



Europe Economics

The Economic Case for Investing in Europe's Defence Industry - Additional Detailed Sectoral Analysis and Comparison Between Selected EU Member States

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Contents

1	Executive Summary.....	1
2	Introduction.....	5
3	Macroeconomic Impacts.....	6
3.1	GDP.....	7
3.2	Tax revenue	8
3.3	Employment	9
3.4	Skilled employment	10
3.5	R&D.....	12
3.6	Exports	13
3.7	Capital intensity.....	16
4	Comparison with Other Sectors.....	17
4.1	GDP.....	17
4.2	Tax revenue	17
4.3	Employment	18
4.4	Skilled employment	18
4.5	R&D.....	19
4.6	Exports	19
4.7	Capital intensity.....	20
5	Conclusions	22
6	Appendix 1: Assumptions, Conceptual Issues and the €100m Investment	24
6.1	Conceptual issues and assumptions	24
6.2	Mapping of defence expenditure categories.....	25
7	Appendix 2: I-O Analysis.....	35
7.1	Basic set up.....	35
7.2	Changes in final demand.....	36
7.3	Multipliers	37
7.4	Richer models.....	38
7.5	Limitations	38
8	Appendix 3: Model of Skilled Employment.....	39
8.1	Relationship between productivities	39
8.2	Calibration	39
8.3	Determination of sectoral proportions.....	39

1 Executive Summary

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 defence industry of selected EU Member States and to compare the short- to medium-term impacts of this investment with an equivalent level of investment in other industries.

This work built an analysis that Europe Economics previously conducted for the European Defence Agency (EDA) using the I-O tables produced by Eurostat. The distinguishing feature of this project is the use of the more detailed I-O tables produced by the statistics offices of certain participating Member States (specifically, Germany, Netherlands, Poland, Spain, and the United Kingdom). While it was originally intended to include France in this study, neither Europe Economics nor the EDA were able to gain access to national defence data at the required level of detail (though we are aware that such data exist).

The comparison of multipliers between results based on national and Eurostat data is the key contribution of this current study: it indicates the extent to which the broad sector definitions in Eurostat affect the modelled impacts of an investment in the defence sector of each Member State.¹

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 Poland, the German multiplier will be lower than the EU multiplier.

¹ The results presented in this study should not be compared with the EU-level multipliers reported in our previous study for the EDA. This is because the structure of the national I-O tables 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 this study should be regarded as lower bounds. Similarly, comparing estimates based on the national I-O tables of different countries would be misleading because the tables used to produce such estimates differ between countries.

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

1.1.2 GDP impacts

As shown in the table below, our calculations suggest that using Eurostat data leads to an underestimate of the impact of an investment in the defence sector on GDP. Indeed, the fact that estimated GDP effects increase with the precision of the definitions of defence activities suggests that the defence sector creates more spillovers per unit of investment than the other sectors with which they are grouped in the Eurostat tables.

The difference between the estimates based on Eurostat and national data is most significant for the UK. This may, at least in part, reflect the more precise disaggregation of sectors that is available in the UK I-O tables (123 sectors) relative to the I-O tables of the other selected Member States. If correct, this would suggest that the estimated impacts for investments other countries would be higher if the level of disaggregation in those countries were the same as in the UK, although various country-specific factors would affect the extent to which this relationship holds.

pMS	Increase in GDP (€m)	GDP multiplier (national data)	GDP multiplier (Eurostat data)
DE	87.9	0.9	0.8
NL	51.6	0.5	0.4
PL	87.4	0.9	0.9
ES	83.7	0.8	0.8
UK	164.8	1.7	1.2

Source: Europe Economics' calculations.

1.1.3 Tax revenue impacts

We calculated the effects of an investment in the defence sector on tax for a definition of tax receipts that includes social contributions. These are shown in the table below. As per the GDP results, Eurostat data appears to underestimate the impact of a hypothetical €100m in the defence sector on tax revenue, particularly for the UK.

pMS	Increase in tax revenue (€m)	Tax revenue multiplier (national data)	Tax revenue multiplier (Eurostat data)
DE	35.9	0.4	0.3
NL	20.4	0.2	0.2
PL	28.7	0.3	0.3
ES	30.7	0.3	0.3
UK	61.6	0.6	0.4

Source: Europe Economics' calculations.

1.1.4 Employment impacts

As shown in the table below, after accounting for induced effects we find that the use of Eurostat data to estimate the employment impacts of investing in the defence sectors of the selected Member States generally resulted in smaller employment multipliers than those estimated using data provided by national statistics offices. An exception to this rule, however, is Spain for which employment effects estimated using national data are lower than those estimated using Eurostat data.

pMS	Number of jobs created	Employment multiplier (national data)	Employment Multiplier (Eurostat data)
DE	1,691	16.9	13.8
NL	741	7.4	6.6
PL	5,262	52.6	51.2

pMS	Number of jobs created	Employment multiplier (national data)	Employment Multiplier (Eurostat data)
ES	1,796	18.0	18.4
UK	2,534	25.3	18.9

Source: Europe Economics' calculations.

1.1.5 Skilled employment

The table below shows that the estimated impact on skilled employment using national data significantly exceeds that estimated using Eurostat data for all countries.² For example, estimated impacts using national data are 94 per cent greater for Poland, 98 per cent greater for Spain and 257 per cent greater for the Netherlands.

