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Design of a Methodology to Evaluate the Direct and Indirect Economic and Social Benefits of Public Investments in Space

Technical note 3

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Executive Summary

The best method to assess the impacts of space investments is a combination of social cost-benefit analysis (SCBA) and multi-criteria analysis, which we term "SCBA-plus". By collecting more and better data, the cost-benefit part of the analysis may become larger over time.

The impacts of investments in space can be substantial. Directly or indirectly, space-related activities affect all or nearly all countries, industries, firms and individuals. Space research has brought the world new materials, new technologies and new ways of communication. Applications are used in a wide range across the economy and society in general: in consumer products, in manufacturing industries, in the development and delivery of professional services, in government services, in intelligence and in defence. Space programmes take place on the edge of knowledge. As with all innovative activities, it is often unclear what the outcomes will be, and how firms will apply these possibilities. Knowledge generation and sharing increase the pace of innovation and decrease production costs.

Public investment decisions depend to a large extent on expected economic, societal and environmental effects. This goes *a fortiori* for public investments in space related activities. The European Space Agency (ESA) aims to identify the economic, societal and environmental effects of public investments in space (related) activities in Europe. The focus in this research is on ex post analysis: analysing the effects of space programmes that have been implemented in the past. Before launching studies to assess the effects of public investments in space, the Agency seeks the most suitable, academically satisfactory methodology or methodologies to do so. In order to grasp the impact of a wide range of (potential) effects, a research methodology is needed which is both systematic and flexible. ESA has commissioned SEO Economic Research, with support from the Dutch National Aerospace Laboratory NLR, to design such a methodology.

Space investments, actors and effects

Three basic units in this report are space investments, effects and actors. A methodology for establishing the impact of space programmes should include all three concepts. An essential first step to identify the effects of space programmes is the establishment of a typology of investments in space (related) programmes. The typology consists of a list of investments, in which each type of investment is described in terms of its main characteristics. An important characteristic is the distance to markets. The main characteristics of investments in space (related) programmes have been listed and classified. Also, a typology of space (related) economic activities and sectors is presented. These activities have been linked to statistical classifications of economic activities.

In assessing the effects of space programmes, it is important to clearly define the policies (projects) involved, and also the base case: the situation without the policy. Appraisal of policies may take place after they have been implemented (ex post) or before (ex-ante). A core concept in appraisal is causality: are certain changes which occur caused by space programmes or not? Causality is not only an important issue in the effects of space programmes on firms and individuals, but also within space programmes themselves, as these are typically a combination of investments aimed at different firms. Moreover, these synergetic investments may be made by different parties.

Space investments affect many actors. The actors most affected by space activities are firms in the space sector itself (upstream and downstream). However, also sectors which are suppliers or clients of firms and organisations in space sectors, may be influenced indirectly. Finally, individuals are important actors, as employees of the space sector, consumers of space related goods and services, or as citizens. Countries represent the collective interests of individuals, both in their role as citizens and consumers, and firms. The interests of groups within society are represented by organisations such as political parties, trade unions or lobby groups.

The effects of space investments can be classified by type of effect and by type of actor. Many effects are quantifiable. Quantifiable effects can be direct economic effects for the sector where the investment is made, indirect economic effects for other sectors or induced effects on spending, and external effects which are not (fully) reflected in prices. Direct effects in the space sector can be classified further into upstream and downstream effects. Among indirect effects we may distinguish backward and forward linkages, induced effects and other effects. Analysis of indirect effects shows which actors experience the final impacts of the investments. Moreover, the analysis of these linkages is very important to avoid the risk of double-counting of benefits. Finally, spin-offs may be direct, indirect or external effects. These are positive effects of research and innovation which are partly reaped by the innovators themselves, but also by other actors.

Unquantifiable effects can be strategic, societal or environmental. Strategic effects occur in defence, but may also consist of increased influence in international politics and science. Furthermore, space exploration offers a venue for countries to cooperate. Finally, there may be long term effects on the position of countries and continents, including effects on innovation, capital intensity and labour productivity, the competitiveness of sectors among countries and on the standing and reputation of countries or continents in the world. Effects on competitiveness and on the standing and reputation of countries are difficult to measure because they occur in the long term and are influenced by many other factors than space investments. Combining the distinctions by types of actors and types of effects leads to a full classification of effects, shown in Table S.1.

Methodologies

In the scientific literature, many methodologies can be found. Most of these, however, are alternative names, specific subtypes, or combinations of a limited number of methodologies. Some of these methodologies are of a monetary nature, such as Financial Analysis, Input-Output Analysis, Computable General Equilibrium Analysis, Cost Effectiveness Analysis, Cost Benefit Analysis and Social Return on Investment. Non-monetary methodologies are Impact Assessment and Multi Criteria Analysis.

Several methodologies, such as Input-Output Analysis and Computable General Equilibrium Analysis, focus on sector effects. A necessary assumption in applying these methodologies is that we can identify a space sector. However, statistical data do not readily specify such a sector. In principle there are possibilities to extract specific space activities from different sectors and put them in a separate space sector. However, this requires some assumptions on the relation between the space activities and other sectors.

Table S.1 Classification of actors and effects (examples in capital letters)

	Quantifiable effects		Unquantifiable effects		
	Direct / Indirect effects	**External effects**	**Strategic**	**Societal**	**Environmental**
Space sector	*Upstream (direct effect) REVENUES LAUNCHER FIRMS* *Downstream (direct effect) REVENUES COMMUNI-CATION FIRMS*	COST SAVINGS THROUGH SPIN-IN (NOT PAID FOR)	INDEPEN-DENCE OF OTHER COUNTRIES		RISK CAUSED BY SPACE DEBRIS
Other sectors	*Indirect Back-ward linkage REVENUES MATERIALS FIRM* *Indirect For-ward linkage REVENUES IN BROAD-CASTING*	COST SAVINGS THROUGH SPIN-OFF (NOT PAID FOR)	COMPETITIVE ADVANTAGES		EFFECTS OF CLIMATE CHANGE ON PRODUCTION COSTS
Individuals	Induced indirect effects: EQUITY PRICES* Other indirect effects: EMPLOY-MENT	CO2 EMISSIONS	LOWER RISK OF INTERUPTED SERVICES SUCH AS GPS	PRIDE IN SPACE ACHIEVEMENTS HEALTH IMPROVE-MENTS USING SPACE TECHNOLOGY	BETTER ENVIRONMENT THROUGH SPACE MONITORING

* higher equity prices caused by higher spending in the economy

The impacts of space investments are very often investigated using Economic Effect Analysis, which shows economic effects which are considered important. Often these are direct effects in the upstream and/or downstream sectors or indirect effects for the end-users of space technologies. Social Cost Benefit analysis has been mainly applied to GMES (Global Monitoring for Environment and Security). Some studies perform a Multi Criteria Analysis for various types of space investments. Only a few studies use Input-Output analysis. Research applying Computed General Equilibrium analysis was not found, probably because of the complex nature of the calculations and the extensive data needs of this methodology. Financial Analysis has hardly been done for space investments, probably because computing only the financial effects for one actor is not acceptable to other stakeholders.

Relevant criteria for the aptness of methodologies to assess these effects are completeness, feasibility, objectivity, clarity of calculations, clear advice, and acceptability. Each of these criteria has been specified further in terms of specific questions. For instance, one of the questions with respect to completeness of a methodology is whether quantifiable and unquantifiable effects are both included. Table S.2 provides the data requirements of the different methodologies. There is no 'ideal' methodology: Each approach has its own advantages and disadvantages, summarised in table S.2.

Data requirements, availability and quality

Several types of data are required for (almost) all methodologies. Examples are investments within space programmes, investments related to space programmes, the size of the markets the investments are aimed at, and statistics on the economy. Other types of data are only needed for specific methodologies, such as Input-Output tables for Input-Output analysis, detailed statistical data for Computed General Equilibrium analysis, a discount rate for Social Cost Benefit Analysis, weights used in a Multi Criteria Analysis and societal and environmental effects for Social Cost Benefit Analysis, Impact Analysis and Multi Criteria Analysis.

Table S.3 shows, for each methodology/data source combination, whether the data source is either not needed, needed but not available or needed and available. Generally, we see that a lot of information is available on the space programmes themselves, but much less on related investments and on the impacts of investments on the economy. Some methodology-specific inputs such as discount rates are relatively easy to obtain, but other data are much harder to find. Data available within ESA can be used to complement macroeconomic data with specific data on investments and on the companies within space industries which work on ESA contracts.

A very important data limitation is the absence of an explicit space sector in economic data. Also, the input-output relations between sectors are only available at an aggregated level. This makes it hard to measure direct and indirect impacts of space programmes.

Given these data limitations, we see two viable roads of assessing the impacts of space programmes which are close to markets:

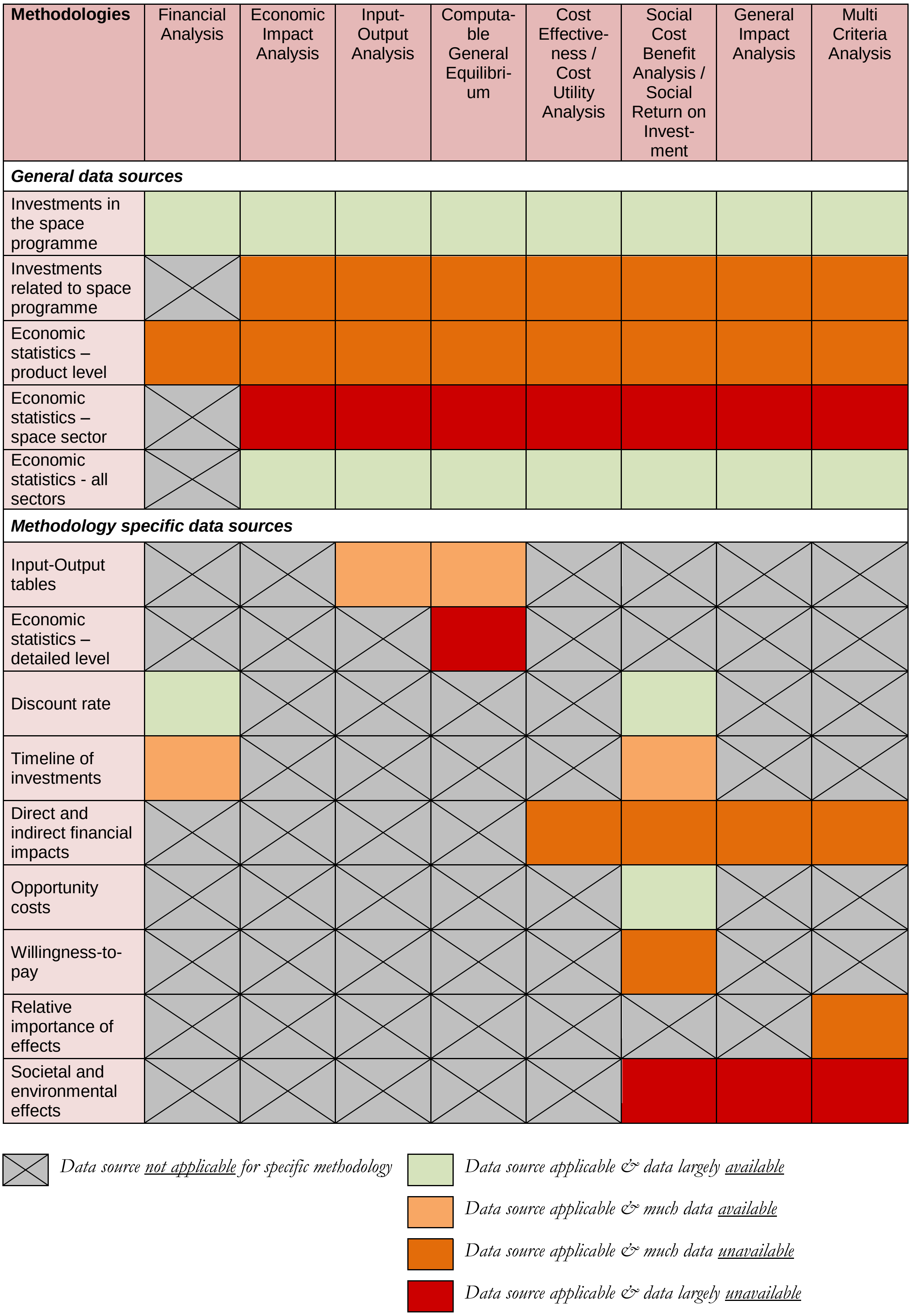
- Research into the direct effects of space investments in specific industries. Such research should then collect its own data, complementing the (well-known) characteristics of the investments with e.g. surveys.
- Research into wider economic effects. This would necessarily be rather aggregated, looking at broad economic sectors and the whole economy.

Efforts to obtain better data may also be in order. This could consist of contacting Eurostat and other statistics bureaus about possibilities to compile 'tailor-made' data which more explicitly shows the space sector and its relations with other economic sectors. Also, efforts to collect societal and environmental data are in order. These effects may be measured through many indicators. Examples of indicators for societal effects are the income distribution and unemployment. Knowledge spill-overs could to some extent be measured through patent citations or scientific publicationsbut these are not ideal indicators. Environmental effects may be measured using for instance CO_2 emissions or ecological footprints.

Table S.2 Advantages & drawbacks of methodologies in terms of criteria

	Methodology features			Usability in decision process		
	Completeness	Feasibility	Objectivity	Clarity of calculations	Clear advice	Acceptability
Monetary methodologies						
Financial Analysis	- Only financial effects. Often single actor but can be extended to multiple actors.	+ Standard accounting approach.	+ Causality tested. Effects can be easily compared due to use of standard rules.	+ Process is clear due to use of standard and transparent accounting rules.	+ Ranks policies and distinction between attractive and unattractive policies.	- Limited acceptability for large project due to incompleteness.
Input-Output Analysis	+/- All actors are taken into account but only direct and some indirect effects.	- Limited: IO tables are only available for main activities, space sector has no separate entry.	+/- Causality tested. Objective due to use of standard IO table. But only relevant for short-run and for small projects.	- Insight in parameters from IO tables but not in calculations behind it.	+Ranks policies and seperates attractive from unattractive policies. Clear and detailed advise.	- Strong assumptions needed about state of the economy. Also not all effects are taken into account.
Computable General Equilibrium Analysis	+ All direct and indirect effects, and to some extent external effects, all actors included.	- Limited: based on IO tables, method requires complex calculations.	+ Causality tested. Objective due to basis of IO tables.	- Calculations form black box.	+ Ranks policies and seperates attractive from unattractive policies. Clear and detailed advise.	- Limited acceptability due to complex calculations.
Cost Effectiveness Analysis / Cost Utilty Analysis	+/- Only main effect & costs are counted, all actors included.	+ Limited data and calculations required.	+ Causality tested. Main effect & costs are weighted adequately.	+ Insightfull calculations.	+/- Ranks policies in terms of attractiveness, no distinction between attractive and unattractive.	- Focus on one effect. Not suitable for policies with more than one relevant effect.
Social Cost Benefit Analysis	+ Some effects are hard to monetize but all effects are listed and actors are taken into account.	- Substantial calculations necessary.	+ Based in economic science. Causality tested. Also substantiated estimated parameters are used.	+/- Risk of black box effect.	+ Ranks policies & distinguishes attractive policies from unattractive ones.	- Some assumptions might be hard to accept; high weights of high-income people & business interests.
Social Return on Investment	+/- Aimed at monetizing social and environmental effects as much as possible.	- Substantial calculations necessary.	+/- Based in economic science. Causality tested. But risk of subjective parameters for intangible effects.	+/- Risk of black box effect.	+ Ranks alternatives & distinguishes attractive ones from unattractive ones.	+ High acceptability due to inclusion of stakeholders.
Non-monetary methodologies						
Impact Assessment	+ Can be applied to all effects and actors.	+ Limited data and calculations necessary.	0 Causality not always tested. No weights used.	0 No calculations made except for estimating separate effects.	- No ranking of policies and no attractiveness conclusion.	+/- Every decision maker can draw his/her own conclusions.
Multi Criteria Analysis	+ Can be applied to all effects and actors.	+/- Depends on depth of analysis.	- Causality not always tested. Subjective weights or methods can be used.	+ Process is clear, assuming the study is transparent on the weights used.	+/- Usually ranks policies but no attractiveness conclusion.	+/- Decision makers can apply their own weights.

Table S.3 Summary data requirements & availability



The proposed evaluation methodology: SCBA-plus

The core of the evaluation methodology we propose for space investments is Social Cost Benefit Analysis (SCBA). This provides a framework that covers all effects that are relevant for society. Effects are weighed, where possible, on the basis of observed market prices or other estimations of monetary values. However, the space sector has a specific nature. For some effects of space investments, putting money values on them may be impossible, or high quality estimations of money values may not be available. Also, if effects cannot be tied to individual investments, for example because they are far from markets, it becomes necessary to replace actual effect estimations by indicators that relate to investment effects. Also, specific data may be unavailable. This is why we combine SCBA with Multi-Criteria Analysis (MCA), a combination which we call “SCBA-plus”. The plus indicates that the methodology includes effects that are hard to monetize or even hard to measure, like strategic effects, societal effects and some environmental effects.

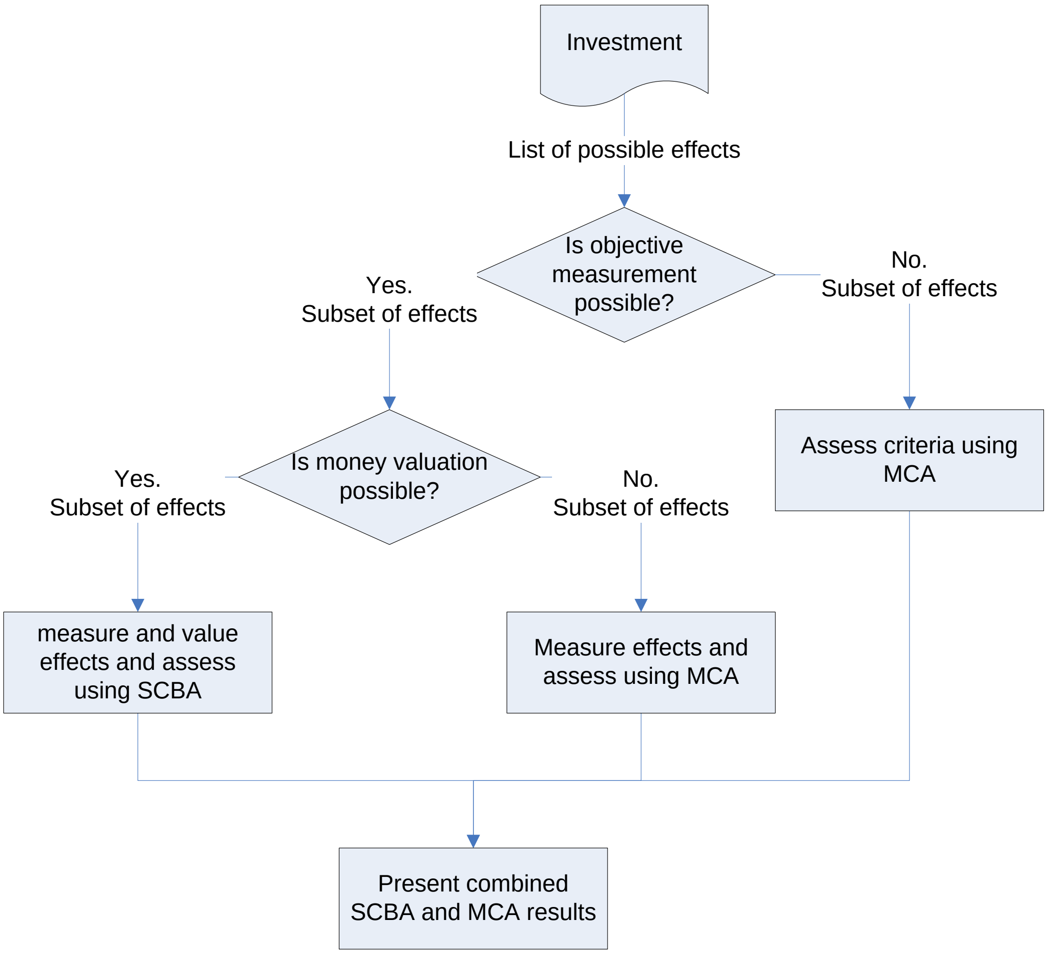
Flow-chart S.1 gives an overview of the set-up of the SCBA-plus methodology. For investments, or programmes of investments, a list of effects should be drawn up that might be the result of the investment. For each of these effects, it should be assessed whether objective measurement *and* money valuation is possible, or not. If both are possible, the effect is measured and valued according to the SCBA-methodology. If either money valuation or objective measurement of the effect is impossible, the effect is treated according to an MCA-methodology. For some of the effects that are treated in the MCA-part of the SCBA-plus methodology, it may be possible to measure effects as such. For others, it may be necessary to introduce indicators of effects, and even to subjectively score indicators, using as much available data as possible to make these scorings as strong as possible.

The SCBA-plus methodology combines the outcomes of the SCBA-part and the MCA-part in a combined presentation for evaluation purposes. In order to arrive at this, the following steps should be taken:

1. define the aim and scope of the evaluation;
2. dentify and characterise the investments;
3. identify the assessment criteria: costs, possible effects and other criteria; and identify the actors involved;
4. quantify and score the effects;
5. weigh the effects;
6. calculate outcomes;
7. perform sensitivity analysis;
8. present the results; and
9. evaluate.

Steps 1 to 3 are general steps that do not depend on whether effects are assessed in the SCBA-part or in the MCA-part of SCBA-plus. However, in step 3 it should be decided *how* effects are going to be assessed in the steps that follow. Table S.4 may be helpful in order to assure that all possible effects are accounted for, and that no double-counting of effects will occur (effects should either be assessed in the SCBA-part, or in the MCA-part).

Flow-chart S.1 SCBA-plus methodology treats effects differently if neccessary



Steps 4 to 7 differ between the SCBA-part and the MCA-part. In step 4, effects are quantified in the SCBA-part. In the MCA-part, if it is possible to quantify effects, this is done. If it is not possible, criteria are set up that have a relation to the effects, and these criteria are scored (or subjectively rated). Step 5 involves weighing of effects. Weighing in the SCBA-part implies putting money values on the effects. In the MCA-part, it involves determining the weights of the criteria. The outcomes (step 6) of the SCBA-part consist of the effects in their own terms and in money terms for target years; the effects in present values over the whole period; and the distribution of effects in the form of an actor analysis. The outcomes of the MCA-part are, first, the effects in their own terms, if available, and approximations of effects, and subjectively rated effects. Secondly, all these need to be measured on the same scale, for which we propose a rescaling to a simple 1 to 10 scale. Combining these scores with the chosen weights per score calculates the MCA's end results. For both the SCBA-part and the MCA-part, the outcomes of sensitivity analyses should be presented to make clear the robustness of results.

The final steps are combining results and using them for evaluation. An example of an end table is Table S.5, in which two projects are compared. The basis for evaluation and comparison is – in summarized form – the row Net Present Value (NPV) of monetized effects minus costs, combined with the row Weighted total score.

Table S.4. Tickbox can be used to check if and how effects are evaluated. *NA*=not applicable.

		SCBA (monetized)	MCA (not monetized)	
			objectively measured effects	effects to be scored/ subjectively rated
Costs			NA	NA
Direct effects	Direct effect 1			
	Direct effect 2			
	etc.			
Indirect effects	Indirect effect 1			
	Indirect effect 2			
	etc.			
External effects	External effect 1			
	External effect 2			
	etc.			
Strategic, societal, and other unquantifiable effects	Unquantifiable effect 1	NA	NA	
	Unquantifiable effect 2	NA	NA	
	etc.	NA	NA	

Table S.5. Monetized effects and scores/ratings can be compared

	Project A	**Project B**
	(Net) 'present' values, SCBA-part	
Investment costs	e.g. 10 bln euro	e.g. 15 bln euro
Recurrent costs	e.g. xa bln euro	e.g. xb bln euro
Calculated effect 1 in money terms	e.g. +ya1 bln euro	e.g. +yb1 bln euro
Calculated effect 2 in money terms	e.g. +ya2 bln euro	e.g. +yb2 bln euro
etc.	...	...
NPV of effects minus costs	**(NPV effects in money terms - investment costs – recurrent costs) = e.g. ya1+ya2-10-xa etc.**	**(NPV effects in money terms - investment costs – recurrent costs) = e.g. yb1+yb2-15-xb etc.**
	Scores, MCA-part	
Score on environment (unweighted)	1	10
Score on innovation (unweighted)	2.5	10
Score on competition (unweighted)	4	7
Weighted total score	**2.1**	**9.7**

NPV: net present value

Data limitations

In the current situation, and without additional data collection effort, data is missing that prevents making the most of the SCBA-plus evaluation methodology. The proposed methodology provides for some flexibility in this respect, which is summarized in Table S.6.

Table S.6. Missing data: strategies and consequences

Missing data on:	*Consequence*	*Consequence, continued*
Related investments (necessary for programme)	Assess effects on related investments in MCA-part.	If not possible, SCBA-plus is not suited.
Related investments (effects of programme)	Assess effects on related investments in MCA-part.	If not possible, note that effects on related investments are missing in the evaluation.
Statistics product market (for indirect effects)	Assess indirect effects in MCA-part. See Impacts.	If not possible, note that indirect effects are missing in the evaluation.
Statistics space sector (upstream/downstream)	Assess upstream/downstream effects in MCA-part. See Impacts.	If not possible, note that upstream/downstream effects are missing in the evaluation.
Monetary valuation of effects	Assess non-monetized effects in MCA-part. See Impacts.	If not possible, note that effects are missing in the evaluation.
Impacts of investments	Assess impacts in MCA-part.	If not possible, if main effect is missing, SCBA-plus is not suited.

Data that are currently missing relate to complementary investments, economic statistics at the product level, economic statistics on the space sector, some monetary valuations (especially if not observed in market prices) and indicators of knowledge spillovers. Data on related investments that are necessary for the space programme, and impact estimations of the main effects of the space investments including knowledge spillovers are considered essential for evaluation purposes.

Data collection

Efforts in the medium term could thus focus on collecting data on related investments that are necessary for space programmes and on doing impact estimations of the main effects of space investments, including knowledge spillovers. Also, in the medium term, efforts could be made to obtain better data on the space sector and its relations with other economic sectors, and a start could be made by collecting data on societal and environmental issues, and on monetary valuations of effects.

On a somewhat longer term, efforts may involve, amongst others, further impact estimations of effects of the space sector, collecting more detailed statistics at the product level and on the space sector, and improving the coverage and quality of monetary valuations. In this way, improvements in data collection, impact estimation and valuation of effects make for stronger evaluations by providing the necessary inputs for the SCBA-plus methodology, by assessing more effects in the SCBA-part of the methodology and by providing more information on which to base scores of MCA-criteria. A no-regret measure is to introduce the proposed SCBA-plus framework as a “way of thinking”: by classifying effects and providing a full picture of effects.

Finally, ESA collects a lot of relevant data for administrative purposes and for decision-making. These data can also be used to improve ex post evaluation of space investments.

Aggregation: from projects to programmes to total investments

ESA’s investments consist of programmes which are combinations of projects. SCBA-plus analysis should start at the level of projects, because these allow detailed analysis. A practical approach is to analyse the most important projects within a programme, and to extrapolate from there. However, assessing programmes is not just adding up projects, because synergy between projects should be estimated separately and included in the results.

The next step is aggregation from investment programmes to total investments. Extrapolating from one programme to another is not advisable. For each type of programme, separate projects could be analysed and if necessary extrapolated to the programme level. Next, the effects of programmes can be added up (SCBA-part) or averaged (MCA-part), if necessary taking account of synergy between programmes.

Applying SCBA-plus to projects and programmes, over time 'standard ratios' will arise, for instance "€ 100 million of investment in R&D on average increases the number of jobs in the space sector permanently by 200". As the body of knowledge grows, it will be better feasible to assess still more projects and programmes.

Indicators
Table S.7 shows the main indicators of effects which should be computed in SCBA: investments, direct and indirect effects, external effects via knowledge spillovers, external effects on the environment, and strategic and societal effects and distributive considerations. The table also summarises the methods which may be used to measure effects at the project level and to aggregrate these effects from the project level to full programmes.

Balanced and efficient research
The effects on for instance knowledge and international co-operation may be more important than e.g. additional turnover in space-related industries. This could in practice make MCA the larger part of the analysis. The challenge in SCBA-plus is firstly to include all the effects and secondly to put as many of these effects as possible in the SCBA part. To prevent extensive and costly research, the analysis may be based on a relatively simple approach via prioritisation of impacts. Benefits in other markets than the space sector and the users of space services may be estimated by experts. For external, societal and strategic effects, expert panels may be used as well.

Proposed first steps
Further possible first steps are:

- define case studies to try out the proposed methodology in a pilot phase. For example, the focus could be on a project that has relatively easy-to-measure effects, and on a project with harder-to-measure effects;
- implementing stricter rules or guidelines on evaluation; giving managers incentives to evaluate may also help.

For the first follow-on activity it is proposed to apply the SCBA-plus method to two of the current ESA programmes. The primary objective of this activity is to start generating a body of knowledge and the associated practical experience in assessing the benefits of European public investments in space.

