in which each model is most appropriate. Little is lost by focusing on the extremes since inferences can be drawn by comparing the analysis of the extremes. For example, a mixed model is likely to be appropriate where the market context is somewhere in between that described for the seller-funded and buyer-funded models.

advanced technology equipment such as advanced combat aircraft, specialised military transport and special mission aircraft, main battle tanks, surface warships and nuclear-powered submarines. However, some commentators on defence equipment projects claim that such projects could and should be funded according to the first model — i.e. private contractors researching, proving concept, and developing military equipment via their own funding (like Apple and the iPhone), and only then selling finished products to governments. In this section we consider the relative merits of these two models of research funding in the defence sector.

6.2.2 Broad characteristics of seller-funded versus buyer-funded research model markets

Seller-funded markets will tend to have the following features:

- There are multiple potential buyers.
- Potential buyers are relatively uncertain, in advance of viewing a final product, of what is technically feasible, what they want, and how much they would be prepared to pay for it.
- Final prices paid include an economic component which compensates for the costs of research that exceed the actual costs incurred in researching the specific product sold. The reason for this is that the rewards of a successful product must also compensate for the risks of researching unsuccessful products.

Buyer-funded markets will tend to have the following features:

- there is one overwhelmingly majority buyer;
- buyers have specific narrow needs, know in some detail what final product they would like to purchase and approximately how much they would be prepare to pay for it, and have some sense of what ought to be technically feasible; and
- final prices paid for research fund only the actual research costs incurred.

We can illustrate these features by contrasting the extent to which research in the pharmaceuticals industry follows the seller-funded model and to what extent the buyer-funded model.

In the case of most major pharmaceuticals products used in the developed world, there are multiple potential buyers — a new pharmaceuticals product of wide developed-world application can be sold to health insurers, charitable hospitals, and government health agencies in multiple countries. These potential buyers have a broad range of needs — there are many diseases that they would be interested, in principle, in treating better, rather than just one or two. The potential buyers are relatively uncertain regarding what is technically feasible in any given timescale — it's not clear whether the easiest drug to develop next will be one that reduces back pain or one that cures MRSA. The efficacy of any treatment, even if it worked, is uncertain in advance (how completely will that back pain be reduced?) and thus there is uncertainty concerning how much it would be worth paying.

As a consequence of these features, the most natural model for most major developed world pharmaceuticals is seller-funding of research and development. As a consequence of that, and the high uncertainty of pharmaceuticals products (on some estimates one must research 10,000 potential drugs to produce one wide-selling one), when a new pharmaceutical is successful it produces what are referred as "blockbuster" returns, vastly exceeding the costs of researching an individual drug.

But this is not the only model of pharmaceuticals research. When there are epidemic threats (e.g. a particular new strain of bird 'flu) or diseases/disorders of high public policy significance (e.g. malaria), there may be just one buyer (government) that knows precisely what it needs. In such cases governments often commission and fund specific research, sometimes through universities and sometimes through companies.

6.2.3 Nature of defence equipment projects and markets

Armed with our understanding of why some research is seller-funded and other research buyer-funded, we can understand better the models used in the defence sector.

In the defence sector, there can be multiple potential buyers — e.g. governments in a number of countries — but it will often be the case that (a) one buyer (or group of buyers agreeing amongst themselves all to purchase the same technology) will comprise the overwhelming majority of purchases — often the national defence agency of the country of the defence supplier; and (b) more fundamentally, other buyers will not purchase a product that has not been endorsed by being purchased by the national defence agency of the country of the defence supplier. In combination, this means that although in due course there may be several potential buyers, everything is contingent upon satisfying one key buyer.

The key buyer typically has specific known needs that arise from its strategic plans. It wants a particular sort of plane or ship or military vehicle. It may not rule out considering innovative new ideas initiated by the defence contractor itself, but it is much less often interested in novel ideas than in the high-quality delivery of what its own internal analysis suggests is possible. The key buyer might also want to retain the option of the fruits of research not initially being shared with others — a new leap forward in some defence technology might provide a strategic advantage for that country that it does not wish to give up. The key buyer is likely to have an interest in ensuring that its national defence companies remain active for precisely these reasons.

As a consequence of the above, it is unsurprising and natural that advanced technology equipment projects research in the defence is often buyer-funded. Although some forms of defence research may well be suitable for seller-funding, it could be highly problematic were the seller-funding model to be imposed universally. For example, some defence projects might involve research that would only be of relevance and value to one specific buyer — e.g. the technology required for nuclear-powered submarines is only of value on such submarines since there are not many alternative uses for such technologies.

Were such projects relatively inexpensive and the costs relatively certain, perhaps a defence contractor could diversify sufficiently that seller-funded research which did not produce a final product the buyer wanted and this could be offset against successful cases. But much defence equipment is costly and subject to uncertainty over costs. For example, unit production costs for an advanced combat aircraft are some €100m; an electronic platform aircraft (e.g. for airborne early warning) might cost some €500m per unit; and a nuclear-powered attack submarine might cost some €1.8bn per copy. Development costs are a multiple of unit production costs. For an advanced combat aircraft, total development costs are at least 100 times unit production costs and might be 200 times. For such an aircraft, development costs might be €10-20bn. These are large magnitudes to be funded by a private firm for one customer. High costs also mean that few units will be purchased and so production runs will be small.

The technical requirements of advanced defence equipment can also create great uncertainty. Neither the buyer nor the contractor can anticipate correctly all future technological unknowns and their ability to resolve them at reasonable cost (i.e. there exist internal uncertainties). There are also external uncertainties associated with changing threats, the emergence of new substitutes and a governments' continued willingness to purchase the equipment.

When projects are very costly to reach final product stage, seller-funding would leave firms highly vulnerable to a form of what economists call "non-renegotiation-proofness": the buyer could indicate a general interest in a product and a likely price it would be prepared to pay, then once all the sunk costs of research had been borne, the buyer could significantly drop its offer price at the last moment. This could leave the defence contractor with the invidious choice between accepting a bad return or entering bankruptcy. Being vulnerable to such threats might mean that very little advanced research would be done in the defence sector on a seller-funded model, except insofar as a government could credibly commit to maintaining a repeat relationship with researchers (e.g. to keep the researcher in business), even if circumstances changed (an arrangement likely to introduce its own alternative inefficiencies).

6.2.4 Implications for private venture funding

As noted, this analysis does not mean that there will never be seller funding of defence equipment projects. Indeed, of all respondents to our survey, 80 per cent have developed new defence systems on a private venture basis, independent from the national MOD. The value of products developed through a private venture can be substantial – one respondent stated that one of the products it had developed on this basis had achieved sales of €40m.

By identifying the features of defence markets which mean that seller funding is less efficient, it is possible to identify the characteristics that a defence equipment project should have if seller funding is to be available. Specifically, we consider that seller funding might be available where defence equipment is not too costly and risky, where it involves few new technical challenges and where there are substantial export market opportunities.

A good example of seller funding is the BAE Hawk. This was originally sold to the UK RAF with an order for 175 aircraft in 1972. BAE subsequently used its own funds to develop an advanced jet trainer and light combat aircraft for export markets. By early 2013, sales and orders for the Hawk jet aircraft totalled almost 1,000 units (including total sales to the UK of 203 units). Another example of the seller-funding of major defence equipment concerned UK main battle tanks. Vickers-Armstrongs developed and produced a main battle tank – the Vickers MBT – which was a private venture project aimed at export markets. This tank was simple and low-cost and produced over the period 1963-1984. It was sold to a number of African nations and a total of 331 units were produced (including all variants).

Interestingly, both the Vickers tank and the Hawk jet trainer were developed from previous successful designs where the technical problems had been resolved (Centurion tank and Hunter jet fighter). This behaviour further supports the need for buyer funding of research and development in the defence sector: seller funding may not have been secured had the initial public investment in the designs not been available.

6.3 Stakeholders' Perspectives on Defence R&D

As discussed above, a defining characteristic of the defence sector is its dynamism and the significant role played by R&D in the sector's past, current and future development. In order to gain a better understanding of the importance of R&D to participants in the defence sector, we invited stakeholders to take part in an online survey.

A link to the online survey was initially sent to the 183 email addresses of companies involved in the air, land and sea defence industries using contact details provided by the EDA. The initial email was not delivered to 11 email addresses and so the total number of contacts made was 172.

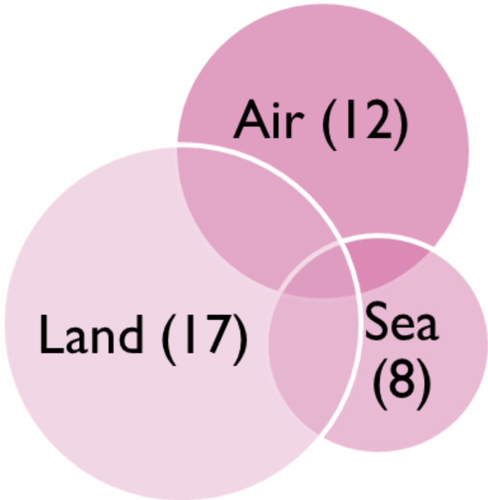
To ensure that the greatest possible response rate was achieved, email reminders were sent to all potential respondents and the initial completion deadline was extended. In addition, the EDA sent a number of emails to its industry contacts to emphasise the importance of the study to the Agency.

In total, we received 26 responses (15 per cent of those successfully contacted) but some of these were incomplete. While the absolute number of responses may seem to be small, we understand that this is typical of surveys in the defence sector. Nonetheless, due to the small sample size, any conclusions drawn from this questionnaire should be treated with care.

6.3.1 Characteristics of respondents

Of the 26 responses received, 21 defence companies identified the sector(s) in which they operate and their home Member State. Responses were received from companies based in nine Member States. As shown in Figure 6.2, more than half of respondents operate in the land sector, 10 in the air sector and eight operate in the sea sector. Some respondents operate in more than one sector.

Figure 6.2: Defence sectors in which respondents operate



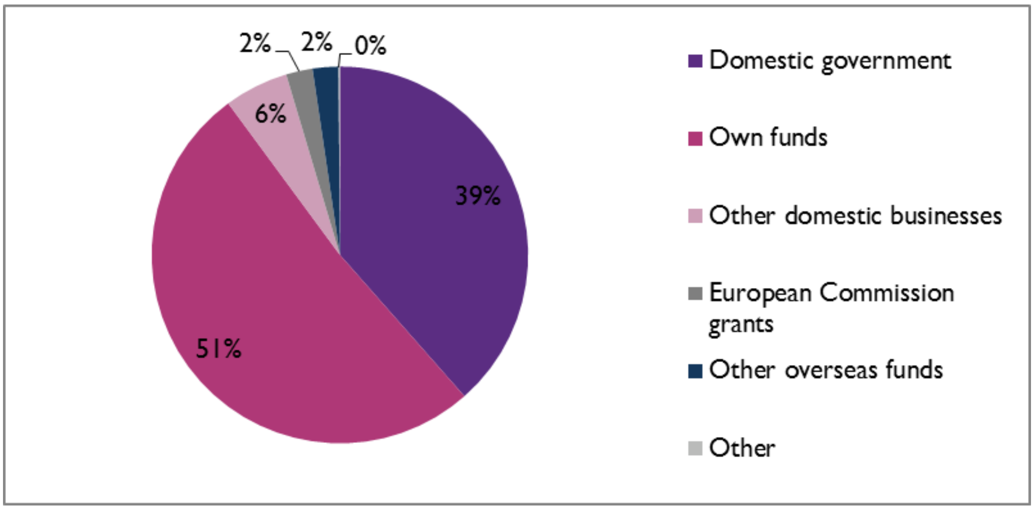
Responses were received from a diverse group of defence companies. The smallest company employs fewer than 10 people and achieved defence sales of less than €1m in the most recent year for which data were available. By contrast, the largest respondent employs more than 100,000 people and achieved defence sales of approximately €17bn.