These results suggest that the proportion of skilled jobs in the defence sectors significantly exceeds the proportion of skilled jobs in civil sectors that belong to the same industry category in the Eurostat data. Therefore, a more precise definition of the defence sector in Eurostat data would almost certainly result in the estimated impact of investment on skilled employment being greater than that presented in our previous report to the EDA.

pMS	Number of skilled jobs created	Skilled employment multiplier (national data)	Skilled employment multiplier (Eurostat data)
DE	384	3.8	2.4
NL	495	5.0	1.4
PL	2,313	23.1	11.9
ES	908.9	9.1	4.6
UK	1,020	10.2	5.4

Source: Europe Economics' calculations.

1.1.6 R&D

The results of our analysis are shown in the table below. The table shows that the estimated impacts of defence sector investment on R&D using national data exceed those estimated using Eurostat data for all countries other than Poland and Spain.

The difference between estimated multipliers for the latter two countries is very small whereas the difference for the UK is particularly significant. As noted above, this may reflect the more precise disaggregation of sectors that is available in the UK I-O tables. Given that R&D is a crucial component of the defence sector it is to be expected that the estimated impacts on R&D rise when defence activities are more precisely defined.

pMS	Increase in R&D (€'000)	R&D Multiplier (national data)	R&D Multiplier (Eurostat data)
DE	7,570	75.7	72.1
NL	2,971	29.7	18.1
PL	3,882	38.8	39.1
ES	5,797	58.0	58.1
UK	14,161	141.6	117.4

Source: Europe Economics' calculations.

² 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.

1.1.7 Exports

Exports are an exogenous final use in the I-O framework and so are invariant to changes in other variables, meaning that it is not possible to calculate the effects of the investment on exports through I-O analysis. We therefore employed an alternative approach involving econometric analysis of macroeconomic data to determine the relationship between defence exports and defence expenditure.

Based on this analysis, we found that for high defence expenditure countries (France, Germany and the UK) a one percentage point increase in the growth rate of defence expenditure is associated with a 1.04 percentage point increase in the growth rate of defence exports. For low expenditure countries (the Netherlands, Poland and Spain) a one percentage point increase in the growth rate of defence expenditure is associated with a 6.35 percentage point increase in the growth rate of defence exports.

1.1.8 Capital intensity

Several Member States do not publish data on the consumption of fixed capital in their input-output tables. Therefore, the value of a Member State level analysis is limited in this case. For completeness, however, the results for the selected Member States are shown in the table below.

pMS	Increase in consumption of fixed capital (€'000)	Capital intensity multiplier (national data)	Capital intensity multiplier (Eurostat data)
DE	13,187	131.9	Data not available
NL	Data not available	Data not available	53.1
PL	11,077	110.8	121
ES	Data not available	Data not available	Data not available
UK	Data not available	Data not available	Data not available

Source: Europe Economics' calculations.

1.1.9 Summary and conclusions

Based on the evidence presented in this report, it appears that using Eurostat data to model the macroeconomic effects of a hypothetical investment in the defence sector results in an underestimate of the true impacts. The core reason for this seems to be the relatively low level of disaggregation of sectors in the Eurostat data, meaning that defence activities cannot be separated from some less productive civil activities.

The national I-O data permit a somewhat more precise definition of the defence sector, resulting in higher estimates of macroeconomic effects. The impact on the results of further refining the definition of the defence sector cannot be known but it is entirely possible that the estimated impacts would increase once again. This hypothesis, and the implications for the macroeconomic impact estimates of an EU-wide investment in the defence sector, could only be tested at such a time as it becomes possible to more precisely identify defence activities in Eurostat data.

Overall, these results suggest that the estimated economic impacts of investing in the EU defence sector (as presented in an earlier Europe Economics report to the EDA) would have been higher, in some cases significantly so, if detailed data for the defence activities had been available at the European level.

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.

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This work built an analysis that Europe Economics previously conducted for the European Defence Agency (EDA) using the I-O tables produced by Eurostat. The distinguishing feature of this project is the use of the more detailed I-O tables produced by the statistics offices of certain participating Member States (specifically, Germany, Netherlands, Poland, Spain, and the United Kingdom (UK)). While it was originally intended to include France in this study, neither Europe Economics nor the EDA were able to gain access to national defence data at the required level of detail (though we are aware that such data exist).

Estimating short-term macroeconomic effects

We have used Input-Output (I-O) analysis to assess the impacts of a €100m investment on the economies of the selected EU Member States. 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. Conclusions are drawn in Chapter 5.

3 Macroeconomic Impacts

The EDA asked Europe Economics to consider a hypothetical investment of €100m in the defence industry of selected participating Member States and to compare the short- to medium-term impacts of this investment with an equivalent level of investment in other industries. We have used I-O techniques to complete this analysis.

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 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.³

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 none of the selected participating Member States is currently operating close to full employment.

In preparation for I-O analysis, we divided the €100m defence investment across I-O sectors for each of the selected participating Member States. 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 tables available from the national statistical offices does not allow us to calculate induced effects using I-O analysis, and so we used national income multipliers as the basis for these calculations.

In this section, we report results that include all of these effects.

³ 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.

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 selected Member State. 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 (i.e. €100m).
- 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 level, 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

3.1.2 Results

The results of our analysis are shown in the table below. Our calculations suggest that using Eurostat data led to an underestimate of the impact of an investment in the defence sector on GDP. Indeed, the fact that estimated GDP effects increase with the precision of the definitions of defence activities suggests that the defence sector creates more spillovers per unit of investment than the other sectors with which they are grouped in the Eurostat tables.