Table S.7 Summary table of selected indicators, measurement and aggregation

	Measurement (project level)	Aggregation (from projects to programmes)
SCBA-part		
Investment costs	- Add up investments in projects in the space programme by ESA and other parties. - Identify and estimate related investments.	Add up project investments to obtain programme investments.
Reduced costs in space sector	Estimate the cost reductions through changes observed over time and/or surveys.	Add up over projects. Estimate and include synergetic effects by analyzing interactions between projects.
Increased revenues in space sector	Estimate net revenues (profits) by subtracting costs of labour, capital etc. From gross revenues. Correct for cost reduction above to avoid double-counting.	Add up net revenues over projects. Estimate and include synergetic effects by analyzing interactions between projects.
Increased profits in other sectors	Estimate cost reductions transferred to other sectors, depending on market conditions. Correct for double-counting.	Add up over projects.
Monetary value of CO_2-reductions	- Estimate volume of CO_2 reduction - Use CO_2 values from European research.	Add up over projects.
MCA-part		
Rating on knowledge spillovers	- Compute additional patent citations and scientific publications - Compute trends in education and knowledge related to the space sector - Use these as inputs for judgements of (panels of) experts	Compute average score of projects within the programme, e.g. weighing by project size.
Score on ecological footprint	Have the footprint computed by a knowledgeable consultant. Translate the footprint to a scale of 1 to 10.	Add up the footprints over projects. Translate the footprint to a scale of 1 to 10.
Score on water availability	Estimate the additional amount of water available. Translate this to a scale of 1 to 10.	Add up amounts of water over projects. Translate this to a scale of 1 to 10.
Score on space debris	Use judgements of (panels of) experts.	Compute average score of projects within the programme, e.g. weighing by project size.
Rating on competition effect	Use judgements of (panels of) experts.	Compute average score of projects within the programme, e.g. weighing by project size.
Rating on international safety effect	Use judgements of (panels of) experts.	Compute average score of projects within the programme, e.g. weighing by project size.
Rating on reputation effect	Use judgements of (panels of) experts.	Compute average score of projects within the programme, e.g. weighing by project size.
Score on (un)employment impact (happiness)	Compute additional jobs. Correct for long term equilibrium effects. Show the figures to (panels of) experts and ask their rating of happiness effects.	Add up the (corrected) additional jobs. Show the figures to (panels of) experts and ask their rating of happiness effects.
Score on distribution impact	Compute effects for (groups of) stakeholders. Compute an inequality index. Translate this to a scale of 1 to 10.	Add up the effects for (groups of) stakeholders. Compute an inequality index. Translate this to a scale of 1 to 10.

Source: SEO Economic Research

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Abbreviations and glossary

Table AG.1 Abbreviations

AHP	Analytical Hierarchy Process
ARTES	Advanced Research in Telecommunications Systems
ASI	Agenzia Spaziale Italiana, the Italian Space Agency
BNSC	British National Space Centre
CBA	Cost Benefit Analysis
CEA	Cost Effectiveness Analysis
CGE	Computable General Equilibrium
CNES	Centre National d'Etudes Spatiales, the government agency responsible for shaping and implementing France's space policy
CUA	Cost Utility Analysis
DLR	Forschungszentrum der Bundesrepublik Deutschland für Luft- und Raumfahrt, Germany's national research center for aeronautics and space
EC	European Commission
ECOS	ESA Costing Tool
EDA	European Defence Agency
EEA	Economic Effect Analysis
EIA	Economic Impact Assessment
EPO	European Patent Office
ESA	European Space Agency
ETS	European Trading System
EU	European Union
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FA	Financial Analysis
FAA	Federal Aviation Administration
FP7	7th Framework Programme
GDP	Gross Domestic Product
GMES	Global Monitoring for Environment and Security
GNSS	Global Navigation Satellite System
HME	Human Spaceflight, Microgravity and Human Exploration
IA	Impact Assessment
IO	Input-Output
IPC	Industrial Policy Committee
ISIC	International Standard Industrial Classification of All Economic Activities
MCA	Multi Criteria Analysis
NACE	European Classification of Economic Activities
NAICS	North American Industry Classification System
NASA	National Aeronautics and Space Administration
NIAG	NATO Industrial Advisory Group
NLR	National Aerospace Laboratory
NPV	Net Present Value
NSO	Netherlands Space Office
PM	Pro Memorie
PRS	Public Regulated Service (Galileo)
QALY	Quality-Adjusted-Life-Year

Table AG.1 (continued) Abbreviations

R&D	Research and Development
ROI	Return on Investment
SCBA	Social Cost Benefit Analysis
SCBA-plus	Combination of SCBA and MCA
SME	Small and medium enterprises
SROI	Social Return on Investment
STEM	Science, Technology, Engineering and Math
TRL	Technology Readiness Levels
TRP	Technology Research Programme
USPTO	United States Patent and Trademark Office
VAT	Value Added Tax

Table AG.2 Glossary

Backward linkages	Impacts (advantages and/or disadvantages) of an investment on direct or indirect suppliers.
Base case	The most likely development should the policy under review not be implemented.
Direct effects	Effects on the industry in which the investment is made.
Distance to markets	The extent to which investments would require additional steps to be reflected in goods and services which are traded in markets.
Double-counting	Error in investment appraisal in which the same benefit is counted twice.
Downstream sector	Operators of satellites and providers of space-enabled products and services. These range from products and services which can only be delivered through space to those which compete with or complement other forms of enabling infrastructures and / or services (Department for Business Innovation and Skills, 2010).
Ecological footprint	Land needed for a certain economic activity.
Effects	All impacts of space investments, positive or negative.
Ex-ante appraisal	Appraisal of policies before they have been implemented.
Ex post appraisal	Appraisal of policies after they have been implemented.
External effects	Effects that occur whenever activities of one actor affect activities or wellbeing of another actor in ways that are not reflected in market transactions.
External effects of knowledge	Benefits of knowledge which are not reaped by the investor but by other actors, without payment. This includes both spin-offs outside the space sector and spin-ins within the space sector.
Forward linkages	Impacts (advantages and/or disadvantages) of an investment on direct or indirect customers of the project services.
Indirect effects	Effects in other industries and financial effects for governments.
Indirect effects of knowledge	Benefits of knowledge which are not reaped by the investor but by other actors, with payment. This includes both spin-offs outside the space sector and spin-ins within the space sector.
Induced effects	Effects of additional household spending.

Table AG.2 (continued) Glossary

Investments in space	The outlay of public and private organisations to make activities in space possible.
Policy	The event under consideration.
Pro Memorie	An effect which is relevant ("to remember"), but which is not expressed in terms of welfare (i.e. money).
Project case	The situation with the policy implemented.
Public investments in space	All the investments in space of public organisations. This includes not only direct investments, but also subsidies or other payments for space activities of other organisations.
Public organisations	Governments; and organisations which are mainly financed by governments.
Social effects	Effects on the well-being of people which are not (fully) reflected in economic or political indicators.
Space programmes	Combinations of investments in space aimed at a common goal.
Space sector	Manufacturers of space hardware, providers of services that enable the launch of systems into space, operators of satellites and providers of space-enabled products and services.
Spill-overs (of space activities)	All effects outside the firms directly involved in space activities.
Spin-in (of space activities)	The use in the space sector itself of knowledge generated in space or non-space activities.
Spin-offs (of space activities)	The use in other sectors of knowledge generated in space activities.
Strategic effects	Long term effects on the competitive and political position of companies, countries and continents.
Quantifiable effects	Effects that can be quantified.
Technology readiness	The extent to which the results of technological investments are ready to be used for production of goods and services.
Upstream sectors	Manufacturers of space hardware and providers of services that enable the launch of systems into space. This comprises systems integrators (primes) and subsystem/component manufacturers for space and ground equipment (Department for Business Innovation and Skills, 2010).
Unquantifiable effects	Effects that cannot be quantified.
Unquantifiable environmental effects	Effects on the environment which cannot be quantified.

1 Introduction

Man must rise above the Earth - to the top of the atmosphere and beyond - for only thus will he fully understand the world in which he lives."
Socrates

Given the importance of space activities to society, the European Space Agency (ESA) has commissioned SEO Economic Research to compare methodologies and assess their value in showing the effects of public investments in space activities. The research consists of three work packages. This report describes the results from Work Package 3, but integrates the results of the previous work packages to provide a complete and self-standing document.

Space systems are becoming increasingly important to society. Applications are used in a wide range across the economy and society in general: in consumer products, in processes in the manufacturing industries, in the development and deliverance of professional services, in government services, in intelligence and in defence. Major sectors of the economy and many citizens depend on space systems and space-based technologies. Most of the services we take for granted in everyday life depend on space to function properly, from telecommunications to television and from weather forecasting to global financial systems.

Investments in space have benefitted the fields of health and medicine, transportation, public safety, consumer goods, environmental protection, computer technology and industrial productivity. These technologies enhance the quality of life, while at the same time contributing to the economy. They also inspire young generations to explore education and careers in science, technology, engineering and math fields.

Space activities yield both economic and societal value. Space-based technologies create business opportunities for innovative companies to provide new services (Hertzfeld, 2002b). Space technology stands at the forefront of science and engineering. Knowledge generation and sharing increases the pace of innovation and decreases production costs. This may also improve competitiveness. Space activities contribute to the knowledge base, providing tools to develop new technologies and applications. Moreover space is becoming increasingly important with respect to the environment, climate change, health matters and matters of security.

Directly or indirectly, space-related activities affect all or nearly all countries, industries, firms and individuals. The impacts of investments in space can be substantial. The space sector however is confronted with large technological and financial risks. Satellites operate in a hostile environment and system development typically requires a multi-year effort. Investments need to be made long before their return is realized. Therefore the sector requires strategic investment decisions. Public investment decisions depend to a large extent on expected economic, societal and environmental effects. This goes *a fortiori* for public investments in space related activities.

The European Space Agency (ESA) intends to identify the economic and societal effects of public investments in space related activities in Europe, both in a qualitative and in a quantitative way. The focus in this research is on ex post analysis: analysing the effects of space programmes that have been implemented in the past. Before launching a study to assess the effects of public investments in space, the Agency seeks the most suitable, academically satisfactory methodology or methodologies to do so.

In order to grasp the impact of a wide range of (potential) effects, a research methodology is needed which is both systematic and flexible. Which methodology is most suitable depends on various factors, such as the relevant effects, sectors and investments, combined with the availability of data. ESA has commissioned SEO Economic Research, with support from the Dutch National Aerospace Laboratory NLR, to design a methodology to assess the effects of public investments in space activities.

The research consists of three work packages. In Work Package 1 the problem was analyzed, all relevant effects, sectors and investments were defined and an overview was given of existing methodologies, their modus operandi, advantages and drawbacks (see TN1, 2011)). In Work Package 2 the primary and secondary data assessment took place (see TN2, 2012). Work Package 3 builds on the results from WP1 and WP2 and aims for the development of an integrated research methodology which is both practical and scientifically sound. This methodology integrates existing approaches with attention to the special nature of space activities and as such yields a usable methodology for all public investments in space. This report describes the results from Work Package 3 (WP3), but integrates the results of WP1 and WP2 so as to provide a complete and self-standing document.

Reading guide

Chapter 2 defines all relevant effects, sectors and investments. An overview of existing methodologies, their modus operandi, advantages and drawbacks is provided in chapter 3. The methodologies are compared using six different criteria. The data requirements of the different methodologies are discussed in chapter 4. The required data is divided into general data sources and methodology-specific data sources. Data sources are assessed on several criteria such as relevance, consistency, reliability, completeness and accessibility. Chapter 5 presents the proposed methodology, including its modus operandi, indicators to be used and the methodology's data requirements. Furthermore attention is given to the place of the methodology in ESA processes. Not all data required by the proposed methodology is currently available. Therefore a stepwise implementation of the methodology is suggested in chapter 6. Chapter 7 concludes.

An overview of all definitions can be found at the beginning of the technical note together with a list with all abbreviations used.

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2 Concepts and definitions

"Space: the final frontier"
Introduction of Star Trek: the original television series

Relevant actors are firms in the space sector and in sectors which are suppliers or clients of firms in the space sectors. Effects may be either quantifiable, such as new products for consumers or cost reductions for, or unquantifiable, such as strategic, societal or environmental effects. In assessing the effects of space programmes, it is important to clearly define the policies involved, and also the base case: the situation without the policy.

Three basic units in this report are space investments, actors and effects. A basic methodology for establishing the impact of space programmes should include all three concepts. In section 2.1, investment are defined in terms of their main characteristics. Section 2.2 describes the actors involved, and section 2.3 classifies the effects of space programmes. Section 2.4 introduces additional relevant concepts in investment evaluation.

2.1 Investments

Space investments differ in many respects. An important characteristic for the analysis of impacts in terms of economic activities is the distance to markets. ESA uses the related concept of 'technology readiness levels' and classifies its programmes accordingly. If we consider the Technology Readiness Levels to indicate a certain stage in a research & development programme, then the levels 1 to 4 focus on the "research" and levels 5 to 9 on the "development". Investments in research programmes have less visible impacts than investments in development programmes, which directly increase the production of goods. The effects of such investments can be ascertained in terms of turnover, linkages with other sectors, employment, etcetera. Differences between investments in terms of measurability of effects are important in designing a methodology for assessing the effects of investments in space.

Public entities are the driving force overall in the space sector; funding research & development, acting as a "launching customer" (or even the only customer) and managing the regulatory environment. In Europe, the primary sources of public investments in space are:

- European Space Agency (ESA)
- European Commission (EC)
- European Defence Agency (EDA)
- European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT)
- National and regional organisations (e.g. national space agencies, regional development organisations).

Each or these organisation will act in consultation with the other as well with the member states of the various supra-national organisations. The EU takes the lead in the overall representation of application programmes for its policies: the European Space Policy through the EC (including Galileo and GMES); the European Defence Policy through EDA. ESA focuses on the overall representation of Europe on programmes in the areas of science, launchers, technology and human space flight. The European Commission has become an important partner for ESA, in line with the established European Space Policy (European Commission, 2007). In addition ESA is cooperating with EDA on a variety of subjects and is a key partner in the development of satellites required by EUMETSAT's mandatory programmes.

The overall turnover of the European space industry is roughly € 6 billion a year (ASD-Eurospace, 2011). Member states annually invest a little under € 3 billion through ESA. Three billion is thus invested by national programmes and commercial entities. In the European context the level of military involvement in space is growing, in particular considering satellite communications, satellite navigation and remote sensing. Military public entities are important players both as a user of space based services (civil and military) and as a developer of space hardware. It wil be difficult to get a full picture of these additional investments, over and above ESA's activities.

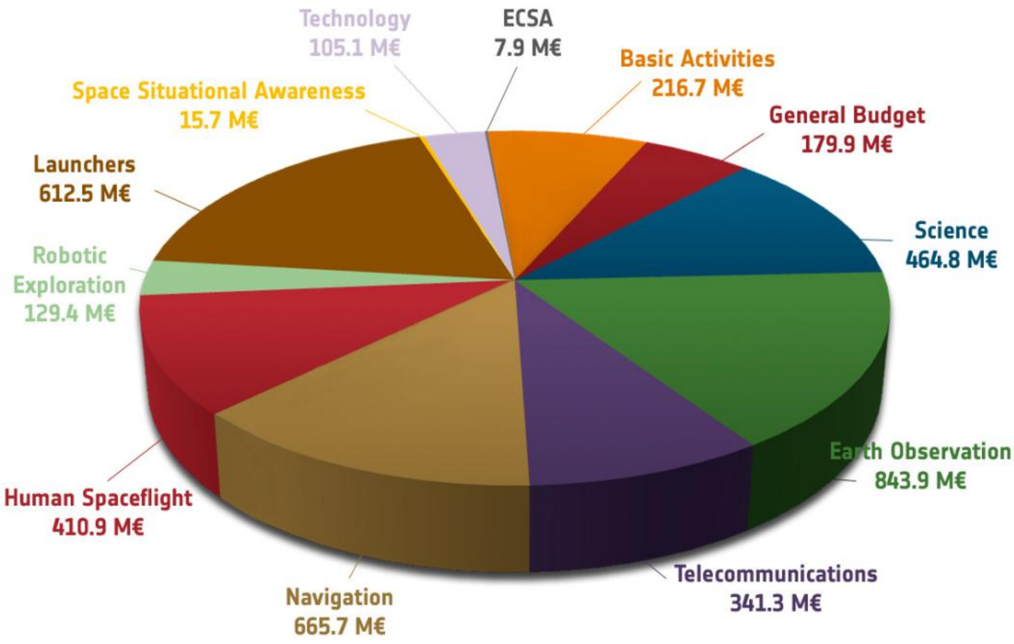
Projects, programmes and total ESA investments

Figure 2.1 provides a high level overview of the ESA programme budgets for 2011[1]. The investments consist of several programmes. In turn, these programmes are combinations of projects. Methodologies to assess the impacts of ESA's activities should be able to assess these impacts on three levels: projects, programmes and total investments. Such analysis necessarily begins with projects, as these are the basic building blocks of investments. In chapter 5 we will discuss whether and how the methodology we will propose may be used to aggregate from projects to programmes and from programmes to total investment.

Private investments can often be directly linked to prior public investments (which may have created skills, production capacity or a new market) and could be considered as one of the benefits of the public investment. Especially investments for which a clear (relatively) short-term return on investment (ROI) can be discerned (development programmes), are more and more taken up by the private sector.

[1] Note that this budget includes contributions by the ESA Member States and also the European Commission.

Figure 2.1 ESA budget by programme for 2011



Source: ESA

2.2 Stakeholders

The interests of groups are represented by institutions such as countries, political parties, trade unions and lobby groups. Many of these organisations are stakeholders with respect to space activities. Moreover, parts of government (e.g. ministries or departments of ministries, regional governments) represent specific interests in society, or their own interests, and therefore also function as stakeholders. Politicians are representatives of groups in society through political parties, but also aim for their own interests, such as re-election, their next job or the glamour of new, impressive projects.

In policy science, the making of new policies is described as actors/stakeholders interacting in policy arenas, trying to form coalitions and agreements by 'trading': making small concessions to achieve more important goals. Information presented by appraisal methodologies may help this process by giving a more precise picture of the effects of policies for society and for specific stakeholders. On the other hand, information may also make negotiations more difficult because the effects identified may be unacceptable to some stakeholders (e.g. if the analysis shows that the gains to other actors are much larger). Some of the methodologies described in this report aim specifically at identifying effects for different stakeholders and at involving stakeholders in the process. This study provides a framework for ways to determine the various kinds of effects, in relation to investment and other costs. The appraisal methodologies that will be investigated need a clear distinction of (groups of) stakeholders. We distinguish at least these stakeholders in space investments[2]:

- ESA
- Individual countries
- The European Union
- (other) international organisations (e.g. OECD)
- Economic sectors
- Individuals

The economic sectors mentioned above need more specification. Companies and institutions whose main activities are to manufacture spacecraft, launch, operate and monitor them or to conduct scientific research related to space, are considered to make up the *space sector*. In the space sector it is common to distinguish the upstream sector (manufacturers of space hardware and providers of services that enable the launch of systems into space) and the downstream sector (operators of satellites and providers of space-enabled products and services) (Department for Business Innovation and Skills, 2010).[3]

Companies and institutions that are suppliers or clients to the space sector, are considered to belong to the *space related sectors*. Examples are clients such as satellite television broadcasting companies or suppliers of hardware such as manufacturers of electronic components, or service suppliers such as insurance companies and financial institutions. The companies in the space sector and space related sectors are the actors most affected by space activities.

In turn the companies in the space related sectors have clients and suppliers in again other sectors. These clients and suppliers are companies and institutions that focus on activities not directly related to space activities. These companies that are only indirectly related to the space sector belong to *other sectors*.

Finally, individuals are important actors, as employees of the space sector, consumers of space related goods and services, or as citizens. Society in general is made up by the collective of all individuals, both in their role as citizens and consumers.

2.3 Effects

A first classification of effects is quantifiable versus unquantifiable effects. Quantifiable effects are effects that can be quantified. Most economic effects, like jobs and production, are (more or less) quantifiable. Unquantifiables on the other hand are effects that currently cannot be quantified, such as happiness or pride. A major challenge for most of the methodologies treated in this report, is to approximate the value (monetary or in some other fashion) of previously

2 We note that there may be many other groups of stakeholders, depending on the projects, programmes or effects involved. Examples are environmental groups for space monitoring programmes and trade unions for effects on employment and wages.

3 Estimates on the size of the upstream and downstream sectors in some European countries are provided by the British National Space Centre (2010) and Davies (2009).

unquantifiable effects. Over time, indicators may become available, putting a value on unquantifiables. Then unquantifiable effects move to the class of quantifiables.

Quantifiable effects: economics, knowledge, environment

Quantifiable effects = effects that can be quantified.
Direct effects = effects on the industry in which the investment is made.
Indirect effects = effects in other sectors and markets, and financial effects for governments.
External effects = effects that occur whenever activities of one actor affect activities or wellbeing of another actor in ways that are not reflected in market transactions.

Direct effects[4]

The direct effects comprise all effects on the sector or industry in which the investment is made. Hence, by definition direct effects of space investments take place in the space sector. These effects include investment and additional production. Production in the space sector leads to economies of scale, which has a reducing effect on prices, stimulating production further.

Within the space sector, a distinction can be made between upstream and downstream effects. Upstream sectors include manufacturers of parts of space hardware. Downstream sectors on the other hand include providers of space enabled products and services. In economic analysis of direct effects, a further distinction into specific industries is required, for two reasons. First, this will yield a more detailed picture of effects. And second, as this report shows, there is no "space sector" in statistical data, there are only specific space industries.

Indirect effects

Investment and additional production in one sector results in additional investment and production in other sectors. Direct effects in the space sector thus lead to ripple effects elsewhere in the economy. These wider economic impacts in other sectors, including the public sector, are called indirect effects.[5] Hence, by definition indirect effects cannot take place in the space sector but pertain to space related sectors, other sectors or individuals.

The size of the indirect effects depends, besides the size of the investment or additional production, on the extent of the linkages between the space sector and the other sectors that are affected.

Backward and forward linkages

Inputs or half products required by the space sector are called backward linkages. Deliveries from the space sector to space related or other sectors are called forward linkages (Hirschman, 1958).

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4 The terms direct and indirect effects are often defined in other ways, for instance as effects which are linked to the objectives of the space programme (direct effects) and other effects (indirect industrial effects) (Cohendet, 1989). In our report the indirect effects are limited to other sectors. There is no a priori reason to prefer one definition or the other, as long as the definitions are clear. The reason to make a sectoral distinction in this report is that this fits in with economy-wide statistical data, which are mostly organized by sector.

5 In the literature, these indirect or wider economic effects are sometimes called "pecuniary externalities", as opposed to "non-pecuniary externalities" or "technological externalities", which are often called external effects (Tresch, 2008, p.100-101). As the term "external" is more commonly understood to represent effects outside of markets, we use the terms "indirect effects" and "external effects" in this report.

Backward and forward linkages are important in investment appraisal for two reasons. First, analysis of these linkages allows seeing not only initial impacts, but also the final impacts of investments. These final impacts are not only important in understanding the impacts better, but also in discerning the effects on different economic sectors and population groups in society. These distributional effects are very important to politicians, as they usually represent specific interests within society.

The second reason why the existence of linkages is very important is the risk of double-counting of benefits (Sactra, 1999; Heatco, 2006; Mackie and Preston, 1998). If the additional turnover in all sectors which are linked to a specific investment would simply be added up, this would ignore that the turnover of say launching companies also represents a cost to communications companies. Therefore, there is a need to correct for costs to see the real, net benefits[6]. These costs do not only involve material goods and immaterial inputs (services) produced by other firms, but also costs of capital and labour. Therefore, additional employment should in principle be counted as costs, not as benefits (European Commission, 2008a; Macilwain, 2010). However, taxes collected on the additional income earned may be considered a benefit to society.

Induced effects

Direct and indirect effects from an economic activity, for instance the manufacturing of a satellite, result in additional household spending in the local economy by employees who work on the satellite. This in turn leads to higher turnover, employment and profits. These effects of additional spending on the economy are called induced effects.

External effects[7]

External effects are costs or benefits for society which occur because the actions of economic actors have effects on third parties that are not reflected in market prices of products and services. A benefit in this case is called a positive externality or external benefit, while a cost is called a negative externality or external cost. When negative externalities are present, a product or service will be overproduced by a competitive market, as the producer does not take into account the external costs when producing the good. The opposite is the case for external benefits. So when substantial external costs or benefits occur, this means that private calculations of benefits or costs differ substantially from society's valuation.

Internalising

Externalities are most likely to occur when property rights are not clearly defined. Therefore individuals have no incentive to care for externalities efficiently. Policy-makers can implement adequate policy measures, such as taxation, to make sure the externalities will be charged to the

[6] We note that backward linkages are mostly captured in prices of products of the space sector, as the goods and services used in production of the sector are included in production costs. Forward linkages are less likely to be included in prices of the space sector, except where there is a monopoly supplier who can charge a monopoly rent at the expense of downstream customers. However, the fact that forward linkages are not included in the prices of the space sector, does not imply that the forward linkages may simply be added up to the effects in the space sector, as these forward linkages are to a large extent an effect on the space sector which is 'passed through' to other sectors.

[7] External effects can either be quantifiable or unquantifiable. If externalities can be made quantifiable in some sort of way, they are listed under quantifiable external effects. If the externalities cannot be made quantifiable, for example if the actions of the space sector make individuals feel proud, the effects are categorized under unquantifiable effects.

producer and the consumer. The externalities are then said to be internalised. Patents are a way of internalising positive external effects of investments in new knowledge

Box 2.1 Spin-offs

Newly developed technologies lead to insights that can be used in other economic sectors, driving productivity across the economy (OECD, 2011; Coe and Helpman, 1995). Such spin-offs can be seen all around us, through numerous technologies and life-saving capabilities (see e.g. Goehlich et al., 2005). Space science spin-offs, although greater in number, are generally smaller in terms of wider economic benefits than spin-offs from space applications like broadcasting and telecommunications. Spin-ins, whereby companies within the space sector acquire and implement innovations developed elsewhere in or outside the space sector, are harder to come by but nevertheless present. This has to do with the fact that space programmes, products and services are often one-offs, with a unique development process associated to it.

Spin-offs and spin-ins can take various forms and occur at different stages in the chain from research and development to product introduction and application:

- ***External effects of knowledge***. These occur when the results of research and development in the context of one programme is also useful for the advancement of knowledge in other disciplines, without payment for the use of this knowledge. When a firm creates new products, based on its own research and development, it is often impossible to keep the specific knowledge involved to itself. Other firms see the new knowledge, and use it. These other firms may be within (spin-in) or outside (spin-offs) of the space sector. In other words, the total benefits of knowledge creation are larger than the private benefits to the actor which pays for the creation of the knowledge. This will lead to a too low level of investments in knowledge creation. This is a specific type of 'market failure'.
- ***Direct effects of knowledge***. Patents are a way to (partially) prevent such 'market failure'. They allow creators of knowledge to collect the benefits of their investment (a least for a certain amount of time). Patents thereby increase the incentives for firms to invest in new knowledge. Therefore spin-offs paid through patents held by firms which carry out space activities are by definition a direct effect.
- ***Indirect effects of knowledge***. Investments in space lead to opportunities for other companies to develop new technologies, products and services. Indirect effects occur when these are commercialised in the market place, causing benefits to companies other than the investing company. These companies may be within (spin-in) or outside (spin-offs) of the space sector.

The importance of spin-offs from space activities was highlighted by several studies (Jaffe, 1996, 1998; Amesse et al., 2002; Chapman, Lohman and Chapman, 1989; Bach, Cohendet and Schenk , 2002; NASA, 2010a) both in qualitative as well as in monetary terms.

Case study evidence has shown that ESA contracts have led to the development of new application technologies and services. ESA's reputation and network have enabled SMEs to increase export sales of space products and other commercial products derived from space technologies. Spin-off effects of ESA projects have been estimated to be around three times the initial investment (Bach, Cohendet and Schenk, 2002; Brendle, Cohendet, and Larue, 1986; Cohendet, 1989).

Unquantifiable effects: strategic and societal impacts

Unquantifiable effects = effects that cannot be quantified. ***Strategic effects*** = long term effects on the competitive and political position of companies, countries and continents. ***Societal effects*** = effects on the well-being of people which are not (fully) reflected in economic or political indicators. ***Unquantifiable environmental* effects** = effects on the environment which cannot be quantified.

Strategic effects
Although they cannot be quantified, strategic and tactical effects are an important type of unquantifiables. An important part of the strategic effects is related to defence. Military forces benefit from secure communications, reconnaissance, location and navigation services, force tracking and remote operation of war-fighting assets. Especially the US invests in military space activities. Europe has a stronger focus on civilian and commercial industries, but attention to the military aspects of space is growing rapidly.

Strategic effects however are not limited to defence alone. They are also related to increased influence in international politics and science. With GMES for example, Europe has an autonomous system which provides independent information on the global environment. Politically, at international level, an independent information source with visible, accepted quality controls helps Europe to occupy a position of credibility with respect to policy statements on global environment issues and associated international agreements (PWC, 2006).

Furthermore, space exploration offers a venue for countries to cooperate. An example is the active partnership of Europe, Japan, Russia and the US in the International Space Station Programme.

Competitiveness and reputation
As a part of strategic effects, there may be long term effects on the competitive and political position of countries and continents. Long terms effects include:

- Effects on innovation (better capital goods, efficient production methods, new or better consumer goods).
- Effects through capital intensity and labour productivity (capital deepening).
- Effects on the competitive position of sectors among countries.
- Effects on the standing and reputation of countries in the world, and of Europe as a whole. The Apollo programme for example significantly benefitted the scientific and technological reputation of the US. It increased the level of prestige and benefitted confidence in the government (Sadeh, 2006).

These effects may be especially relevant for the space sector, which provides many innovations and stimulates the development of knowledge. This may lead to clusters of firms in specific locations which benefit from each other (Marshall, 1890). An important example of such a cluster is the 'Aerospace Valley' around Toulouse in France. Over time, the knowledge generated in such clusters may reinforce economic activities, and vice versa. Also, there is a certain 'glamour' attached to space activities. This is for instance reflected in much media attention in for astronauts from their own country.