With respect to defence export sales, it is clear that the importance of exports relative to domestic sales differs significantly between respondents. Interestingly, based on the responses received it appears that exports to non-EU countries are more important to companies that operate in all three defence sectors than to those that operate in fewer sectors.

6.3.2 Sources of funds

As shown in Figure 6.3, responses to our survey suggest that the most important source of funding for R&D is the companies' own resources. Domestic government is the second greatest source, although this is generally more important for larger companies. European Commission grants, other overseas funds and other domestic businesses contribute very little to defence R&D funding.

Figure 6.3: Percentage of R&D funds from certain sources



6.3.3 R&D activities

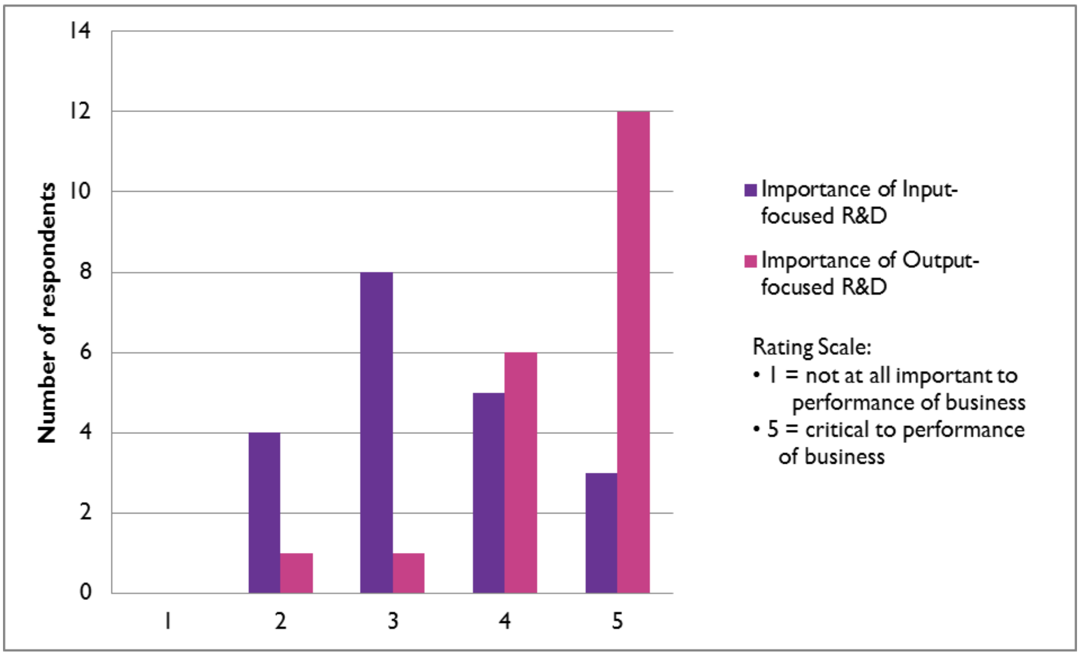
In order to understand the importance of different types of R&D to the future success of the business, we asked respondents to rate the importance of input-focused and output-focused R&D, respectively. We defined input-focused R&D as that which aims to introduce new or substantially changed production processes and output-focused R&D as that which aims to introduce new or substantially improved defence systems.

A majority of respondents believe output-focused R&D is critical to the success of their businesses. Only one respondent stated that it is not important; this firm did, however, state that input-focused R&D is important.

In contrast, only 40 per cent of respondents rated input-focused R&D as very important to the success of their business. All those that stated that input-focused R&D was not important to their business reported that output-focused R&D is important.

These findings suggest that R&D is important to all those that operate in the defence sector, although the type of R&D that is considered most important to the success of the firm is not consistent across the industry. The findings further suggest that firms that operate in more than one sector generally consider both input- and output-focused R&D to be critical to the success of their business, while those that operate in only one sector may consider one type of R&D to be relatively less important.

Figure 6.4: Importance of input-focused R&D and output-focused R&D



We then asked respondents to specify the number of new defence systems that had been developed by the company over the past 10 years, and the total value of these systems.

Respondents generally found it difficult to answer this question, and so the response rate was relatively low and the range of responses extremely wide. With respect to the number of new systems, responses ranged from zero to "more than 50 platforms and large systems".[74] Estimated values ranged from €2m to more than €2bn.

6.3.4 Pattern of sales of new defence systems

6.3.4.1 Sales to the public sector

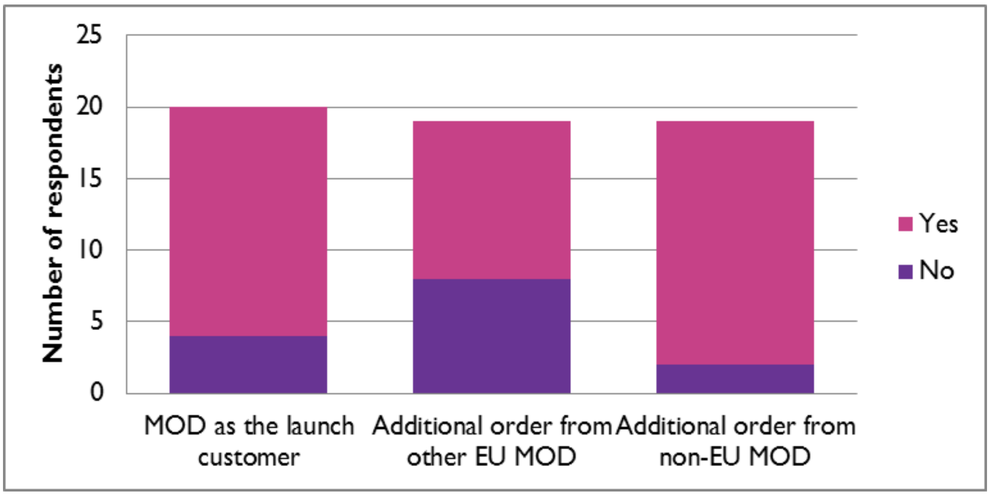
The objective of any R&D activity is to develop a product or process that can improve the profitability of the company. Input-focused R&D seeks to improve production processes and so should lead to a reduction in manufacturing costs, thereby improving profitability by influencing the supply-side of the market. Output-focused R&D aims to introduce new or substantially improved defence systems and so aims to secure an increase in sales, thereby improving profitability by influencing the demand side of the market.

With respect to output-focused R&D, the process by which innovations developed through R&D activities reach the market is of interest to this study since new products and defence systems would be worth little to a company if sales are not achieved. We asked stakeholders to explain both how their products reach the market and to explain the extent to which the national MOD (which we supposed would be a key route to market in many cases) influenced exports of new systems and products.

Figure 6.5 shows that the national Ministry of Defence (MOD) is typically the launch customer for new defence systems. Companies are generally successful in achieving additional orders from non-domestic MOD, especially those from countries outside of the EU.

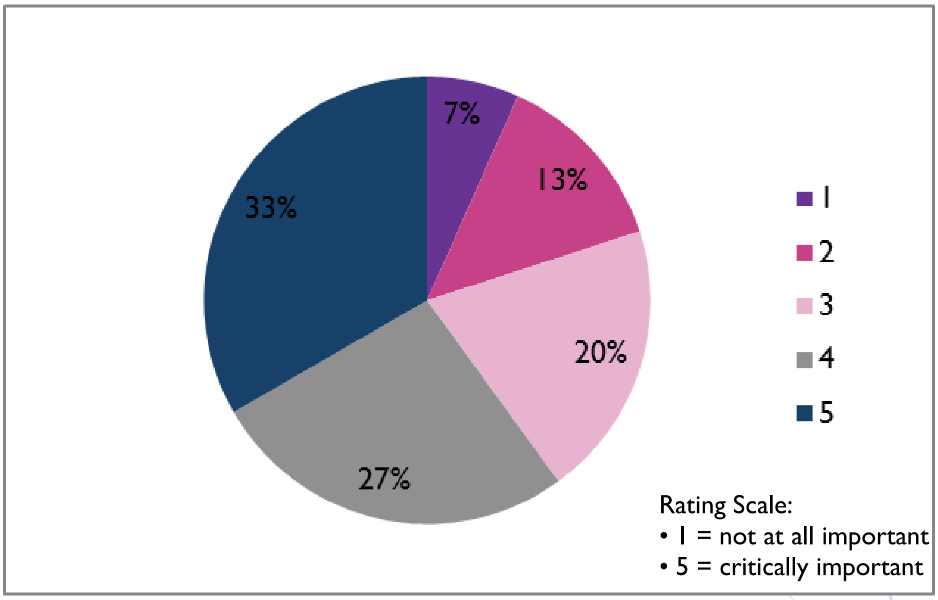
74 One respondent stated that 350 product lines had been developed, which we consider would include more than defence systems. Therefore, this response was excluded when analysing responses to this question.

Figure 6.5: Launch path for new systems and products



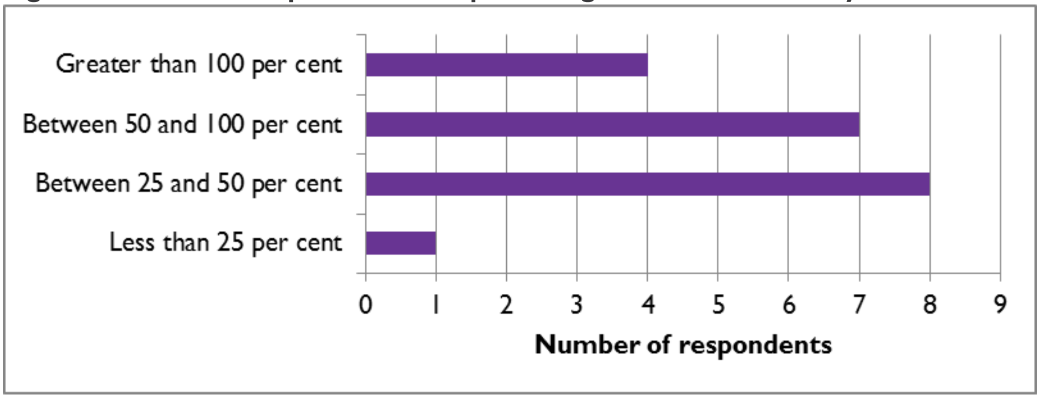
To further develop an understanding of the pattern of sales for a new defence system, we asked respondents to specify the importance of sales to the national MOD for achieving defence exports. Figure 6.6 shows that more than 50 per cent of those that responded to this question believe that sales to national MOD are essential, if not pre-requisite to achieving defence exports. Only 7 per cent believe that sales to MOD have no influence on defence exports at all.

Figure 6.6: Importance of sales to national MOD for achieving export sales



Building on the above questions, we asked respondents to estimate the value of total export sales as a percentage of the total value of orders placed by its own MOD. Our survey found that while the national MOD is generally the launch customer for new defence systems, exports are a significant component of total sales for many respondents. As shown in Figure 6.7, more than half of those that responded to this question indicated that the value of their export sales is greater than 50 per cent of the value of their national MOD orders.

Figure 6.7: Value of export sales as a percentage of value of order by national MOD



6.3.4.2 Involvement of the private sector

Of all respondents to our survey, 80 per cent have developed new defence systems on a private venture basis, independent from the national MOD. The value of products developed through a private venture can be substantial – one respondent stated that one of the products it had developed on this basis had achieved sales of €40m.