The difference between the estimates based on Eurostat and national data is most significant for the UK. This may, at least in part, reflect the more precise disaggregation of sectors that is available in the UK I-O

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

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 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.

tables (123 sectors) relative to the I-O tables of the other selected Member States. If correct, this would suggest that the estimated impacts for investments other countries would be higher if the level of disaggregation in those countries were the same as in the UK, although various country-specific factors would affect the extent to which this relationship holds.

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

pMS	Increase in GDP (€m)	GDP multiplier (national data)	GDP multiplier (Eurostat data)
DE	87.9	0.9	0.8
NL	51.6	0.5	0.4
PL	87.4	0.9	0.9
ES	83.7	0.8	0.8
UK	164.8	1.7	1.2

Source: Europe Economics' calculations.

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.

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.
- To include indirect effects, we multiplied these percentages by the direct plus indirect increases in GDP in each Member State.
- To include induced effects, we multiplied these percentages by the total increase in GDP (including induced effects) in each Member State.

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.⁸

⁸ 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

3.2.2 Results (total tax receipts including social contributions)

We calculated the effects of an investment in the defence sector on tax for a definition of tax receipts that includes social contributions. These are shown in the table below. As per the GDP results, Eurostat data appears to underestimate the impact of a hypothetical €100m in the defence sector on tax revenue, particularly for the UK.

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

pMS	Increase in tax revenue (€m)	Tax revenue multiplier (national data)	Tax revenue multiplier (Eurostat data)
DE	35.9	0.4	0.3
NL	20.4	0.2	0.2
PL	28.7	0.3	0.3
ES	30.7	0.3	0.3
UK	61.6	0.6	0.4

Source: Europe Economics' calculations.

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.⁹ This was estimated for both direct effects (multiplying with direct increases in output) and indirect effects (multiplying with indirect increases in output).
- The following methodology was used to calculate the induced employment effects:
 - Using national level employment data and data on GDP at current prices, 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

As shown in the table below, after accounting for induced effects we find that the use of Eurostat data to estimate the employment impacts of investing in the defence sectors of the selected Member States

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.

⁹ 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.

generally resulted in smaller employment multipliers than those estimated using data provided by national statistics offices. An exception to this rule, however, is Spain for which employment effects estimated using national data are lower than those estimated using Eurostat data.

The particularly large multiplier observed for Poland reflects that country's relatively low labour productivity, which means that a greater amount of labour is required to meet a given increase in demand, meaning that the impact of the €100m investment on employment would be greater for Poland than for other Member States, all else being equal.

Table 3.3: Employment effects and multipliers by Member State (including induced effects)

pMS	Number of jobs created	Employment multiplier (national data)	Employment Multiplier (Eurostat data)
DE	1,691	16.9	13.8
NL	741	7.4	6.6
PL	5,262	52.6	51.2
ES	1,796	18.0	18.4
UK	2,534	25.3	18.9

Source: Europe Economics' calculations.

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 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.¹⁰ 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

¹⁰ 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.

well as the economic activity according to NACE codes. However, access to the EU-LFS micro-data is severely limited.¹¹

Given these constraints, it was necessary to adopt the following (second-best) approach based on a simple economic model. 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.¹² 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:

- value added per worker in the year of the latest I-O table;
- proportion of workers with tertiary education in the economy, i.e. the proportion of skilled workers; and
- income distribution, which shows the average income earned by those with various levels of education. By assumption, in our model incomes are proportional to 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 selected 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.¹³

3.4.2 Results

The table below shows that the estimated impact on skilled employment using national data significantly exceeds that estimated using Eurostat data for all countries.¹⁴ For example, estimated impacts using

¹¹ 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>

¹² The distribution of capital between workers would depend on the shape of the production function.

¹³ 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.

¹⁴ 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

national data are 94 per cent greater for Poland, 98 per cent greater for Spain and 257 per cent greater for the Netherlands.

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

pMS	Number of skilled jobs created	Skilled employment multiplier (national data)	Skilled employment multiplier (Eurostat data)
DE	384	3.8	2.4
NL	495	5.0	1.4
PL	2,313	23.1	11.9
ES	908.9	9.1	4.6
UK	1,020	10.2	5.4

Source: Europe Economics' calculations.

These results suggest that the proportion of skilled jobs in the defence sectors significantly exceeds the proportion of skilled jobs in civil sectors that belong to the same industry category in the Eurostat data. Therefore, a more precise definition of the defence sector in Eurostat data would almost certainly result in the estimated impact of investment on skilled employment being greater than that presented in our previous report to the EDA.

It is also interesting to note that there is a wide spread of skilled employment multipliers after induced effects have been accounted for. As for the total employment effect estimate above, the particularly large multiplier observed for Poland reflects that country's relatively low labour productivity, which means that a greater amount of labour is required to meet a given increase in demand. Hence, the €100m investment in the Polish defence sector would lead to a greater increase in skilled employment, all else being equal, than would an identical investment in other Member States.

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 selected Member State.

3.5.2 Results

The results of our analysis are shown in the table below. The table shows that the estimated impacts of defence sector investment on R&D using national data exceed those estimated using Eurostat data for all countries other than Poland and Spain.

The difference between estimated multipliers for the latter two countries is very small whereas the difference for the UK is particularly significant. As noted above, this may reflect the more precise disaggregation of sectors that is available in the UK I-O tables. Given that R&D is a crucial component of the defence sector it is to be expected that the estimated impacts on R&D rise when defence activities are more precisely defined.