Effects on competitiveness are difficult to measure, because they occur in the long term and are influenced by many other factors than space investments alone. Effects on capital goods are reflected in statistics, but the analysis of many relevant factors is rather complicated. The identification of effects on the competitiveness of sectors and countries would require in-depth analysis, as done for instance by Porter (1990). This will only yield effects for specific industries, not for the economy as a whole. Economic models, on the other hand, do cover the full economy, but distinguish only limited numbers of sectors or industries. International competition, however, occurs at the level of thousands of products. Therefore, these models only reflect competitiveness at an aggregated level.

Finally, the standing and reputation of countries is hard to measure. If adequate measures are available, there is a host of other factors which influence the image of countries, such as wars, terrorism, trade policies, and economic downturns starting in specific countries or continents.

Societal effects

Societal effects regard the quality of life of individuals (health, happiness). These effects are not (fully) reflected in economic or political indicators. For example, the effects of GPS do not only pertain to its financial value to firms, but also to the happiness of its users[8]. As another example, its it is known that being unemployed has a strong negative effect on happiness, which is only partly reflected in the economic loss of production. Another example of a societal effect is pride. European citizens may take pride in European space programmes or in the services that are offered as a result.

Box 2.2 Examples of effects which are difficult to measure

Several effects of space investments are hard to estimate. Important examples are:

1. Dynamic networking effects, or other forms of learning mechanisms for society that could be important effects from space activities. For instance, space can be considered as a key vector of globalization. It stimulates deregulation and globalisation of telecommunications and broadcasting.
   The globalising effects of space programmes may be included in computations of cost reductions arising from economies of scale or scope in economic sectors which benefit from space programmes (e.g. large scale agriculture might benefit more from space monitoring than subsistence farming). Effects on deregulation are harder to assess, as these involve decisions made by governments.

2. Space applications may have an inherently cohesive impact on society, in that they are largely independent of terrestrial infrastructure and population density, and globally accessible. Potentially, their development would be relatively more beneficial to the peripheral and less developed zones of the globe.
   These effects may be considered as part of the distributional effects of space programmes. It may be possible to measure to what extent disadvantaged regions benefit from space, but it is very hard to assess the value to society of such reductions of inequality.

[8] We note, however, that the value of GPS to users is reflected to a large extent in their willingness-to-pay for smartphones, navigation systems etc. which contain GPS possibilities.

Unquantifiable environmental effects
Unquantifiable environmental effects consist of those effects on the environment that cannot be measured or assessed. An example is the influence of space monitoring on the awareness of global warming, which may lead to increased attempts to reduce greenhouse gas emissions.

Appraisal of unquantifiable effects
As (unquantifiable) strategic, societal and environmental effects are difficult to quantify, they are neglected by most traditional economics methodologies, or in these methodologies treated as *pro memorie* (PM) items.[9] In modern economics, a lot of efforts have been made to incorporate unquantifiable effects. If it is possible to calculate or approximate the monetary value of a societal or strategic effect, then it can be compared to economic effects in a quantitative way. Some effects that appear to be unquantifiable at first glance can be made quantifiable, and by making the effects quantifiable they are also made comparable.

For instance, health effects can be measured by quality-adjusted-life-years (QALY's) (Hirth et al, 2000). The value of natural resources can be approximated by the willingness-to-pay of citizens to prevent pollution or (destructive) utilization or by the costs of restoring the original situation afterwards (Carlsson & Johanson-Stenman, 2010). By applying such monetary techniques for (formerly) unquantifiable effects, the scope of economic methodologies is enlarged.

Actors/effects grid

Table 2.1 shows a cross table for actors and effects. This table acts as a grid, in which all possible effects of the space sector can be allocated. The grid is the basic reference for the evaluation of all the methodologies in this report.

2.4 Basic concepts in investment evaluation

A dynamic world
Direct effects like investments in the space sector are visible immediately, indirect effects may come with some delay, but external effects may take years to disseminate. When the impact of space related activities is to be determined, effects taking place both in the short and in the long run should be taken into account.

Accounting systems and statistical databases are designed for grasping existing patterns, taking place in the present and the (recent past). Existing structures offer limited opportunity for detecting structural (disruptive) changes. In order to detect, determine and quantify the effect of such changes, the utilization of old structures and methodologies will not suffice. Methods have to be adapted to the new circumstances, or even be replaced by new ones.

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9 *Pro memorie* denotes an effect which is relevant ("to remember"), but which is not expressed in terms of welfare (i.e. money).

Table 2.1 Classification of actors and effects (examples in capital letters)

	Quantifiable effects		Unquantifiable effects		
	Direct / Indirect effects	**External effects**	**Strategic**	**Societal**	**Environmental**
Space sector	*Upstream (direct effect) REVENUES LAUNCHER FIRMS* *Downstream (direct effect) REVENUES COMMUNI-CATION FIRMS*	COST SAVINGS THROUGH SPIN-IN (NOT PAID FOR)	INDEPEN-DENCE OF OTHER COUNTRIES		RISK CAUSED BY SPACE DEBRIS
Other sectors	*Indirect Back-ward linkage REVENUES MATERIALS FIRM* *Indirect For-ward linkage REVENUES IN BROAD-CASTING*	COST SAVINGS THROUGH SPIN-OFF (NOT PAID FOR)	COMPETITIVE ADVANTAGES		EFFECTS OF CLIMATE CHANGE ON PRODUCTION COSTS
Individuals	Induced indirect effects: EQUITY PRICES* Other indirect effects: EMPLOY-MENT	CO2 EMISSIONS	LOWER RISK OF INTERUPTED SERVICES SUCH AS GPS	PRIDE IN SPACE ACHIEVEMENTS HEALTH IMPROVE-MENTS USING SPACE TECHNOLOGY	BETTER ENVIRONMENT THROUGH SPACE MONITORING

* higher equity prices caused by higher spending in the economy

An economic approach is very well suited for covering quantifiable direct and indirect effects, and most of the external effects. Most economic methodologies yield insights in quantifiable measures like jobs and added value. Stocks and flows of resources, goods and services, either expressed in volume or in monetary value, and prices are the essential dimensions of economic methodologies.[10]

Policy, base case and project case

The policy is the intervention under consideration, the 'thing happening' of which one wants to know the effects. A policy can for instance be an investment in a satellite or a tax reduction. The effects of an investment are measured by comparing a situation in which the policy is applied, with a situation without the policy applied. The situation without the policy is called the base case. Constructing the base case is not trivial. Apart from future developments, it involves

[10] Monetary value is not to be confused with welfare. Money is the unit of account at a given point in time. However, the sheer total in Euros or dollars of an investment or a consumer good is just an approximation of welfare. Monetary value is influenced by inflation and exchange rates.

defining where the money not spent on the investment, policies etcetera will end up. The situation with the policy applied, is referred to as the project case. For ex-ante evaluations, several project cases can be defined, which for instance vary in scope, size and timing. For ex post evaluations a comparison vis-à-vis a variety of base-cases could be made.

Ex post and ex-ante appraisal

The impacts of policies can be assessed afterwards (ex post) or before they have taken place (ex-ante). Ex post appraisal involves measuring the effects that have taken place in reality, while ex-ante appraisal needs to forecast these effects. Ex-ante appraisal usually begins with constructing one or more scenarios for the future, which serve as the base case. The impacts are then predicted in the context of these scenarios. In monetary appraisal methodologies, future impacts are usually discounted using a rate of time preference or discount rate. Measuring impacts ex post might seem simple at first sight because the impacts can be observed, but there is an important complication: the hypothetical base case or no-project-alternative is typically not observed and has to be predicted or constructed.

ESA is looking for the best methodology (or combination of methodologies) to assess the impacts of space investments ex post. The methodologies presented in this report are valid for both ex-ante and ex post evaluations.

Causality

A core concept in appraisal is causality: are certain changes caused by space programmes or not? Research into causality requires information on similar changes in comparable situations. For instance, in ex post analysis of the effects of a space programme we may observe growing economic activity in the region where the programme was implemented. We do not, however, observe what would have happened without the space programme. This implies that this scenario has to be constructed or predicted in some way. One possibility to do this is to compare the developments in the regions involved to otherwise comparable regions (same country, similar characteristics) without space programmes.

We note that causality is not only an important issue in the effects of space programmes on firms and individuals, but also within space programmes themselves: one investment may only be useful if another investment is also made, and vice versa. Moreover, these synergetic investments may be made by different parties

3 Methodologies

"Though this be madness, yet there is method in it."
Hamlet, William Shakespeare

Many methodologies are availble, but most of these are alternative names, specific subtypes, or combinations of a limited number of methodologies. Some of these methodologies are of a monetary nature, some are non-monetary. Relevant criteria for the aptness of methodologies to assess these effects are completeness, feasibility, objectivity, clarity of calculations, clear advice, and acceptability. There is no 'ideal' methodology: each approach has its own advantages and disadvantages.

In this report six main monetary methods and two non-monetary methods are distinguished. These as well as related methodologies found in the literature are listed in table 3.1.[11] The monetary methods are described in section 3.1, the non-monetary methods in section 3.2. In section 3.3 the aptness of the various methodologies is determined.

Table 3.1 Overview of existing methodologies for economic appraisal

Methodology	**Abbreviation**	**Linked terms used in literature**
Monetary methods		
Financial Analysis	FA	Business Case & Investment Analysis & Portfolio Analysis.
Input-Output Analysis	IOA	Input-Output Models & Leontief Analysis
Computable General Equilibrium	CGE	General Equilibrium Analysis & General Equilibrium Models & CGE Models & Spatial General Equilibrium Models & New Economic Geography (NEG) Models
Cost Effectiveness Analysis / Cost Utility Analysis	CEA / CUA	Cost Effectiveness Ratio (CER) & Cost Utility Ratio & Incremental Cost Effectiveness Ratio (ICER)
Social Cost Benefit Analysis	SCBA	Cost Benefit Analysis/Benefit Cost Analysis & Cost Analysis & Indicative or quick scan CBA
Social Return on Investment	SROI	SROI ratio & Social Impact Measurement
Non-monetary methods		
Impact Assessment	IA	Impact Analysis & Economic or Environmental Impact Analysis & Balance Sheet Analysis & Score Card Analysis & Analysis Key Performance Indicators & Economic Effect Analysis & B.E.T.A
Multi Criteria Analysis	MCA	Multi Criteria Decision Analysis & Outranking (MCA) Approach & Descriptive MCA & Value Function Approach & (Non-) Compensatory MCA & Dominance Approach & Conjunctive/Disjunctive Selection Approaches & Lexiographic Ordering & Concordance/discordance Analysis & Linear Additive Models (LAM) & Analytical Hierarchy Process (AHP)

11 Besides these methodologies also many types of data gathering techniques can be discerned. Not all available techniques for data gathering are relevant when evaluating investments in space. In Appendix A an overview of techniques is divided into techniques relevant for evaluation of investments in space and techniques which are not suitable for this purpose.

3.1 Monetary methods

Financial Analysis

Description

Financial Analysis gives an overview of the monetary effects of a policy for a specific actor. Financial Analysis is the main tool which firms use to decide upon their investments. In most cases a Financial Analysis will not be the main evaluation tool that is used for government policies. More than as a separate evaluation tool, Financial Analysis will then be used as part of the other methodologies described below, to calculate part of the effects.

Advantages & drawbacks

The simplicity of Financial Analysis forms both its main advantage and its main drawback. Due to the standard accounting approach the methodology is clear and objective. The main drawback is that the methodology is very incomplete: only financial benefits and costs are taken into account and often only for one actor. Due to this incompleteness Financial Analysis is not accepted as a final evaluation methodology for large government projects. The assumption that only financial effects for specific firms are important is especially inappropriate for the space sector, which causes possibly large external and unquantifiable effects.

Input-Output Analysis

Description

Input-Output analysis (IO analysis) traces the effects of an investment throughout the economy by using detailed data on interactions between industries or sectors within the economy. Multipliers show how an input change (i.e. an investment) affects total output. IO analysis is basically static and built around IO matrices: transaction tables in which the values of transactions between industries are specified. Various IO analyses have been carried out for the space sector in recent years (see FAA, 2010; Goss Gilroy Inc., 2010 and NASA 2009).

Advantages & drawbacks

The advantage of IO Analysis is that the ideas behind it are simple and the mathematics straightforward. A drawback of this methodology is that the data requirements are immense. In order to be able to single out values and multipliers for specific regions and industries, full transaction information for all the cells in the IO table is needed.

An important (and often implicit) assumption is that the production factors labour, capital and land are available. Since IO analysis assumes a fixed production structure, it does not allow the analysis of structural shifts in policies or technology. It assumes the economic system under study to be in an equilibrium state. Industries are supposed to have a (more or less) homogeneous output and a known, invariable production structure. Given the static nature of IO analysis, it only provides short term information. In order to incorporate long term effects, a series of IO analyses has to be implemented, which all have the same dimensions in regions and industries. Finally, IO analysis does not take non-financial and unquantifiable effects into account.

Computable General Equilibrium Analysis

Description

Computable General Equilibrium Analysis (CGE Analysis) is a methodology in which the effects of economic shocks or policy measures are calculated using a model which simulates the entire economy. CGE models include factor (capital, labour) and commodity markets and model the behaviour of production sectors, households and governments.

CGE models are often based on (aggregated) Input-Output tables. They estimate the same direct effects of policy measures as IO Analysis does. As opposed to IO analysis, GCE analysis also adjusts prices and wages. Prices and wages are adjusted until production and employment in the entire economy are in an equilibrium state. CGE analysis therefore is an economy wide impact analysis.

No studies were found that estimate the effects of space activities on the economy using GCE analysis. This probably has to do with the large data requirements and complexity of the methodology.

Advantages & drawbacks

The major advantage of CGE Analysis is that it yields results which take into account all indirect effects throughout the whole economy. Furthermore, CGE models are based both on a consistent theoretical model of the economy and on empirical data which describe national economies.

As GCE uses IO tables, the drawbacks with respect to the immense data needs of these tables also apply to GCE. Another drawback is that policies have to be large enough in order to show any impact on the economy. As space activities are relatively small compared to the size of the economy as a whole, this is again an important drawback in the context of this study.

The assumption that the economy will end up in an equilibrium is only valid for the long-term; in the short term markets are usually not in an equilibrium. Prices and wages do not adjust instantaneously to changes in the economy. Therefore markets can be out of equilibrium during an adjustment period. Moreover, there might be institutional or market barriers which limit the efficient functioning of markets.

Finally, CGE Analysis concentrates on direct and indirect effects; it does not take non-financial and unquantifiable effects into account. This is an important limitation in appraisal of space programmes, as these programmes are expected to yield important external and strategic benefits, which are not in the scope of CGE Analysis.

Cost Effectiveness Analysis

Description

Cost-Effectiveness Analysis (CEA) is a tool to compare different technological options or policy programmes which have identical objectives. It summarises the outcome of a comparison using a single quantifiable indicator. It also provides a measure of the effectiveness of an option. The objective itself is not assessed. Cost-Utility Analysis (CUA) is an extension to CEA, in the sense that it uses a quality-adjusted indicator to describe the objective. One study by Mathematica (1972) was found that applied CEA with respect to space investments.

Advantages & drawbacks

CEA is simple and effective, and capable of taking all kinds of effects into account, quantifiable as well as unquantifiable effects. An advantage of cost-utility analysis over cost-effectiveness analysis is that a richer indicator can be used to determine a cost-effectiveness ratio which includes more than one objective. However, at the same time this has the drawback that the relative weight of the different objectives becomes obscured through the use of one single cost-utility measure.

The main limitations of CEA and CUA are that they do not take secondary or indirect effects into account. As the latter situation applies to space programmes, this is an important drawback in the present study. Another drawback of CEA is that only the cost-effectiveness is analysed, not the relevance of realising an objective.

Social Cost Benefit Analysis[12]

Description

In Social Cost Benefit Analysis (SCBA) all the costs and benefits of investments or policies are systematically evaluated and where possible monetised to make them comparable. In addition, SCBA provides an overall picture of how the effects are distributed among stakeholders[13]. In principle, SCBA has the ambition of including and monetising all the effects of a policy, including societal and environmental effects.

In SCBA, the *willingness-to-pay* of firms and households is estimated for each impact of the project or policy. This is done market-by-market, with special care to avoid double-counting. If possible, existing markets are used, where the *willingness-to-pay* can be observed from choices made by suppliers and customers. Often, economic methods are used which describe specific markets (transport, energy) or the economy as a whole (Computable General Equilibrium Analysis, Input-Output Analysis[14]). For impacts which are not related to markets, other methods such as surveys may be used. The value of impacts is calculated year-by-year, for a period of decades. The future costs and benefits are translated into present values using discounting.

A Cost Benefit Analysis (CBA) can be conducted at several levels of detail. Different extensions to the name Cost Benefit Analysis are used to point out the extensiveness of the analysis conducted; for example Cost Analysis, Indicative CBA and Quick Scan CBA. The most complete form is the Social Cost Benefit Analysis. This complete form is discussed in more detail in this section.

SCBA is based in economic science and is often used in practice. Several studies have applied SCBA to the space sector, most of which relate to GMES services (see Indra, 2004; Whitelaw, 2004; Whitelaw, Costa and Scott, 2004; Ecorys, 2004; AETS, 2005; ESYS, 2004; European Commission, 2009b; Booz & Co, 2011; PWC, 2001 and NATO Industrial Advisory Group,

12 This text is adapted from two SCBA manuals: Zerbe and Bellas (2006) and Eijgenraam et al. (2000).
13 Here, stakeholders are defined as actors with an interest in the space investment or its effects.
14 In this report, these economic modelling methods are also described as separate appraisal methods.

2011). Almost all of these studies focus on the benefits to end-users and society in terms of cost-savings or additional production, without estimating the direct effects on the space sector. External and non-quantifiable effects were often not included or only qualitatively addressed. In addition, costs of infrastructure were not always included. Input data mainly consisted of estimates on cost-savings and additional production.

Advantages & drawbacks

All relevant advantages and disadvantages of an investment project are recorded and quantified in the best possible way. By allocating a suitable monetary value to project effects wherever possible and then adding them up, it is possible to present information in a well-organised manner which facilitates a comprehensive assessment. Social cost-benefit analyses limit, wherever possible, the compilation of long lists of diverse advantages and disadvantages which complicate rather than simplify a comprehensive analysis of project effects.

A social cost-benefit analysis also has a disciplining effect because it prevents double-counting. It requires an adequate insight into the relationships among the various impacts. A cost-benefit analysis therefore makes demands on the research, not only on the analysis itself, but also on the underlying research projects. This reduces subsequent criticism.

It is not always possible to express all effects in monetary terms and add them up. External effects may be partly monetised, but for strategic effects this is very hard. This is a serious limitation in all monetary methodologies. Still, non-priced effects can often be reliably expressed in monetary terms. Effects which cannot be expressed in monetary terms must be weighed up in political-administrative terms against the sum of the effects which can be expressed in monetary terms.

Box 3.1 Limitations of SCBA

SCBA works well when costs and benefits are associated to existing markets. In such a case, consumers' surplus and producers' surplus normally give extremely accurate values. However, as we depart from existing markets, calculations become more difficult. There are several objections to the use of SCBA:

1. Problems in attaching valuations to costs and benefits, especially when departing from existing markets. Techniques such as contingent valuation are available, but not accepted as valid by all economists.
2. SCBA may not (explicitly) cover everyone affected (i.e. all third parties) – inevitably there are a huge number of potential "stakeholders" who stand to be affected (positively or negatively) by an investment decision. There is a risk that some groups might be left out of the decision process.
3. Distributional consequences. Costs and benefits mean different things to different income groups. Those receiving benefits and those burdened with the costs of a project may not be the same. Are the losers to be compensated? This equity issue is important to policy makers.
4. Social welfare is measured as the sum of the *willingness-to-pay* of individuals. This might not be an appropriate criterion in the eyes of policymakers.

Apart from these limitations, SCBA has important advantages (see the text of this section). Any assessment methodology which includes SCBA should take account of its limitations and try to correct for them.

Finally, social cost-benefit analysis may seem like a black box to non-economists. The fact that some benefits should be disregarded to prevent double-counting, is not always obvious to people who find it important to account for all the benefits.

Social Return on Investment[15]

Description
Social Return on Investment (SROI) can be seen as a special form of SCBA. The main difference between SROI and SCBA is the focus of SROI on societal and environmental impacts and the involvement of stakeholders. It overcomes the difficulties faced by SCBA in estimating societal and environmental impacts by focusing on the most important sources of value as defined by stakeholders. No studies were found in which SROI was applied to a case regarding space activities.

Advantages & drawbacks
The advantage of SROI is the emphasis on the embedding of the methodology in the decision making process which may lead to a wide basis for acceptance. Another advantage is that as many effects as possible are taken into account, with special attention for societal and environmental effects.

The downsides of SROI are that societal and environmental effects are difficult to monetize and might need subjective assumptions to include them in the analysis. The involvement of stakeholders and the special attention to societal and environmental effects also imposes risks of subjectivity. The interests of strong stakeholders might be over-emphasized while the interests of smaller or less organised stakeholders might be underexposed. Strategic input from stakeholders can be partially overcome by a correct set-up of the survey or interview.

For space investments, the inclusion of strategic effects in SROI is nearly impossible. In SROI, as opposed to SCBA, the base case is not explicitly defined which can cause problems calculating effects in later stages.

3.2 Non-monetary methods

Impact Assessment[16]

Description
The goal of an Impact Assessment (IA) is not to rank the alternatives but to give a clear overview of the effects of the alternatives. In an Impact Assessment all effects are treated separately, positive effects as well as negative effects. Each effect is assessed in quantitative or qualitative terms. As in SCBA, the effects consist of direct, indirect, external, strategic, societal and environmental effects. An Impact Assessment can be integral or can explicitly be conducted for

15 The description of the SROI methodology is mainly based on Boyle and Murphy (2005), Steed and Nicholles (2011).

16 Many definitions of Impact Assessment (IA) are used in the literature. The term is used as a synonym for evaluation methodologies in general and to describe a subset of evaluation methodologies. To avoid confusion, in this study the term Impact Assessment is used to describe a subset of evaluation methodologies.

the most important or the largest effects, also called an assessment of the Key Performance Indicators. An important subtype of Impact Assessment is Economic Impact Assessment (EIA) in which only the economic effects are included. Another type often applied is Economic Effect Analysis (EEA), which only includes the economic effects considered to be of importance. An example of EEA in the space sector is the B.E.T.A. (Bureau d'Économie Théorique et Appliquée) methodology. This methodology can be used to evaluate spin-off effects. The methodology is based on extensive interviewing of key persons in each firm that received a contract. The methodology does not allow the estimation of the long term effects of programmes on the economy as a whole.

The Impact Assessments that have been found in the literature differ in scope, for instance in terms of effects considered, industries taken into account or geographical range. The main data sources for these studies are surveys, workshops and interviews to estimate turnover, employment and/or costs and profits. None of the studies was an Impact Assessment in the sense that it contained all effects. Many studies however were found in which an assessment was made of a part of the economic effects of a space activity (EEA) (see Space Foundation, 2011; RPA, 2007; ASD-Eurospace, 2010; Bullock et al., 2002; Patureau et al., 2002; British National Space Centre, 2008, 2009; Davies, 2009; SIA, 2011; VEGA and Booz Allen Hamilton, 2004; ESA, 2005; Technofi, 2007 and Ecorys, 2009). In only a few cases all economic effects (direct, indirect and induced) were given (EIA) (see Oxford Economics, 2009; Department for Business Innovation and Skills, 2010 and California Space Authority, 2010). In some studies economic effects were extended with external, societal or strategic effects (see OECD, 2011; UK Space Agency, 2010; PWC, 2006; Danish Agency for Science, 2008; NDP Consulting, 2011; NASA, 2007, 2008, 2010b; Schnee, 2009; Sadeh, 2006; Hertzfeld, 1998, 2002a; Technopolis, 2010; Fisher, 2009; Centre for Strategy & Evaluation Services, 2011 and Hallonsten, Brenner and Holmberg, 2004). Several studies applied the B.E.T.A. methodology (see Brendle, Cohendet and Larue, 1986; Cohendet, 1989; Amesse et al., 2002; Bach et al., 1995 and Bach, Cohendet and Schenk, 2002).

Advantages & drawbacks
Advantages of the IA are that it can incorporate different kinds of effects and that the information is processed in an explicit way. IA is also capable of dealing with different numbers of policies, criteria and actors. Another advantage of IA is that it is a relatively simplistic analysis, so the amount of data and calculations necessary are limited.

A drawback of IA is that it does not provide a ranking of policies or an attractiveness conclusion. Different policies are not fully comparable after the analysis has been conducted. In this way every decision maker can draw his/her own conclusions and the analysis does not provide full help in the decision making process. The additional downside of the subtypes is that they do not provide a complete overview of all the effects.

Multi Criteria Analysis

Description
In Multi Criteria Analysis (MCA) policy alternatives (e.g. various space programmes) are first scored on different criteria. Second, the different criteria are weighed. The main goal of MCA is to structure the effects of the alternatives to aid the decision maker. It provides a systematic way

to measure and weigh effects for the relevant actors, where effects are not necessarily monetized (as opposed to Social Cost Benefit Analysis). It also provides a tool to aggregate the different effects.

MCA not only gives an assessment of the merits of an investments. It also provides a communication and interation tool for the different actors that are involved. MCA can help to explicitly take account of conflicts between actors regarding the impacts of a plan. These impacts may be estimated in a more or less objective, neutral way. This may reduce differences between stakeholders to discussions about the weights and the policies to be chosen. Normally, stakeholders will look at the "magic number": the effect for their own country, region, company etcetera.

An example is a case when several actors agree that an alternative will have an estimated effect but disagree on the value of this effect. MCA might then be helpful in taking into account these different views by using different weighting schemes, proposed or inspired by the stakeholders, in turn. This shows how weighting affects the outcome of the analysis. Also, a part of the results may not change if the weighting is altered. These 'robust' results are an important starting point for reaching consensus among stakeholders.

When a Multi Criteria Analysis is conducted, several goals might be pursued:
- Structure the policies and scores on criteria;
- Identify a single most-preferred policy;
- Rank all policies;
- Indentify acceptable policies or policies that need to be considered in a next phase;
- Combine positive features of policies;
- Involve stakeholders in the analysis.

These goals are relevant in ex ante analysis, but also ex post it is useful to structure effects, compare policies and to involve stakeholders.

The descriptive approach of MCA is comparable to the Impact Assessment. However in most cases MCA will be more sophisticated and the analysis is followed up by a synthesis, consisting of assigning weights across the criteria. The MCA methods can be divided in non-compensatory methods, partially compensatory methods and fully compensatory methods. The main difference between the different types of MCA is how the synthesis is conducted. Non-compensatory methods do not permit trade-offs between criteria. Fully compensatory methods do allow for trade-offs between criteria; the scores on the different criteria are combined in one single value. Partially compensatory methods do not combine all criteria to one single value but make a selection depending on the importance of a criterion: a strong performance on one criterion can compensate a weak performance on another criterion.

MCA has been applied to evaluate policy options and investments in space programmes, to prioritize space programmes and to benchmark space activity in different countries (see RPA, 2007; Smith, Dolgin and Weisbin, 2003; Tavana, 2006; Futron, 2010 and European Commission, 2009a, 2010a). The data with respect to the criteria and weights used mainly came from consulting experts.

Advantages & drawbacks
Advantages of the MCA approach are that it can incorporate a very diverse range of information and that the information is processed in a very explicit way. Also, MCA offers flexibility in the number of policies, the criteria, the weighting and the involvement of stakeholders. The flexibility of the MCA also forms a risk; MCA lacks methodological rigor. The weighing of the different criteria is difficult however, and is open for subjectivity or even manipulation.

3.3 Aptness of methodologies

The described monetary and non-monetary evaluation methodologies all have their own advantages and disadvantages (see table 3.2). The aptness of the various methodologies is partly expressed in terms of characteristics of the general methodology: completeness, feasibility and objectivity. The aptness in terms of usability for policy makers is linked to the clarity of calculations, the ambiguity (or not) of results and the acceptability. Each of these criteria has been specified further in Appendix B.

Completeness
The first characteristics on which the methodologies can be compared is the capability to take many different type of effects and actors into account; the completeness of the methodologies. This completeness is indicated by the shaded area in Figure 3.1. The intensity of the shaded area (black versus hatched) represents to which extent the effects on the actors are taken into account. When effects are only listed but not made fully comparable to other effects, which is the case in for example Multi Criteria Analysis, the area is hatched. When effects are made fully comparable, by translating effects to monetary values, as is the case with all quantifiable effects in Cost Benefit Analysis, the area is filled in. In practice this means that the non-monetary methodologies, IA and MCA are represented by shaded areas and monetary methodologies by a combination of shaded and filled in areas.

Box 3.2 Interpretation of completeness

The proposed (set of methodologies) presented in this report should cover all possible effects from space activities. One approach aimed at completeness might be to identify an optimal methodology to measure each effect separately. However, this would create a patchwork of effects measured by different methods (in other words, an impact analysis). This would be complete in the sense of covering all effects, but incomplete in the sense that the effects are not made comparable. Therefore, in this report, an approach aimed at different methods for different methodologies is considered as only partially complete.