6.3.4.3 Offsets

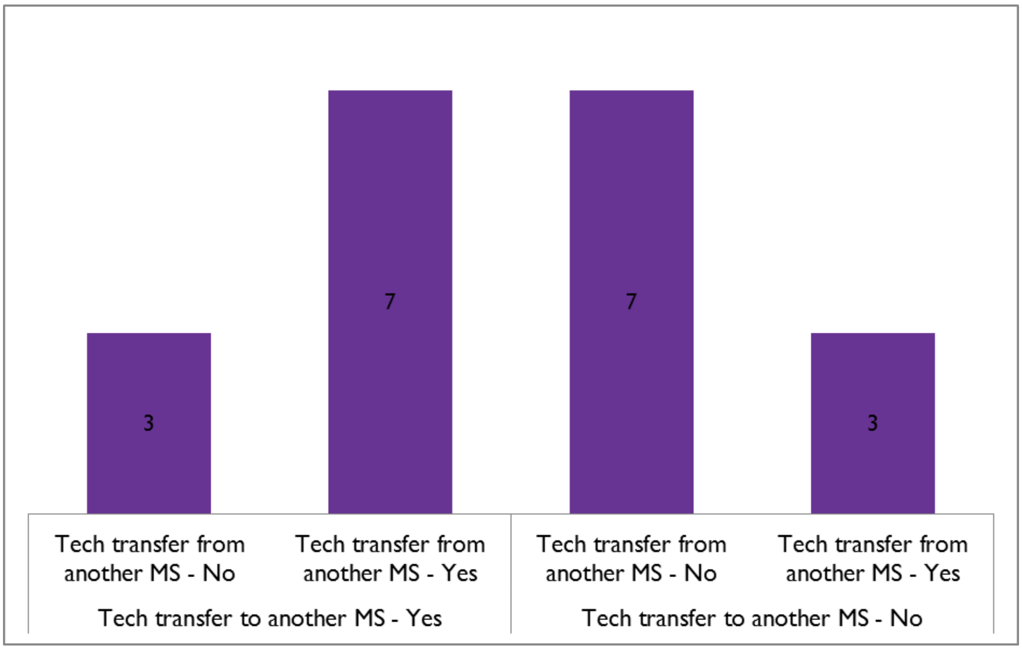
Offsets can be an important element of defence sales to non-domestic customers and so our survey asked stakeholders about the use of offsets in the defence sector.[75]

Respondents were first asked if they have transferred technology to another Member State as part of an offset (i.e. only intra-EU transfers were considered). Ten of 20 respondents to this question stated that they have transferred technology to another Member State.

Respondents were then asked if they have received technology transfer from another Member State. As shown in Figure 6.8, seven of the 10 respondents that have transferred technology to another Member State have also received a technology transfer from another Member State. The same number of respondents had received a technology transfer from another Member State in the group of respondents that had not transferred technology to another Member State.

[75] An 'offset' is an arrangement whereby an importing country makes it a condition that the supplier places orders with national suppliers. It can take the form of 'direct offset', which relates to the equipment concerned, or an 'indirect offset' that relates to products of other industries, or a combination of the two. Offsets are scaled to the size of the transaction: a '100 per cent offset' requires the supplier to make purchases equal to 100 per cent of the value of the contract.

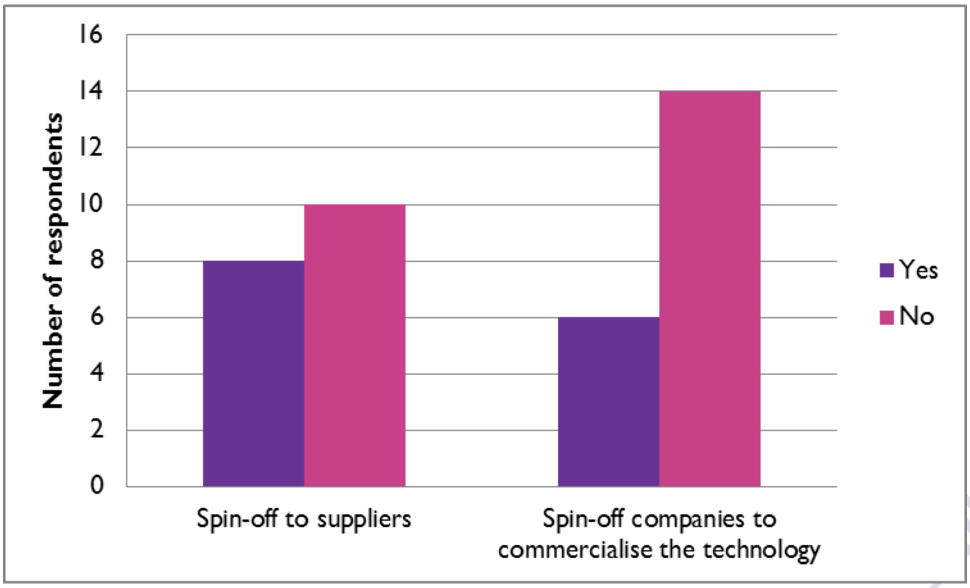
Figure 6.8: Number of companies that have experienced technology to and from another EU MS



6.3.5 Impact of R&D

Our survey results confirm our conjecture that spin-offs and technology transfer are important elements of the economic contribution of the defence sector. However, as shown in Figure 6.9, more respondents have created technologies that have led to a spill-over effect for their suppliers than have created a spin-off company (or companies) to commercialise the technology developed through defence R&D / R&T.

Figure 6.9: Downstream effects of investments in R&D/R&T



Unfortunately, the response rate to questions on the spill-over effect of existing investments in defence R&D was very low – only four responses were achieved. We consider that this response rate is too small for analytical purposes.

7 Conclusions

The analysis contained within this report demonstrates that, at the EU level, the impact on GDP, tax and employment of investing €100m in the health, education, transport and defence sectors are extremely similar.

Taking these results alone shows that defence spending has a macroeconomic role alongside other forms of public spending. However, there are several reasons to believe that the overall macroeconomic benefit of investing in the defence sector should exceed that of investing in other sectors.

First, while the employment impacts of investing in the defence sector are broadly equivalent to the impacts of investing in the health and transport sectors, defence investments have a far greater impact on skilled employment than do investments in the other sectors considered in this report. In an increasingly knowledge-based and skills-based European economy, our analysis suggests that investments in the defence sector are more likely to create jobs that will be sustainable in the long term and will add value to the European economy than are equivalent investments in other sectors.

Second, the importance of R&D to the past, current and future success of the European economy is widely acknowledged and has a sound economic basis in R&D models of endogenous growth. Investments in the defence sector are likely to make a significant contribution to the future economic growth of the EU thanks to the significant impact that such investments have on R&D.

The impact on R&D due to defence investments is between 12 and 20 times greater than the impact of investments in the other key components of public expenditure (transport, health and education). Defence R&D can create significant spin-offs and technology-transfer to other civil and defence applications. Therefore, the economic impact of investing in the defence sector exceeds that which has been captured in the I-O analysis.

We also draw a number of lessons from the case studies:

- Defence spending can take different forms, reflected in the acquisition of Gripen, Rafale and Typhoon (or other types of defence equipment). Studies based solely on the macroeconomic impacts of defence spending, by their blunt nature fail to identify the more detailed microeconomic impacts of such spending.
- There remain considerable opportunities for increasing the efficiency of European collaborative programmes. For example, work-sharing for both development and production could be allocated on the basis of competition: a single prime contractor might manage the programme rather than an industrial consortium and committee arrangements; and the number of major partner nations might be restricted to two partners so as to minimise transaction costs (bilateral collaboration).
- Investment in defence capabilities can sometimes produce spectacular economic as well as defence benefits, when a Ministry of Defence identifies a military requirement that is shared by a number of nations, and then commissions a national supplier to develop a cost-effective solution. The resulting export sales, over several decades, far exceed the numbers required for that country's own defence requirements (in the case of Oto Melara's 76mm naval guns, by a factor of three).
- Investments in the EU defence sector can also lead to a significant cost saving relative to the next best alternative. For example, Germany's investment in the Leopard 2 enabled it to equip its cavalry regiments with a highly capable system for a cost that was 45 per cent lower than the next best alternative.

- There is some indicative support for the claim that arguments for defence spending might be based on wider economic and industrial benefits, including technology spin-offs, but there is a lack of really robust evidence underpinning this view.
- EU defence companies appear to earn economic rent on their operations and, in some cases, this rent appears to be substantial. For example, the economic rent earned on exports of Leopard 2s was equivalent to 18 per cent of the cost of the Leopard programme. The earning of economic rent indicates that the sector makes a net contribution to the economy, over and above the contribution that the same resources would make if employed elsewhere. Moreover, our analysis suggests that a significant proportion of this economic rent is earned outside the EU and so the rent is more than simply a transfer between EU taxpayers and EU defence companies.
- Investment in the defence sector can have important benefits for companies that operate in the civil sector. For example, the civil and military aeronautics industries are closely linked. Under-investment in military aeronautics could endanger the position of the civil aeronautics industry in the EU (as non-EU competitors would then benefit from greater military investment in R&D).
- Defence spending can re-purpose resources from the manufacturing sector in general, i.e. from occupations where labour productivity is probably around the sector average, to uses in areas within the defence sector in which productivity is exceptional. In 2010 and 2011, Oto Melara achieved a turnover per employee that was over one-third higher than both that of the industry to which it belongs, and the average for Italian manufacturing.
- Defence investment enables nations to discover solutions that are cost-effective for them. Purchasing defence systems "off-the-shelf" is often advocated as a way of avoiding the enormous development costs and risks of new systems. Whether or not this is the right choice, there is usually a good case for examining this option, as a default position. But sometimes the "shelf" lacks systems that suit a nation's circumstances and defence philosophy. Compact naval guns are such a case. The relatively small ships deployed by European coastal navies require capable, compact and multi-purpose guns. Their absence would probably have required different types of ships, resulting in a lower level of naval capability, or significantly higher costs.
- Although there are clearly some advantages in purchasing non-EU "off-the-shelf" defence products and services in some areas (and such products and services are purchased at present), it should also be recognised that non-EU "off-the-shelf" solutions can also have some potentially adverse consequences:
  - For example, the Typhoon was estimated to have created 100,000 high-wage / high-skill jobs, exports valued between €13.4bn and €17.8bn, and import-savings valued between €39.3bn and €67.1bn while maintaining European independence and security of supply. These benefits would be lost if non-EU off-the-shelf solutions were purchased.
  - Purchasing non-EU off-the-shelf solutions could create classic issues of security of future. Absent a sufficient mass of investment in the EU defence industry, skills and capacities could deteriorate; rebuilding these would potentially be slow and expensive. For example, even if the EU were to undertake some work on the Joint Strike Fighter (JSF), it is unlikely that this work alone would be sufficient to maintain the design skills necessary for developing a new European combat aircraft.

As regarding whether defence research is better funded by direct investment in research or by the sellers of defence equipment themselves, we have argued that because, in the defence sector:

- it will often be the case that (a) one buyer (or group of buyers agreeing amongst themselves all to purchase the same technology) will comprise the overwhelming majority of purchases — often the national defence agency of the country of the defence supplier; and (b) more fundamentally, other buyers will not purchase a product that has not been endorsed by being purchased by the national defence agency of the country of the defence supplier; and

- the key buyer typically has specific known needs that arise from its strategic plans;

it is unsurprising and natural that advanced technology equipment projects research in the defence is often buyer-funded.

Appendices

Europe Economics

8 Appendix 1: Assumptions, conceptual issues and the €100m investment

8.1 Conceptual Issues and Assumptions

8.1.1 Activities covered by defence investment

The EDA classifies defence expenditure into four broad categories: personnel costs; investment; operation and maintenance; and other. We assumed that a €100m 'investment' would not be spent on deploying or recruiting more personnel (as this is a function of military need), and would therefore be spent in the second category as well as the infrastructure part of the fourth category. In 2010, the 'investment' category accounted for 22.1 per cent of defence expenditure in EDA participating Member States and infrastructure investment accounted for 2.8 per cent.[76]

We also note that the 'investment' category is further broken down into defence equipment procurement expenditure and defence R&D expenditure (which has a further Research and Technology (R&T) sub-category).