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

pMS	Increase in R&D (€'000)	R&D Multiplier (national data)	R&D Multiplier (Eurostat data)
DE	7,570	75.7	72.1
NL	2,971	29.7	18.1
PL	3,882	38.8	39.1
ES	5,797	58.0	58.1
UK	14,161	141.6	117.4

Source: Europe Economics' calculations.

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 through 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 the six countries under study for the years 1988-2011.

- defence export data in \$m in 1990 prices from the Arms Trade database;¹⁵
- defence expenditure data in \$m in 2010 prices from the SIPRI Military Expenditure Database 2011;¹⁶ and
- GDP data in \$ in 2005 prices from the National Accounts Estimates of Main Aggregates, United Nations Statistics Division.¹⁷

There were no missing data points and in this respect we had a complete panel.¹⁸

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 analysis¹⁹ 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 \$

¹⁵ <http://armstrade.sipri.org/armstrade/page/toplist.php>

¹⁶ <http://milexdata.sipri.org>.

¹⁷ <http://data.un.org/Data.aspx?q=gdp+at+constant+price&d=SNAAMA&f=grID%3a102%3bcurrID%3aUSD%3bpcFlag%3a0>.

¹⁸ 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 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.

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).

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, we employed random effects panel data models. Panel data models exploit variations both across individual countries as well as within the same 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 six samples, based on (i) the number of countries included and (ii) the time period included.

The samples formed based on the countries included were

- all selected countries;
- countries with high expenditure on defence (annual expenditure of more than €40bn); and
- countries with low expenditure on defence (annual expenditure of less than €20bn).

For each of these three samples, the two samples based on the time period included were

- the entire period 1988-2011; and
- the period 2000-2011.

It was not possible 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 24, which is not enough for reliable econometric analysis.²⁰ All models were run on each of the six samples.

All our regressions had the following basic form:

Table 3.6: 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

²⁰ While it would be feasible to run an econometric model on so few observations, the results would not be reliable and so we did not run such models during this project.

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 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

First, all the models were run on the three samples corresponding to the time period 1988-2011. We found that the absolute levels, first differences, logarithms and growth rate models were inconsistent with the normality of residuals assumption, and were thus rejected outright. However, we found that the Ramsey RESET test indicated that the only remaining model – the Arellano-Bond model – was not specified correctly. Thus, we could not carry out any meaningful analysis on any sample if the full 24-year time period was included.

Next, we shifted to the three samples where only data for the years 2000-2011 were included. We found that the logarithms and first differences models were inconsistent with the normality of residuals assumption for all three samples, so these were rejected outright. For the absolute levels model, only the sample with the three high expenditure countries was not inconsistent with normal residuals, but this model failed the Ramsey RESET test. The logarithms model was consistent with the normality of residuals assumption for the low expenditure and high expenditure country samples, but both of these also failed the Ramsey RESET test. The remaining model – the Arellano-Bond model – was consistent with normal residuals for all three samples, but only the high expenditure and low expenditure samples also passed the Ramsey RESET test.

Based on the analysis described above, the two models using the Arellano-Bond methodology on the high expenditure and the low expenditure countries were chosen as our central models.

- High expenditure countries. The Arellano-Bond model suggests that a one percentage point increase in the growth rate of defence expenditure is associated with a 1.04 percentage point increase in the growth rate of defence exports.
- Low expenditure countries. The Arellano-Bond model suggests that a one percentage point increase in the growth rate of defence expenditure is associated with a 6.35 percentage point increase in the growth rate of defence exports.

As an illustration, the following table uses these relationships to find the increase in defence exports in each of the six countries if defence expenditure had been increased by €100m in the same year for which the input-output analysis has been carried out.

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.

Table 3.7: Increase in exports by country

Country	Year	Increase in exports (€m)
Germany	2009	8.1
Netherlands	2011	56.7
Poland	2005	5.6
Spain	2005	8.5
UK	2005	2.9

The extremely large figure for the Netherlands is due to a combination of two factors – (i) a strong relationship between export growth and expenditure growth and (ii) the value of exports is high in relation to total expenditure. Some other countries with strong relationships between export growth and expenditure growth have low export levels in relation to expenditure levels and vice versa.

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 GDP accounted for by CFC, and multiplied the increase in GDP as a result of induced effects with these percentages for each Member State.

3.7.2 Results

Several Member States do not publish data on the consumption of fixed capital in their input-output tables. Therefore, the value of a Member State level analysis is limited in this case. For completeness, however, the results for the selected Member States are shown in the table below.

Table 3.8: Capital intensity effects and multipliers by Member State (including induced effects)

pMS	Increase in consumption of fixed capital (€'000)	Capital intensity multiplier (national data)	Capital intensity multiplier (Eurostat data)
DE	13,187	131.9	Data not available
NL	Data not available	Data not available	53.1
PL	11,077	110.8	121
ES	Data not available	Data not available	Data not available
UK	Data not available	Data not available	Data not available

Source: Europe Economics' calculations.

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.

Our analysis was based on data obtained from national statistical offices in the selected Member States and the methodology employed was as follows.

- For each type of impact, we calculated the increase that would result from a €1 investment in every sector. 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.

4.1 GDP

The GDP results by Member State are shown below.