Table 3.2 Advantages & drawbacks of methodologies in terms of criteria

	Methodology features			Usability in decision process		
	Completeness	Feasibility	Objectivity	Claraty of calculations	Clear advice	Acceptability
Monetary methodologies						
Financial Analysis	- Only financial effects. Often single actor but can be extended to multiple actors.	+ Standard accounting approach.	+ Causality tested. Effects can be easily compared due to use of standard rules.	+ Process is clear due to use of standard and transparent accounting rules.	+ Ranks policies and distinction between attractive and unattractive policies.	- Limited acceptability for large project due to incompleteness.
Input-Output Analysis	+/- All actors are taken into account but only direct and some indirect effects.	- Limited: IO tables are only available for main activities, space sector has no separate entry.	+/- Causality tested. Objective due to use of standard IO table. But only relevant for short-run and for small projects.	- Insight in parameters from IO tables but not in calculations behind it.	+ Ranks policies and seperates attractive from unattractive policies. Clear and detailed advise.	- Strong assumptions needed about state of the economy. Also not all effects are taken into account.
Computable General Equilibrium Analysis	+ All direct and indirect effects, and to some extent external effects, all actors included.	- Limited: based on IO tables, method requires complex calculations.	+ Causality tested. Objective due to basis of IO tables.	- Calculations form black box.	+ Ranks policies and seperates attractive from unattractive policies. Clear and detailed advise.	- Limited acceptability due to complex calculations.
Cost Effectiveness Analysis / Cost Utilty Analysis	+/- Only main effect & costs are counted, all actors included.	+ Limited data and calculations required.	+ Causality tested. Main effect & costs are weighted adequately.	+ Insightfull calculations.	+/- Ranks policies in terms of attractiveness, no distinction between attractive and unattractive.	- Focus on one effect. Not suitable for policies with more than one relevant effect.
Social Cost Benefit Analysis	+ Some effects are hard to monetize but all effects are listed and actors are taken into account.	- Substantial calculations necessary.	+ Based in economic science. Causality tested. Also substantiated estimated parameters are used.	+/- Risk of black box effect.	+ Ranks policies & distinguishes attractive policies from unattractive ones.	- Some assumptions might be hard to accept; high weights of high-income people & business interests.
Social Return on Investment	+/- Aimed at monetizing social and environmental effects as much as possible.	- Substantial calculations necessary.	+/- Based in economic science. Causality tested. But risk of subjective parameters for intangible effects.	+/- Risk of black box effect.	+ Ranks alternatives & distinguishes attractive ones from unattractive ones.	+ High acceptability due to inclusion of stakeholders.

Table 3.2 Advantages & drawbacks of methodologies in terms of criteria (continued)

	Methodology features			Usability in decision process		
	Completeness	Feasibility	Objectivity	Claraty of calculations	Clear advice	Acceptability
Non-monetary methodologies						
Impact Assessment	+ Can be applied to all effects and actors.	+ Limited data and calculations necessay.	0 Causality not always tested. No weights used.	0 No calculations made except for estimating separate effects.	- No ranking of policies and no attractiveness conclusion.	+/- Every decision maker can draw his/her own conclusions.
Multi Criteria Analysis	+ Can be applied to all effects and actors.	+/- Depends on depth of analysis.	- Causality not always tested. Subjective weights or methods can be used.	+ Process is clear, assuming the study is transparent on the weights used.	+/- Usually ranks policies but no attractiveness conclusion.	+/- Decision makers can apply their own weights.

Feasibility

The larger the shaded area in Figure 3.4 the more extensive the analysis is, and consequently the data requirements will be higher. Monetary methodologies will require more background data while non-monetary methodologies require less data.

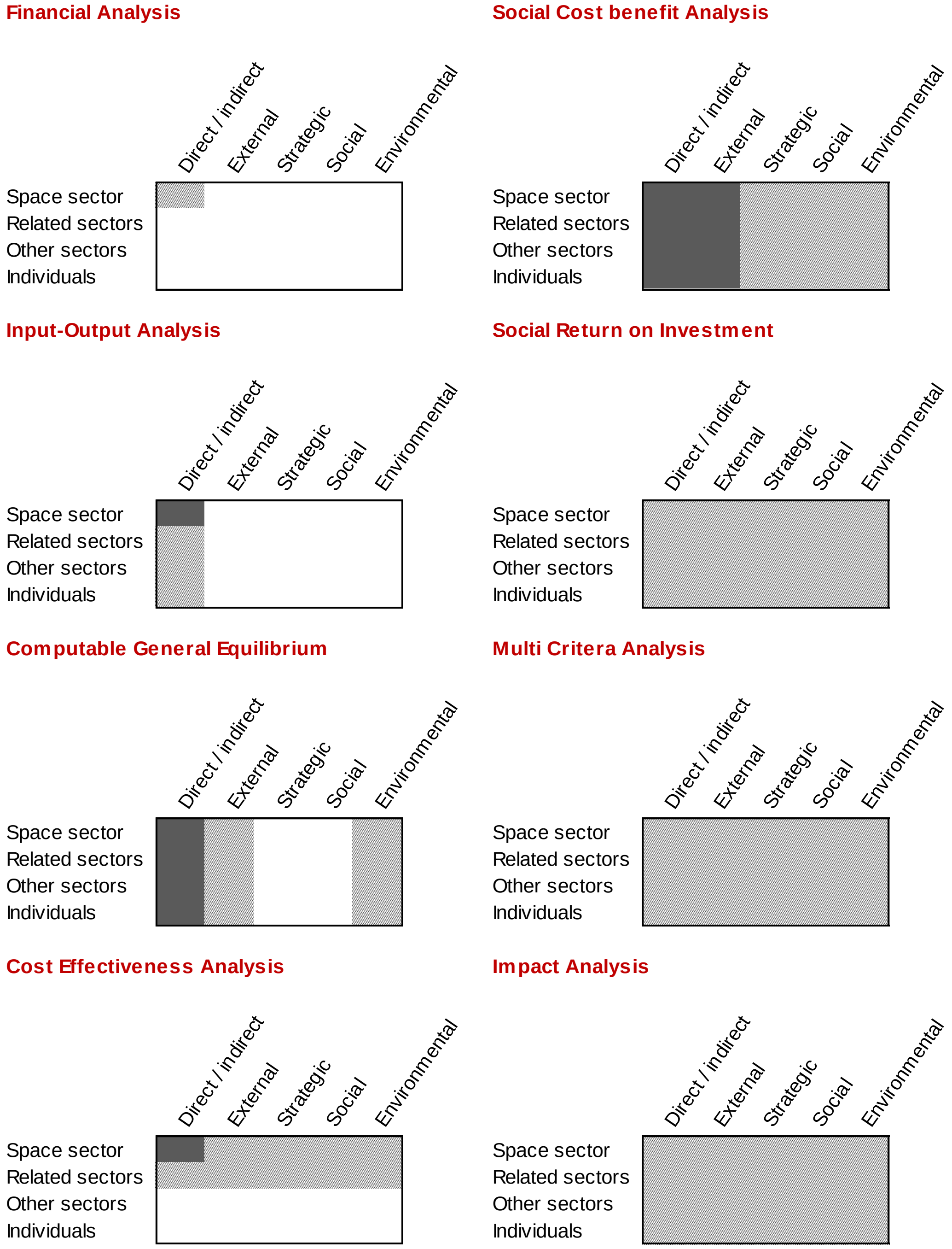
As noted in the discussion of the methodologies above, the use of IO tables to evaluate public investments in space might be difficult since the space sector does not have a separate entry in the available IO tables. SCBA and SROI will require the most extensive analysis. Some effects may be relatively easy to monetise, but to monetise other effects, intensive desk research or (expert) survey may be needed. The more often these types of analyses are conducted, the more parameters have a generally accepted value.

Objectivity

The more standardized approaches and values are used in a methodology, the more objective it is. Financial Analysis, Computable General Equilibrium Analysis, Cost Effectiveness and Cost Benefit Analysis can all be regarded as highly objective. In these methods, causal links between investments and effects are based on parameters estimated on 'hard' data. Financial Analysis has a strong basis in accounting rules, CGE is based on calculated IO tables and CEA and SCBA have a strong basis in economic science. Over the years, extensive guidelines for SCBA have been developed which contain, among others, standardised parameters.

In contrast, in MCA the stakeholders influence the weights that are put on the effects, which makes the methodology subjective. Impact Assessment provides an overview of effects of policies rather than a ranking of policies. As no weights are used in the analysis, the methodology cannot be called either objective of subjective. However, the lack of weights may lead to a skewed picture in which unimportant effects are presented on equal terms with more important impacts.

Figure 3.1 Graphical representation of completeness of methodologies



Clarity of calculations

Some methodologies have a risk of a black box effect, meaning that stakeholders know the input and the output of calculations but not the process in between. Methodologies that suffer from the black box effect are Input-Output Analysis and Computable General Equilibrium. Due to the use of Input-Output tables and complicated methods, even the researchers themselves cannot fully understand the separate effects in IO Analysis and CGE. Social Cost Benefit Analysis and Social Return on Investment also face the risk of the black box effect. However this can partly be avoided by a clear presentation of the calculations and results and by a thorough communication with stakeholders.

Methodologies that consist of a more transparent process are Financial Analysis and Cost Effectiveness Analysis, mainly due to their focus on a limited range of effects. The clarity of calculations of Multi Criteria Analysis is due to the use of weights instead of extensive calculations.

Clear advice

Methodologies that give a clear advice to the decision maker provide a full ranking of policies and also distinguish attractive from unattractive policies. Financial Analysis, Input-Output Analysis, Computable General Equilibrium, Social Cost Benefit Analysis and Social Return on Investment all provide these. Multi Criteria Analysis is able to provide a ranking in some cases, depending on the type of MCA, see section 3.2.2. But MCA does not provide the decision maker with an attractiveness conclusion.

Acceptability

The acceptability of a methodology is linked with some of the other characteristics. A methodology which takes only part of the types of effects into account will not be accepted to assess policies which have suspected effects outside that limited scope. This also holds for methodologies of which the calculations are a black box for stakeholders, or for subjective methodologies.

Financial Analysis limits its scope to financial effects. Due to this the outcome of this methodology is not accepted to assess large projects. IO Analysis uses assumptions about the state of the world which only hold in the short term. The outcome of Cost Benefit Analysis and Computable General Equilibrium will be more accepted among stakeholders with an economic background. The outcome of Impact Assessment and Multi Criteria Analysis will generally be more accepted by stakeholders as there is room for interpretation. Note that this also creates friction as different stakeholders might still not agree on the outcome of the analysis

4 Data

"A man should look for what is,
and not for what he thinks should be."
Albert Einstein

A lot of information is available on the space programmes themselves, but much less on related investments and on the impacts of investments on the economy. Data available within ESA can be used to complement macroeconomic data. A very important data limitation is the absence of an explicit space sector in economic data.

The data required by the methodologies presented in Chapter 3 are discussed in section 4.1, whereby the required data is divided into general data sources and methodology-specific data sources. The available data sources with respect to the economic impact of space activities are identified, categorized and analyzed in section 4.2. The aptness of the various data sources is determined using several criteria such as relevance, consistency, reliability, completeness and accessibility. Section 4.3 concludes by aggregating data requirements and data availability into one single table.

4.1 Data requirements

Some data are required by each methodology; these data requirements are discussed in section 4.1.1. This holds for example for the size of the investment under consideration. Other data are only used in a specific methodology or in a few methodologies. These methodology specific data requirements are discussed in section 4.1.2.

General

Investments in the space programme
Investment data on the size of investments in the space programme in terms of money is required by all methodologies. Also, the composition of these investments has to be known in terms of the types of activities the space programme pays for.

Investments related to the space programme
National or local governments may decide to complement specific space investment programmes with other investments, e.g. in space activities as well, in infrastructure or in amenities. These investments may be directly connected to (or needed for) the space programme, but they may also be aimed at facilitating additional economic growth which is expected as a consequence of the space programme. Adding an estimate of the investments which are connected to the actual space programme may require additional research, for instance by interviewing local governments about their total investment plans and predicting the net (additional) investments caused by the space programme.

Economic statistics – product level

Investments lead to products and services, which are sold in markets, in which private parties and/or governments are the customers. Data on the size and growth of these markets in terms of turnover, value added and profits are needed to assess the impact of the investment. Also needed is a more qualitative picture of the impact of the investment programme: did it lead to completely new products, to improved products, to cost savings, or to other market changes?

If the distance to markets is large, as in fundamental research, the number of jobs and the production created may be estimated, but the aim and the most important potential benefit is in innovation. However, for a specific fundamental research project, the eventual effect on innovation may be either zero or very large, and impossible to predict. For these investments, other indicators than market information may be appropriate, such as research quality or type of research results.

Economic statistics – sector level

All methodologies (except for Financial Analysis) need economic statistics, including:

- Data on the size of space industries, in terms of present investments, turnover, jobs and value added.
- Sectoral data. To assess where and how the space program will impact the economy, data are needed on value added and employment per economic sector.
- Economy-wide data. The state of the economy can be measured using GDP growth and labour market indicators, in particular unemployment.

Method-specific data

Input-Output tables

Input-Output analysis and sectoral GCE analysis needs data on the relations between industries or economic sectors. These relations are usually described by an Input-Output table in which each cell describes the output of one sector delivered to another sector.[17]

Detailed statistical data

Computable General Equilibrium (CGE) Analysis needs to be 'fed' with detailed statistical data. These models predict the effects of space programmes on (sectoral) production, consumption, employment, imports and exports, government expenditures and taxes. The economic data needed includes all these variables. Usually, these data are available from Eurostat and national statistics bureaus, but only at an aggregated (sectoral) level.

Discount rate and timeline of investments

A discount rate is needed to compute net present values in Financial Analysis, Social Cost Benefit Analysis and Social Return on Investment. Available discount rates are usually in real terms, i.e. not including inflation. This implies that financial data have to be corrected for inflation before the discount rate is applied. Inflation data are readily available, for example from Eurostat or statistical bureaus. The timeline of investments is also needed to compute a net present value and

[17] As the ratios of inputs and outputs are fairly constant over time, it is not a big problem if input-output tables are not very recent. If the table is a few years old, researchers may derive these ratios from the table, after which the ratios are multiplied by recent figures of production by sector.

is consequently required for Financial Analysis, Social Cost Benefit Analysis and Social Return on Investment.

Direct and indirect financial impacts
The methodologies which try to give a full assessment of all effects, such as Social Cost Benefit Analysis, Social Return on Investment and Multi Criteria Analysis, are based in part on the (direct) effect on the market involved (e.g. the market for launchers or satellites), indirect effects on other markets and external effects outside of markets. Results from Input-Output Analysis or CGE models may be used for this. These impacts are usually only available for investments with a small distance-to-markets.

Opportunity costs
This base case is typically not observed and has to be predicted or constructed. SCBA usually begins with constructing one or more scenarios, which serve as the base case. The impacts are then predicted in the context of these scenarios. In other methodologies the effects of an investment or policy option are not measured as the difference between the base case and the project case. The base case in these methodologies is therefore not made explicit either. However, it is implicitly present and therefore relevant for these other methodologies as well.

Willingness-to-pay
Social Cost Benefit Analysis (SCBA) and Social Return on Investment (SROI) attempt to express all effects in financial terms. Effects which are not measured in financial terms thus have to be monetised. To monetise such effects, the SCBA and SROI need a willingness-to-pay: the maximum value citizens and firms would want to pay to reach a positive effect or to avoid a negative effect. Measuring or estimating the willingness-to-pay is sometimes part of the SCBA/SROI, but in other cases external studies are used.

Aptness of data sources

Table 4.1 lists all general and methodology-specific data sources. The scope of the data source describes the actors to which the data applies. The column indicators/output describes the character of the data, the unit of account of the data. The next eight columns represent criteria on which the data sources are evaluated. There are three possible scores: negative (-), intermediate (+/-) or positive (+). The criteria on which the data is scored are:
- Relevance: Is the data source important in evaluating the impacts of space programmes?
- Consistency: Does the data source provide information without (seeming) contradictions?
- Reliability: Does the data source provide information which can be trusted to be a correct representation?
- Accuracy: Are the data precise or rough approximations?
- Level of measurement (unit of analysis): Do the data contain information on many specific parts or only on total values? For instance, do the data describe economic sectors, space programmes, individual projects, individual companies or (groups of) citizens? A more specific level of measurement is especially important with respect to distinctions between actors.
- Completeness: Does the data source provide a full picture of the impacts it describes, or only a part?

Table 4.1 Assessment of data sources: economic data on space sector not adequate

Data	Scope/sectors	Indicators / output	Relevance	Consistency	Reliability	Accuracy	Level of measurement	Completeness	Repeatability	Accessibility	# minuses
General data sources											
Investments in the space programme	Space sector	Size of investments Types of investments Projects, companies	+	+	+	+	+	+/-	+	+	-0.5
Related investments	All sectors	Size of investments Types of investments	+	+	+	+	+/-	-	-	+/-	-3
Economic statistics – product level	Specific space markets	Turnover, employment	+	+/-	+/-	+/-	+/-	+/-	-	+/-	-4
Economic statistics – space sector	Space sector	Employment, value added	+	-	+/-	+/-	+/-	-	-	-	-5.5
Economic statistics – all sectors	All sectors	Unemployment: rate and benefits Production per sector	+	+	+	+	+/-	+/-	+	+	-1
Methodology-specific data sources											
Input-Output tables	All sectors	Detailed tables per country	+/-	+	+	+	-	+	+	+/-	-2
Economic statistics – detailed level	Space industries	Production, value added, wages, employment, investments	+	-	+/-	+/-	-	-	+	+/-	-4.5
Discount rate	Whole economy	Percentage per year	+	+	+/-	+/-	+	+	+	+	-1
Timeline of investments	Space sector	Investments by year	+/-	+	+	+/-	+/-	+	+	+	-1.5
Direct and indirect financial impacts	All sectors	Benefits (and costs)	+	+/-	+/-	+/-	+/-	+/-	-	+/-	-4
Opportunity costs	Whole economy	Lost benefits	+	+	+	+	+/-	+	+	+/-	-1
Willingness-to-pay	Citizens and firms	Money values	+/-	+	+/-	+/-	+/-	+/-	+/-	+/-	-3.5
Relative importance of effects	Politicians, stake-holders, civil servants	Weights	+/-	+/-	+/-	+/-	+/-	+/-	+/-	+/-	-4
Societal and environmental effects	Society, environment	Social indicators Emissions to the environment	+	+/-	+/-	+/-	+/-	-	-	+/-	-4.5

Data source applicable & data largely available

Data source applicable & much data available

Data source applicable & much data unavailable

Data source applicable & data largely unavailable

- Repeatability: Are the data available for every year, or with another fixed frequency (e.g. once in every three years), or only in specific years without a fixed frequency, or only in one year?
- Accessibility: Can the data be obtained for use in the assessment of the effects of space programmes?

From table 4.1 there appear two main types of data problems:
- In economic statistics, a major problem is a lack of separate data on the space sector and space industries. Also, there is no standard classification of space related activities. Finally, and partly as a consequence of these factors, market information is fragmented;
- For many data sources, there are limitations with respect to the criteria reliability, accuracy, level of measurement, completeness, repeatability and accessibility.

The number of negative (-) and intermediate scores (+/-) on the criteria are an indication of the aptness of the available data. Therefore the number of negative and intermediate scores (counted as 1/2) are added up in the last column of table 4.1. These total scores are translated into different colours ranging from green to red. With respect to the general data sources, data is especially inadequate with respect to related investments, economic statistics on the product level and economic statistics of the space sector. Most of the general data sources score negatively or intermediate on the criteria level of measurement, completeness, repeatability and accessibility.

Methodology-specific data sources that are inadequate are detailed statistical economic data, direct and indirect financial impacts, willingness-to-pay and the relative importance of effects. Most of these data sources score negative or intermediate with respect to reliability, accuracy, level of measurement and accessibility.

4.2 Data availability

General

Investments
The total size of investments in space programmes is usually available, although sometimes military or other considerations may prevent full disclosure[18]. For related investments, attaining completeness may be a serious problem. As these other investments are not yearly outlays of ESA, but individual and incidental investments by various actors, repeatability will also be a problem.

Discount rate and timeline of investments
Discount rates are proscribed for SCBA by the EU (European Commission, 2008a) or by large ESA members such as Germany and/or France. The timelines of investments are needed for social cost-benefit analysis and financial analysis and generally available through the entity that makes the investment.

Economic statistics
Robust, internationally comparable statistics and data do not exist for the space sector. As a result we encounter completeness and repeatability problems when assessing the role of the space

18 Some statistics are classified. Reconnaissance and intelligence budgets are a classical example of this.

sector in the economy. Several national or regional organizations publish official statistics on space activities and some consultancy firms have compiled industry data in the past. However, country comparisons remain difficult as industry definitions differ between organizations and countries. Most industrial classifications used by national or international statistical agencies provide no breakdown for the space industry, although the underlying, non-published data would in principle allow such a breakdown. Therefore, accessibility is a problem too.

To include space activities explicitly in Computed General Equilibrium analyses, detailed statistical data are needed. Such data are available for most countries, but only at a sectoral level. Specific industries are often not separately described by these data. Relevant data may be available from trade associations such as Eurospace, the trade association of the European space industry. Eurospace annually publishes its "Industry Facts & Figures" report, which provides a comprehensive review of the European space industry.

Method-specific

Input-Output tables

Input-Output tables for European countries needed for the estimation of the indirect and induced effects are provided by OECD and Eurostat. These however do not contain a space sector. Rather, the industries of the space sector are dispersed over other economic sectors, of which these industries often form only a small part. Therefore, the IO tables which are published only implicitly contain space activities. No input-output tables are available within ESA.

Extracting space industries from more general economic sectors in IO tables would require strong (and often unfounded) assumptions, for instance that the input/output structure of a space industry is equal to the input/output structure of the broad sector from which it is extracted. This implicitly assumes that the ripple effects caused by the space sector are similar to those caused by other subsectors in the same main classification category. A more promising approach is to address Eurostat and possibly national statistics bureaus. As mentioned, they often have detailed input/output data internally. But perhaps they would be willing to make a non-standard aggregation of this detailed information, in which specific space industries are added up to a space sector. This would also yield a clear-cut definition and classification of the space industries, including data on value added, turnover, jobs and investments.

Opportunity costs of investments

An assessment of the opportunity costs is only possible on the basis of simplifying assumptions. A useful assumption in cost-benefit analysis is that the money would be used for tax reductions or reduction of the national debt. This implies that, given that specifying alternative expenditures is usually not practically feasible, the opportunity costs of the space programme may best be computed as the lost benefits of tax reduction.

Relative importance of effects

There are many methods to establish the relative importance of effects in Multi Criteria Analysis. One possibility is to use the Analytic Hierarchy Process which uses pair wise comparison (Hafeez, Zhang & Malak, 2002). Input from actors affected by the policy must be interpreted extra carefully as input can be influenced (strongly) by their own specific stake in the policy. Part of strategic input from stakeholders can be overcome by a correct set-up of the survey or interview. Also consistency checks will be done in each sound Multi Criteria Analysis. But the dependency on the input of stakeholders makes MCA vulnerable to subjectivity.

Societal and environmental effects
Data on the societal and environmental effects of space programmes were hardly found in this study. Apparently, research focuses more strongly on the 'hard' economic effects than on the 'soft' effects on social indicators and the environment.

4.3 Data available within ESA

General

Investments
ESA's tendering process provides it with detailed financial information on the parties receiving the contracted budgets and on the kind of services and products these budgets are spent on, i.e. the types of activities. So specific investments can be linked to specific economic entities and even to products or services. Limited information on related investments is available within ESA.

Discount rate and timeline of investments
The timeline of investments, needed for social cost-benefit analysis and financial analysis, is usually available. In some cases however, it may be difficult to ascertain exactly in which year the investments were made. ESA programmes are clearly structured in projects and phased in time, both at individual programme level and at ESA overall level. A detailed planning of activities within a programme is maintained. Project start and end dates, and all the associated payments are known.

Economic statistics
Although some financial data at product level may be disaggregated from ESA's financial records, these are expected to be of limited or no statistical value. Some data may be derived from the ESA Space Industry Questionnaire. ESA does have detailed insight in the number of jobs directly linked to the projects it has contracted.

The financial data ESA maintains at individual project level provides a wealth of information on the revenue side of the space sector.[19] It also provides a clear picture on turnover and number of jobs involved.

A more reliable source of financial background information on the entities doing business with ESA are the results from the Financial Audits that ESA executes on average every five years.

The ESA PSS forms show to some level the purchases of products and services that can be considered to originate outside the space sector. Note however that the level of detail is very limited.

19 Note that the ESA budget accounts for about half of all space spending in Europe.

Method-specific

Economic statistics at the detailed level cannot be easily derived from data currently available within ESA. Note that relevant data is to some level currently collected by ESA via EMITS Entity Questionnaire and through the Space Industry Questionnaire.

With respect to the timeline of investments, a lot of detailed data is available within ESA. ESA programmes are clearly structured in projects and phased in time, both at individual programme level and at ESA overall level. A detailed planning of activities within a programme is maintained. Project start and end dates, and all the associated payments are known. In most projects, ESA approves all payments up to the lowest sub-contractor level. So a detailed timeline of ESA's investments is available.

There is no data readily available within ESA on the relative importance of effects or the weighing criteria applied by ESA's stakeholders on potential benefits when deciding to invest in an ESA programme. However, implicitly this kind of data is available and could likely be made explicit if this kind of background information would be recorded as part of the iterations between ESA and the Member State delegates when establishing the details of an ESA investment programme.

4.4 Conclusions

For each methodology/data source combination, the table 4.2 shows whether the data source is required and to what extent required data is available. Data adequacy is measured by scoring the data on various criteria (see table 4.1). Generally, we see that a lot of information is available on the space programmes themselves, but much less on related investments and on the impacts of investments on the economy. Some methodology-specific inputs such as discount rates are relatively easy to obtain, but other data are much harder to find. Appendix D gives a detailed breakdown of data required, available and missing for each methodology.

A very important data limitation is the absence of an explicit space sector in economic data. Also, the input-output relations between sectors are only available at an aggregated level. This makes it hard to measure direct and indirect impacts of space programmes. Societal and environmental effects are hardly known. Given these data limitations, we see two viable roads of assessing the impacts of space programmes which are close to markets:

- Research into the direct effects of space investments in specific industries. Such research should then collect its own data, complementing the (well-known) characteristics of the investments with e.g. surveys.
- Research into wider economic effects. This would necessarily be rather aggregated, looking at broad economic sectors and the whole economy.

Also, efforts to obtain better data may be in order. This could consist of contacting Eurostat and other statistics bureaus about possibilities to compile 'tailor-made' data which more explicitly show the space sector and its relations with other economic sectors. Finally, it is advisable to collect societal and environmental data.

Table 4.2 Summary data requirements & adequacy

Methodologies	Financial Analysis	Economic Impact Analysis	Input-Output Analysis	Computable General Equilibrium	Cost Effective-ness / Cost Utility Analysis	Social Cost Benefit Analysis / Social Return on Investment	General Impact Analysis	Multi Criteria Analysis
General data sources								
Investments in the space programme								
Investments related to space programme	X							
Economic statistics – product level								
Economic statistics – space sector	X							
Economic statistics - all sectors	X							
Methodology specific data sources								
Input-Output tables	X	X			X	X	X	X
Economic statistics – detailed level	X	X	X		X	X	X	X
Discount rate		X	X	X	X		X	X
Timeline of investments		X	X	X	X		X	X
Direct and indirect financial impacts	X	X	X	X				
Opportunity costs	X	X	X	X	X		X	X
Willingness-to-pay	X	X	X	X	X		X	X
Relative importance of effects	X	X	X	X	X	X	X	
Societal and environmental effects	X	X	X	X	X			

X *Data source not applicable for specific methodology*

Data source applicable & data largely available

Data source applicable & much data available

Data source applicable & much data unavailable

Data source applicable & data largely unavailable

5 Proposed methodology: SCBA-plus

"To infinity, and beyond!"
Buzz Lightyear (Toy Story)

We propose as the preferered methodology for ex post appraisal of space investments a combination of Social Cost-Benefit Analysis (SCBA) and MCA (Multi-Criteria Analysis), which we term "SCBA-plus". Many indicators exist which can be used to estimate effects which can be used in SCBA-plus. A stepwise plan shows how first monetisable effects are included, then quantifiable but non-monetisable effects and finally unquantifiable effects.

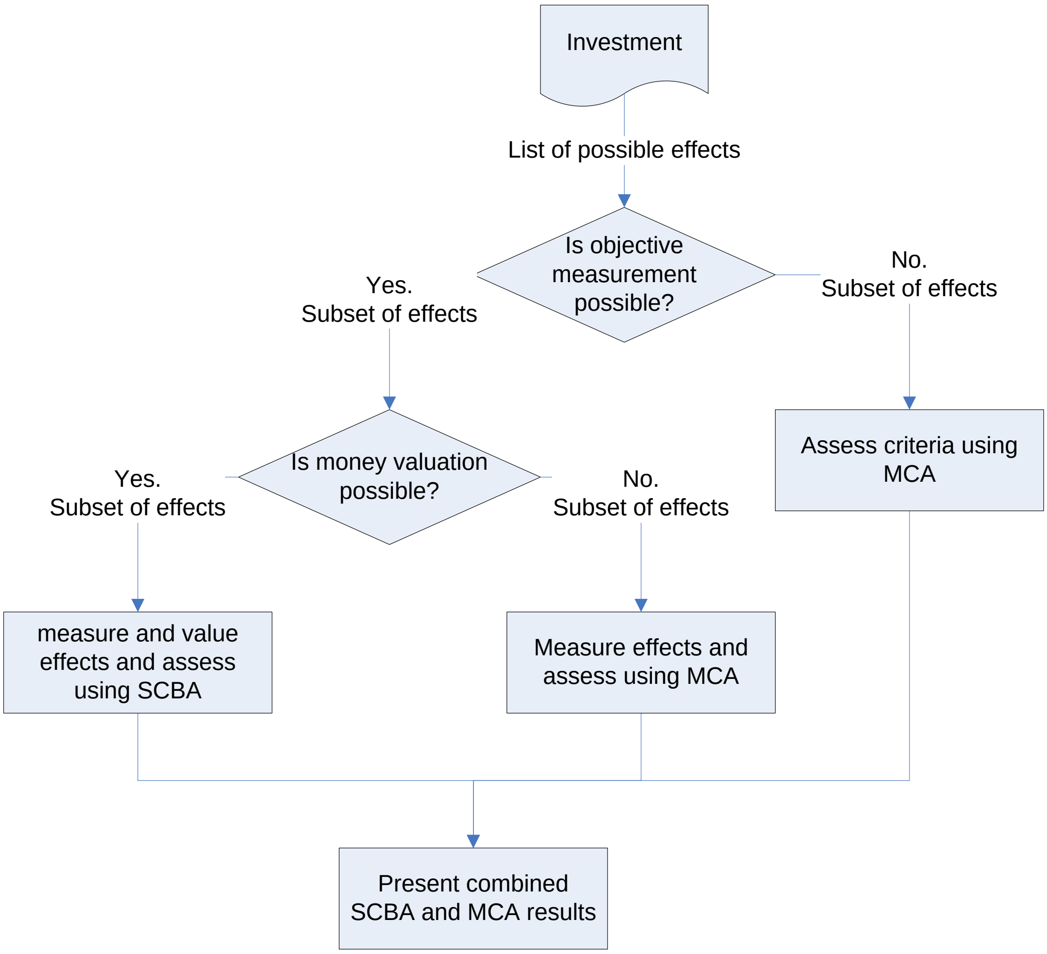
This chapter describes the proposed methodology for evaluating space investments. It assumes that data that can realistically be collected, is in fact available. On the basis of this assumption the current chapter presents an 'ideal' methodology. The design of the overall methodology involves a distinction between effects of investments that can be monetized (i.e., measured and expressed in money terms) and effects that cannot be monetized. However, in the short run we are not in this ideal situation of complete data availability. Chapter 6 will therefore explain the consequences of missing data and will describe how to evaluate investments in this less-than-ideal situation. It will also give concrete steps for the data collection effort in the medium and long term.