We therefore assumed that the €100m investment would be broken down between the following expenditure categories: equipment procurement; non-R&T R&D; R&T and infrastructure. We inspected recent trends in expenditure and based our calculations on the average of the last three years of defence spending.

8.1.2 Geographical distribution of the investment

We divided the total expenditure of €100m between the 26 EDA Member States in proportion to the average investment spending over the three most recent years for which data were available (2008-10). To do this, we calculated the total investment spending as the sum of equipment procurement, non-R&T R&D R&T and infrastructure spending for each country. We then calculated the proportion of total EU investment expenditure accounted for by each Member State and splitting the €100m according to those proportions.

8.1.2.1 Supply side's reaction to investment

In our quantitative analysis, we have treated the one-off €100m investment as an increase in final demand for the relevant products and services.

The response of companies to this increase in demand would determine the follow through effect on the various macroeconomic variables. In particular, the level of capital formation as a response to this increase in demand would depend on whether companies respond by creating additional capacity as well as

[76] EDA Additional Defence Data 2010. At the time of writing, 2010 is the latest year for which defence data is available.

employment (a 'long run' response), or by temporarily increasing employment but working with the fixed capital already in place (a 'short run' response). This, in turn depends in large part upon whether companies view the additional demand as permanent or temporary. An expectation of permanent increases in demand usually leads to higher levels of capital formation than an expectation of temporary increases in demand.

The relationships inherent in the input-output tables are consistent with companies responding to a mixture of temporary and permanent demand changes, and would therefore not be useful to quantify a response to an event that companies know represents a wholly temporary demand increase. However, we consider that it is reasonable to assume that the nature of the €100m investment would be such that the companies would initially be unable to fully assess whether the demand increase is temporary or permanent. As capacity building decisions are, in fact, made in response to expected rather actual future demand, we assume that companies would build an expectation of the mix of temporary and permanent demand changes likely to occur in their relevant industry, and respond accordingly.

Furthermore, as €100m is a negligible amount compared to total investment expenditure in the European defence sector, we consider that past experience would serve as a good basis to form expectation regarding the mixture of temporary and permanent demand in the future. Therefore, the relationships inherent in input-output tables would be a good indicator of the companies' response to the €100m injection.

8.1.3 I-O classification system

The Eurostat I-O tables are divided sectorally according to the NACE classification system.[77]

One challenge for our analysis arose from the fact that a new classification, NACE Rev. 2, replaced the old classification, NACE Rev. 1.1 in all official statistics on 1 January 2008. For some Member States, the most recent I-O table is from a year prior to the introduction of NACE Rev. 2 whereas tables are available for later years.

We want our results to be as relevant as possible to the economy of the EU in 2013 and so chose to use the most recent I-O table that was available for each Member State. This required us to conduct two separate mapping exercises, given differences in the definitions of sectors between NACE Rev. 1.1 and NACE Rev 2.

8.2 Mapping of defence expenditure categories

8.2.1 Step 1: Latest Available Tables by Member State

We collected the latest available I-O tables from Eurostat for each participating Member State and for the EU. No tables were available for three Member States, while for one Member State the available tables were too sparsely populated to be useful for analysis. Of the remaining 22 participating Member States, 10 were before 2008 (NACE Rev. 1.1) and 12 were from 2008 or later (NACE Rev. 2). The EU table was from 2008, but covered the EU-27, not just the participating Member States. However, since there was no table referring to the participating Member State, we decided used the EU-27 table for aggregate analysis.

[77] "Nomenclature générale des Activités économiques dans les Communautés Européennes" (Statistical classification of economic activities in the European Communities)

Table 8.1: Latest available tables by MS

Member State	Latest available table	NACE classification Rev.
AT	2008	2
BE	2005	1.1
BG	No tables available	Not applicable
CY	No tables available	Not applicable
CZ	2009	2
EE	2005	1.1
FI	2009	2
FR	2009	2
DE	2008	2
EL	2010	2
HU	2008	2
IE	2009	2
IT	2005	1.1
LV	1998	1.1
LT	2005	1.1
LU	Tables unusable	Not applicable
MT	No tables available	Not applicable
NL	2009	2
PL	2005	1.1
PT	2008	2
RO	2008	2
SK	2005	1.1
SI	2005	1.1
ES	2005	1.1
SE	2010	2
UK	2005	1.1
EU-27	2008	2

8.2.2 Step 2: Mapping defence categories to I-O sectors

The next step was to map the defence categories to I-O categories. The mapping from the four defence sector categories to I-O sectors was carried out as follows

- Official definitions (confidential) were received from EDA for (i) Equipment procurement, (ii) Research and Development (R&D), (iii) Research and Technology (R&T) and (iv) Infrastructure.
- These definitions were used to identify the products and / or services that are included within each of the four defence sector categories.
- Broad NACE Rev. 1.1 and NACE Rev. 2 sectors containing these products and / or services were identified using official documentation on the NACE classification system.[78]
- The relevant I-O sectors were identified as those containing the corresponding NACE / CPA code. Each I-O sector corresponds to at least one two digit NACE / CPA code level in both Rev. 1.1 and Rev. 2 classifications. Thus, no NACE sector had to be broken down to arrive at the corresponding I-O sector.

Table 8.2 presents the results of the mapping exercise.

[78] Eurostat (2002) 'Statistical Classification of Economic Activities in the European Community, Rev. 1.1' http://ec.europa.eu/eurostat/ramon/nomenclatures/index.cfm?TargetUrl=LST_CLS_DLD&StrNom=NACE_1_1&StrLanguageCode=EN&StrLayoutCode=EN
Eurostat (2008) 'NACE Rev. 2: Statistical classification of economic activities in the European Community' http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-RA-07-015/EN/KS-RA-07-015-EN.PDF

Table 8.2: Mapping exercise results

Defence sector	I-O sectors according to NACE Rev. 1.1	I-O sectors according to NACE Rev. 2
Equipment procurement	29 – Machinery and equipment not elsewhere classified (including weapons and ammunition) 30 – Office machinery and computers 31 – Electrical machinery and apparatus not elsewhere classified 32 – Radio, television and communication equipment and apparatus 33 – Medical, precision and optical instruments; watches and clocks 34 – Motor vehicles, trailers and semi-trailers 35 – Other transport equipment 50 – Trade, maintenance and repair services of motor vehicles and motorcycles; retail sale of automotive fuel 51 - Wholesale trade and commission trade services, except of motor vehicles and motorcycles 52 - Retail trade services, except of motor vehicles and motorcycles; repair services of personal and household goods	16 – Fabricated metal products, except machinery and equipment (includes weapons and ammunition) 17 – Computer, electronic and optical products 18 – Electrical equipment 19 – Machinery and equipment n.e.c. 20 – Motor vehicles, trailers and semi-trailers 21 – Other transport equipment 28 – Wholesale and retail trade and repair services of motor vehicles and motorcycles 29 – Wholesale trade services, except of motor vehicles and motorcycles 30 – Retail trade services, except of motor vehicles and motorcycles
R&D	73 – Research and development services 74 – Other business services (including technical testing and analysis services)	47 – Architectural and engineering services; technical testing and analysis services 48 – Scientific research and development services
R&T	73 – Research and development services 74 – Other business services (including technical testing and analysis services)	47 – Architectural and engineering services; technical testing and analysis services 48 – Scientific research and development services
Infrastructure	45 – Construction work	27 – Constructions and construction works

8.2.3 Step 3: From Mapping to Division of Expenditure

As shown in Table 8.2, only one of the defence spending categories corresponds to a single I-O sector. Therefore, it was necessary to divide the expenditure on each of the other categories between the several corresponding I-O sectors. In this section, we describe our approach to each defence category in turn.

8.2.3.1 Equipment Procurement

The optimal approach to allocating the total expenditure on equipment procurement between I-O sectors would be to use data on relative expenditure on each I-O category. The difficulty with this approach is that breakdowns of defence spending by industrial sector are rarely published and, to our knowledge, only the UK publishes a detailed enough breakdown. Therefore, we chose to apportion equipment procurement expenditure to I-O categories based on UK data and assumed that similar patterns of expenditure are observed across the EU. The following paragraphs describe our approach in greater detail.

Table 8.3 shows the sectoral breakdown of UK defence expenditure from 2004/05 to 2010/11.

Table 8.3: UK defence spending by sector

VAT exclusive at Current Prices (£ million)

SIC(92)/SIC(03)/SIC(07) Section		2004/05	2005/06	2006/07	2007/08	2008/09 [1]	2009/10 [2]	2010/11
Total		**14 490**	**16 030**	**16 490**	**16 450**	**18 540**	**20 590**	**20 430**
A, B	Agriculture, Fishing and Mining	-	-	-	-	-	-	-
C	Manufacturing, excluding those industries itemised below	1 350	1 740	1 640	1 910	2 350	2 460	2 430
	Weapons & Ammunition	820	1 030	1 080	900	1 030	1 720	1 480 [3]
	Data Processing Equipment	110	70	50	40	100	100	80
	Other Electrical Engineering	150	180	200	250	220	260	250
	Electronics	910	1 160	1 000	950	920	670	670
	Precision Instruments	690	750	600	530	540	690	720
	Motor Vehicles & Parts	220	330	300	320	490	450	410
	Shipbuilding & Repairing	1 060	1 100	1 150	1 110	1 250	2 290	2 900 [4]
	Aircraft & Spacecraft	1 810	1 730	1 960	2 100	2 480	2 640	2 140 [5]
D, E	Electricity, Gas & Water	230	260	280	220	350	400	350
F	Construction	1 230	1 310	1 380	1 270	1 680	1 640	1 770
G	Wholesale, Retail & Repair of Motor Vehicles	160	180	230	280	330	350	420
H, I, J	Hotels & Restaurants	200	250	230	150	160	170	170
	Transport via Railways	60	70	70	80	80	60	50
	Other Land Transport (incl. via pipelines)	20	30	20	40	50	90	100
	Water, Air and Auxiliary/freight supply transportation	380	370	450	560	520	420	610 [6]
	Post & Courier Services	10	10	10	10	10	10	10
	Telecommunications	310	300	330	270	180	150	220
K, L, M, N, O, P Q, R, S, T	Financial Services, Business Activities, Education, Health, & Other Service Activities excluding those industries itemised below [7,8]	2 750	2 800	2 880	2 670	2 510	2 590	2 200
	Real Estate & Renting	1 230	1 460	1 500	1 690	2 090	2 160	2 180
	Computer Services	790	930	1 110	1 120	1 190	1 250	1 270

Source: DASA(Defence Expenditure Analysis)

Source: United Kingdom Defence Statistics 2012, Table 1.12

Using these data, we estimated the percentage of equipment procurement expenditure accounted for by individual product categories. Our approach required the following assumptions:

- percentages are the same for equipment procurement and Operations and Maintenance spending;
- ships and aircraft are not purchased through retail or wholesale channels, but directly from producers;
- the breakdown between wholesale and retail is in proportion to the relative size of the wholesale and retail sectors at the EU level;
- the relative spending across the sectors is the same for all participating Member States; and
- the manufacturing sub-categories correspond to I-O sectors as follows.

Manufacturing category	NACE Rev. 1.1 I-O sector	NACE Rev. 2 I-O sector
Weapons & Ammunition	29	16
Data Processing Equipment	30	17
Other Electrical Engineering	31	18
Electronics	32	17
Precision Instruments	33	17
Motor Vehicles & Parts	34	20
Shipbuilding & Repairing	35	21
Aircraft & Spacecraft	35	21

Given these assumptions, we calculated the total expenditure on each manufacturing category between 2004/05 and 2010/11:

NACE Rev. 1.1 I-O sector	Expenditure (£ m)	NACE Rev. 2 I-O sector	Expenditure (£ m)
29	8,060	16	8,060
30	550	17	11,350
31	1,510	18	1,510
32	6,280	20	2,520
33	4,520	21	25,720
34	2,520		
35	25,720		

In addition to the manufacturing I-O sectors presented in the table above, three service sectors are included in our definition of equipment procurement. As shown in Table 8.2, these are:

- wholesale and retail trade and repair services of motor vehicles;
- wholesale trade services other than motor vehicles; and
- retail trade services other than motor vehicles.