Table 4.1: GDP multiplier comparison by Member State

Member State	Transport (1)	Transport (2)	Education	Health	Defence
DE	1.2	-	1.6	1.5	0.9
NL	0.7	-	0.9	0.8	0.5
PL	1.2	-	1.7	1.6	0.9
ES	1.6	1.3	1.7	1.6	0.8
UK	2.1	2.0	2.1	2.1	1.7

Source: Europe Economics' calculations.

Note: ES and UK have 2 sectors relating to land transport. For the purpose of this table, Transport 1 refers to railway transport and Transport 2 refers to other land transport for ES and UK.

In general, there is a very clear ranking across Member States, with education having the highest multiplier, followed by health, transport and defence. The differences between sectors are fairly substantial. However, not too much should be read into this as the 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.

4.2 Tax revenue

The tax revenue results by Member State are shown below.

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

Member State	Transport (1)	Transport (2)	Education	Health	Defence
DE	0.5	-	0.6	0.6	0.4
NL	0.3	-	0.4	0.3	0.2
PL	0.4	-	0.6	0.5	0.3
ES	0.6	0.5	0.6	0.6	0.3
UK	0.8	0.7	0.8	0.8	0.6

Source: Europe Economics' calculations.

Note: ES and UK have 2 sectors relating to land transport. For the purpose of this table, Transport 1 refers to railway transport and Transport 2 refers to other land transport for ES and UK.

Again, there is a very clear ranking across Member States, 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

The employment results by Member State are shown below.

Table 4.3: Employment multiplier comparison by Member State

Member State	Transport (1)	Transport (2)	Education	Health	Defence
DE	22.0	-	25.2	30.6	12.0
NL	11.7	-	17.9	16.7	7.4
PL	75.8	-	130.4	121.5	52.6
ES	38.2	30.5	43.9	37.1	18.0
UK	32.7	32.5	45.1	38.6	25.3

Source: Europe Economics' calculations.

Note: ES and UK have 2 sectors relating to land transport. For the purpose of this table, Transport 1 refers to railway transport and Transport 2 refers to other land transport for ES and UK.

The results show that education almost has the highest multiplier in most countries, though health is slightly higher in Germany. 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.

4.4 Skilled employment

The results for skilled employment are shown below. 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.

Table 4.4: Skilled employment multiplier comparison by Member State

Member State	Transport (1)	Transport (2)	Education	Health	Defence
DE	2.9	-	3.1	3.1	3.3
NL	0.6	-	0.3	0.3	5.0
PL	14.2	-	11.7	12.3	23.1
ES	7.6	6.3	6.5	6.3	9.1
UK	16.9	10.9	6.7	6.3	10.2

Source: Europe Economics' calculations.

Note: ES and UK have 2 sectors relating to land transport. For the purpose of this table, Transport 1 refers to railway transport and Transport 2 refers to other land transport for ES and UK.

The results show that the defence sector has the highest skilled employment multiplier in all selected Member States other than the UK and is significantly greater than those of the comparison sectors in the Netherlands and Poland.

Among the comparison sectors, the general ranking of transport, health and education is not consistent. 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

Investment in defence has by far the largest R&D multiplier. The table below shows that the defence multiplier is between six and 297 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 (1)	Transport (2)	Education	Health	Defence
DE	6.0	-	13.1	7.9	75.7
NL	0.2	-	0.7	0.1	29.7
PL	3.0	-	3.5	3.4	38.8
ES	4.0	3.0	3.4	3.7	56.0
UK	7.4	6.2	10.4	16.0	141.6

Source: Europe Economics' calculations.

Note: ES and UK have 2 sectors relating to land transport. For the purpose of this table, Transport 1 refers to railway transport and Transport 2 refers to other land transport for ES and UK.

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 and compare them with the defence sector.

Table 4.6 shows the percentage of output for each of the comparison sectors that is accounted for by exports.

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

Member State	Transport (1)	Transport (2)	Education	Health	Defence
DE	3.1%	-	0.0%	0.0%	7.8%
NL	33.4%	-	0.0%	0.5%	8.7%
PL	14.1%	-	0.1%	0.2%	0.8%
ES	3.6%	14.7%	0.0%	0.0%	1.3%
UK	4.5%	4.1%	6.1%	0.7%	2.8%

Source: Europe Economics' calculations.

Note: ES and UK have 2 sectors relating to land transport. For the purpose of this table, Transport 1 refers to railway transport and Transport 2 refers to other land transport for ES and UK.

The table shows that the share of exports in the transport sector is very high for the Netherlands. This is not entirely surprising because, by their very nature, land transport services may only be exported at borders and access to borders is presumably greater in countries such as the Netherlands, which has a relatively large land border relative to its geographic area.

The table further shows that the education sector is highly domestic and the small amount of exports is, presumably, due to students from outside the country coming to study within it, or due to national 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 education is mostly likely to benefit domestic consumers of education services.

Finally, the figures presented above indicate that 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 relevant country for medical treatment. However, the flow of medical tourists within Europe generally involve Western Europeans travelling to Central or Eastern Europe and so is unlikely to be significant for the majority of countries included in this study.²³ 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

Comparison with defence exports

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 and 2010, the UK won export orders worth £7.3bn and £5.8bn, respectively.²⁴ In 2010, Germany's total exports of defence equipment to EU countries amounted to €1,528m.²⁵

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 investment in defence is likely to have a much greater export impact than in any of the three comparison sectors.