Section 5.1 assesses methodologies for evaluating space investments and introduces the proposed evaluation methodology, coined "SCBA-plus". Section 5.2 explains this methodology in more detail. Section 5.3 discusses aggregation issues. Section 5.4 elaborates on how the methodology can be applied in practice with the help of indicators. Section 5.5 describes the data requirements. Section 5.6 explains how the methodology interacts with ESA processes.

5.1 SCBA-plus, a combination of SCBA and MCA

The methodology we propose is a combination of Social Cost-Benefit Analysis (SCBA) and Multi-Criteria Analysis (MCA), which we term "SCBA-plus". The premise is that if effects of investments can be measured in an objective way, they should be measured, and presented in a clear way. If these effects can also be valued in money terms, they should be valued as such, and again be presented in a clear way. The vehicle for assessing monetizable effects is Social Cost-Benefit Analysis. However, effects that cannot be monetized are no less important. Such effects can be assessed using MCA. Examples are societal impacts, some environmental impacts and the distribution of effects. Specifically, for investments or parts of investments that have a large distance to markets, it is practically impossible to calculate with enough certainty their effects and valuations in money terms. In its simplest form, the design of this combined methodology is illustrated in the following flow-chart.

Flow-chart 5.1 Overview of the SCBA-plus methodology



We elaborate on this flow-chart in the remainder of this section and in the next section. Subsection 5.1.1 explains why SCBA-plus is best suited for evaluating space investments. Subsection 5.1.2 relates the other methodologies to the framework of SCBA-plus. Subsection 5.1.3 elaborates on measurement and money valuation issues.

Assessing methodologies for space investments

Chapter 3 summarized the advantages and disadvantages of a variety of possible evaluation methodologies. An integral evaluation method should be complete (i.e. cover all effects) and should be flexible enough to accommodate evaluations of one investment, evaluations of aggregations of investments, and comparing different investments. Preferably, an integral evaluation method should go as far as possible in ranking investments. Comparing and ranking investments is not only useful in ex ante evaluations, but in ex post evaluations as well. Although there is no choice any more between investments in ex post evaluations, for learning purposes and for future projects knowing which project was more useful and which project was less useful is still very valuable.

Completeness implies that Financial Analysis (covering only financial effects) and Cost Effectiveness & Cost Utility Analysis (covering only the main effect and costs, without questioning the relevance of the objective) by themselves cannot serve as the ideal method. Input-Output Analysis only covers effects for which markets exist, and is especially suited for short-run impacts of smaller projects (see chapter 3), which would mean that it is only applicable to a part of space investment programmes.

Of the monetary methodologies, this leaves Computable General Equilibrium Analysis (CGE), Social Cost Benefit Analysis (SCBA) and Social Return on Investment (SROI). Computable General Equilibrium Analysis does not include external effects and is limited by the availability of (Input-Output) data. This is why we see Social Cost Benefit Analysis as a stronger alternative than CGE. SCBA in principle includes all possible effects on society ('welfare'). CGE may provide input for or complement SCBA, by calculating the indirect effects of space investments. This way CGE provides a firm, state-of-the-art basis for computing distribution effects. SCBA's weaker characteristic is that some non-market effects cannot, or only with much difficulty, be monetized, and that there is usually no weighing of distribution effects. Here, we see that the aim of calculating the SROI can be a valuable complement to SCBA, by giving more attention to hard-to-monetize and distribution effects.

Turning to non-monetary methods, an important drawback of Impact Analysis is its inability to rank alternatives, making it impossible to really compare different investments. In this respect, SCBA is much better equipped for evaluating space investments. A drawback of Multi-Criteria Analysis relative to SCBA is that MCA gives rankings partly based on subjective weights. This is because the different criteria need weighing, while they do not have a common denominator[20]. There is usually no objective base for weighing. An MCA may have as a drawback that weights are subjective, but without a common denominator like money subjective weights are the price to be paid for comparability.

The evaluation methodology we propose, SCBA-plus, is a combination of SCBA and MCA. All effects that can be measured and monetized should be calculated using SCBA, for SCBA is able to sum effects using the most objective weighing method (money prices that reflect social values), and because SCBA at the same time gives a continuous ranking of investments. Effects that cannot be measured, or that cannot be monetized, can be assessed using MCA, which at least is able to produce rankings of investments. In evaluating effects, appropriate attention should be given to non-market effects and distribution effects, which we thus include explicitly in our methodology.

Integrating methods: methods besides SCBA and MCA

If a Financial Analysis already has been performed, its output (covering only financial effects for some actors) can provide valuable, if incomplete, input for SCBA and/or MCA. The same goes for Cost Effectiveness & Cost Utility Analysis (covering only the main effect and costs), where the value of reaching the objective is missing (see chapter 3). Indirect effects (be it additional welfare or not) can be calculated by applying Computable General Equilibrium analysis, which

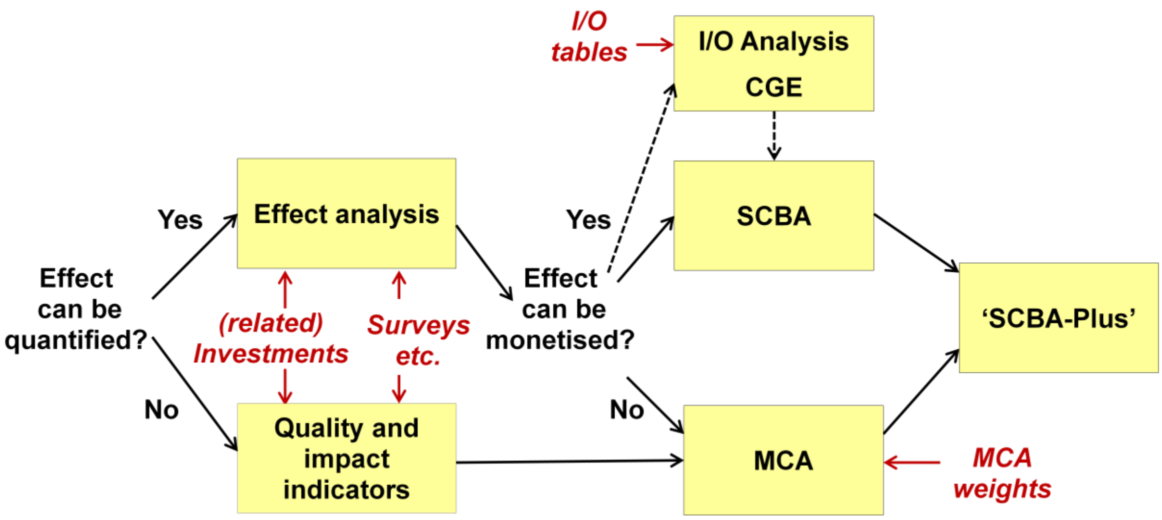
20 Defining such a denominator (e.g., scores of 1 to 10 per criterion) does not solve the problem: it implies an implicit weighing of (non-comparable) criteria.

usually uses Input/Output tables as input for calibration. We integrate parts of the SROI method in our SCBA-plus methodology, namely concerning hard-to-monetize and distribution effects. If Impact Analysis or MCA has been performed, its output can be a useful starting point for SCBA, especially in identifying possible effects and their potential magnitude. If Impact Analysis has been performed, its output can be a useful starting point for MCA.

Combining methodologies

Figure 5.1 shows how the questions "Can the effect be quantified?" and "Can the effect be monetised?" determine the methodology to be chosen: SCBA or MCA. It also shows that other methodologies such as I/O analysis and CGE analysis can be used to provide more detail.

Figure 5.1 Proposed SCBA-plus method integrates different methologies and inputs



Measurement and valuation of effects

At the core of our proposed evaluation methodology are two questions: can effects of investments be measured? And can they be put in money terms?

Assume for simplicity that there are only two types of space investments: investments that are close to markets and investments that have a larger distance to markets. This distinction matters for the *measurability* of effects of space investments. Investments in the creation of new knowledge may – eventually – have caused breakthroughs, but the causality, and the nature, impact and value of the breakthroughs are usually not known for specific investments. A shorter distance to markets gives more possibilities to tie effects and valuations with greater certainty to specific investments. The strength of any evaluation method is determined for a great deal by the strength of the *empirical evidence* on the (causality of) the effects of the investment. The best estimate of the magnitude of the effects should be used. Ideally, a causal relationship is established and the causal effect is estimated with a great deal of certainty. However, effects are usually measured in the real world instead of inside a lab. It is not always easy to isolate the effects of an investment from other influences on an outcome variable.

Investments – and certainly programmes of investments – cannot always simply be termed "close to markets" or "far from markets". Some may lie in between, others may have elements that belong to both categories. Hence, our proposed methodology depends on distinguishing effects (of investments), not on distinguishing investments per se.

SCBA can be applied to effects of a specific investment if the eventual effects *and* money values thereof can be ascertained with some acceptable degree of certainty. Effects that are not yet measured in money terms are to be valued against a "money price" in an SCBA. This price should reflect the social value of a positive or negative effect. For some effects this social value can be measured (almost) directly on markets via market prices. If a market price does not exist, it may be possible to derive a money price nonetheless. We come back to this in subsection 5.2.2. For some effects, however, monetizing with a high enough degree of certainty is not a possibility. If social values in money terms cannot be derived, SCBA loses much of its appeal. Assessing these effects involves scoring multiple criteria without a common denominator. Using MCA in this case gives the advantage of being able to still compare outcomes of different investments.

Applicability to the space sector

The space sector has unique characteristics. It is on the cutting edge of developing new technologies, delivers public goods such as navigation, provides breakthroughs in sciences and inspires people all over the world. The question may be raised whether an appraisal methodology which can be applied to many sectors - such as SCBA-plus - is applicable to such a special sector.

We note, however, that every sector has characteristics which makes the sector special. For instance agriculture is essential to our survival, our prosperity is built on energy sources and transport, and personal computers make us more productive. The people working in these sectors consider their activities as special, in part for these reasons. The requirements for high reliability typically imposed on space systems, the long lead times (a decade or more) associated with space systems and the need for technological innovation, are for instance also found in the aeronautics sector, the defense sector and the energy sector. Even the economic effects of investing in space may thus not be much different from the effects of investing in a different sector (like the ones identified above).

We note, however, that knowledge spillovers are more important in the space sector than in many other sectors. Therefore, these spillovers deserve special attention in analysis of the broader impacts of the space sector. In assessing the impacts of other sectors, a social cost-benefit approach would suffice for most effects. In the SCBA-plus method, knowledge spillovers and other hard-to-measure these impacts may be assessed in the MCA part of the assessment. In that sense, the SCBA-plus method is tailored to analysis of the space sector, by including a substantial MCA-part next to SCBA.

Therefore the fact that the space sector has a special, unique nature does not in itself provide a reason not to apply appraisal methods used in other sectors, but it is reason for a special mix of methods. The SCBA-plus method provides a comprehensive toolset and does not make a-priori assumptions on what effect should be critical in assessing the space sector. Amongst space sector investments there is great diversity in effects, which warrants the use of an assessment method which aims for completeness and provides insight in the relative importance of effects.

To conclude, the nature of effects of space activities, or limits to available data, may be such that these effects are more difficult to identify than in other sectors. In the proposed SCBA-plus method, this is partly covered by using MCA instead of SCBA for these effects. To assess whether this approach is applicable to the space sector, we present indicators of important effects of space activities in section 5.4, and we discuss the required and available data in section 5.5 and chapter 6.

5.2 The SCBA-plus evaluation methodology

The aim of SCBA-plus is to give an overview of *all* effects of investments. The choice to be made is which effects can be monetized (and hence treated in an SCBA-fashion), and which effects cannot be monetized (and hence treated in MCA-fashion). All the effects, monetizable or not, will be accounted for in this framework, and will be presented in end tables that summarize all the available information. The general framework of this proposed methodology consists of the following steps:

1. definition of the aim and scope of the evaluation;
2. identification and characterisation of investments;
3. identification of assessment criteria: costs, possible effects and other criteria; and of actors;
4. quantifying and scoring: quantifying the effects that can be measured and rating orscoring the other criteria; this includes strategic, societal and environmental effects;
5. applying weights: valuation of effects in money terms (*SCBA*) or assigning weights to effects (*MCA*);
6. calculating outcomes and setting up tables: net present values of benefits minus costs and benefit-cost-ratios (for effects assessed using *SCBA*), and combining scores and weights to calculate end results (for effects assessed using *MCA*);
7. sensitivity analysis;
8. presenting the combined results, including non-monetized effects;
9. evaluation.

Subsection 5.2.1 describes steps 1 to 3. Subsection 5.2.2 turns to steps 4 to 7 for SCBA and subsection 5.2.3 to the same steps for MCA. Subsection 5.2.4 explains steps 8 and 9.

Aim and scope, identification of investments and assessment criteria

Step 1. Definition of aim and scope of evaluation

For whom and for what purpose is the evaluation undertaken? For example, an evaluation of investments that are being paid for internationally should include criteria for all relevant countries, but an evaluation of an investment paid by one country can confine its criteria to the boundaries of that country (and might optionally include criteria for other countries). Also, the purpose could be to evaluate one project, or a programme or other aggregation of projects, or to compare the (net) benefits of different projects or programmes.

Step 2. Identification and characterisation of investments
The identification of investments is important as it defines the basis for calculating effects and costs and scoring/rating criteria. If the evaluation includes programmes of investments, it becomes necessary to define the investment projects that are part of these programmes.

If it is clear what investments are to be assessed, these can be characterised to greater detail by for instance the scope of the investment, the perceived distance-to-markets or the programme objectives as identified by the investors.

Step 3. Identify assessment criteria: costs, possible effects, other criteria, and actors
This involves determining the (financial) costs of the investment, listing possible negative and positive effects of that investment, determining other criteria, identifying the actors involved, and classifying effects in order to help avoid omissions or double counting. Another very important procedure here is to check how possible effects are going to be treated in the remainder of the evaluation: in the SCBA-part or in the MCA-part.

Costs
Determining the costs involved in the investments are of obvious importance. Monetized benefits can be compared to costs, and the net value of monetized benefits minus costs (or the benefit-cost-ratio) of investments may be compared to that of other investments, and there are always budgetary restrictions.

Listing of effects
Listing all possible effects is the starting point for quantifying and monetizing effects. Classifying effects may be very helpful here (see also section 2.3). In order not to omit effects for which no market exists, a distinction can be made between effects without spillovers, and external or spillover effects. External effects are all effects that come about by actions of producers, consumers and governments in response to the investment, but which are not taken into account by these parties, usually because there is no market (price) for these effects. Another useful distinction is between direct effects and indirect (or wider economic) effects. Direct effects can be defined as all the effects that relate to the actors directly involved or influenced by the investments, or – somewhat broader – all the effects on the market in question. Indirect effects are then the effects on other actors or on other markets. This distinction is useful for not omitting effects on other markets, but perhaps even more useful because it helps to avoid double counting. Indirect effects may just be the direct effects transferred to another market, or they may actually be additional to these direct effects. Computable General Equilibrium analysis and/or Input/Output analysis can be used to shed light on indirect effects.

Another category of effects is unquantifiable effects, consisting of strategic effects, societal effects, and the unquantifiable part of environmental (or external) effects.

Box 5.1 Indirect effects of space investments

In chapter 2 indirect effects are defined as effects of space investments outside the space sector. Upstream and downstream effects within the space sector fall within the category of direct effects. Backward and forward linkages to other sectors fall within the category of indirect effects. Indirect effects may also come about through e.g. the functioning of the labour market. Classifying effects in this way decreases the risk of double counting (or forgetting) effects. It can also be helpful in determining who are the ultimate beneficiaries of the investment, i.e. who ultimately receives the (positive) effects of the investment. If effects ripple through the economy – without getting bigger or smaller – one has to decide where to measure these effects. Measuring them everywhere, so to speak, would certainly lead to (more than) double counting. But there is more to it than that: by rippling through the economy, the effects may actually get bigger or smaller. In economic terms, a necessary condition for this is that markets are not functioning perfectly, e.g. in the case of economies of scale in production.

Box 5.2 External effects of space investments

A positive external effect of space investments can be the creation of knowledge for which third parties pay no price or not the full price. A negative external effect may be pollution due to the production or consumption of goods or services, if that pollution is not priced according to its social cost. Both types of effects are part of the evaluation methodology. If markets exist where prices fully reflect social costs and benefits, there are no externalities. If markets for some effects do not naturally exist, the government can try to create markets with appropriate prices, e.g. by taxing pollution or subsidizing the creation of knowledge. In an optimal case, the external effects will then be fully internalized.

Notice that there is a link between appropriation and external or spillover effects. For example, if a space investments leads to knowledge spillovers (a positive external effect), the investor by definition cannot reclaim the benefits of these spillovers: there is no price for this effect. This may lead the investor to under invest in knowledge creation and may be a reason for policies like subsidies or patents.

Actors

Identifying the actors involved, and relating actors to costs, benefits and other criteria is of importance for several reasons. First, it helps to distinguish costs to society from money that is only changing hands. Costs are money that once spent cannot be otherwise employed. Second, it shows who bears the costs and who gets the benefits. Third, and related to this, it provides a basis for calculating changes in the *distribution* of welfare. Important actors in the evaluation of space investments are countries, which often (particularly in ESA) co-operate in funding these investments.

Treatment of identified effects in the evaluation

For all of the costs and possible effects of investments, a choice has to be made how to measure them in the remainder of the evaluation. In descending order of desirability:

- objective measurement of causal effects, and valuation in money terms (SCBA-part);
- objective measurement of causal effects, without valuation in money terms (effect in MCA-part);

- using indicators to approximate effects, or subjectively rate effects (criterion in MCA-part).

Some of the effects that are related to specific investments and that can in principle be measured can be very hard to quantify in practice. Other effects cannot be measured because they cannot be related to a specific investment. This is especially the case for (part of) investments with a large distance to market. In these cases, an estimation of effects based on empirical evidence will have to be replaced by indicators that approximate effects, or subjective rating of the effects. These approximations or subjective ratings will be termed criteria in the MCA-part. Project-internal criteria may be used to help to rate or score criteria. These may be objectively measurable (like length of investment period) or subjectively measurable (like quality of research).

Double counting of effects is to be avoided. This implies that effects that can be monetized (and which should be treated in the SCBA-part) do not enter the MCA-part. Equally, effects that are measured, but not monetized should not be replicated in criteria that assess the same effect. Setting up a tick-box table can be very helpful here, also to prevent omitting effects. See Table 5.1.

Table 5.1 Table to check if and how effects are evaluated. *NA*=not applicable.

		SCBA (monetized)	**MCA (not monetized)**	
			objectively measured effects	effects to be approximated or subjectively rated
Costs			NA	NA
Direct effects	Direct effect 1			
	Direct effect 2			
	etc.			
Indirect effects	Indirect effect 1			
	Indirect effect 2			
	etc.			
External effects	External effect 1			
	External effect 2			
	etc.			
Strategic, societal and other unquantifiable effects	Unquantifiable effect 1	NA	NA	
	Unquantifiable effect 2	NA	NA	
	etc.	NA	NA	

SCBA-part: quantifying, valuation, discounting, calculation, sensitivities

The output of the SCBA-part essentially consists of monetized values of social benefits of investments and social costs; and of information on how these effects are distributed through the economy and on who receives benefits and who pays costs. An SCBA is aimed at answering the question whether a specific investment does or does not raise social welfare[21]. Because SCBA uses a common denominator for effects and costs (a money metric like "euros"), the net benefits of different investments can be compared directly with each other. Also, these net benefits could be summed for aggregation purposes.

Although the aim of the SCBA-part is to produce monetized effects, presenting the effects of investments 'in their own terms' is equally important: it facilitates understanding of the effects, and of the calculation of the monetized value of effects.

Step 4. Quantifying effects

Quantifying effects means putting numbers on all the effects identified in step 3, including societal, environmental and distribution of effects. Some of these effects are in money terms by nature (like cost decreases), others may be in any type of measurement, like the amount of people who benefit from an improved technology in the form of more useful consumer goods. Quantification involves determining the amount of people who are influenced by the investment times the positive or negative effect per person, for each of the identified effects. The less certain the estimate of an effect is, the more important it becomes to perform sensitivity analysis (see step 7). If an estimate of the strength of an effect becomes too uncertain, it gets the character of an assumption. In the ideal situation one uses as little assumptions as possible.

Estimates of the effects of an investment can be used to calculate what the world would have looked like without the investment. The latter is called the 'base case' and includes behavior of actors in the absence of the investment. In ex post evaluations, with enough data, we know what the world was like in the past, but we do not know yet what it would have been like without the investment. For this, we need to estimate the effects first, and then correct outcomes on the basis of these estimations. A cruder method is to calculate the base case first, i.e. the state of the world as if a specific investment would not have taken place, for example on the basis of historical comparisons, and then to compare the real world outcomes to this base case. The choice between the two methods depends on the availability of empirical evidence on effects (e.g. through statistical analysis) and on the ease with which a reliable base case can be constructed on the basis of past trends.

The effects of a *programme* of investments are the effects of all investments combined. If one is interested in the share of specific investments within the programme, it becomes necessary to distinguish investments that can have an effect on their own, and to estimate any cross-effects between these investments[22]. The more cross-effects there are, the less easy it becomes to estimate effects of any specific investment within a programme. Or the other way around: the more independent an investment is from other investments, the easier it becomes to isolate the effects of that investment. A reason to try to isolate effects from specific investments is that some investments may have been more welfare enhancing than others.

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21 SCBA is usually applied ex ante. Appendix E describes the differences in methodology between ex post and ex ante SCBA.

22 Examples of cross-effects are: - Costs may be lower if investments are carried out at the same time, e.g. because of economies of scale. - Costs may be higher because demand for scarce inputs is increased. - Effects may be higher or lower because the positive or negative effects of one investment may spill over to another investment.

For every year in which the investment may have had effects, calculations should be made for costs and for positive and negative effects. Usually one or more target years are chosen in which effects occur. Effects may change over time because of changes in the base case, changes in population, et cetera. For example, effects are sometimes assumed to develop linearly between target years. In choosing the target years, preferably one takes into consideration the way the time dimension plays a role in the MCA-part (see subsection 5.2.3).

Step 5. Valuation of effects

Different types of effects require different types of measurement. The goal of the SCBA-part is to measure effects in a common denominator, money. In this step effects that are not yet measured in money terms are valued against a “money price”. This price should reflect the social value of a positive or negative effect. For some effects this social value can be measured (almost) directly on markets via market prices. If a market price does not exist, it may be possible to derive a money prices nonetheless.

Box 5.3 Deriving social values in money terms for non-monetary effects[23]

An SCBA measures the value people give to the use and existence of goods and services, broadly defined. Any “intrinsic value” (e.g. the value of nature for birds) is in itself not part of SCBA. The value of nature for recreation, and the value of knowing that nature parks and species like birds exist, is part of SCBA.

An approach to value non-monetary effects in money terms is to try to estimate the willingness of people to pay or accept some change in circumstances. This can be estimated using “revealed preference” (market outcomes) or “stated preference”. Examples of revealed preference are the travel cost method, the hedonic price method and the averting behaviour method. Other methods do not estimate willingness to pay/accept, but estimate prevention or recovery cost.

Instead of estimating monetary values case-by-case one can also use estimators from previous studies. This is called “transfer of benefits”. This introduces an assumption in the SCBA, namely that the previous estimator is suited for the effect of the investment at hand.

Notice that in practice there is often a degree of transfer of benefits. For example, using general statistical relations between house prices and parks for a specific case (park) is a form of benefit transfer.

For monetized effects, presenting them in their own terms before monetizing gives a clearer picture of what is going on. The monetary value is Q1 x Q2 x P, where Q1 is strength of effect per person, Q2 is number of people involved and P is the social value. Presenting at least Q1 x Q2 on the one hand and Q1 x Q2 x P on the other makes calculations more transparent and outcomes more understandable.

Costs and effects occur at different points in time. Usually money values are assigned in constant price levels, e.g. price levels of ‘today’, because if general price inflation or deflation occurs, prices

23 Based on Ruijgrok, Brouwer & Verbruggen (2004), Waardering van Natuur, Water en Bodem in Maatschappelijke Kosten-batenanalyses. Aanvulling op de Leidraad OEI.

of different years cannot be summed up (they differ in purchasing power, which is relevant for the social value perspective). Relative price changes may occur during the period under consideration, which may impact on costs and valuations.

Step 6. Calculating outcomes, discounting, and setting up tables

Discounting

Costs and effects that occur at different points in time have different value today. Basically, money not spent on an investment could have otherwise been employed, which would have given a return (return on alternative investment). A *discount rate* is applied to correct for this return on alternative investment. A risk-free rate derived from market data during the investment period seems most appropriate. In ex post analysis, the calculated effects in money terms can be discounted to the year in which the investment started.

Outcomes

If all ('present' values of) benefits and costs have been calculated, benefits minus costs and benefit-cost-ratios can be calculated and presented. These should be accompanied by the distribution effects in sofar these are in money terms However, if not all effects are included in the SCBA-part, calculating benefit-cost-ratios does not make much sense. In that case, the value of benefits minus costs is a money value to be added to the outcomes of the MCA-part.

If all effects *are* included in the SCBA-part, the value of social benefits minus social costs gives an indication whether an investment has (>0) or has not (<0) increased social welfare. These values can be compared across investments to provide information on which investments benefit society the most. They can also be used to add up the effects of several investments (see section 5.3). Social benefits divided by social costs gives an indication whether an investment has or has not increased social welfare as well (>1 resp. <1)..

Presenting outcomes: setting up summary tables

Although the aim of SCBA is to calculate these numbers, they alone do not suffice for an understanding of the effects of the investment under consideration. In general, all calculations, assumptions etc. used in the analysis should be transparent. Specifically, at least the following information should be provided:

- investment costs;
- calculated effects and recurrent costs in the target years;
- the monetized value of the effects in the target years;
- 'present' value of costs;
- net 'present' value of effects;
- distribution effects if in money terms.

A way to present information in a structured way is to use tables. We propose that the SCBA-part should contain the following tables: costs and effects in target years; 'present' values of costs and benefits; and costs and effects distinguished by actors.

Table 5.2 presents the effects in their own terms and in money terms, for several target years, to give as complete a picture as is possible.

Table 5.2 Costs and effects in target years

	Investment year	**Target year 1, say: 10 years after investment year**	**Target year 2, say: 20 years after investment year**	***etc.***
Investment costs (euro's)	e.g. 10 bln euro	-	-	-
Recurrent costs (euro's)	-	e.g. 1 bln euro	e.g. 1 bln euro	e.g. 1 bln euro
Calculated effect 1 (persons x effect)	*e.g. 0*	*e.g. ...*	*e.g. ...*	*e.g. ...*
Calculated effect 1 in money terms	0	(persons x effect x money value)	(persons x effect x money value)	(persons x effect x money value)
Calculated effect 2 (persons x effect)	*e.g. 0*	*e.g. ...*	*e.g. ...*	*e.g. ...*
Calculated effect 2 in money terms	0	(persons x effect x money value)	(persons x effect x money value)	(persons x effect x money value)
etc.				

Table 5.3 presents the effects in present values (i.e. discounted and added up over the whole period), under alternative assumptions (see also step 7).

Table 5.3 Costs and effects, (net) 'present' values, base analysis and sensitivity analyses

	(Net) 'present' value, base analysis	**(Net) 'present' value, sensitivity analysis 1**	***etc.***
Investment costs (euro's)	e.g. 10 bln euro	...	
Recurrent costs (euro's)	e.g. x bln euro	...	
Calculated effect 1 in money terms	e.g. +y1 bln euro	...	
Calculated effect 2 in money terms	e.g. +y2 bln euro	...	
etc.		...	
NPV of effects minus costs	**(NPV effects in money terms - investment costs – recurrent costs) = e.g. y1+y2-10-x etc.**	**...**	

NPV: net present value

What is missing in the tables so far is the *distribution* of effects. Table 5.4 gives this distribution in the form of an actor analysis.