To allocate the equipment procurement expenditure to these I-O sectors we first considered the split of manufacturing expenditure between 2004/05 and 2010/11 between motor vehicles and other equipment (excluding ships and aircraft):

Category	Expenditure (£ m)	Percentage
Motor vehicles	2,520	10.75%
Other manufacturing products	20,920	89.25%

We assumed that the breakdown between wholesale and retail trade services of motor vehicles and wholesale and retail trade services of other products is the same as the breakdown between the manufacture of motor vehicles and that of other products. Therefore, the spending on wholesale and retail trade services can be divided in this proportion between motor vehicles and others.

We then assumed that the spending could be divided between wholesale and retail according to the relative size of the sectors at the EU level. According to the 2008 EU tables, the relative sizes of the sectors are as follows.

Category	Expenditure (£ m)	Percentage
Wholesale	1,202,984	59.73%
Retail	811,161	40.27%

Multiplying the proportion of expenditure on other manufacturing products by the proportion of expenditure on wholesale products (and similarly for the other categories) leads to the following division of wholesale and retail spending:

I-O sector	Percentage
Wholesale and retail of motor vehicles	10.75%
Wholesale other	53.31%
Retail other	35.94%

Combining these estimates with those of the manufacturing categories results in the following division of defence equipment procurement expenditure between I-O categories:

NACE Rev. 1.1 I-O sector	Expenditure (£ m)	Percentage	NACE Rev. 2 I-O sector	Expenditure (£ m)	Percentage
29	8,060	15.77%	16	8,060	15.77%
30	550	1.08%	17	11,350	22.21%
31	1,510	2.95%	18	1,510	2.95%
32	6,280	12.29%	20	2,520	4.93%
33	4,520	8.84%	21	25,720	50.32%
34	2,520	4.93%	28	210	0.41%
35	25,720	50.32%	29	1,039	2.03%
50	210	0.41%	30	701	1.37%
51	1,039	2.03%			
52	701	1.37%			

8.2.3.2 Research and Development

For this expenditure category, the question is how to allocate the additional funds between R&D and testing services, which fall under two different I-O sectors in both classifications. We have allocated all the additional funds solely to R&D for the following reasons.

- There are certain types of testing that do not form part of R&D, e.g. testing that finished products achieve certain functional or health and safety standards.
- While R&D typically involves some testing, the expenditure is made on a per-project basis, where the organisation carrying out the project then employs testing services. Technically, this is equivalent to saying the R&D sector employs testing services as an input. Thus, the boost to testing services would be captured as an increase in requirements for testing services as a result of the increase in demand for R&D services.

8.2.3.3 Research and Technology

As R&T forms a subset of R&D, we have allocated all the R&T funds to the I-O sector corresponding to R&D.

8.2.3.4 Infrastructure

The infrastructure defence category corresponds to a single I-O sector and so the full additional expenditure on infrastructure would be allocated to the I-O sector relating to construction.

8.2.4 Step 4: Final Division of Funds

The following final steps were carried out

- We calculated the average over the three most recent years of defence expenditure in each of the four defence categories.
- Using the preceding discussion, we broke this average down for each Member State and for the EU into the various I-O sectors, using NACE 1.1 sectors for States with tables prior to 2008 and NACE 2 sectors for those with 2008 or later tables.
- We divided the €100m investment across Member States and I-O sectors according to this distribution.

Dividing investment funds according to the discussion above, the final demand broken down for each MS by I-O sector is as shown in Table 8.4 and Table 8.5.

Table 8.4: Additional demand by I-O sector – NACE Rev. 1.1 MS (€)

I-O Sector	BE	EE	IT	LV	LU	LT	PL	SI	SK	ES	UK
1	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-
16	-	-	-	-	-	-	-	-	-	-	-
17	-	-	-	-	-	-	-	-	-	-	-
18	-	-	-	-	-	-	-	-	-	-	-
19	-	-	-	-	-	-	-	-	-	-	-
20	-	-	-	-	-	-	-	-	-	-	-
21	-	-	-	-	-	-	-	-	-	-	-
22	-	-	-	-	-	-	-	-	-	-	-
23	-	-	-	-	-	-	-	-	-	-	-
24	-	-	-	-	-	-	-	-	-	-	-
25	-	-	-	-	-	-	-	-	-	-	-
26	-	-	-	-	-	-	-	-	-	-	-
27	-	-	-	-	-	-	-	-	-	-	-
28	-	-	-	-	-	-	-	-	-	-	-
29	103,815.74	21,003.59	944,879.28	10,014.46	24,064.06	15,543.24	364,002.46	21,670.50	40,502.77	640,239.23	2,639,569.63
30	7,084.20	1,433.25	64,476.87	683.37	1,642.09	1,060.64	24,838.88	1,478.76	2,763.84	43,688.78	180,119.52
31	19,449.35	3,934.92	177,018.33	1,876.16	4,508.28	2,911.95	68,194.01	4,059.86	7,587.99	119,945.56	494,509.94
32	80,888.69	16,365.08	736,208.67	7,802.83	18,749.67	12,110.61	283,614.82	16,884.71	31,557.99	498,846.45	2,056,637.38
33	58,219.25	11,778.69	529,882.67	5,616.05	13,494.98	8,716.56	204,130.41	12,152.69	22,713.71	359,042.35	1,480,254.93
34	32,458.52	6,566.88	295,421.31	3,131.07	7,523.75	4,859.67	113,807.22	6,775.39	12,663.40	200,174.05	825,274.87
35	331,282.98	67,023.86	3,015,173.08	31,956.83	76,790.04	49,599.52	1,161,556.23	69,152.02	129,247.07	2,043,046.29	8,423,043.54
36	-	-	-	-	-	-	-	-	-	-	-
37	-	-	-	-	-	-	-	-	-	-	-
40	-	-	-	-	-	-	-	-	-	-	-
41	-	-	-	-	-	-	-	-	-	-	-
45	152,802.98	74,562.89	555,308.21	54,417.58	8,702.29	16,861.01	655,266.94	46,125.12	70,368.09	465,306.06	1,911,164.29
50	2,704.88	547.24	24,618.44	260.92	626.98	404.97	9,483.94	564.62	1,055.28	16,681.17	68,772.91
51	13,382.70	2,707.53	121,802.68	1,290.95	3,102.05	2,003.65	46,922.90	2,793.51	5,221.14	82,532.08	340,262.14
52	9,029.14	1,826.74	82,178.71	870.99	2,092.92	1,351.84	31,658.28	1,884.74	3,522.64	55,683.34	229,570.51
55	-	-	-	-	-	-	-	-	-	-	-
60	-	-	-	-	-	-	-	-	-	-	-
61	-	-	-	-	-	-	-	-	-	-	-
62	-	-	-	-	-	-	-	-	-	-	-
63	-	-	-	-	-	-	-	-	-	-	-
64	-	-	-	-	-	-	-	-	-	-	-
65	-	-	-	-	-	-	-	-	-	-	-
66	-	-	-	-	-	-	-	-	-	-	-
67	-	-	-	-	-	-	-	-	-	-	-
70	-	-	-	-	-	-	-	-	-	-	-

I-O Sector	BE	EE	IT	LV	LU	LT	PL	SI	SK	ES	UK
71	-	-	-	-	-	-	-	-	-	-	-
72	-	-	-	-	-	-	-	-	-	-	-
73	19,753.98	2,039.32	319,811.01	250.09	2,598.38	-	183,318.71	25,588.39	6,229.08	495,208.46	6,236,249.20
74	-	-	-	-	-	-	-	-	-	-	-
75	-	-	-	-	-	-	-	-	-	-	-
80	-	-	-	-	-	-	-	-	-	-	-
85	-	-	-	-	-	-	-	-	-	-	-
90	-	-	-	-	-	-	-	-	-	-	-
91	-	-	-	-	-	-	-	-	-	-	-
92	-	-	-	-	-	-	-	-	-	-	-
93	-	-	-	-	-	-	-	-	-	-	-
95	-	-	-	-	-	-	-	-	-	-	-

Table 8.5: Additional demand by I-O sector – NACE Rev. 1.1 MS (€)

I-O Sector	AT	CZ	FI	FR	DE	EL	HU	IE	NL	PT	RO	SE	EU
1	-	-	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-
16	105,851.39	85,491.30	231,413.98	2,370,083.33	1,791,758.86	597,479.18	49,891.84	26,519.44	468,724.76	108,970.67	67,807.87	301,969.95	11,085,647.65
17	149,058.72	120,387.87	325,874.52	3,337,524.30	2,523,134.37	841,363.36	70,257.12	37,344.37	660,052.86	153,451.25	95,486.27	425,230.63	15,610,682.49
18	19,830.72	16,016.36	43,354.23	444,023.06	335,676.91	111,934.68	9,346.98	4,968.28	87,813.20	20,415.10	12,703.46	56,572.53	2,076,839.70
19	-	-	-	-	-	-	-	-	-	-	-	-	-
20	33,094.98	26,729.29	72,352.76	741,018.61	560,202.52	186,804.90	15,598.94	8,291.44	146,549.18	34,070.23	21,200.48	94,412.44	3,465,984.13
21	337,778.89	272,808.45	738,457.51	7,563,094.71	5,717,622.56	1,906,596.08	159,208.20	84,625.31	1,495,732.12	347,732.71	216,379.45	963,606.33	35,375,044.38
22	-	-	-	-	-	-	-	-	-	-	-	-	-
23	-	-	-	-	-	-	-	-	-	-	-	-	-
24	-	-	-	-	-	-	-	-	-	-	-	-	-
25	-	-	-	-	-	-	-	-	-	-	-	-	-
26	-	-	-	-	-	-	-	-	-	-	-	-	-
27	114,328.57	273,392.58	317,563.77	2,639,108.01	3,242,976.37	179,008.83	38,015.68	34,993.11	596,485.46	25,958.15	49,800.69	34,509.25	11,656,149.12
28	2,757.91	2,227.44	6,029.40	61,751.55	46,683.54	15,567.08	1,299.91	690.95	12,212.43	2,839.19	1,766.71	7,867.70	288,832.01
29	13,645.11	11,020.53	29,831.16	305,523.15	230,972.39	77,019.96	6,431.47	3,418.57	60,422.46	14,047.21	8,740.99	38,926.40	1,429,030.76
30	9,206.18	7,435.41	20,126.70	206,132.56	155,834.11	51,964.38	4,339.23	2,306.47	40,766.26	9,477.47	5,897.43	26,263.14	964,148.76
31	-	-	-	-	-	-	-	-	-	-	-	-	-