4.7 Capital intensity

Several Member States do not publish data on the consumption of fixed capital in their input-output tables. Therefore, the value of a Member State level analysis is limited in this case. For completeness, however, the results for the selected Member States are shown in the table below.

²³ See Lunt, N. et al (2011), "Medical Tourism: Treatments, Markets and Health System Implications: A scoping review", page 13.

²⁴ United Kingdom Defence Statistics 2011, Table 1.13. The Air sector accounted for 68 per cent of 2010 exports.

²⁵ 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 Verteidigung (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 (1)	Transport (2)	Education	Health	Defence
DE	214.5		201.9	213.9	131.9
NL	Data not available		Data not available	Data not available	Data not available
PL	207.4		150.9	155.3	110.8
ES	Data not available	Data not available	Data not available	Data not available	Data not available
UK	Data not available	Data not available	Data not available	Data not available	Data not available

Source: Europe Economics' calculations.

Note: ES and UK have 2 sectors relating to land transport. For the purpose of this table, Transport 1 refers to railway transport and Transport 2 refers to other land transport for ES and UK.

5 Conclusions

Based on the evidence presented in this report, it appears that using Eurostat data to model the macroeconomic effects of a hypothetical investment in the defence sector results in an underestimate of the true impacts. The core reason for this seems to be the relatively low level of disaggregation of sectors in the Eurostat data, meaning that defence activities cannot be separated from some less productive civil activities.

The national I-O data permit a somewhat more precise definition of the defence sector, resulting in higher estimates of macroeconomic effects. The impact on the results of further refining the definition of the defence sector cannot be known but it is entirely possible that the estimated impacts would increase once again. This hypothesis, and the implications for the macroeconomic impact estimates of an EU-wide investment in the defence sector, could only be tested at such a time as it becomes possible to more precisely identify defence activities in Eurostat data.

Overall, these results suggest that the estimated economic impacts of investing in the EU defence sector (as presented in an earlier Europe Economics report to the EDA) would have been higher, in some cases significantly so, if detailed data for the defence activities had been available at the European level.



Appendices



Europe Economics

6 Appendix 1: Assumptions, Conceptual Issues and the €100m Investment

6.1 Conceptual issues and assumptions

6.1.1 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.

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 in each selected Member State.

6.1.1.1 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 in each selected Member State.

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 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 relatively negligible amount compared to total investment expenditure in the defence sectors of the selected, 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.

6.2 Mapping of defence expenditure categories

6.2.1 Step 1: Latest available tables by Member State

We collected the latest available I-O tables from each selected Member State from the relevant national statistics office. The date of the most recent table, and the standard classification system on which the national classification used in the table is based, are shown in the table below.

Table 6.1: Latest available tables by Member State

Member State	Latest available table	Basis of classification system
DE	2009	CPA
NL	2011	NACE Rev 2
PL	2005	NACE Rev 1.1
ES	2005	NACE Rev 1.1
UK	2005	NACE Rev 1.1

6.2.2 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 sectors containing these products and / or services were identified using official documentation on the national classification systems.
- The relevant I-O sectors were identified as those containing the corresponding national NACE / CPA code. Each I-O sector corresponds to at least one two digit NACE / CPA code level in each country. Thus, no NACE / CPA sector had to be broken down to arrive at the corresponding I-O sector.

Table 6.2 presents the results of the mapping exercise.

Table 6.2: Mapping exercise results: relevant codes in national statistics

Member State	Equipment procurement	R&D	R&T	Infrastructure
DE	25 26.1-26.4 26.5-26.8 27 29 30 45	72	72	41 43
NL	25 26 27	72	72	41 43

Member State	Equipment procurement	R&D	R&T	Infrastructure
PL	29	73	73	45
	30			
	45			
	29			
	30			
	31			
	32			
	33			
	34			
	35			
ES	50	59	59	40
	31			
	32			
	33			
	34			
	35			
	36			
	37			
	41			
	67			
UK	69	108	108	88
	70-71			
	72			
	73			
	74			
	75			
	76			
	77			
	78			
	80			
	89			

6.2.3 Step 3: From mapping to division of expenditure

As shown in Table 6.2, only two of the defence spending categories correspond to a single I-O sector in every Member State (R&D and R&T). 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.

6.2.3.1 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 6.3 shows the sectoral breakdown of UK defence expenditure from 2004/05 to 2010/11.

Table 6.3: UK defence spending by sector

SIC(92)/SIC(03)/SIC(07) Section		VAT exclusive at Current Prices (£ million)						
		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	1 080	1 100	1 150	1 110	1 250	2 290	2 900 ⁴
	Aircraft & Spacecraft	1 810	1 730	1 660	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 I.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 Member State level; and
- the manufacturing sub-categories correspond to I-O sectors as follows.