Table 5.4 Effects for actors, (net) 'present' values, base analysis

	Space sector: ESA and direct partners	**Space sector: upstream**	**Space sector: down-stream**	**Other sectors: backward**	**Other sectors: forward**	**Indivi-duals**	***Total***
Investment costs Recurrent costs Calculated effect 1 in money terms Calculated effect 2 in money terms *etc.*							
NPV of effects minus costs							

NPV: net present value

A table like 5.4 can also be set up with countries as actors. In that case, the first row of the table is replaced by country A, B and so on, and per country a further distinction could be made between the space sector, other sectors, and individuals.

Step 7. Sensitivity analysis

The outcomes of the SCBA-part depend on the estimated effects and the monetary valuations. If there is uncertainty about the estimated effects and valuations applied, a sensitivity analysis can show what the effect on outcomes is if different effect estimations and valuations are used. If effects are estimated via the estimation of a base case, using different scenarios for this base case will show in what ways outcomes depend on assumptions on the base case. The results of the most important sensitivity analyses can be presented in a table like Table 5.3. We recommend always applying sensitivity analysis to the discount rate.

MCA-part: rating, weights, outcomes, sensitivities

MCA exists in various forms. Since one of the purposes of the evaluation methodology is to rank different investments (see subsection 5.1.1), we limit ourselves to MCAs that are able to produce rankings. Trade-offs between criteria should be permitted in order to combine scores into one single value, precisely for ranking and comparison purposes. In other words, the MCA that is most suited for comparison purposes is of a *fully compensatory* nature (see chapter 3). The information used in the criteria needs to be *cardinal* to be able to produce such rankings, i.e. the information needs to give quantity and not only order.

As in the SCBA-part, we would like to stress that although the MCA-part is aimed at combining multiple scores per investment into a single value, *all* the information that serves as input should be presented as well, if only because it helps in understanding the effects and the calculations of the MCA-results.

Step 4. Rating/scoring investments on multiple criteria

The MCA-part's purpose is to rate/score all effects that cannot be put in money terms. By definition, this includes the unquantifiable environmental/external effects, strategic effects and societal effects. Quantifiable effects and criteria that have been objectively measured are already of a cardinal nature. There is no need to separately rate/score these effects and criteria. Effects and criteria that have not been objectively measured need a more subjective scoring, primarily based on the judgement of experts on the effect/criterion in question. These judgements may partly be based on information that is not causally related to effects, but may be thought to have some relation to these effects. We propose that the judgments are expressed in terms of grades, with a minimum of 1 and a maximum of 10, where 10 = most desirable and 1 = least desirable. Although an MCA cannot predict welfare gains or losses, a 1 to 10 scale may stimulate interpretation in terms of the (social) desirability of investments. The objectively measured effects or criteria need to be transposed to this 1 to 10 scale, something to which we will turn below.

Table 5.5 is a simple example of combined scores on criteria (competition effect), objectively measured effects (effect on environment) and objectively measured criteria (patent citations, as an approximation of an effect on innovation).

Table 5.5 Objectively measured effects and criteria, and subjectively rated criteria

		Project A	**Project B**	**Project C**
Measures in own terms	Measured effect on environment	10 forests of 1,000 hectares saved	50 forests of 1,000 hectares saved	150 forests of 1,000 hectares saved
Measures that approximate an effect	Patent citations, measuring effect on innovation	5 patent citations	30 patent citations	12 patent citations
Measures that are subjectively rated	Score on competition effect	4	7	10

In the table example above, it is estimated that project A has saved 10 forests, project B 50 forests and project C 150 forests. The effect on innovation is not known, but the amount of patent citations is 5 for project A, 30 for project B and 12 for project C. It is assumed that patent citations are a good indicator of effects on innovation. If patent citations by themselves are not considered to be a good indicator, they need to be supplemented with other indicators, and these together should form input for subjective scoring. The competition effect is scored like this: project A receives a 4, project B a 7 and project C a 10. We propose that subjectively rated measures only receive scores < 5.5 if the effects are thought to be *negative* (e.g., a worsening of competitive positions), in order to facilitate evaluation later on (see subsection 5.2.4)[24].

The effects and scores in Table 5.5 can be thought of as effects over the whole evaluation period, or as an average per year. If projects differ in their timing of effects, and this difference is important for evaluation, this should be reflected in the table and in the scores/weights. For example, assume that the sole difference in timing is in the effect on the environment, i.e. forests saved, and that there are two main periods, then the environmental effect could be split up into 'measured effect in first period' and 'measured effect in second period'. It should be take into consideration, moreover, that there is consistency between the time dimension in the MCA-part and the SCBA-part. The SCBA-part works with target years, and preferably the criteria in the MCA-table works with the same target years, in order to facilitate a combined presentation of effects and scores on criteria (see subsection 5.2.4).

24 An exception could be made for indicators that are thought of as scoring badly even if no negative effects occur (e.g. because negative effects are thought not to occur).

The measured effects on forests saved and via patent citations need to be expressed in the same 1 to 10 scale as the scores for the competition effect. To do this:
- define minimum and maximum effects. Preferably, these are set such that critera score < 5.5 only if effects are considered to be negative[25]. E.g., there is no natural minimum or maximum for forests saved; a a project could actually lead to the destruction of forests. Here, the maximum is set to 150, and the minimum to -150. For patent citations, there could be considered to be a natural minimum of 0. There is no natural maximum; the maximum is set to 30.
- calculate scores. This can be done using the formula: score = 1 + 9 * (effect minus minimum)/(maximum minus minimum). So, project A scores on environment: 1 + 9 * (10--150)/(150--150) = 5.8, and project B: 1 + 9 * (50--150)/(150--150) = 7.0.
This gives the scores in Table 5.6. Understanding this table requires that the input to it (in the form of table 5.5) is presented as well.

Table 5.6 Scored criteria, derived from table 5.5

Category	Project A	Project B	Project C
Score on environment	5.8	7.0	10
Score on innovation	2.5	10	4.6
Score on competition	4	7	10

Step 5. Assigning weights to the criteria in order to make them comparable and summable

Although it may seem that criteria are now comparable (table 5.6), in fact they are not, because the importance of a difference in expert rating of competitiveness of 3 (7-4) may not necessarily be greater than a difference in the score on environment of 2.6 (3.6-1), for example. What is needed here are weights that reflect the importance of the effects or indicators in evaluation. The weights can be chosen so that they are between 0 and 1 and sum up to 1. For example: 0.4 for environment, 0.5 for innovation and 0.1 for competition. Going back to table 5.5 may be helpful to determine the weights. However, in general, determining weights is subjective. In any case, the weights should be established before the computations are made, to avoid manipulation of results through arbitrary changes in the weights.

Step 6. Calculating outcomes

This involves combining scores and weights to calculate end results. In our example we get Table 5.7, where we include the weights applied. Again, these end scores can only be fully understood if the input in the form of table 5.5 is presented as well.

Table 5.7 End scores including weights

Category	Weight	Project A	Project B	Project C
Score on environment	0.4	5.8	7.0	10
Score on innovation	0.5	2.5	10	4.6
Score on competition	0.1	4	7	10
End score		**4.0**	**8.5**	**7.3**

25 Again, an exception can be made for indicators that are thought of as scoring badly even if no negative effects occur, see innovation/patent citation in the example in the text.

Contrary to the results in the SCBA-part, there is no 'natural' tipping point in the end score between a desirable and an undesirable project. In the SCBA-part, an NPV<0 would indicate that for the effects measured and monetized, the balance is negative; and an NPV>0, positive. The best equivalent for the end scores in an MCA-table is that an end score >5.5 is a 'desirable' balance of effects, and an end score <5.5, 'undesirable'.

In both the SCBA-part and the MCA-part, projects can be compared: in the SCBA-part in terms of NPVs, and in the MCA-part in terms of end scores. Actor analysis can be added to the MCA-part by setting up tables like Table 5.5 per country.

Notice that in the SCBA-part we took one investment and its effects as an example, whereas here in the MCA-part we have been comparing three projects A, B, and C. The reason is that the MCA-part works especially well when comparing projects. If only one space project is being evaluated, say project A in table 5.5, the effects in own terms and the measures that approximate effects cannot be compared to other space projects, hence (end) scores cannot be calculated like we did above. There are several remedies for this:

- decide not to score all MCA-criteria (and thus not to calculate an end score). In that case table 5.5 is in fact the end table. The information in that table can be combined with the SCBA-plus results to give as complete a picture as possible; or
- decide to (subjectively) rate the (objectively calculated) effects in own terms and measures that approximate effects. These ratings will be based on ideas of what constitutes "small" or "big" effects; or
- add the outcomes of other projects, space projects or not, preferably at least a succesful and a less succesful project. Project A will be compared to these projects.

In the SCBA-part, NPVs could be used to add up the effects of several investments (see section 5.3). The end scores of the MCA-part, however, cannot be used in the same way. A score of 7 plus a score of 7 simply is not a score of 14. The average score over several investments may provide information on the average 'desirability' of projects, but that may not be enough for an adequate evaluation of summed investments. For aggregation purposes, it may be more insightful to go back to table 5.5, using the (objectively measured) effects in own terms and measures that approximate effects, and summing these up. We return to this in section 5.3.

Step 7. Sensitivity analysis

The results of the MCA-part may be sensitive to amongst others the weights used and the scores applied. The sensitivity analysis thus varies the weights and the scores to see if outcomes become much different. The scores to be varied are the ones that exhibit the most uncertainty, usually the criteria that are least objective. For example, if scores for expert opinion are based on averages over 10 experts, an alternative may be to fill in the average plus or minus the standard deviation. Results of sensitivity analysis can be presented in a table like Table 5.8.

Table 5.8 Sensitivity analysis may show that MCA results are not robust

	Project A	Project B	Project C
End score, base analysis	4.0	8.5	7.3
End score, sensitivity analysis 1	5.6	8.1	6.6
End score, sensitivity analysis 2	6.9	6.5	6.1

We stress that the results of the MCA-part may be very sensitive to the *subjective* weights used in the analysis. Therefore it is very important to use different sets of weights, to assess whether the results of the analysis are either robust or fully dependent on the weights used.

Presentation and evaluation

Step 8. SCBA-plus: presenting the combined results, including non-monetized effects
The overall presentation consists of three tables: one that highlights the effects; one to give the end results; and one summarizing sensitivity analyses.

The SCBA-part gives two basic tables: a table with quantified and with monetized effects in reference years; and a table with the present value of costs and monetized effects over the whole period, including the net present value of benefits minus costs. The MCA-part gives two basic tables as well: a table with quantified effects and with ratings for criteria for the effects that could not be objectively quantified; and a table with scores for all effects, including the weighted sum of these.

Combining the results gives the following two tables:
- a table with quantified effects, and with scores/ratings on criteria for effects that could not be quantified;
- the end table with monetized effects and scores/ratings on effects that could not be monetized.

An example of the overall table with quantified effects is Table 5.9, based on a combination of Table 5.2 and Table 5.5. Compared to Table 5.2, we assume that more than one project is evaluated, and for presentation purposes, we simplify compared to Table 5.6 by looking at only two projects[26].

[26] Furthermore, also for presentation purposes, we identify three time periods (investment year, first target year, second target year), two monetizable effects, and three non-monetizable effects. Lastly, the effects in the MCA-part are interpreted as being a yearly average, so that these are the same for the two target years.

Table 5.9 Overall table: Costs, effects and scores/ratings

	Project A			**Project B**		
	Investment year	Target year 1	Target year 2	Investment year	Target year 1	Target year 2
SCBA-part						
Investment costs (euro's)	e.g. 10 bln euro	-	-	e.g. 15 bln euro	-	-
Recurrent costs (euro's)	-	e.g. 1 bln euro	e.g. 1 bln euro	-	e.g. 0.8 bln euro	e.g. 0.8 bln euro
Calculated effect 1 (persons x effect)	*e.g. 0*	*e.g. ...*	*e.g. ...*	*e.g. 0*	*e.g. ...*	*e.g. ...*
Calculated effect 1 in money terms	0	(persons x effect x money value)	(persons x effect x money value)	0	(persons x effect x money value)	(persons x effect x money value)
Calculated effect 2 (persons x effect)	*e.g. 0*	*e.g. ...*	*e.g. ...*	*e.g. 0*	*e.g. ...*	*e.g. ...*
Calculated effect 2 in money terms	0	(persons x effect x money value)	(persons x effect x money value)	0	(persons x effect x money value)	(persons x effect x money value)
MCA-part						
Measured effect on environment	-	10 forests of 1,000 hectares saved	10 forests of 1,000 hectares saved	-	50 forests of 1,000 hectares saved	50 forests of 1,000 hectares saved
Patent citations, measuring effect on innovation	-	5 patent citations	5 patent citations	-	30 patent citations	30 patent citations
Score on competition effect	-	4	4	-	7	7

Continuing with our example, consider Table 5.10, an end table with monetized effects and scores/ratings on effects that could not be monetized.

Table 5.10 Overall table: Monetized effects and scores/ratings[27]

	Project A, base analysis	Project B, base analysis
(Net) 'present' values, SCBA-part		
Investment costs	e.g. 10 bln euro	e.g. 15 bln euro
Recurrent costs	e.g. xa bln euro	e.g. xb bln euro
Calculated effect 1 in money terms	e.g. +ya1 bln euro	e.g. +yb1 bln euro
Calculated effect 2 in money terms	e.g. +ya2 bln euro	e.g. +yb2 bln euro
etc.	...	...
NPV of effects minus costs	**(NPV effects in money terms - investment costs – recurrent costs) = e.g. ya1+ya2-10-xa etc.**	**(NPV effects in money terms - investment costs – recurrent costs) = e.g. yb1+yb2-15-xb etc.**
Scores, MCA-part		
Score on environment (unweighted)	8.2	10
Score on innovation (unweighted)	2.5	10
Score on competition (unweighted)	4	7
Weighted total score	**4.9**	**9.7**

NPV: net present value

As before, we would like to stress that table 5.10 should not be presented without table 5.9, for the latter gives important information about effects that serves as input for the summary table 5.10. It remains to show the sensitivity of results. See Table 5.11.

Table 5.11 Overall table: Sensitivity analyses

		Base analysis	Sensitivity analysis I	*etc.*
Project A	NPV of effects minus costs (SCBA-part)	e.g. ya1+ya2-10-xa etc.	...	...
	Weighted total score (MCA-part)	4.9	...	...
Project B	NPV of effects minus costs (SCBA-part)	e.g. yb1+yb2-15-xb etc.	...	...
	Weighted total score (MCA-part)	9.7	...	...

An actor table might be added which combines the actor tables (described above) of the SCBA-part and the MCA-part.

Step 9. Evaluation

Now that all results have been presented, how does one evaluate? There are three types of evaluation: evaluating a single project or programme; mutually comparing projects or

27 Notice that relative to Table MCA3 the scores and total scores of projects A and B in the MCA-part have changed. This is because project C has been omitted, and MCA-scores are typically relative scores (interdependent scores). Results of the SCBA-part do not exhibit such dependence.

programmes; and aggregating outcomes over investments. We discuss the first two types here and turn to aggregation in section 5.3.

Evaluation of projects/programmes

For each project or programme, we know that the monetized costs and effects (SCBA-part) and the non-monetized effects (MCA-part) cannot directly be compared to each other. How can one answer the question "do we think that this project/programme was good for society"? The first step is to check whether the project/programme belongs to one of the following two situations:

- the NPV of monetary effects minus costs is positive, and there are only positive non-monetary effects. In that case, the project/programme is estimated to have had a positive impact on welfare. The NPV can be found in Table 5.11, or Table 5.10. The signs of the non-monetary effects can be checked in Table 5.5 (where a subjective score > 5.5 should represent a positive effect).
- the NPV of monetary effects minus costs is negative, and there are only negative non-monetary effects. In that case, the project/programme is estimated to have had a negative impact on welfare. Again, the NPV can be found in Table 5.11 or Table 5.10, and the signs of the non-monetary effects can be checked in Table 5.5 (where a subjective score < 5.5 should represent a negative effect).

If a project/programme does not belong to any of these two categories, the following options remain:

- a combination of a positive NPV of monetary effects with only negative non-monetary effects;
- a combination of a negative NPV of monetary effects with only positive non-monetary effects;
- a combination of a positive NPV of monetary effects with both positive and negative non-monetary effects;
- a combination of a negative NPV of monetary effects with both positive and negative non-monetary effects.

In these cases, although there is no objective way to come up with a "good for welfare" or "bad for welfare" calculation, one can use Table 5.11 or Table 5.10 to compare the value of monetary effects to the weighted score of non-monetary effects.

Comparing projects/programmes

The goal of comparing projects or programmes with each other is to rank these according to (social) desirability. This can be useful in both ex ante and ex post evaluations. The basis for this is Table 5.11 or Table 5.10. Projects/programmes are compared on the basis of the monetary balances (SCBA-part) and the weighted end scores (MCA-part). Clearly, a project/programme outranks another if both the monetary balance and the weighted end score is larger. In all other cases there is no objective way to come up with a ranking. However, said tables can still be used to compare the value of monetary effects and the weighted score of non-monetary effects across projects/programmes.

Discussion

One figure?
Is there a way to come up with one figure that sums up all the information, be it monetary, quantitative or subjective? If so, such a figure would somehow combine the NPV of monetary effects (SCBA-part) and the weighted end score (MCA-part). This would require either giving the NPV a score (between 1 and 10), or expressing weighted end scores in monetary terms. The latter is simply impossible. The first idea would imply that the smallest NPV would get a 1, the largest would get a 10, and the remaining NPVs would be scored in the same way as in the MCA. This only works if investments or programmes are compared to each other. The resulting scores could be combined with the weighted end scores in the MCA-part into one figure, where it remains to chose the weight for the NPV-score as well. One may argue that this in the end would not actually gain something for evaluation purposes, because more objective information (the SCBA-part) is combined with lower-value information (including subjective weights). Moreover, the coverage of monetary versus non-monetary effects may differ between projects/programmes, further complicating weighing issues.

Coverage of effects
The methodology presented in this chapter only works well for ranking and comparison purposes if there is a common set of effects that is being estimated. For some projects, some effects may be more relevant than for other projects. This should be expressed in the value of these effects, which may be zero if effects are irrelevant for a particular project. In the MCA-part, the weights of the different criteria apply equally across all projects, which implies that projects cannot be *too* different. If different projects would require different weights for the same criteria, it is better to group together projects with the *same* weights and compare these to each other.

5.3 Aggregration of investments

A number of European entities have been identified in section 2.1 as the primary source of funding for European public investments in space. For the individual entities, such as ESA or the EU, these investments typically consist of programmes which are combinations of projects. As the projects are more concrete and detailed than total investment for a programme, SCBA-plus analysis should start at the level of projects. This raises the question how the impacts of a whole programme, or all of a specific entity's investments, or even all public investments in space at European level, may be evaluated. This section tries to provide an answer to this question.

From projects to programmes
First, we define projects as units within an investment programme which cannot be partially implemented without (almost) completely losing the benefits of the project. An example is building a launcher: in principle this may be split up into building separate stages, but the launcher can only be used if all stages are built. In other words, there is a strong interdependence between the different parts of a project.

Next we may consider an investment programme. Again, there is interdependence between the parts: in this case the different projects within the programme. This synergy is the reason why the projects have been put together in a programme. However, some projects may not be indispensible.

Assessing the impacts of programmes then consists of assessing the impacts of the projects within the programme, including the synergy between them. However, it may be very cumbersome and costly[28] to do research into the effects of each of many projects within a programme. A practical approach is to analyse the most important projects, and then to extrapolate from there. For instance, if the investment programme is € 500 million in size, and five important projects within the programme with total investments of € 250 million have net social welfare benefits of € 400 million, we may compute a rough estimate of the social welfare benefits of the whole programme as (500/300)*x*400= € 800 million.

However, synergy between projects should be looked into separately. Taking again the example: the estimate above implicitly assumes that the synergy between on the one hand the five projects and on the other hand the other projects is just as large as the synergy between the five projects, relative to the size of the impacts. If there are reasons to assume that the relative synergy may be different, this would call for a correction of the estimate.

From programmes to total investment

The next step is aggregation from investment programmes to total investments. Investment programmes are to a large extent separate units, otherwise they would have been combined into one programme. Therefore synergy effects may be relatively small in this aggregation step. However, extrapolating from one programme to another is not advisable: building launchers is totally different from earth observation or basic R&D. For each type of programme, separate projects could be analysed and if necessary extrapolated to the programme level. Next, the effects of programmes can be added up, if necessary taking account of limited synergy between programmes.

Applying SCBA-plus to projects and programmes, over time 'standard ratios' will arise, for instance "€ 100 million of investment in R&D on average increases the number of jobs in the space sector permanently by 200". As the body of knowledge grows, it will be better feasible to assess still more projects and programmes.

Aggregation: the SCBA- and the MCA-part

In section 5.2 we have already paid some attention to the issue of aggregation with respect to the SCBA- and the MCA-part of the SCBA-plus methodology. The end results of SCBA (net present values of welfare changes in money terms) are very well suited for evaluating one project, for comparing different projects, *and* for aggregating outcomes; see above. The end results of an MCA (summed, weighted scores of different criteria) *by themselves* are less well suited for aggregating outcomes. This is one of the reasons why it is preferable to assess as many effects as possible in the SCBA-part.

Here, we illustrate what aggregation could look like, building on the example tables of section 5.2. First, we repeat the summary table 5.10 in the form of table 5.12.

28 In general, the costs of analysis should be only all small part of the costs of the investments analysed.

Table 5.12 Overall table: Monetized effects and scores/ratings (based on table 5.10)

	Project A	**Project B**
(Net) 'present' values, SCBA-part		
Investment costs	e.g. 10 bln euro	e.g. 15 bln euro
Recurrent costs	e.g. xa bln euro	e.g. xb bln euro
Calculated effect 1 in money terms	e.g. +ya1 bln euro	e.g. +yb1 bln euro
Calculated effect 2 in money terms	e.g. +ya2 bln euro	e.g. +yb2 bln euro
etc.	...	...
NPV of effects minus costs	**(NPV effects in money terms - investment costs – recurrent costs) = e.g. ya1+ya2-10-xa etc.**	**(NPV effects in money terms - investment costs – recurrent costs) = e.g. yb1+yb2-15-xb etc.**
Scores, MCA-part		
Score on environment (unweighted)	8.2	10
Score on innovation (unweighted)	2.5	10
Score on competition (unweighted)	4	7
Weighted total score	**4.9**	**9.7**

NPV: net present value

Let's assume that the evaluation is about the aggregate effect of project A and B. For simplicity, assume that costs and effects of these projects are not interdependent. Summing up the SCBA-scores and calculating simple average scores over the two projects would give table 5.13.

Table 5.13 Overall table: Monetized effects and scores/ratings, summed over two projects

	Project A plus B
(Net) 'present' values, SCBA-part	
Investment costs	e.g. 10 + 15 bln euro = 25 bln euro
Recurrent costs	e.g. xa + xb bln euro
Calculated effect 1 in money terms	e.g. ya1 + yb1 bln euro
Calculated effect 2 in money terms	e.g. ya2 + yb2 bln euro
etc.	...
NPV of effects minus costs	**(NPV effects in money terms - investment costs – recurrent costs) = e.g. ya1+yb1+ya2+ yb2-25-xa-xv etc.**
Scores, MCA-part	
Score on environment	9.1
Score on innovation	6.3
Score on competition	5.5
Weighted total score	**7.3**

NPV: net present value

Notice that presenting both table 5.13 and table 5.12 would provide the most information for evaluation purposes. Notice too, that instead of calculating simple averages of MCA-scores, one could opt for weighted averages, for instance based on the size of the investments in the projects.

We have argued before that a summary table like table 5.12 should be complemented with the table in which effects are measured in their own terms. The same goes for a table with summed investments like table 5.13. Consider again table 5.9, in the form of table 5.14, where for space considerations we only present the MCA-part for one year.

Table 5.14 Overall table, MCA-part (based on table 5.9)

	Project A	**Project B**
MCA-part		
Measured effect on environment	10 forests of 1,000 hectares saved	50 forests of 1,000 hectares saved
Patent citations, measuring effect on innovation	5 patent citations	30 patent citations
Score on competition effect	4	7

Summing the results over project A and B gives table 5.15. Here, we have again used a simple average for the scored (competition) effect.

Table 5.15 Overall table, MCA-part, summed over projects

	Project A+B
MCA-part	
Measured effect on environment	60 forests of 1,000 hectares saved
Patent citations, measuring effect on innovation	35 patent citations
Score on competition effect	(5,5)

Not only does table 5.15 provide valuable background information for the summary table 5.13, it also gives *more* information about the aggregate impact of project A plus B.

Finally, we present an example of a full SCBA-plus results table as it would look after the calculations have been made (table 5.16). Note that the numbers in table 5.16 are fictional, while the programmes are real The next section how the indicators in table 5.16 can be computed.

Table 5.16 Overall table: Monetized effects and scores/ratings based on selected indicators (real projects; fictitious numbers)

	ISS Exploitation	Climate Change Initiative
SCBA-part		
Investment costs	1,600 M€	170 M€
Recurrent costs		
Reduced costs in space sector	80 M€	5 M€
Increased revenues in space sector	60 M€	10 M€
Increased profits in other sectors	35 M€	5 M€
Monetary value of CO_2-reductions	0 M€	30 M€
Net present value of effects minus costs	**600 M€**	**450 M€**
MCA-part		
Rating on knowledge spillovers	9	9
Score on ecological footprint	5	10
Score on water availability	4	10
Score on space debris	8	8
Rating on competition effect	9	8
Rating on safety effect	6	8
Rating on reputation effect	10	10
Score on (un)employment impact (happiness)	8	7
Score on distribution impact	7	9
Weighted total score	**7.3**	**8.8**

Source: SEO Economic Research

5.4 Applying SCBA-plus in practice: indicators

In section 5.2 we presented the methodology of SCBA-plus. Here, we focus on how ESA might apply this in practice. We do this by giving attention to the ingredients of the evaluation methodology: investments (subsection 5.4.1), direct and indirect effects (subsection 5.4.2), external effects via knowledge spillovers (subsection 5.4.3), external effects on the environment (subsection 5.4.4), and strategic and societal effects and distributive considerations (subsection 5.4.5). Table 5.17 presents these ingredients in the format of table 5.16 and summarises the methods which may be used to measure effects at the project level and to aggregate these effects from the project level to full programmes. The indicators and measurement methods used are explained in the next subsections, while the aggregation methods have been described in section 5.3.

Table 5.17 Summary table of selected indicators, measurement and aggregation

	Measurement (project level)	Aggregation (from projects to programmes)
SCBA-part		
Investment costs	- Add up investments in projects in the space programme by ESA and other parties. - Identify and estimate related investments.	Add up project investments to obtain programme investments.
Reduced costs in space sector	Estimate the cost reductions through changes observed over time and/or surveys.	Add up over projects. Estimate and include synergetic effects by analyzing interactions between projects.
Increased revenues in space sector	Estimate net revenues (profits) by subtracting costs of labour, capital etc. From gross revenues. Correct for cost reduction above to avoid double-counting.	Add up net revenues over projects. Estimate and include synergetic effects by analyzing interactions between projects.
Increased profits in other sectors	Estimate cost reductions transferred to other sectors, depending on market conditions. Correct for double-counting.	Add up over projects.
Monetary value of CO_2-reductions	- Estimate volume of CO_2 reduction - Use CO_2 values from European research.	Add up over projects.
MCA-part		
Rating on knowledge spillovers	- Compute additional patent citations and scientific publications - Compute trends in education and knowledge related to the space sector - Use these as inputs for judgements of (panels of) experts	Compute average score of projects within the programme, e.g. weighing by project size.
Score on ecological footprint	Have the footprint computed by a knowledgeable consultant. Translate the footprint to a scale of 1 to 10.	Add up the footprints over projects. Translate the footprint to a scale of 1 to 10.
Score on water availability	Estimate the additional amount of water available. Translate this to a scale of 1 to 10.	Add up amounts of water over projects. Translate this to a scale of 1 to 10.
Score on space debris	Use judgements of (panels of) experts.	Compute average score of projects within the programme, e.g. weighing by project size.
Rating on competition effect	Use judgements of (panels of) experts.	Compute average score of projects within the programme, e.g. weighing by project size.
Rating on international safety effect	Use judgements of (panels of) experts.	Compute average score of projects within the programme, e.g. weighing by project size.
Rating on reputation effect	Use judgements of (panels of) experts.	Compute average score of projects within the programme, e.g. weighing by project size.
Score on (un)employment impact (happiness)	Compute additional jobs. Correct for long term equilibrium effects. Show the figures to (panels of) experts and ask their rating of happiness effects.	Add up the (corrected) additional jobs. Show the figures to (panels of) experts and ask their rating of happiness effects.
Score on distribution impact	Compute effects for (groups of) stakeholders. Compute an inequality index. Translate this to a scale of 1 to 10.	Add up the effects for (groups of) stakeholders. Compute an inequality index. Translate this to a scale of 1 to 10.

Source: SEO Economic ResearchInvestments

The starting point for evaluating the benefits of a public investment in space is of course the investment itself. Establishing a detailed characterisation of these investments is therefore of prime importance. The following characteristics of investments are discussed: funding source, investor objectives, and distance to market.

Funding source

When considering European public investments in space, funding sources can be found at European Union level, multi-national organisations, nation states, national public entities and regional and local public entities, such as:

- European Space Agency (ESA)
- European Commission (EC)
- European Defence Agency (EDA)
- European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT)
- National space agencies (CNES, DLR, ASI, BNSC, NSO, ...)
- Universities and national science programmes
- Regional and local development programmes

The major part of overall European public investment in space is funded through the European organisations listed above (ESA, EC, EUMETSAT) and by the various national space agencies. These organisations in general provide a detailed account of the actual investments made, although usually confidentiality restrictions apply to some extent. Furthermore, the investments can in most cases indeed be clearly identified as a public investment *in space* rather than a public investment in broader terms. This is much less the case when considering space investments embedded in more general (national) science or regional development programmes, where an investment in the space sector could be just one out of a multitude of investments in a multitude of economic sectors.