I-O Sector	AT	CZ	FI	FR	DE	EL	HU	IE	NL	PT	RO	SE	EU
32	-	-	-	-	-	-	-	-	-	-	-	-	-
33	-	-	-	-	-	-	-	-	-	-	-	-	-
34	-	-	-	-	-	-	-	-	-	-	-	-	-
35	-	-	-	-	-	-	-	-	-	-	-	-	-
36	-	-	-	-	-	-	-	-	-	-	-	-	-
37	-	-	-	-	-	-	-	-	-	-	-	-	-
38	-	-	-	-	-	-	-	-	-	-	-	-	-
39	-	-	-	-	-	-	-	-	-	-	-	-	-
40	-	-	-	-	-	-	-	-	-	-	-	-	-
41	-	-	-	-	-	-	-	-	-	-	-	-	-
42	-	-	-	-	-	-	-	-	-	-	-	-	-
43	-	-	-	-	-	-	-	-	-	-	-	-	-
44	-	-	-	-	-	-	-	-	-	-	-	-	-
45	-	-	-	-	-	-	-	-	-	-	-	-	-
46	-	-	-	-	-	-	-	-	-	-	-	-	-
47	-	-	-	-	-	-	-	-	-	-	-	-	-
48	6,580.21	44,110.05	77,240.61	7,419,418.86	2,616,789.35	18,260.46	4,594.30	-	199,959.83	14,979.59	8,273.39	346,216.14	18,047,641.00
49	-	-	-	-	-	-	-	-	-	-	-	-	-
50	-	-	-	-	-	-	-	-	-	-	-	-	-
51	-	-	-	-	-	-	-	-	-	-	-	-	-
52	-	-	-	-	-	-	-	-	-	-	-	-	-
53	-	-	-	-	-	-	-	-	-	-	-	-	-
54	-	-	-	-	-	-	-	-	-	-	-	-	-
55	-	-	-	-	-	-	-	-	-	-	-	-	-
56	-	-	-	-	-	-	-	-	-	-	-	-	-
57	-	-	-	-	-	-	-	-	-	-	-	-	-
58	-	-	-	-	-	-	-	-	-	-	-	-	-
59	-	-	-	-	-	-	-	-	-	-	-	-	-
60	-	-	-	-	-	-	-	-	-	-	-	-	-
61	-	-	-	-	-	-	-	-	-	-	-	-	-
62	-	-	-	-	-	-	-	-	-	-	-	-	-
63	-	-	-	-	-	-	-	-	-	-	-	-	-
64	-	-	-	-	-	-	-	-	-	-	-	-	-
65	-	-	-	-	-	-	-	-	-	-	-	-	-

9 Appendix 2: I-O Analysis

Input-output (I-O) analysis was pioneered by Russian-American economist Wassily Leontief in the 1930s as a model of general equilibrium where various sectors of the economy are inter-linked.[79] The computational tractability of the model made it very useful for analysing the effects of otherwise complicated inter-industry transactions on the economy. This work won Leontief the Nobel Prize in Economics in 1973.

The tractability of the model arises from a very restrictive assumption regarding production technology – that of fixed coefficients. Producing one unit of any good or service requires certain quantities of various inputs in a fixed proportion. This means that inputs are not substitutable at all. Fixed coefficients is an extreme assumption, and can only be said to hold true in the short run – in the medium run input proportions can and do change. Therefore, all I-O analysis must be understood in a purely short run context. Moreover, the use of I-O analysis should be restricted to understanding or predicting the short run effects of a change in status quo. Its use by the former socialist bloc countries for setting production targets in five-year plans and the resultant problems exposed its limited usefulness for long-term analysis.

9.1 Basic set up

For illustrative purposes, assume that the economy has three sectors: agriculture, industry and services. There are two factor inputs: labour and capital. The end uses for the products of each sector are surmised in one quantity called final demand (in a more complicated model, this would be broken down into household consumption expenditure, government consumption expenditure, gross fixed capital formation and net exports).

In this simplistic model, the production of any sector can be looked at by use – the produce is used as inputs by any or all of the three sectors, and is sold to final demand. The entire economy may be surmised in the following three equations.

$$X_{AA} + X_{AI} + X_{AS} + X_{AD} = X_A$$
$$X_{IA} + X_{II} + X_{IS} + X_{ID} = X_I$$
$$X_{SA} + X_{SI} + X_{SS} + X_{SD} = X_S$$

Here:

- Sectors are represented by the following subscripts: A = agriculture, I = industry, S = services;
- X_{ij} is the intermediate demand for the produce of sector i by sector j, where $i, j \in \{A, I, S\}$;
- X_{iD} is the final demand for the produce of sector i;
- X_i is the total production of sector i; and
- all units are in money terms.

The assumption of fixed coefficients is interpreted in the following way. Take the industry sector. It needs to use X_{AI} of the produce of the agriculture sector to produce X_I of final produce. Consequently, it needs

[79] See Leontief, Wassily (1936) 'Quantitative Input and Output Relations in the Economic System of the United States' *Review of Economic Statistics*, Vol. 18, p105-125, Leontief, Wassily (1937) 'Interrelation of Prices, Output, Savings and Investment' *The Review of Economic Statistics,* Vol. 19, p109-132 and Leontief, Wassily (1941) *The Structure of the American Economy 1919-1939*, Cambridge (Mass.).

$\frac{X_{AI}}{X_I} = a_{AI}$ worth of the agricultural produce that to produce product worth one unit currency. The assumption is that a_{AI} is the *fixed* technical coefficient of intermediate consumption that provides one link between the industry and agriculture sectors – regardless of the amount that the industry sector produces this proportion would remain constant. Similar intermediate consumption coefficients may be calculated for links between each pair of sectors.

$$a_{ij} = \frac{X_{ij}}{X_j} \; for \; i,j = A,I,S$$

The system of equations can then be represented in terms of the fixed technical coefficients, the total production of each sector and the final demand facing each sector as follows.

$$\begin{aligned} a_{AA}X_A + a_{AI}X_I + a_{AS}X_S + X_{AD} &= X_A \\ a_{IA}X_A + a_{II}X_I + a_{IS}X_S + X_{ID} &= X_I \\ a_{SA}X_A + a_{SI}X_I + a_{SS}X_S + X_{SD} &= X_S \end{aligned}$$

Using matrix notation, this may be re-written as follows.

$$\begin{bmatrix} a_{AA} & a_{AI} & a_{AS} \\ a_{IA} & a_{II} & a_{IS} \\ a_{SA} & a_{SI} & a_{SS} \end{bmatrix} \begin{bmatrix} X_A \\ X_I \\ X_S \end{bmatrix} + \begin{bmatrix} X_{AD} \\ X_{ID} \\ X_{SD} \end{bmatrix} = \begin{bmatrix} X_A \\ X_I \\ X_S \end{bmatrix} \Rightarrow \boldsymbol{A} \cdot \boldsymbol{X} + \boldsymbol{X_D} = \boldsymbol{X}$$

9.2 Changes in final demand

With this set up, it now becomes possible to analyse the effects on the economy when the final demand changes for the produce of a certain sector. The problem is straightforward – we have a new set of final demands X_{iD} (contained in the vector $\boldsymbol{X_D}$) and a set of technical coefficients a_{ij} (which are contained in the matrix $\boldsymbol{A}$) that are known. We need to know what the total produce of each sector should now be, i.e. we need to find the X_is (contained in the vector $\boldsymbol{X}$). In terms of the three-equation set up, the problem is simple – there are three equations with three unknown variables to solve for. Simple algebraic manipulation leads us to the new final outputs.

For computational reasons, it is easier to work with matrices, as in actual models the number of sectors is much higher than three, and algebraic manipulation becomes harder. Thus, in matrix terms, the solution is given by manipulation of the basic set-up equation.

$$\boldsymbol{X} = (\boldsymbol{I} - \boldsymbol{A})^{-1} \cdot \boldsymbol{X_D}$$

Here

- $\boldsymbol{I}$ is an identity matrix with 1 along the diagonal and 0 elsewhere; and
- $(\boldsymbol{I} - \boldsymbol{A})^{-1}$ is the inverse of the matrix $(\boldsymbol{I} - \boldsymbol{A})$

Once the new total outputs have been calculated, the effects on several macro variables may be obtained.

- GDP effects: Since GDP is simply the sum total of all goods and services produced in the economy, the new GDP is obtained by adding up all new total production figures for all sectors in the economy.
- Income effects: to calculate these, one simply needs to multiply the change in output in each sector with the per unit compensation of employees in that sector. This, again, is a fixed coefficient, and is derived in the same way as the other technical coefficients.
- Employment effects: to calculate these, one needs to multiply the change in output in each sector with the number of employees it takes to produce one currency unit worth of produce. This is also a fixed coefficient, and can be calculated using initial total produce and initial employment.

- Capital effects: to calculate the increase in earnings of capital, one needs to multiply the change in output in each sector with the per unit contribution of capital.
- Tax effects: in richer models (such as the one proposed for the project), with explicit inclusion of the government and taxes, one would need to multiply the change in sectoral output by the tax rate, which is also assumed to be fixed.

9.3 Multipliers

When the final demand for any particular sector changes, any effects on macro variables are the result of three kinds of effect:

- Direct effect: This is the effect of the concerned sector having to produce more output to meet an increase in final demand. This would result in additions to GDP, employment, income, taxes, etc.
- Indirect effect: In order to produce more, the sector concerned would need more inputs from other sectors than earlier, thus increasing the demands faced by a variety of sectors. Other sectors would then need to increase their production to fulfil this additional demand for intermediate consumption. But, in turn, such increases in output would increase demand for intermediate consumption, necessitating a further increase in output of various sectors. The sum total of these knock-on effects is the indirect effect.
- Induced effect: In richer models than the one described here, an increase in incomes would lead to further increases in final demand across some or all sectors, over and above the initial increase in final demand. The consequent changes to production, output, etc. are the induced effects.

A multiplier in the I-O context is simply the change in any macro variable as a result of a unit change in final demand. From the above, it is clear that if final demand for agricultural produce increased by a unit, the increase in total agricultural produce would be greater than one unit, as the indirect effects of having to produce more intermediate inputs and the induced effects of having to respond to higher final demand due to an increase in incomes would mean that significantly more would have to be produced than just to satisfy a unit increase in demand. Similarly, the increase in GDP would also be greater than one unit, given that the direct, indirect and induced effects on all other sectors would also be taken into account.

Multipliers can be of various types. The output/GDP multiplier is the increase in GDP as a result of a unit increase in final demand for the sector. Similarly, we may have income, employment, tax and other multipliers.

The attraction of the I-O system as represented in matrix form is that multipliers for each sector can be derived very simply from the $(\boldsymbol{I}-\boldsymbol{A})^{-1}$ matrix and comparisons can be made across sectors. For instance, once the GDP multipliers have been calculated for all sectors, the one with the highest multiplier would have the greatest effect on GDP for a unit increase in final demand. The derivation of the various multipliers is given as follows.

- Output/GDP multiplier: for sector i, this is the sum of all elements in the ith column of the matrix $(\boldsymbol{I}-\boldsymbol{A})^{-1}$
- Income multiplier: for sector i, this is the ith element of the vector $\boldsymbol{W}\cdot(\boldsymbol{I}-\boldsymbol{A})^{-1}$, where $\boldsymbol{W}$ is the vector of wage coefficients[80] for each sector.
- Employment multiplier: for sector i, this is the ith element of the vector $\boldsymbol{E}\cdot(\boldsymbol{I}-\boldsymbol{A})^{-1}$, where $\boldsymbol{E}$ is the vector of employment coefficients[81] for each sector.
- Tax multiplier: for sector i, this is the ith element of the vector $\boldsymbol{T}\cdot(\boldsymbol{I}-\boldsymbol{A})^{-1}$, where $\boldsymbol{T}$ is the vector of tax coefficients[82] for each sector.

[80] Calculated as the initial proportion of compensation of employees to total output for each sector.
[81] Calculated as the initial proportion of sectoral employment to total output for each sector.

- Capital multiplier: for sector i, this is the ith element of the vector $\boldsymbol{C} \cdot (\boldsymbol{I} - \boldsymbol{A})^{-1}$, where $\boldsymbol{C}$ is the vector of capital coefficients[83] for each sector.

Lastly, it must be noted that multipliers can be calculated with or without induced effects. To include induced effects, households must be included as one of the productive sectors in the economy.

9.4 Richer models

The basic I-O framework can be modified or made richer through various extensions. Some of them are as follows.[84]

- Endogenous final demand: here the final demand sections are regarded not as external, but dependant on the level of output. Household consumption, household investment and government are all included as productive sectors in the economy.
- Dynamic models: here, linkages across time are allowed, and it is assumed that induced investment in one period will lead to an increase in output in the next period.