Manufacturing category	DE	NL	PL	ES	UK
Weapons & Ammunition	25.4	25.4	29	31	67
Data Processing Equipment	26.1, 26.2	26.1, 26.2	30	32	69
Other Electrical Engineering	27	27	31	33	70-71,72
Electronics	26.4	26.4	32	34	73,74,75
Precision Instruments	26.5, 26.7, 26.8	26.5, 26.7, 26.8	33	35	76
Motor Vehicles & Parts	29	29	34	36	77
Shipbuilding & Repairing	30.1	30.1	35	37	78
Aircraft & Spacecraft	30.3	30.3	35	37	80

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

DE		NL		PL		ES		UK	
I-O sector	Spend (£ m)	I-O sector	Spend (£ m)	I-O sector	Spend (£ m)	I-O sector	Spend (£ m)	I-O sector	Spend (£ m)
25	8,060	25	8,060	(29)	8,060	31	8,060	67	8,060
26.1-26.4	6,830	26	11,350	(30)	550	32	550	69	550
26.5-26.8	4,520	27	1,510	(31)	1,510	33	1,510	70-71	882
27	1,510	29	2,520	(32)	6,280	34	6,280	72	628

DE		NL		PL		ES		UK	
I-O sector	Spend (£ m)	I-O sector	Spend (£ m)	I-O sector	Spend (£ m)	I-O sector	Spend (£ m)	I-O sector	Spend (£ m)
29	2,520	30	25,720	(33)	4,520	35	4,520	73	1,958
30	25,720	45	1,950	(34)	2,520	36	2,520	74	2,774
				(35)	25,720	37	25,720	75	1,555
								76	4,520
								77	2,520
								78	10,860
								80	14,860

In addition to the manufacturing I-O sectors presented in the table above, one service sector is included in our definition of equipment procurement (a measure of wholesale, retail and repair of motor vehicles). Combining the figures for these sectors with those of the manufacturing categories results in the following division of defence equipment procurement expenditure between I-O categories:

DE		NL		PL		ES		UK	
I-O sector	Spend (£ m)	I-O sector	Spend (£ m)	I-O sector	Spend (£ m)	I-O sector	Spend (£ m)	I-O sector	Spend (£ m)
25	8,060	25	8,060	(29)	8,060	31	8,060	67	8,060
26.1-26.4	6,830	26	11,350	(30)	550	32	550	69	550
26.5-26.8	4,520	27	1,510	(31)	1,510	33	1,510	70-71	882
27	1,510	29	2,520	(32)	6,280	34	6,280	72	628
29	2,520	30	25,720	(33)	4,520	35	4,520	73	1,958
30	25,720	45	1,950	(34)	2,520	36	2,520	74	2,774
45	1,950	45	1,950	(35)	25,720	37	25,720	75	1,555
				50	1,950	41	1,950	76	4,520
								77	2,520
								78	10,860
								80	14,860
								89	1,950

6.2.3.2 Research and development

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

6.2.3.3 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.

6.2.3.4 Infrastructure

The infrastructure defence category corresponds to a single I-O sector in three Member States and so the full additional expenditure on infrastructure would be allocated to that I-O sector.

In Germany and the Netherlands, however, two categories are relevant and hence the question arises of how to distribute infrastructure expenditure between these categories. Our approach was to distribute the expenditure based on the relative sizes of the two construction sectors in each country. On this basis, approximately 22 per cent of the expenditure was allocated to sector 41 in Germany while the corresponding figure for the Netherlands was 48 per cent. The remainder was allocated to sector 43 in each case.

6.2.4 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 into the various I-O sectors.
- We divided the €100m investment across I-O sectors according to this distribution.

Table 6.4: Additional demand by I-O sector (€)

DE		NL		PL		ES		UK	
I-O sector	Additional demand	I-O sector	Additional demand	I-O sector	Additional demand	I-O sector	Additional demand	I-O sector	Additional demand
1	0	1	0	1	-	1	-	1	0
2	0	2	0	2	-	2	-	2	0
3	0	3	0	5	-	3	-	3	0
5	0	4	0	10	-	4	-	4	0
6	0	5	0	11-14	-	5	-	5	0
07-09	0	6	0	15	-	6	-	6-7	0
10-12	0	7	0	16	-	7	-	8	0
13-15	0	8	0	17	-	8	-	9	0
16	0	9	0	18	-	9	-	10	0
17	0	10	0	19	-	10	-	11	0
18	0	11	0	20	-	11	-	12	0
19	0	12	0	21	-	12	-	13	0
20	0	13	0	22	-	13	-	14	0
21	0	14	0	23	-	14	-	15	0
22	0	15	0	24	-	15	-	16	0
23.1	0	16	0	25	-	16	-	17	0
23.2-23.9	0	17	0	26	-	17	-	18	0
24.1-24.3	0	18	0	27	-	18	-	19	0
24.4	0	19	12437245	28	-	19	-	20	0
24.5	0	20	17513986	29	11,567,404	20	-	21-23	0
25	10404106	21	2330055	30	789,339	21	-	24-27	0
26.1-26.4	8816383	22	0	31	2,167,094	22	-	28	0
26.5-26.8	5834561	23	3888568	32	9,012,816	23	-	29-30	0
27	1949156	24	39688082	33	6,486,931	24	-	31	0
28	0	25	0	34	3,616,608	25	-	32	0
29	3252897	26	0	35	36,912,361	26	-	33	0
30	33200200	27	0	36	-	27	-	34	0
31-32	0	28	0	37	-	28	-	35	0
33	0	29	0	40	-	29	-	36	0