It appears that with reasonable effort ESA should be able to establish a semi-complete picture of investments in space by the European organisations listed above (ESA, EC, EUMETSAT) and by the various national space agencies of its Member States. It will require much more effort to include also those investments in space made by other national or regional organisations. There may however be a possibility to collect such data through the national space agencies, since it is likely that they are aware of such additional space activities.

When identifying investments and the associated funding sources, there is a risk of double-counting. The budget of a national space agency is likely to appear on the expense list of a ministry of science or economic affairs. In turn, the budget made available to ESA by its Member States could be on the expense list of a national space agency. Similar situations apply to EUMETSAT and EDA. As another example, the EC is funding ESA to execute major parts of the Galileo and GMES systems development, and using the EU Framework Programme to provide funding for associated application development.

Investor objectives

Determining the source of an investment provides a first indication of the reasons behind that investment or the high-level goals that are envisioned. For instance, one of the goals of the EU Framework Programmes is to foster the competitiveness of European Industry; a primary reason for the existence of ESA is to improve European capabilities for space science and space research; or a regional investment in a space project may focus on the creation of high-tech jobs.

When evaluating the results of an investment, the objectives identified at the start of a public investment programme are usually explicitly available, although in some cases confidential. When an ESA programme is approved by the ESA Ministerial Council, a detailed description of the proposed activities and the overall goals of that programme have been established in consultation with the ESA Member States that are willing to participate in this programme. For individual Member States, varying reasons may lay behind the decision to contribute funding to a particular ESA programme. These objectives may well be recorded in national archives, and accessible for evaluation.

The EU Framework Programmes do not provide as much detail in the activities that will be funded as is the case for ESA programmes. But they do define clear boundaries on the type of activities that can be funded, and they state a set of high-level goals that are to be achieved. Even when for instance national (space) agencies provide subsidies, the application for such subsidies is usually evaluated vis-à-vis explicitly published requirements on foreseen results.

By identifying such specific objectives behind specific public investments in space, a more in-depth evaluation of the effects of these investments with respect to these objectives can be made, by providing some weighing of any generic set of results.

Distance to market

There is a large variation in space activities funded by European public organisations. Looking at ESA, the primary objectives of the ARTES programme are linked to industrial competitiveness in the satellite communications market, whereas the Galileo and GMES programmes (jointly executed with the EU) focus on infrastructure development. European independence is a strong driver for the development of the Galileo satellite navigation system and for the continued development of the Ariane launcher family. On the other hand, an important reason for the existence of the International Space Station is to foster international cooperation. Similar considerations lie behind all identified space investment programmes, at the global, but also at the local level.

Notwithstanding such a varied set of objectives behind the different space investment programmes, a general objective of all investments is to provide for economic growth, either in the short-term or in the long term. Short term and long term results can be characterised by the “distance to market” of the result of an investment (be it a product, a service, knowledge ...). In the narrow sense (i.e. within the context of an individual project) the concept of Technology Readiness Levels (TRL) can be used to establish the distance to market, since the TRL of the output result of such a project indicates the potential market for this output. Low TRL usually translates to a large distance to market. However, a high TRL of a specific project does not automatically translate to a short distance to market. Consider for instance the set-up of a satellite system for monitoring pulsars; the system itself will have a high TRL (it is actually built and working), but the results provided by the system (radio-frequency characteristics of pulsars) have a large distance to a future market for pulsar based navigation equipment.

Direct and indirect effects of space investments

A space investment implies using factors of production to produce an output. Using factors of production poses a cost. The purpose of calculating direct and indirect effects is to measure the value of the output: for the space sector (direct effects), for other sectors (indirect backward and forward linkages), and for individuals (indirect induced effects)[29].

Direct effects

As explained in chapter 2, direct effects of space investments are defined as effects within the space sector[30]. A further distinction can be made between upstream and downstream effects. Upstream sectors include manufacturers of parts of space hardware, downstream sectors include providers of space enabled products and services. Benefits for the space sector broadly come in two forms: reduced costs of production, and increased revenues. The eventual (net) effect on the space sector is the resulting effect on total profits.

Cost reductions

Cost reductions within the space sector come about if the investment produces a technology, a product or a service that is used within the space sector itself and which lowers (the money value of) factor input per unit of output produced. Since costs are measured in money terms, the value for the space sector is the total cost reduction. Notice that part or whole of this cost reduction may in fact be transferred to other sectors and eventually to consumers. The approach here is to measure the cost reduction only once. If the cost reduction is transferred, this means that sales prices are reduced, which may increase sales and hence revenues. Measuring this benefit boils down to calculating the average profit margin on the extra sales and multiplying the profit margin by the extra sales. If there are economies of scale in production, the extra sales and production lead to an additional cost reduction.

Increases in revenues

The space investment may lead to new or improved products or services and in this way to higher sales or higher profit margins. The benefit for the space sector is the amount of extra sales times the profit margin (the excess of sales price over variable costs) and existing sales times the increase in the profit margin. Notice that if a new product *X* lowers demand for existing product *W*, this decrease in demand should be taken into account as well to arrive at the net increase in revenues. If economies of scale exist in production, the extra sales and production also lead to a cost reduction. Notice further that the value consumers (or other sectors) attach to the new or improved products is reflected in their willingness to pay, and in this way reflected in the increased revenues for the space sector. So, also here increases in revenues should be measured only once. In practical terms, data availability may be a deciding factor where to measure such increases in revenues. Usually, measurement closer to the 'source' is easier, i.e. measuring the increase in revenues for the producer. Part of the increase in revenues may take place by selling knowledge via patents.

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29 To this should be added the external effects in production and consumption, and possible effects that are hard to measure and/or value like strategic, societal and some environmental effects. See subsections 5.2.3 to 5.2.5.

30 I.e. to the extent that these effects are reflected in market prices, or in another way taken into account in transactions: otherwise they would be external effects.

Indirect effects

As explained in chapter 2, indirect effects of space investments are the effects in other sectors than the space sector[31], be it space related sectors, other sectors including the public sector, or individuals. Inputs or half products required by the space sector are called backward linkages. Deliveries from the space sector to space related or other sectors are called forward linkages. Effects of additional household spending on the economy are called induced effects.

An essential distinction to be made is between indirect effects that are *transferred* direct effects, and indirect effects that are *additional to* direct effects. Suppose the space sector lowers it costs and increases its profits by doing so. If the space sector acts as a monopoly, consumers will not or hardly gain anything by this cost decrease. If, however, the cost decrease leads to a consumer price decrease, consumers gain. The point is that double counting in the latter case should be avoided. Counting the initial cost decrease plus the total gain for consumers leads to perfect double counting if the whole cost reduction is transferred to consumers in the form of lower prices[32]. Here, we will restrict attention to indirect effects that are additional to (already calculated) direct effects.

Space related sectors and other sectors

Most backward and forward linkages will constitute a transferral of direct effects. The best way to calculate *additional* effects is to focus on increases in profits in the other sectors as a result of backward and forward linkages. An example of how this may come about is through economies of scale in production in the other sectors. This leads to a cost decrease in these sectors, additional to the effects calculated within the space sector.

Additional effects may also come about via the public sector, i.e. through changes in government expenditures and revenues. For example, increased production and consumption may lead to more tax receipts in the form of profit taxes and value added taxes. The simplest way to take account of this is to include these in the calculation of effects on production and consumption (changes in profits-before-tax and changes in willingness to pay against market prices including VAT).

Calculating only increases in profits in space related sectors and other sectors would be misguided. Some sectors may benefit, others may lose. The decrease in profits should be part of the calculation of indirect effects as well.

Individuals

What goes for other sectors also goes for individuals: only effects should be calculated that have not already been calculated elsewhere, i.e. as part of direct effects (within the space sector) or indirect effects (in other sectors). Net increases in sales revenues represent willingness to pay for new or improved products or services.

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31 Again, to the extent that these effects are reflected in market prices, or otherwise taken into account in transactions: otherwise they would be external effects.

32 In reality, part of the total benefit may accrue to producers, and part to consumers. If one would want to know what eventually benefits who, one should estimate the transfer of effects through the whole production-consumption chain. This would make clear how the effects work, and how benefits are distributed.

Benefits for individuals over and above the price paid for consumer goods are captured in the economic concept of consumer surplus. Put simply, product or service *X* has a value to users, and this value may be higher than the price that has to be paid. If a new or improved product has a higher value in use for the same price as existing products, this increased value should be counted as part of benefits. An example are GMES services, whose monitoring may lead to less severe crisis and less economic damage, without people paying individual fees that exactly reflect the value of these improvements. Calculating effects like this can in practice prove very cumbersome. A practical approach may be to only try calculations if the effects are thought to be significant.

External effects: knowledge spillovers

A knowledge spillover is a non-rival knowledge market externality that has the effect of stimulating technological improvements by others through one's own innovation. A spillover of knowledge occurs when the results of research and development in the context of one programme is also useful for the advancement of knowledge in other disciplines, without payment for the use of this knowledge. While intellectual property law gives firms some ability to protect knowledge they have created, it is often impossible to keep the knowledge developed to themselves. Other firms see the new knowledge, and use it. These other firms may be within (spin-in) or outside (spin-off) of the space sector. More generally, commercial development and use of new knowledge will tend to cause it to spread, despite any desire of the inventor to prevent such spread. Economic exploitation of new knowledge requires commercialisation of new products embodying that knowledge or the incorporation of that knowledge into new production processes. Such a process of commercialisation tends to reveal at least some aspects of the new knowledge to other economic agents. In other words, the total benefits of knowledge creation are larger than the private benefits to the actor which pays for the creation of the knowledge.

Knowledge spillovers are particularly likely to result from basic research, but they are also produced by applied research and technology development. This can occur, for example, by the mobility of (R&D) workers (Almeida and Kogut, 1999), the exchange of information and ideas at technical conferences, technological literature (including patent documents), reverse engineering and even industrial espionage (Maurseth and Verspagen, 2002). Other vehicles for the transmission of technical knowledge are news releases, licenses, colloquia and companies' mergers and acquisitions.

The economic effects of knowledge spillovers of specific space investments are hard to observe and measure. Direct evidence of knowledge spillovers of recent publicly supported space programmes, as in several other technology areas, is therefore hard to come by. This is mainly because of the difficulty in tracking the complete flow of knowledge generated by space investments through to other activities, as much of it may relate to tacit knowledge passed on through people, rather than codified knowledge (Oxford Economics, 2009) or as Nobel Prize winner Paul Krugman put it: *Knowledge flows are [...] invisible; they leave no paper trail by which they may be measured and tracked* (1991). Since Griliches's paper on measuring contributions of R&D to economic growth (1979), economists however have attempted to quantify the extent and impact of knowledge spillovers. Beginning in the nineties, knowledge spillovers were empirically assessed with advanced econometric techniques, focusing on the extent to which these spillovers varied across sectors and with distance (Groot, 2001). The key concept in the literature is the knowledge production function, describing the relationship between innovational output (such as patents and scientific articles) and inputs in the production of knowledge (university research and industry R&D).

Measurement and indicators: patent citations?
Various studies have suggested to use patent citations data as a measure of knowledge spillovers (Almeida and Kogut, 1999; Caballero and Jaffe, 1993; Jaffe et al., 1993; Jaffe and Trajtenberg, 1996; 1998). Patent documents contain references to earlier patent documents. The legal purpose of the patent references is to indicate which parts of the knowledge described are claimed in the patent and which parts have been claimed earlier. The interpretation of patent citations offered by Jaffe et al. (1993) is that a reference to a previous patent indicates that the knowledge in the patent was in some way useful for developing the new knowledge described in the citing patent. The references can therefore be seen as spillovers from the knowledge described in the cited patent to the knowledge in the citing patent (Maurseth and Verspagen, 2002). Verspagen (1997) also conducted an extensive study on patent citation data and concluded that citations provide a measure for knowledge spillovers. Jaffe et al. (2000) performed a survey among R&D managers to test whether the picture of knowledge flows produced by patent citations was consistent with the managers' impressions. The results suggest that communication between inventors is reasonably important, and that patent citations do provide an indication of communication, albeit one that also carries a fair amount of noise. They found that around one half of patent citations correspond to spillovers. This implies that *aggregate* patent citation flows may be used as proxies for knowledge spillover intensity, for example between categories of organisations or between countries.

In an ex post analysis it should be possible to determine how often patents were cited by other patents. This requires that one keeps track of what patents applications have been a direct result of the investment and count the number of times *these* patents are cited in *other* patents. For this, one needs patent citation data.

ESA currently keeps track of patents originating within the various ESA programmes. As part of the standard ESA contract conditions, all contractors are obliged to provide a “Statement of Invention” at the end of each contract. This statement includes which inventions have been made and which Intellectual Property Rights have been (or will be) registered in the course of or resulting from work undertaken for the purpose of the contract. Furthermore, at contract signature relevant background Intellectual Property is also identified, providing a proxy for actual patent citations.Citation data can be obtained by the United States Patent and Trademark Office (USPTO) and the European Patent Office (EPO). There are however important differences between the European and US patenting systems. A European patent is nothing more than a collection of patents in individual countries. Innovators may apply for a European patent within one year after applying to their national patent office. Therefore patent data from EPO cover only a subsample of patents applied for. Second, EPO patent examiners, rather than the inventors or the applicants, add a large number of the patent citations. This means that the inventors may not have been aware of a cited patent. In the US the inventors themselves add the majority of citations. The reason behind this is that the US system requires inventors to provide a complete description of the technical state-of-the-art, whereas the European system does not.

Still it is reasonable to assume that a reference in the European case can be seen as an indicator of technological relevance (Maurseth and Verspagen, 2002). Since patents are public, inventors should have reasonable knowledge about existing patents in their field.

There are some doubts, however, on the issue whether patent citations are indeed a good indicator of knowledge spillovers in case of the space sector. It requires that new technology, as a rule, is patented, and there are indications that space companies patent less than in other sectors like pharmaceuticals. It may also be difficult to relate patents or patent citations specifically to the space sector.

Scientific publications

Another alternative is to measure the number of scientific publications related to a space programme. This should only include publications in peer-reviewed journals and books with a substantial impact factor. A limitation of this indicator is that it applies mainly to non-applied science. ESA is recommended to ensure that researchers involved in spaace programmes report all their publications related to the programme, including the extent to which each publication depended on ESA funding.

Alternative indicators

A question is what other indicators may measure knowledge spillovers from space innovation. Innovation is obviously related to skills, education, knowledge, and competence. This would suggest that indicators of skills etc. could be used as proxies of innovation effects. Examples of such indicators would be the number of students who finish space-related education, the number of researchers in space activities by level (master, PhD, professor) and the average education level of people working in the space sector. However, measuring e.g. the educational attainment of employees in the space sector has drawbacks too. The relation from education to innovation and from innovation to spillovers is at best an indirect one. Therefore, these indicators coud provide some trends but not very exact information. It seems that the choice is between objective measurement of patent citations as a direct indicator (and missing many spillovers because some technologies that may spill over are not patented), or using more indirect indicators that are easier to measure, but which are less closely correlated to innovation itself.

Conclusion

It appears that all indicators of knowledge spillovers discussed have severe limitations. A combination of imperfect indicators may be the least bad option. This combination would include on the one hand measuring patents, patent citations and scientific articles related to space R&D. On the other hand indicators of education and knowledge levels would provide some insight in trends.

External effects: environmental indicators

This section provides examples of indicators of environmental effects of space activities. This is necessarily a selection out of a much larger set of possible indicators. Space activities affect the physical environment in many ways. Launchers emit substances into the atmosphere and the production of launchers and satellites also entails emissions. On the other hand, space activities such as environmental monitoring may reduce pollution in agriculture, navigation and communication satellites may reduce pollution from physical transport, and space-related R&D

may lead to cleaner technologies. Moreover, the physical environment has many facets, ranging from many types of pollutants in the atmosphere, the sea, rivers and soil, to the availability of water, arable land, light/sunshine, temperature etcetera. Intended effects of space activities are often positive, such as a higher production in agriculture or more efficient transportation. These effects are included in the indirect effects of space activities. The indicators below relate to *external* effects of space activities: effects which are not (fully) taken into account in market activities.

CO_2 emissions

A very important environmental effect is the effect on *CO_2 emissions*. CO_2 is the most important contributor to the greenhouse effect[33]. Moreover, other emissions to the atmosphere are in many industrial processes positively correlated to CO_2 emissions. Measuring the CO_2 impact of space activities is by no means simple, if only because almost all economic sectors emit CO_2. A practical approach could be to make a distinction between:

- Spaceflight
- Energy-intensive industries such as electricity generation, refineries, basic chemicals and steel production
- Other industry
- Transport
- Services and other sectors
- Households

For each of these industries, the average ratio between CO_2 emissions and production could be computed, for all ESA countries together. These sector-by-sector ratios could then be used to provide a rough estimate of the effect of changes in production and consumption on the level of CO_2 emissions.

CO_2 emissions can be monetised, but the methods used differ. It is very difficult, if not impossible, to estimate the true future damage caused by CO_2 emissions[34]. An alternative would be to estimate the costs which should be made to compensate for additional CO_2 emissions by reducing CO_2 emissions in other activities, e.g. electricity generation[35]. These costs, however, may be higher or lower than the true damage caused by CO_2 emissions. The specific nature of spaceflight, whereby CO_2 and other gases are emitted into the atmosphere at (extremely) high altitudes may require specific attention when estimating the damage caused or when monetising these emissions.

Ecological Footprint

An often-used indicator in environmental economics is the *Ecological Footprint*. This indicator shows how much land area is needed for production and/or consumption. For instance, the

33 Although most scientists conclude that human emissions increase the greenhouse effect, there is discussion about this conclusion. In this report we assume, as many governments do, that it is worth wile to reduce greenhouse-related emissions.

34 This procedure assumes that the effects on production have been estimated at the sectoral level described above.

35 In the EU, an Emissions Trading System (ETS) which caps total CO_2 emissions is covering more and more economic sectors. As far as the CO_2 emissions caused by space activities occur in these sectors, these emissions will be compensated by CO_2 reductions in other sectors within ETS. Therefore, this part of CO_2 emissions is not indicative of an increased greenhouse effect, but of CO_2 reduction costs.

ecological footprint of consuming beef (including beef production) has been estimated to be 157 square meters per kilogramme (Collins and Fairchild, 2007). However, accurately measuring ecological footprints is not easy. The most important effects in terms of ecological footprints may be expected in spaceflight activities themselves and via the services provided on other sectors, especially agriculture. ESA is already doing work on the ecological footprint of space activities[36]. Future impact assessments of monitoring activities aimed at agriculture may be directed by ESA to include the effects on the ecological footprint of agriculture.

Reductions in land use caused by e.g. space monitoring or navigation systems will lead to both cost reductions (of land) and a smaller ecological footprint. The footprint effect should be interpreted as an indicator of the external (non-market) effects only. As the ecological footprint is an aggregated indicator of many environmental effects, it is not easy to monetise.

Water availability
Water is scarce in many areas. As the earth warms up, some places will become dryer. Also, the seasonal variability of rainfall is expected to increase. A lack of water may reduce agricultural production, hamper industrial processes which depend on cooling water and affect nature in wetlands. Therefore, the availability of water in dry areas and dry periods is an important environmental indicator. Space activities, in particular monitoring, may enable a more efficient use of water in agriculture. The effects on the availability of water could be measured by first defining dry areas and dry periods, and then estimating the effect of space activities on water efficiency. The effects on agriculture and other economic effects, however, are already included in the indirect effects. The relevant indicator for environmental effects is therefore the net availability of water for nature.

Space debris
The near-earth 'environment' of space contains much debris from satellites. Space missions often add to this amount. Therefore, the contribution of a mission to 'space pollution' is an important indicator. This could for instance be measured as the change – caused by a space mission – in the probability that future missions will experience an impact with a debris object over a certain size, speed and mass.

Strategic and societal effects and distribution of effects

As described in section 2.3.2, space activities have impacts on societies which are in the realm of influence, status, attitudes and feelings. If, for instance, countries can increase their international influence, they benefit in terms of opportunities for trade and reductions in (military) risk. And consumers pay large amounts of money to buy goods and services which make them happy. Similarly, if space activities contribute to international influence, pride or the happiness of citizens, this may reflect a substantial value to society. This section presents selected indicators of strategic and societal effects and discusses the distribution of effects. All of these have in common that their monetary value cannot be calculated.

Competitiveness: trade surplus and surveys
International competitiveness is determined by many thousands of specific products which are traded internationally. If other countries are more competitive, these goods are often imported,

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36 www.esa.int/esaMI/ESTEC/SEMN7QZW5VG_0.html

and if your own country is more competitive, this may offer opportunities for export. This all adds up to a country's *trade surplus* (or trade deficit). OECD collects and provides these figures[37]. Import tariffs, export subsidies and regulations may influence international trade, but generally speaking the trade surplus can be seen as an important indicator of competitiveness at the country level. As trade fluctuates from year to year, a long term average may be better than statistics for specific years. Trade surpluses and deficits may also be added up over ESA countries, providing a measure of these countries' overall competitiveness *vis-à-vis* other countries.

To obtain an indicator of ESA's contribution to competitiveness, we also need to know *why* countries are competitive. Apart from currency exchange rates, this is largely determined by production costs, which in turn are strongly influenced by wages, as labour is a large input in production. Production costs may also be influenced by technologies used in production. This influence is already included in the indirect effects and spin-off effects of space activities. But other factors, such as the international image of a country, may also have an impact on competitiveness. Such factors can only be measured through surveys, for example the Executive Surveys used in the World Economic Forum's Global Competitiveness Index to capture concepts that require a qualitative assessment (World Economic Forum, 2011). Questions about the relation between space activities and competitiveness could be included in such surveys.

Safety: military spending in space

However we would wish differently, the world is not automatically a safe place. Military spending is needed to check the ambitions of other countries to control resources and people, and of terrorist groups to undermine societies. Part of this spending is in space, for instance in monitoring of military activities on the ground. ESA's space activities are not aimed at military goals, but they may contribute to these goals nonetheless by developing space systems and technologies which can be used in both civilian and military applications ("dual use").

It is not easy to measure this influence of ESA's activities on military applications. Military activities are by nature kept secret. Moreover, the extent to which ESA's activities contribute to military applications would be hard to assess, even if the military applications were known in detail. Therefore, the only indicators available are rather broad. A first possibility is to estimate the total budget spent on military space activities by ESA countries. This would yield an estimate of the size of the activities which may benefit. This may be complemented by estimating the financial size of ESA's activities which may have benefits to military applications. This could be done by taking ESA's full budget, and then subtracting amounts spent on activities which are evidently not related to military space activities. For specific satellite services or products, it may be possible to estimate the size of the sales (and thus importance) of these services and products to military users (or other 'peacekeepers'), for instance when considering the future market for the Galileo Public Regulated Service (PRS) or the services of the Global Monitoring for the Environment and Security (GMES) system.

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37 OECD also computes indicators of competitiveness based on individual markets (Durand and Giorno, 1987). However, these 'markets' are still rather aggregated, each containing many products. Some proposals for indicators concentrate on production costs at the micro-economic (product) level (Siggel, 2007), but these are hard to implement for all products.

Standing and reputation of countries

The standing and reputation of countries are determined to a large extent by their economic achievements and by their diplomatic and military contributions to international safety. Therefore, standing and reputation overlap strongly with competitiveness and military contributions. The relation of standing and reputation with diplomatic efforts (Wang, 2007) is not covered by these previous indicators, but is very hard to measure. Moreover, the relation between ESA's activities (in part diplomatic themselves) and international diplomacy is not obvious, notwithstanding the large number of co-operative space projects that ESA executes with non-Member States.

The standing and reputation of countries may be measured through surveys among citizens of other countries. Questions on space activities could be included in these surveys. However, we should realise that the results may overlap strongly with competitiveness and contributions to international safety. The wording of survey questions should be tailored to prevent this overlap as far as possible.

Happiness, unemployment and pride

The happiness of people and therefore of societies is strongly influenced by the level of unemployment. Unemployment is not only an economic inefficiency for society and a financial problem for individuals. Having a job is also an important factor in the happiness of people, which exceeds the financial effect (Frey and Stutzer, 2002). Thus, unemployment levels are not only economic indicators, but also indicators of social well-being. Therefore, the influence of space activities on unemployment, as measured as a part of indirect and induced effects, should also be included as an indicator of an important societal impact.

National pride may be influenced by a country's contribution to space activities. Pride may in particular be influenced by conspicuous events, such as landing on the moon or the presence of a fellow countryman on the International Space Station. As space activities have become rather normal in the public eye, these effects are likely to be limited. Therefore, we suggest using unemployment impacts as the main indicator of the influence of space activities on happiness and pride.

Income distribution

An equitable income distribution is an important goal of most governments. Progressive taxes, social security and subsidies are the main policy instruments used. If space activities would benefit the poor more than the rich, this could be seen as positive. Therefore, it is useful to not only estimate the effects of space activities for society as a whole, but also for separate income groups within society. The result can be used in the evaluation in two ways. First, the final tables (subsection 5.2.4) can be supplemented by an actor analysis, in which different income groups are identified. The actor analysis in that case is a separate input for evaluation, next to the tables showing the effects for society as a whole. The second option is to include the effect on the income distribution in the MCA-part. Estimating this effect can be done by calculating the net effects for separate income groups: their shares in the benefits minus their shares in taxes paid to finance the space activities. In this way, the (re)distributional effect of the space activities is computed. Of course, this requires that the groups deemed important are defined beforehand, and that information is available on their share in taxes and in the benefits of space.

5.5 Data requirements

As described in chapter 4, some types of data are needed for all evaluation methodologies, and some are needed for specific evaluation methodologies. All evaluation methodologies except Financial Analysis need data on investments in the space programme, on investments related to the space programme, and economic statistics at the product level, for the space sector and for all sectors[38]. Specifically, SCBA needs data on the timing of investments and effects, on the impacts of investments, both direct, indirect and external, on the willingness to pay or other monetary valuation methods, and needs an appropriate discount rate. MCA especially needs information on the impacts of investment, both direct, indirect and external, and on the relative importance of these impacts. Our SCBA-plus methodology is a combination of SCBA and MCA, with the aim of treating effects as much as possible in the SCBA-part, which means that ideally data is available on:

- investments in the space programme,
- investments related to the space programme,
- economic statistics at the product level, for the space sector and for all sectors,
- the timing of investments and effects,
- the impacts of investments[39], and on
- the willingness to pay or other monetary valuation methods.

These requirements imply that there is a need for time series data on the mentioned variables.

Only if by their nature impacts or monetary valuation is impossible, or if it is theoretically possible but in practice not or hardly so, are effects treated in the MCA-part, which – logically – loosens the data requirements, to data on:

- investments in the space programme,
- investments related to the space programme,
- economic statistics at the product level, for the space sector and for all sectors,
- the impacts of investment, especially the relative importance of these impacts.

In section 5.4 we have described examples of using indicators in practice. In subsection 5.1.3 we have stressed that the strength of evaluation depends to a large extent on the evidence base of effect estimations. In chapter 6 we turn to the practical issue of how to apply SCBA-plus in the situation where some of the required data is missing.

5.6 Using SCBA-plus in ESA processes[40]

If the SCBA-plus approach is to be established as the standard way in which ESA evaluates the economic benefits of public investments in space, this approach and the activities it constitutes become part of the normal operations executed by ESA. Although at first the application of

38 Financial Analysis does not need data on investments related to the space programme and economic statistics for the space sector and for all sectors.

39 If indirect effects are estimated by applying Computable General Equilibrium analysis, Input/Output tables and economic statistics at a relatively detailed level are required as well.

40 See Appendix F for a description of how ESA establishes an investment programme.

SCBA-plus will likely be organised in an ad-hoc fashion to evaluate a specific (set of) programme(s), in the long run, the steps as presented in section 5.2 will need to be integrated in the day-to-day activities undertaken by ESA, and in the way ESA communicates with its stakeholders and other external entities. This way a body of knowledge can be built up, which enables better analysis over time.

The first three steps of the SCBA-plus approach are (see subsection 5.2.1):
- Step 1. Definition of aim and scope of evaluation
- Step 2. Identification and characterisation of investments
- Step 3. Identify assessment criteria: costs, possible effects, other criteria, and actors

Although in this report we focus on the ex post analysis of investments in space, a first iteration of the above three steps could be executed around the time a new investment programme is established. At that moment the basic input to execute these steps is already available. Such attention for economic benefits early-on in the establishment of an investment programme also helps to flag the start of data collection over the lifetime of the respective investment programme.

Here, a distinction between the application of the SCBA-plus method to ESA's own investment programmes and the application to other public investments in space is to be made, since it is likely that ESA will have a much more detailed insight into its own programmes than into third party programmes. One can assume that the amount of control that ESA will have over an overall assessment process like the SCBA-plus approach, is much lower (if at all present) for public space investment programmes that are executed by other entities than for those programmes executed under the ESA umbrella. It is therefore advised that ESA focuses its efforts in this area on its own investment programmes and communicates to external entities both on the steps taken and on the results found. In other words "to lead by example".

When looking at the steps of the SCBA-plus approach in more detail, it can be observed that the first stage in establishing an investment programme focuses on defining the aim and scope of this programme. Step 1 of the SCBA-plus approach ("definition of aim and scope of evaluation") provides an opportunity to also consider at an early stage the options to evaluate to what level the original aim and scope (the goals) are achieved over the course of an investment programme. The SCBA-plus approach will in itself provide a generic set of assessment criteria which may even help in identifying new goals for the investment programme under consideration. It also provides the opportunity to include in the investment programme itself agreements and instructions on for instance data collection efforts or feedback on project results.