The model chosen in this proposal is a static model with exogenous final demand. However, the granularity of sectors and final demand is more than in the simple example followed in this section.

9.5 Limitations

The primary limitation of the I-O framework is that it is essentially a short run approximation, and does not work well when sectors are operating at full capacity. To capture long-term effects, macro-economic growth models would need to be used.

A secondary limitation is that effects of an increase in final demand may be greatly exaggerated if the economy is already close to full employment. In full employment conditions, the extra resources required to effect increased production may simply not be available.

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82 Calculated as the initial proportion of net taxes to total output for each sector.
83 Calculated as the initial proportion of capital requirements to total output for each sector.
84 For a more detailed discussion, see Eurostat (2008) 'Eurostat Manual of Supply, Use and Input-Output Tables' http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-RA-07-013/EN/KS-RA-07-013-EN.PDF, p510-534.

10 Appendix 3: Model of Skilled Employment

Let the economy consist of a large but finite number (N) of workers.

Let the following assumptions hold:

- Workers may be of two types: skilled (S) and unskilled (U). Thus, we have $N_U + N_S = N$, where N_i is the number of workers of type i. Each type is defined by a (constant) productivity level, p_U or p_S.
- The economy is close to competitive, so that wages are reflective of productivity.

Define the proportion of skilled workers as $x = \frac{N_S}{N}$.

Let V, V_S and V_L denote total, skilled and unskilled output, where $V_U + V_S = V$.

10.1 Relationship between productivities

Productivity is defined as output per worker. It can be shown that national productivity ($p = \frac{V}{N}$) and the productivities of the two types of worker ($p_i = \frac{V_i}{N_i}, i \in \{U, S\}$) are related according to the following equation.

$$p = xp_S + (1 - x)p_U$$

10.2 Calibration

- Eurostat data would give value added per worker while calculating employment impacts for the Member State in question as a whole. This would fix p.
- Publicly available EU-LFS data would give information on the proportion of workers with tertiary education in the economy as a proportion of total worker, i.e. this would fix x.
- Eurostat data on income distribution would give the average income earned by those with various levels of education. By assumption, wages equal productivity in our model. Combined with data from the EU-LFS on the number of workers at each education level, this would give us the relative productivity level of skilled and unskilled workers, i.e. this would fix $\frac{p_S}{p_U}$.
- Solve for p_S and p_U

10.3 Determination of sectoral proportions

The productivity relationship given above can also be shown to hold for each sector, i.e.

$$p^j = x^j p_S + \left(1 - x^j\right) p_U$$

Here, the superscript j denotes the sector.

To determine x^j we simply need to use the calibrated values of p_S and p_U and the sectoral productivity as calculated based on Eurostat data.

11 Appendix 4: Additional Results

11.1 GDP

According to our calculations, an additional investment of €100m in the EU defence sector would lead to an increase in European GDP of €96.26m. This is consistent with a multiplier of 0.96, i.e. each additional Euro invested in European defence would lead to an increase of €0.96 in European GDP.

The increases in output and the GDP multiplier of each Member State are shown in the table below.

Table 11.1: GDP effects and multipliers by Member State (excluding induced effects)

Member State	Investment (€m)	Increase in GDP (€m) (excl. induced effects)	GDP multiplier (excl. induced effects)
AT	0.79	0.29	0.36
BE	0.83	0.29	0.35
BG	0.32	Table not available	Table not available
CY	0.12	Table not available	Table not available
CZ	0.86	0.43	0.50
EE	0.21	0.08	0.40
FI	1.86	0.92	0.49
FR	25.09	14.71	0.59
DE	17.22	9.12	0.53
EL	3.99	0.76	0.19
HU	0.36	0.13	0.37
IE	0.20	0.05	0.24
IT	6.87	4.00	0.58
LV	0.12	0.05	0.46
LT	0.12	0.04	0.39
LU	0.16	Table not usable	Table not usable
MT	0.00	Table not available	Table not available
NL	3.77	1.35	0.36
PL	3.15	1.53	0.49
PT	0.73	0.22	0.30
RO	0.49	0.21	0.42
SK	0.33	0.14	0.41
SI	0.21	0.10	0.48
ES	5.02	2.25	0.45
SE	2.30	1.03	0.45
UK	24.89	12.97	0.52
EU-27	**100.00**	**96.24**	**0.96**

Source: Europe Economics' calculations
Note: LU tables are too sparsely populated – several sectors are restricted

We have found that the multipliers for individual Member States are all below that for the EU-27. This is because the Member State level analysis does not take into account the spill-over effects of an increase in demand for products of other EU Member States, while the EU level analysis does.[85]

[85] More specifically, the input coefficients in the EU-27 table reflect inputs produced anywhere in the EU whereas in the Member State level tables they reflect only inputs produced in that Member State. The structure of the I-O tables available from Eurostat makes it impossible to include spill-over effects arising from increases in imports at the Member State level. As such, the estimates for Member States in the above table should be regarded as lower bounds.

At the Member State level, the multipliers are generally in the 0.30-0.60 range. France, Italy, the UK, Germany and the Czech Republic have high multipliers of 0.50 or higher, whereas Greece and Ireland have low multipliers of below 0.25. This clearly illustrates that investments in some Member States would lead to higher GDP effects than others.

11.2 Production tax

The €100m investment would result in an increase in EU production tax receipts by €10.59m. This is consistent with a multiplier of 105.91, i.e. an investment of €1,000 would lead to an increase in production tax receipts by €105.91.

The detailed results by Member State are shown in the table below.

Table 11.2: Production tax effects and multipliers by Member State (excluding induced effects)

Member State	Investment (€m)	Increase in production tax receipts (€000) (excl. induced effects)	Production tax multiplier (increase in production tax receipts per €1,000 investment) (excl. induced effects)
AT	0.79	9.27	11.71
BE	0.83	6.50	7.82
BG	0.32	Table not available	Table not available
CY	0.12	Table not available	Table not available
CZ	0.86	6.79	7.89
EE	0.21	2.16	10.28
FI	1.86	1.69	0.91
FR	25.09	1,061.72	42.32
DE	17.22	185.12	10.75
EL	3.99	45.24	11.35
HU	0.36	4.81	13.41
IE	0.20	2.14	10.53
IT	6.87	116.65	16.99
LV	0.12	Production tax data not available	Production tax data not available
LT	0.12	0.74	6.43
LU	0.16	Table not usable	Table not usable
MT	0.00	Table not available	Table not available
NL	3.77	- 24.31	- 6.45
PL	3.15	61.42	19.52
PT	0.73	8.28	11.31
RO	0.49	15.46	31.67
SK	0.33	6.15	18.44
SI	0.21	4.64	22.17
ES	5.02	36.52	7.28
SE	2.30	52.13	22.71
UK	24.89	39.72	1.60
EU-27	**100.00**	**10,591.25**	**105.91**

Source: Europe Economics' calculations
Note: LU tables are too sparsely populated – several sectors are restricted

The results differ vary widely by Member State, but Member State multipliers are universally lower than the EU multiplier. The production tax multiplier depends on the magnitude of additional GDP as well as sector specific tax rates. Among countries with large defence investment, France has the highest multiplier, owing to a large GDP multiplier as well as moderate tax rates in the sectors with the largest increases in output. Spain and the UK have much lower multipliers in contrast, given that some sectors that experience large increases in output are subsidised in net terms. Of particular interest is the Netherlands, where production tax receipts would decline, indicating heavy production subsidies in key sectors.

11.3 Total tax

A €100m investment in the EU defence sector would lead to an increase in total tax receipts (excluding social contributions) by €26m, excluding induced effects. This is consistent with a multiplier of 0.26, i.e. each euro of investment would add €0.26 to total tax receipts (excluding social contributions).

The detailed results by Member State are shown in the table below.

Table 11.3: Total tax effects (excluding social contributions) and multipliers by Member State (excluding induced effects)

Member State	Total tax rate	Increase in total tax receipts (€m) (excl. induced effects)	Total tax multiplier (excl. induced effects)
AT	28.40%	0.08	0.10
BE	31.10%	0.09	0.11
BG	Table not available	Table not available	Table not available
CY	Table not available	Table not available	Table not available
CZ	18.50%	0.08	0.09
EE	20.40%	0.02	0.08
FI	30.10%	0.28	0.15
FR	25.60%	3.76	0.15
DE	23.70%	2.16	0.13
EL	20.60%	0.16	0.04
HU	26.60%	0.04	0.10
IE	22.50%	0.01	0.05
IT	27.70%	1.11	0.16
LV	22.30%	0.01	0.10
LT	20.30%	0.01	0.08
LU	Table not usable	Table not usable	Table not usable
MT	Table not available	Table not available	Table not available
NL	24.40%	0.33	0.09
PL	20.80%	0.32	0.10
PT	24.00%	0.05	0.07
RO	18.70%	0.04	0.08
SK	18.60%	0.03	0.08
SI	24.50%	0.02	0.12
ES	24.20%	0.54	0.11
SE	37.20%	0.38	0.17
UK	29.10%	3.77	0.15
EU-27	**26.80%**	**25.79**	**0.26**

Source: Europe Economics' calculations

Note: LU tables are too sparsely populated – several sectors are restricted

Member State multipliers are universally smaller than the EU multiplier, and lie general in the range 0.07-0.17. States that experience larger increases in GDP per unit investment and have higher tax rates would have higher total tax multipliers. Thus, Sweden, with the highest tax rate also has the highest tax multiplier. States like the UK, Italy and France have high tax multipliers owing to large GDP multipliers and moderate tax rates. Greece and Ireland have the lowest multipliers, owing to below average tax rates and extremely small GDP increases.

Since these results have been arrived at by applying the total tax rate to the total increase in GDP, they can be shown to be accurate to the extent that (i) the total tax rate is constant across all sectors of the economy and/or (ii) the increase in GDP follows the same pattern as existing GDP. We know both these conditions to be false. The tax rate are unlikely to be constant across all sectors as production tax rates vary across sectors, even as income tax rates might be more uniform. From the section on GDP effects, we know that increases in GDP are concentrated in a few key sectors. Thus, these estimates must be treated only as approximations, with a lower degree of confidence attached to their accuracy than estimates for production taxes.

Results (including social contributions)

We have also calculated the effects for a definition of tax receipts that includes social contributions. These are shown in the tables below.

Table 11.4: Total tax effects (including social contributions) and multipliers by Member State (excluding induced effects)

Member State	Total tax rate (including social contributions)	Increase in total tax receipts (€m) (excl. induced effects)	Total tax multiplier (excl. induced effects)
AT	44.20%	0.13	0.16
BE	47.00%	0.14	0.17
BG	Table not available	Table not available	Table not available
CY	Table not available	Table not available	Table not available
CZ	33.40%	0.14	0.17
EE	30.70%	0.03	0.12
FI	43.00%	0.40	0.21
FR	44.10%	6.49	0.26
DE	40.20%	3.67	0.21
EL	34.00%	0.26	0.06
HU	40.40%	0.05	0.15
IE	29.90%	0.01	0.07
IT	40.30%	1.61	0.23
LV	32.90%	0.02	0.15
LT	28.70%	0.01	0.11
LU	Table not usable	Table not usable	Table not usable
MT	Table not available	Table not available	Table not available
NL	38.90%	0.52	0.14
PL	32.80%	0.50	0.16
PT	35.90%	0.08	0.11
RO	28.80%	0.06	0.12
SK	31.50%	0.04	0.13
SI	38.90%	0.04	0.19
ES	36.70%	0.82	0.16
SE	45.90%	0.47	0.21
UK	37.40%	4.85	0.19
EU-27	**40.40%**	**38.88**	**0.39**

Source: Europe Economics' calculations
Note: LU tables are too sparsely populated – several sectors are restricted

11.4 Employment

Our calculations show that a €100m investment in the EU defence sector would lead to the creation of 1,809.65 jobs. This is consistent with an employment multiplier of 18.10, i.e. each €1m invested would create 18.10 jobs.