DE		NL		PL		ES		UK	
I-O sector	Additional demand	I-O sector	Additional demand	I-O sector	Additional demand	I-O sector	Additional demand	I-O sector	Additional demand
35.1, 35.3	0	30	0	41	-	30	-	37-38	0
35.2	0	31	7610459	45	20,823,313	31	12,752,769	39-41	0
36	0	32	0	50	2,798,565	32	870,226	42	0
37-39	0	33	8216816	51	-	33	2,389,166	43	0
41	4109535	34	3009011	52	-	34	9,936,401	44	0
42	0	35	0	55	-	35	7,151,677	45-46	0
43	14721275	36	0	60	-	36	3,987,218	47	0
45	2517122	37	0	61-62	-	37	40,694,941	48	0
46	0	38	0	63	-	38	-	49	0
47	0	39	0	64	-	39	-	50	0
49	0	40	0	65	-	40	9,268,318	51-52	0
50	0	41	0	66	-	41	3,085,347	53	0
51	0	42	0	67	-	42	-	54-56	0
52	0	43	0	70	-	43	-	57	0
53	0	44	0	71	-	44	-	58	0
55-56	0	45	0	72	-	45	-	59	0
58	0	46	0	73	5,825,569	46	-	60	0
59-60	0	47	0	74	-	47	-	61	0
61	0	48	0	75	-	48	-	62	0
62-63	0	49	0	80	-	49	-	63	0
64	0	50	0	85	-	50	-	64	0
65	0	51	0	90	-	51	-	65	0
66	0	52	0	91	-	52	-	66	0
68	0	53	0	92	-	53	-	67	10,606,888
69-70	0	54	0	93	-	54	-	68	0
71	0	55	0	95	-	55	-	69	723,795
72	15194765	56	5305778			56	-	70-71	1,160,194
73	0	57	0			57	-	72	826,953
74-75	0	58	0			58	-	73	2,568,458
77	0	59	0			59	9,863,937	74	3,650,240
78	0	60	0			60	-	75	2,045,726

DE		NL		PL		ES		UK	
I-O sector	Additional demand	I-O sector	Additional demand	I-O sector	Additional demand	I-O sector	Additional demand	I-O sector	Additional demand
79	0	61	0			61	-	76	5,948,280
80-82	0	62	0			62	-	77	3,316,298
84.1-84.2	0	63	0			63	-	78	14,291,663
84.3	0	64	0			64	-	79	0
85	0	65	0			65	-	80	19,555,628
86	0	66	0			66	-	81	0
87-88	0	67	0			67	-	82	0
90-92	0	68	0			68	-	83	0
93	0	69	0			69	-	84	0
94	0	70	0			70	-	85	0
95	0	71	0			71	-	86	0
96	0	72	0			72	-	87	0
97-98	0	73	0			73	-	88	7,679,853
		74	0					89	2,566,183
		75	0					90	0
		76	0					91	0
								92	0
								93	0
								94	0
								95	0
								96	0
								97	0
								98	0
								99	0
								100	0
								101	0
								102	0
								103	0
								104	0
								105	0
								106	0

DE		NL		PL		ES		UK	
I-O sector	Additional demand	I-O sector	Additional demand	I-O sector	Additional demand	I-O sector	Additional demand	I-O sector	Additional demand
								107	0
								108	25,059,842
								109	0
								110	0
								111	0
								112	0
								113	0
								114	0
								115	0
								116	0
								117	0
								118	0
								119	0
								120	0
								121	0
								122	0
								123	0
								115 NM	0
								116 NM	0
								117 NM	0
								118 NM	0
								119 NM	0
								121 NM	0
								101 NPISH	0
								108 NPISH	0
								114 NPISH	0
								116 NPISH	0
								117 NPISH	0
								118 NPISH	0
								120 NPISH	0
								121 NPISH	0

DE		NL		PL		ES		UK	
I-O sector	Additional demand	I-O sector	Additional demand	I-O sector	Additional demand	I-O sector	Additional demand	I-O sector	Additional demand
								122 NPISH	0

7 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.²⁶ 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.

7.1 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.

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

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 $\frac{X_{AI}}{X_I} = a_{AI}$ 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

²⁶ 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.).

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.

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

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.

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

7.2 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 \mathbf{X}_D) and a set of technical coefficients a_{ij} (which are contained in the matrix \mathbf{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_i s (contained in the vector \mathbf{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.

$$\mathbf{X} = (\mathbf{I} - \mathbf{A})^{-1} \cdot \mathbf{X}_D$$

Here

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

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.

7.3 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 $(I - A)^{-1}$ 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 i th column of the matrix $(I - A)^{-1}$.
- **Income multiplier:** for sector i , this is the i th element of the vector $W \cdot (I - A)^{-1}$, where W is the vector of wage coefficients²⁷ for each sector.
- **Employment multiplier:** for sector i , this is the i th element of the vector $E \cdot (I - A)^{-1}$, where E is the vector of employment coefficients²⁸ for each sector.
- **Tax multiplier:** for sector i , this is the i th element of the vector $T \cdot (I - A)^{-1}$, where T is the vector of tax coefficients²⁹ for each sector.
- **Capital multiplier:** for sector i , this is the i th element of the vector $C \cdot (I - A)^{-1}$, where C is the vector of capital coefficients³⁰ 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.

²⁷ Calculated as the initial proportion of compensation of employees to total output for each sector.

²⁸ Calculated as the initial proportion of sectoral employment to total output for each sector.

²⁹ Calculated as the initial proportion of net taxes to total output for each sector.

³⁰ Calculated as the initial proportion of capital requirements to total output for each sector.

7.4 Richer models

The basic I-O framework can be modified or made richer through various extensions. Some of them are as follows.³¹

- 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.

7.5 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.

³¹ 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.

8 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 $V_U + V_S = V$.

8.1 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.

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

8.2 Calibration

- Eurostat data gives 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 gives 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 gives 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

8.3 Determination of sectoral proportions

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

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

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.