The results for the Member State level analysis are shown in the table below.

Table 11.5: Employment effects and multipliers by Member State (excluding induced effects)

Member State	Investment (€m)	No. of jobs created (excl. induced effects)	Employment multiplier (no. of new jobs per €m investment) (excl. induced effects)
AT	0.79	4.56	5.76
BE	0.83	5.32	6.41
BG	0.32	Table not available	Table not available
CY	0.12	Table not available	Table not available
CZ	0.86	17.48	20.34
EE	0.21	5.18	24.68
FI	1.86	16.10	8.65
FR	25.11	209.77	8.36
DE	17.23	167.82	9.74
EL	3.99	23.39	5.87
HU	0.36	5.78	16.10
IE	0.20	0.94	4.62
IT	6.87	76.45	11.13
LV	0.12	Employment data insufficient	Employment data insufficient
LT	0.12	Employment data insufficient	Employment data insufficient
LU	0.16	Table not usable	Table not usable
MT	0.00	Table not available	Table not available
NL	3.70	20.75	5.50
PL	3.15	91.17	28.97
PT	0.73	8.89	12.14
RO	0.49	13.79	28.24
SK	0.33	7.81	23.41
SI	0.21	3.86	18.46
ES	5.02	50.88	10.13
SE	2.30	14.01	6.10
UK	24.90	221.06	8.88
EU-27	**100.00**	**1,809.65**	**18.10**

Source: Europe Economics' calculations

Note: LV and LT employment data is missing for several key investment sectors

Note: LU tables are too sparsely populated – several sectors are restricted

Our results show a wide spread of employment multipliers. Those Member States that have relatively higher per capita incomes and labour productivity tend to have lower multipliers. This can be explained by the fact that a given amount of output can be created by fewer people in these Member States.

The fact that the EU level multiplier is relatively high does not mean that as a whole EU workers are unproductive. Rather, this reflects the relatively higher GDP impact at the EU level due to the incorporation of intra-EU trade. Moreover, the fact that the EU employment multiplier is smaller than that of some Member States despite the EU GDP multiplier being higher than those of all Member States is because some Member States have productivities that are so low relative to the EU average that even a relatively small GDP increase can only be achieved by a relatively large addition to the workforce.

11.5 Skilled employment

At the EU level, 475.93 full time skilled jobs would be created. This accounts for 26.30 per cent of all jobs, and is consistent with a skilled employment multiplier of 4.76, i.e. each €1m invested would create 4.76 jobs at the EU level.

The results of the Member State level analysis are shown in the table below.

Table 11.6: Skilled employment effects and multipliers by Member State (excluding induced effects)

Member State	No. of skilled jobs created (excl. induced effects)	No. of skilled jobs created as a proportion of total jobs created	Skilled employment multiplier (no. of new skilled jobs per €m investment) (excl. induced effects)
AT	1.23	26.93%	1.55
BE	0.75	14.05%	0.90
BG	Table not available	Table not available	Table not available
CY	Table not available	Table not available	Table not available
CZ	2.05	11.73%	2.39
EE	0.80	15.47%	3.82
FI	2.72	16.92%	1.46
FR	66.77	31.83%	2.66
DE	23.92	14.25%	1.39
EL	2.65	11.34%	0.67
HU	0.69	11.97%	1.93
IE	0.12	13.15%	0.61
IT	7.53	9.85%	1.10
LV	Employment data insufficient	Employment data insufficient	Employment data insufficient
LT	Employment data insufficient	Employment data insufficient	Employment data insufficient
LU	Table not usable	Table not usable	Table not usable
MT	Table not available	Table not available	Table not available
NL	3.76	18.14%	1.00
PL	22.37	24.54%	7.11
PT	1.02	11.46%	1.39
RO	2.96	21.50%	6.07
SK	1.64	21.02%	4.92
SI	0.64	16.53%	3.05
ES	9.47	18.61%	1.89
SE	1.44	10.25%	0.63
UK	58.72	26.56%	2.36
EU-27	**475.93**	**26.30%**	**4.76**

Source: Europe Economics' calculations
Note: LV and LT employment data is missing for several key investment sectors
Note: LU tables are too sparsely populated – several sectors are restricted

The most jobs would be created in Member States receiving the most investment, along with Poland, due to its low worker productivity. As a percentage of total jobs, skilled jobs are the highest in France, Austria, the UK and Poland, and the lowest in Italy. The skilled employment multipliers for Member States are lower than that for the EU, except for Poland and Romania. This, again, is due to the low worker productivity in these countries.

In our view, these estimates are unlikely to be very accurate, given that we have followed a second best methodology in absence of access to micro-level data. The variance of the assumption of our model with reality is exhibited by the frequent instances of sector productivity being either lower than the unskilled or higher than the skilled productivities derived.[86] Thus, our model tells us that several sectors are composed only of skilled or unskilled labour, which is clearly not true and introduces a significant degree of arbitrariness into the analysis. While these are the best estimates that may be calculated given the data available, they are likely to be less accurate than, for instance, the results on total employment.

[86] For instance, in the EU table, only 17 of the 65 sectors had productivities lying between the calculated skilled and unskilled productivities.

11.6 R&D potential

In the EU, the €100m investment would lead to an increase in R&D value added by €10.77m. This is consistent with a multiplier of 107.74, i.e. every €1,000 of investment in EU defence would raise R&D value added by €107.74.

The results of the Member State level analysis are shown in the table below.

Table 11.7: R&D effects and multipliers by Member State (excluding induced effects)

Member State	Investment (€m)	Addition to R&D value added (€000) (excl. induced effects)	R&D multiplier (addition to R&D value added in € per €1,000 investment) (excl. induced effects)
AT	0.79	4.25	5.36
BE	0.83	9.08	10.92
BG	0.32	Table not available	Table not available
CY	0.12	Table not available	Table not available
CZ	0.86	20.40	23.73
EE	0.21	1.32	6.31
FI	1.86	27.05	14.52
FR	25.09	3,140.86	125.20
DE	17.22	1,217.70	70.71
EL	3.99	4.66	1.17
HU	0.36	1.88	5.23
IE	0.20	0.08	0.41
IT	6.87	196.97	28.68
LV	0.12	0.19	1.61
LT	0.12	0.01	0.07
LU	0.16	Table not usable	Table not usable
MT	0.00	Table not available	Table not available
NL	3.77	67.35	17.87
PL	3.15	117.96	37.49
PT	0.73	10.79	14.74
RO	0.49	3.85	7.90
SK	0.33	3.03	9.08
SI	0.21	15.03	71.86
ES	5.02	284.24	56.62
SE	2.30	116.08	50.57
UK	24.89	2,847.04	114.41
EU-27	**100.00**	**10,773.60**	**107.74**

Source: Europe Economics' calculations

Note: LU tables are too sparsely populated – several sectors are restricted

The bulk of the EU increase in R&D value added would be concentrated in three Member States – France, the UK and Germany. This is because most R&D investment would take place in these States, and because these States have large and well developed defence research establishments. This is borne out by the fact that these three States have three of the four highest national multipliers. There is a wide spread when looking at multipliers, which arises from the fact that several countries do not spend large portions of their defence spend on R&D.

Our analysis also showed that the main factor leading to an increase in R&D spend is direct effects of R&D investment – the addition to R&D value added from indirect effects is relatively modest.

11.7 Capital intensity

A €100m investment in European defence would lead to an increase in the consumption of fixed capital by €13.10m by way of direct and indirect effects. This is consistent with a multiplier of 130.97, i.e. every €1,000 of investment would be accompanied by an increase in the consumption of fixed capital by €130.97.

The results of the Member State level analysis are shown in the table below.

Table 11.8: Capital intensity effects and multipliers by Member State (excluding induced effects)

Member State	Investment (€m)	Addition to consumption of fixed capital (€000) (excl. induced effects)	Capital intensity multiplier (addition to consumption of fixed capital in € per €1,000 investment) (excl. induced effects)
AT	0.79	37.13	46.87
BE	0.83	46.28	55.70
BG	0.32	Table not available	Table not available
CY	0.12	Table not available	Table not available
CZ	0.86	64.34	74.85
EE	0.21	8.05	38.36
FI	1.86	133.88	71.89
FR	25.09	CFC data not available	CFC data not available
DE	17.22	CFC data not available	CFC data not available
EL	3.99	124.56	31.25
HU	0.36	14.07	39.20
IE	0.20	5.65	27.82
IT	6.87	CFC data not available	CFC data not available
LV	0.12	5.49	46.50
LT	0.12	4.52	39.12
LU	0.16	Table not usable	Table not usable
MT	0.00	Table not available	Table not available
NL	3.77	153.21	40.65
PL	3.15	202.57	64.37
PT	0.73	30.91	42.20
RO	0.49	CFC data not available	CFC data not available
SK	0.33	22.94	68.81
SI	0.21	14.06	67.21
ES	5.02	CFC data not available	CFC data not available
SE	2.30	134.42	58.56
UK	24.89	CFC data not available	CFC data not available
EU-27	**100.00**	**13,096.78**	**130.97**

Source: Europe Economics' calculations

Note: LU tables are too sparsely populated – several sectors are restricted

Several Member States do not publish data on the consumption of fixed capital in their input-output tables, including the five biggest recipients of the hypothetical defence investment. Therefore, the value of a Member State level analysis is limited in this case. Of the countries that do publish information, the Czech Republic and Finland have the highest multipliers, Estonia and Lithuania have the lowest, and Poland has the highest absolute addition to consumption of fixed capital.

12 Appendix 5: Opportunities for Further Research

The research presented in this report has provided some instructive insights to the economic benefits that derive from investments in the defence sector, and the extent to which these benefits exceed those that could be achieved through public investment in alternative sectors.

However, we consider that there are a number of areas in which there is significant potential for further research which would contribute to a fuller understanding of the contribution of the defence sector to the European economy. In this section, we discuss a number of potential avenues for this research.

12.1 Extension to individual Member States

The analysis presented in this report has relied entirely on I-O tables that are published by Eurostat. These tables contain only 64 sectors but we are aware of some Member States where the national statistical offices produce I-O tables with a much more granular break-down of the economy. For instance, Austrian tables contain 65 sectors, German tables contain 73 sectors and UK tables contain 122 sectors.

We consider that it would be feasible to extend the methodology used in this report to the I-O tables produced by individual Member States. This research would allow the defence sector to be more tightly defined and so should provide more robust estimates of the impacts of investing in the defence sector.

12.2 Wider macroeconomic benefits

Another potentially fruitful avenue for future research would be to analyse the macroeconomic benefits of the provision of defence services (as opposed to defence investment or investment spill-overs). Solid and adequate defence forces provide the preservation of peace, the protection of security and trade routes, the underpinning of international diplomacy, and the support of the projection of national political values. These primary purposes have profound macroeconomic implications — few countries can flourish economically without secure defence arrangements.

We consider that it would be possible to model the macroeconomic implications of defence spending as akin to an insurance premium, and to model changes in the optimal level of defence spending (e.g. associated with changes in the perceived future balance of geopolitical or other risks) as a change in the risk profile against which insurance was sought.

Using a fully specified insurance modelling and estimation approach would be the most robust approach to this analysis but it could become a lengthy and involved task. In pursuing this analysis it would be important to note that the timescales over which full impacts of any sub-optimality in defence investment would be felt might be significant, but there could be some highly non-trivial macroeconomic impacts of sub-optimal defence expenditure even in the short term.

12.3 Spin-offs

In this report, we have attempted to identify the economic impacts of defence spin-offs. However, we have found the availability of data to be limited, particularly for studies of spin-offs from defence aerospace. We consider that there is likely to be scope for further research on this issue although the risk that necessary data and information would not be available (or would not be provided to the researchers) cannot be ruled out.