By integrating the SCBA-plus approach at an early stage in the specification of an investment programme, the identification and characterisation of the investments – step 2 of the SCBA-plus approach – is made more easy. Stakeholders in the investment programme (for ESA in particular the Member State delegates) are closely involved in the definition of the programme and can bring their inputs more readily to the table then at a later stage. Also, the identification of assessment criteria such as costs, possible effects, other criteria, and actors – step 3 – is best closely linked to the definition of programme details. Again, the SCBA-plus needs and requirements in themselves may help in establishing the investment programme, for instance by bringing forward effects or actors that may otherwise have been overlooked.

Considering the continuous nature of most space programmes (for instance the ESA General Science and Technology Programme which has been running for many years and is updated regularly) it is advisable to schedule individual assessments at regular intervals (for instance bi-annual) rather than at the end of a specific programme. After each interval, the results of the steps 1, 2 and 3 can be revisited and then the remaining steps of the SCBA-plus approach are to be undertaken:

- Step 4. Quantifying effects (SCBA/MCA)
- Step 5. Valuation of effects (SCBA/MCA)
- Step 6. Calculating outcomes (SCBA/MCA)
- Step 7. Sensitivity analysis (SCBA/MCA)
- Step 8. SCBA-plus: presenting the combined results, including non-monetized effects
- Step 9. Evaluation

It is likely that at least some of the specific assessments included in the overall SCBA-plus approach yield results that are more widely applicable than for a single investment programme alone. Therefore by scheduling an SCBA-plus assessment at regular intervals, it can cover more than just a single programme in an efficient way. Furthermore, this allows for a comprehensive reporting on public space investments whereby both the individual programmes and the public space investment at ESA or even European level can be addressed and compared. On a basic level, regularity in this type of assessments provides a clear long term perspective and supports the buiding up knowledge and – not in the least – the results in the overall management processes of ESA.

When scheduling the execution of the SCBA-plus assessments at regular intervals, the data collection efforts can be aligned to these intervals and become part of ESA's business routine. This build-up of a body of knowledge is of great importance to ensure continuity over time of both the collected data and the assessments themselves. Much of the data that is currently already available within ESA is collected on an annual or multi-annual basis. For instance the EMITS Entity Questionnaire is to be updated annually by all entities doing business with ESA, providing input on e.g. employment, turnover etcetera. Also programme status updates are provided to the ESA Member State delegates at regular intervals. If other entities (such as the OECD, European Union, national space agencies or Eurospace) decide to adopt a similar approach to evaluate the space investment programmes under their control, regular reporting intervals facilitate the exchange of economic data with these entities.

6 Implementation

If you cry "Forward,"
you must make plain in what direction to go.
Anton Chekov

In the short term, a simplified version of the ideal methodology presented in chapter 5 can be applied. Another step towards better evaluation is to collect better data, in particular on the composition, economic relations and impacts of the space sector, and on complementary investments made by other actors. Also, ESA could improve its own data and use these data not only for decision making and administrative purposes, but also for ex post evaluation. For the first follow-on activity it is advisable to apply the SCBA-plus method to two of the current ESA programmes.

This chapter starts off from the current situation of less-than-complete data availability. This deviates from the 'ideal' situation that has been assumed in chapter 5. The SCBA-plus methodology can still be applied, be it in modified form because of missing data. A data collection effort is needed in order to get to (or at least in the direction of) the ideal situation that has been assumed in chapter 5.

Section 6.1 describes what the SCBA-plus methodology looks like in the current case of less-than-complete data. Section 6.2 defines the data collection effort for the long term, and sketches possibilities for the medium term. Section 6.3 turns to improvements in ESA's own data. Section 6.4 concludes with the first steps that can be taken.

6.1 Analysis based on currently available data

This section describes what data are currently missing and how the SCBA-plus evaluation methodology can still be applied to some extent in this situation. These steps provide a start in generating a body of knowledge within ESA.

SCBA-plus needs data on investments in the space programme, on investments related to the space programme, and economic statistics at the product level, for the space sector and for other sectors. Also, some specific data for he SCBA-part and the MCA part are needed. In chapter 4, we have seen that data on investments in the space programme and economic statistics for other sectors are largely available. For related investments and economic statistics at the product level however, much data is unavailable, and for economic statistics on the space sector, data is even largely unavailable.

Investments related to the space programme
This concerns the size and type of investments that are complementary to ESA programmes (see chapter 4). The consequences for SCBA-plus are as follows. If complementary investments are necessary conditions for the ESA space investments, a component of the integral investment programme is missing, and it is not possible to relate (social) costs and effects to this complete programme. If complementary investments are not so much a condition for, but a causal effect

of ESA space investments, part of the effects of those ESA space investments cannot be calculated.

If complementary investments are *necessary conditions for* the ESA space investments, the benefits minus costs that the SCBA-part aims to calculate is lacking essential data and is no longer meaningful. In that case, it is better to score costs and effects of those complementary investments in the MCA-part. However, if there is not enough data on complementary investments to be able to score criteria on the basis of e.g. expert opinion, the necessary complementary investments will be missing in the evaluation altogether. In this case, evaluation according to the SCBA-plus methodology should not be considered a meaningful exercise. Gathering data on complementary investments is then the first priority.

If complementary investments are *effects of* the ESA space investments, costs and effects of ESA space investments can still be calculated in the SCBA-part, but now with the effects on (and of) the complementary investments missing. If some data on those complementary investments is available, that can be used to score criteria in the MCA-part, e.g. on the basis of expert opinion. If no such information is available, and scoring criteria for the complementary investments is not possible, it should be noted in the evaluation that effects on (and of) complementary investments may exist, but are not known.

Economic statistics at the product level
This concerns value added, profits and employment in specific space-related markets, i.e. the markets for goods and services on which the space investments have an impact (outside the space sector). It also involves data on the effect of space investments in terms of new/improved products, cost savings and other market changes (see chapter 4 and subsection 5.4.2). The consequences for SCBA-plus are that part of the effects cannot be calculated, namely the indirect effects (wider economic impacts) on markets outside the space sector. This consequence is more serious if the indirect effects are possibly of significant size and either the indirect effects are additional to the direct effects or the distribution of effects is thought to be important.

In this case the SCBA-part cannot include calculations of indirect effects. If *some* information on indirect effects is available, it may be used to score criteria in the MCA-part, e.g. through expert opinion. If no such information is available, and scoring criteria for indirect effects is not possible, it should be noted in the evaluation that indirect effects may exist, but are not known.

Economic statistics on the space sector
This concerns employment, value added, present investments, and especially costs and revenues of the space sector. As stated in chapter 4, there is no standard classification of space related activities, and space market information is fragmented in its availability. The result is a lack of separate and robust data on the space sector and space industries. The consequences for SCBA-plus are that upstream and downstream effects within the space sector cannot be calculated. This, in turn, may have consequences for calculating indirect effects, i.e. effects on other markets than the space sector.

Whether the SCBA-part can still be applied in this case depends on the ability to calculate the most important effects without the information just mentioned. If the main effect on welfare can be calculated, for example by measuring effects for consumers, SCBA can be applied, be it without a complete actor analysis (distribution effects). If *some* information exists on the effects via the space sector, that information can be used to score criteria in the MCA-part, e.g. through expert opinions.

Missing specific data

Ideally, for the SCBA-part data is available on the timing of investments and effects, the impacts of investments, and on the willingness to pay or other monetary valuations. For the MCA-part, enough data should be available to assess the impacts of investments, especially the relative importance of these impacts (see chapters 4 and 5). Currently, data is missing on the impacts of investments and on their monetary valuations, the more so for investments with a larger distance-to-market, and for effects that cannot be monetized, like societal and some environmental effects (see chapter 4).

If monetary valuations are missing, but impacts are estimated, the evaluation will be based mainly on the MCA-part. If impacts are not estimated, but enough data is available to score criteria in the MCA-part, e.g. through expert opinion, the evaluation can still be based mainly on the MCA-part, although the evidence base will be much weaker. If there is so little data that criteria cannot be scored in the MCA-part, the methodology breaks down.

SCBA-plus in the situation without additional data collection effort

Table 6.1 summarizes this section. It shows that SCBA-plus can be applied in the present situation with much important data missing, provided that there is at least some information available. In general, the implication is that more effects are assessed in the MCA-part of the SCBA-plus methodology.

Table 6.1 Consequences of missing data for SCBA-plus.

Missing data on:	Consequence	Consequence, continued
Related investments (necessary for programme)	Assess effects on related investments in MCA-part.	If not possible, SCBA-plus is not suited.
Related investments (effects of programme)	Assess effects on related investments in MCA-part.	If not possible, note that effects on related investments are missing in the evaluation.
Statistics product market (for indirect effects)	Assess indirect effects in MCA-part. See Impacts.	If not possible, note that indirect effects are missing in the evaluation.
Statistics space sector (upstream/downstream effects)	Assess upstream/downstream effects in MCA-part. See Impacts.	If not possible, note that upstream/downstream effects are missing in the evaluation.
Monetary valuation of effects	Assess non-monetized effects in MCA-part. See Impacts.	If not possible, note that effects are missing in the evaluation.
Impacts of investments	Assess impacts in MCA-part.	If not possible, if main effect is missing, SCBA-plus is not suited.

6.2 Additional data collection effort

Improvements in data collection, impact estimation and valuation of effects make for stronger evaluations by providing more and better inputs for the SCBA-plus methodology (see Table 6.1), by assessing more effects in the SCBA-part of the methodology and providing more information on which to base scores of MCA-criteria (see flow-chart 5.1). Chapter 4 and section 6.1 have described that missing data related to complementary investments, economic statistics at the product level, economic statistics on the space sector, impacts of investments (e.g. high quality estimates of QALYs, Quality Adjusted Life Years) and their monetary valuations (especially if not observed in market prices). In general terms, this constitutes the additional data collection effort. Section 6.1 has shown that data on related investments that are necessary for the space programme, and impact estimations of the main effects of the space investments, are essential for evaluation purposes. Assessing the impacts of space programmes which are close to markets could be pushed forward by research into (see chapter 4):

- the direct effects of space investments in specific industries. Such research should then collect its own data, complementing the characteristics of the investments with e.g. surveys. This type of reseach has already been done for specific investments and industries (e.g. Cohendet, 1989), but should be expanded to cover alle relevant investments and industries;
- the wider economic effects. This would necessarily be rather aggregated, looking at broad economic sectors and the whole economy. Constructing input-output tables is a useful first step.

Also, chapter 4 concluded that efforts to obtain better data may be in order, consisting of:

- contacting Eurostat and other statistics bureaus about possibilities to compile 'tailor-made' data which more explicitly shows the space sector and its relations with other economic sectors.;
- collecting data on societal and environmental issues.

All these efforts should pay special attention to need for time series data to be collected. Regarding measurement of the space sector and its relations to other economic sectors, it is worth mentioning the OECD publication "Measuring the Space Economy" (OECD, 2012), the first part of which examines a.o. methodological issues including definitions and industrial classification, principal actors and data sources.

Data collection in the medium term, up to 5 years

Efforts in the medium term could focus on the following:

- doing impact estimations of the main effects of space investments, using SCBA-plus as a framework which steers the research, an in which results are 'fitted in';
- collecting data on related investments that are necessary for space programmes.

The reasons for focusing on these two is that they are essential for evaluation purposes. Impact estimations of the main effects are by no means trivial (see subsection 5.1.3 and section 5.4). The effort here is twofold: collecting the data necessary for estimation of effects; and performing a sound estimation of effects on the basis of the data collected. Although evaluations have an ex post character, it is important to introduce the evaluation framework from the beginning (see section 5.6), and start collecting the necessary data from the start.

Also, efforts could be made to obtain better data on the space sector. Requests to Eurostat and other statistics agencies could gain force if these are carried out together with OECD and other organisations interested in economic data on space activities and its relations with other economic sectors.

A start could be made by collecting data on societal and environmental issues, and on monetary valuations of effects. A first step could be to contact consultants who have a broad, international view on social issues and environmental effects, respectively. These consultants could then carry out exploratory studies aimed at identifying the full range of relevant effects. Further studies could aim at the possibilities to express these effects in money terms.

The costs of these steps are hard to assess. Eurostat and other agencies may or may not require financial support to construct better data. Consultants will have to be paid of course; for first exploratory studies the costs could be in the order of magnitude of 100 K€ per study.

Data collection in the long term, 5-10 years
Efforts in the long run involve further impact estimations of effects of the space sector, collecting more detailed statistics at the product level and on the space sector, and improving the coverage and quality of monetary valuations. Further, efforts could be directed towards (improved) estimations of forward/backward linkages, wider economic benefits, and distribution of effects. We note that activities in the long term will depend to a large extent on the data found in the medium term.

6.3 Using and improving data within ESA

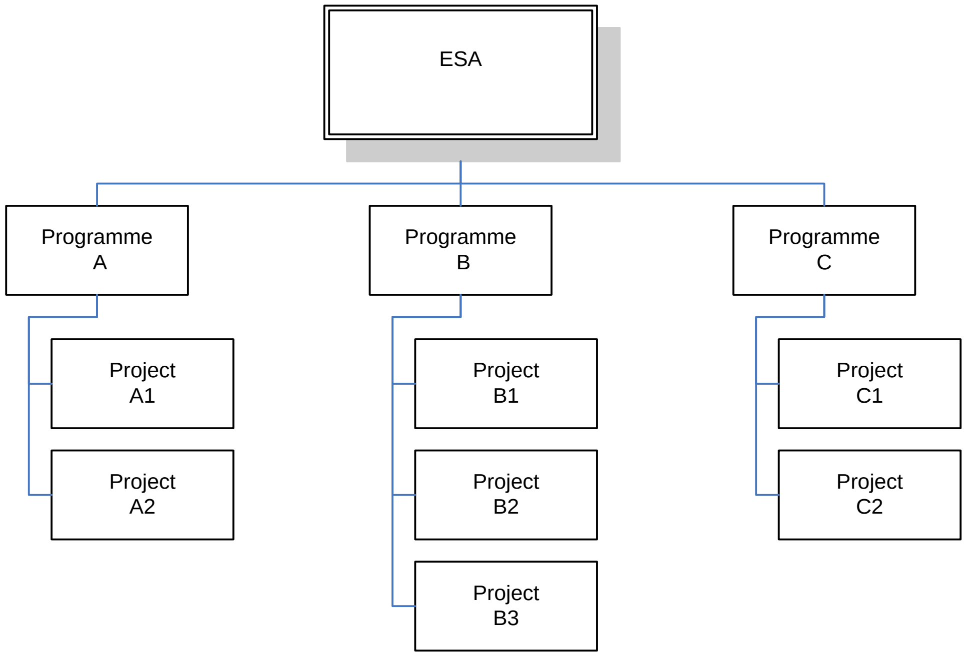
A major part of the data required for assessing the economic benefits of public space programmes needs input from parties outside of ESA. However, valuable data is already available within ESA or could be collected by ESA with limited additional effort. This data is primarily linked to ESA's own investment programmes, but addresses to some extent the wider economic status of the space sector. Detailed financial and economic data on the individual programmes executed by ESA is available, both looking at finance coming into the ESA organization, and payments going out of ESA.

For individual ESA programmes it is exactly known:

- what the total budget is;
- where the parts of this budget originate, i.e. which country and which organization.

In addition, when a funding agreement for a particular programme is established, the specific activities to be undertaken in the context of this programme are defined. Usually this is done through a number of individual but coherent projects (see Figure 6.1). For instance for a typical science mission, part of the budget is allocated to the manufacturing of the satellite platform, the manufacturing of the scientific instruments (satellite payload), acquisition of a launch vehicle, satellite operations, science support and the science teams themselves. This allows for a first budgetary subdivision between the space sector, space related sectors and other economic sectors. This kind of data aggregation is currently not normal practice within ESA, but could likely be undertaken with limited effort.

Figure 6.1 ESA programmes consist of several projects



The projects are typically assigned to industry through a competitive tendering process, although for specific cases direct negotiation is applied. The specific requirements that ESA applies to industrial tenders ensure that it is known to great detail how the project budget is spent. A tender typically specifies, among other things:

- organisation of the industrial consortium;
- budget allocated to individual parties within the consortium;
- nationality of industrial parties and allocated budget per nation (geographic return);
- cost per work-package;
- man-hour cost (total and per labour category);
- material cost (categorized);
- external services / supplier cost;
- travel and subsistence cost;

Although budgetary allocations may change from during the execution of a project, it may be assumed that they provide a reliable source of information on the way the investment funds are spent. ESA typically uses this budget breakdown before the start of a project, in order to evaluate the overall soundness of a project's organisation, and the overall cost/performance ratio. Further on, not much use of this data is made. We advise ESA to combine the available project-level data to provide a higher level economic view (i.e. at programme level or even at ESA level).

Within each ESA programme (and associated to each project managed by ESA) a percentage of the overall programme budget is allocated to ESA itself. This budget is used to fund for instance the ESA staff responsible for managing individual programmes and projects (man-hour cost, office environment, travel and subsistence), or the ESA internal facilities (test and verification facilities, communication systems, ground operations equipment) to be used.

Financial data on programmes and projects as described above is managed within ESA using financial data management systems. For larger projects all financial data linked to a Tender and the subsequent project is managed electronically through the ESA Costing Tool (ECOS). It is assumed that all available financial data at project level can be aggregated to programme level, but also categorized according to the items listed above. At the moment such aggregation of data is not routinely executed, with some exceptions. For instance, the national delegates are regularly informed of the geographic return status of individual ESA programmes.

All rates, tariffs and overheads (e.g. man hour cost, facility cost, material cost etc.) applied by entities doing business with ESA are periodically subjected to a (financial) audit[41]. In essence, this means an analysis of the suppliers cost structure as recorded in the cost accounting and time recording systems and as reconciled to the actual financial statements and/or budget forecast. These audits provide ESA with knowledge regarding the audited entities on e.g.:

- average labour cost per category of direct employees;
- full time equivalent allocated to direct hours sold on projects, indirect hours, proposals & tenders, applied research, product development;
- overheads linked to indirect employees and company expenses;
- financial statements;
- personnel overview and statistics.

Organisations doing business with ESA are required to register using an ESA maintained electronic registration system (ESA Procurement Regulations and related Implementing Instructions, ESA-REG-001). This registration is commonly referred to as the EMITS Entity Questionnaire (http://emits.esa.int). Through this questionnaire, ESA has access to for instance detailed information on:

- Staff and facilities; e.g. number of staff, male/female ratio, breakdown by staff function, staff dedicated to R&D / Space R&D, etc.
- Key financial figures; e.g. turnover and profit (total vs. space, other sectors such as defence, customers, ESA programme), external financing vs. budget financing, etc.

Registered entities are required to maintain the data in the EMITS Entity Questionnaire on an annual basis. However, the data as provided is not strictly checked for consistency and accuracy by ESA. Note that part of this information is already available to ESA in its own databases; for instance the total contracted value for a specific company in the various ESA programmes. ESA could simplify the task of filling in the Entity Questionnaire, by generating part of the required data from ESA's own data, and presenting this to the external entities for confirmation.

A further source of industrial information is the ESA Space Industry Questionnaire which collects general company information, data on the supply chain (sales and purchases) and on technologies and R&D. The questionnaire does not only address the traditional space companies, but also SMEs, research centers and institutions.

To a certain extent, data provided to ESA through financial audits, EMITS and the Space Industry Questionnaire overlap. It seems that within ESA these three efforts to collect data are not linked and focus on their own immediate goals. Note also that the level of trust that can be

41 Implementing instruction on Audit Rights, ESA/IPC(2009)97 Rev. 2, Paris, 26th November 2009.

put on the various datasets is different; there is a big difference between the results of the financial audits of individual companies (which certify the rates a company can charge to ESA) and the data available in the EMITS Entity Questionnaires (which sometimes are updated “just-in-time” for a proposal delivery deadline).

ESA is advised to consider these data collection efforts at a more holistic level. By tuning the focus of these various efforts and the way data is described and stored, it can be made sure that the collected data can be compared, checked for consistency and used to make valid assessments at a higher level than for individual companies. Note however, that specific attention will have to be paid to ensuring the confidentiality of data collected on individual entities.

On a regular basis, ESA reports the progress achieved in its programmes to the ESA Member States through the Programme Boards linked to the various programmes. The progress reports contain a breakdown of ESA’s expenses within a specific programme, detailed to show the financial return per nation and industrial entity. A short-list of (periodic) financial reports issued by ESA is given in Table 6.2. From the above it is clear that ESA may have a detailed view on the overall expenses associated with a specific programme. At the moment, however, all this data is not by default aggregated to a level that is suitable as input for the assessment of the benefits of ESA’s own programmes. Nevertheless, the richness of the available data provides a clear starting point for the economic evaluation of ESA’s own investment programmes.

Table 6.2 Available ESA financial reports.

Report	Ref	Available data
ESA Annual Report	ESA	Statement of income and expenditure. Statement of assets and liabilities. Consolidated cash flow statement. Statement of changes in net assets/equity. Number of patent applications filed.
Status of confirmed subscriptions to optional programmes.	ESA/C	Tables of subscriptions to optional programmes as confirmed by the participating States. As percentage. As Euro corrected to reference economic conditions.
ESA Long Term Plan	ESA/C	Projection of available resources from Member States, European Union, Other. Long term expenditure corridors by programme categories.
European Space Agency Industrial Policy Committee. Basic Technology Research Programme. Preliminary Selection of Activities for the TRP 2011-2013.	ESA/IPC	Budget allocation and number of projects/activities per service domain and sub domain. Budget per project/activity. Current and target Technology Readiness Level (TRL) per project/activity.
European Space Agency Human Spaceflight, Microgravity And Exploration Programme Board. Progress Report on Human Spaceflight, Microgravity and Human Exploration Programmes	ESA/PB-HME	Cost at completion and actual payments per annum at sub programme level, divided per cost code (staff, running, facilities, services), direct / indirect.
Programme Board On Satellite Navigation. The European GNSS Evolution Programme – Status Report.	ESA/PB-NAV	Project budget, project status, project planning. The status of geographical return based on actual commitments to date. Geo-Distribution (contract value) of Companies Participating in the Programme (linked to individual projects).)

6.4 Short term activities

Based on the results of the current study, this section presents a short term plan defining a set of activities that are proposed as follow-on to the current study and thus constitute the first steps of the stepwise implementation as described in this chapter.

Although ex post evaluations are by definition backward looking, in order to evaluate, one needs to look forward. Evaluations should begin before an investment programme is started, even: when an investment programme is being drawn up. A no-regret measure is to introduce the proposed SCBA-plus framework as a "way of thinking". Further possible first steps (apart from additional data collection and using/improving data within ESA) are:

- define case studies to try out the proposed methodology in a pilot phase. For example, the focus could be on a programme that has relatively easy-to-measure effects, and on a programme with harder-to-measure effects. This gives information on what works well and what works less well in the proposed methodology, so that it can be improved and further specified; it may be the start of building up a body of knowledge; and it may stress the need for further data improvements;
- implementing stricter rules or guidelines on evaluation may help to generate a body of knowledge as well, much the same way guides for the appraisal of transport projects have been a stimulus for further research; giving managers incentives to evaluate may also help here.

For the first follow-on activity it is proposed to apply the SCBA-plus method to two of the current ESA programmes. The primary objective of this activity is to start generating a body of knowledge and the associated practical experience in assessing the benefits of European public investments in space.

In selecting the ESA programmes to be assessed it would be most beneficial to take both a programme that is considered "close-to-market" and one that is "distant-to-market" (i.e. more research oriented). Such a selection is most likely to bring forward the widest set of challenges typically associated with this kind of assessments, and thus provide ample opportunity to advance the practical implementation of the SCBA-plus methodology. Note that it may be useful to consider a set of ESA programmes which are closely linked together, rather than one single programme for either of the two assessments to be executed.

We propose to select the following two programme types:

- Telecommunication: Investments in telecom capabilities have strong impacts on available products, production costs and employment in the space sector and the telecom sector, but also wider economic effects in many other sectors. The ESA ARTES set of programmes focuses on telecommunications R&D and prototyping, but generates outputs that are typically ready for direct commercial application.
- Science: Here, the impacts are to a large extent positive external effects (spin-offs). We expect the impact to vary strongly between different projects. These effects are difficult to measure, but nonetheless very important. ESA's science programme is established in consultation with national delegations, scientists and industry. Projects are implemented

in steps, whereby at each step a decision to continue or not is made based on an evaluation of the relative merit of these projects. The results of these evaluations provide valuable input for identifying the (potential) effects of the science programme.

The follow-on activity should, for each of the selected programmes, encompass the following tasks:

- data collection:
  - collection and aggregation of economic data available within ESA;
  - collection and aggregation of economic data from external (European) parties;
- SCBA-plus assessment for both selected programmes individually:
  - definition of the aim and scope of the evaluation;
  - identification and characterisation of investments;
  - identification of assessment criteria: costs, possible effects and other criteria; and of actors;
  - quantifying and scoring: quantifying the effects that can be measured and rating (scoring) the other criteria; this includes strategic, societal and environmental effects;
  - applying weights: valuation of effects in money terms (SCBA) or assigning weights to effects (MCA);
  - calculating outcomes: net present values of benefits minus costs and benefit-cost-ratios (for effects assessed using SCBA), and combining scores and weights to calculate end results (for effects assessed using MCA);
  - sensitivity analysis;
  - presenting the combined results, including non-monetized effects;
  - evaluation;
- identification of lessons learned and way forward:
  - comparison of the two assessment efforts and results;
  - identification of data collection improvements;
  - identification of methodology improvements;
  - specification of follow-on activities.

It is estimated that the above set of activities can be undertaken within a time period of about one year and could be started on short notice, assuming the necessary steps can be taken within ESA to start-up the tendering process for these activities. The estimated costs would be between 250 K€ and 500 K€ per programme. For later evaluations, the costs might be around 250 K€ because of learning effects.

7 Conclusions

The world is round
and the place which may seem like the end
may also be only the beginning.
Ivy Baker Priest

The road ahead for ESA consists of choosing SCBA-plus as a framework methodology, collecting additional data and using ESA's own data for evaluation. An important first step is to apply this methodology to space programmes, to test its usefulness and to gain experience.

Any evaluation technique for judging plans or projects should be logically and consistently connected to the nature of the decision problem concerned. Each approach has its advantages and disadvantages. However, any methodology for establishing the impact of space programmes should include three basic units: (programmes of) investments, actors and effects.

The strength of an investment evaluation method depends on its coverage of relevant effects, on the valuation or weighing of different effects, on the evidence base for the estimation of effects, and in the end on the availability of data. SCBA-plus provides a framework that covers all effects that are relevant for society, and values (weighs) effects if possible on the basis of observed market prices or on other estimations of monetary values. The plus in SCBA-plus indicates that the methodology includes effects that are hard to monetize or even hard to measure, like strategic effects, societal effects and some environmental effects. This is achieved by combining Social Cost-Benefit Analysis (SCBA) with Multi-Criteria Analysis (MCA).

Relative importance of MCA and SCBA
Roughly speaking, most effects in existing markets will be measured using SCBA and most external, societal and strategic effects will be estimated using MCA. Where possible, SCBA is used because this method has a more objective nature than MCA. This does not imply that the effects measured using MCA are less important. On the contrary, in analysing space investments the effects on for instance knowledge and international co-operation may be more important than e.g. additional turnover in space-related industries. Moreover, so far much less is known about the external, societal and strategic effects than about the direct economic effects. This could in practice make MCA constitute the most important and most innovative part of the SCBA-plus analysis. The challenge in SCBA-plus is firstly to include *all* the effects and secondly to put as many of these effects as possible in the SCBA part.

Limiting the efforts needed
The level of effort needed is an important aspect in making choices on evaluation. The wide range of effects of space activities implies the risk that the analysis could become very extensive, and therefore tedious and costly. To prevent this, the analysis may be based on a relatively simple approach via prioritisation of impacts. The analysis of economic effects to be included in the SCBA part may be based on the direct impacts on firms in the space sector and the effects on sectors using space services (space related sectors). Indirect benefits in other markets can be

estimated by experts. For the external, societal and strategic effects, which are more likely to be covered in the MCA part of SCBA-plus, two or three expert panels may be used who build up routine in estimating effects and comparing projects and programmes. The panels should consist of a mix of economists and space sector specialists from industry and public organisations. However, the overall goal is to base results as much as possible on objective measurements of identified effects, even if money valuation for certain effects is not possible. Measured effects, albeit non-monetary measurements, provide a valuable result on their own and are also input to the expert panels identified above.

On balance, more effort will probably be needed for the MCA part than for the SCBA part. For both parts, measurement of an important part of the effects is complemented with expert opinions to fill in 'gaps'. However, the variety of external, societal and strategic effects will require several different types of expertise.

Sensitivity of results

Some of the results of the analysis may be sensitive, leading to debates about the merits of certain projects or programmes. Having this discussion is unavoidable in a world in which accountability becomes ever more important. However, the debate should not be based on results which are not (yet) well-founded. Therefore, it is recommended to collect second opinions from independent experts, especially for results which are subject to debate. Also, it may be advisable to present the results of the analysis together with plans for future improvements, for instance focusing space investments on types of programmes or projects which prove to yield positive results.

Data availability

In the previous chapters we showed that the SCBA-plus method is in principle applicable to space investments. However, the availability of data may be improved. By gathering better data, more effects can be shifted from the MCA part of the analysis to the SCBA part, making the results more objective and easier to aggregate.

SCBA-plus as a framework

A no-regret measure is to introduce the proposed SCBA-plus framework as a "way of thinking", a framework where existing research fits in and which shows what gaps should be filled. Much information is available on space programmes, but much less on related investments and on the impacts of investments on the economy. Data on related investments that are necessary for the space programme, and impact estimations of the main effects of the space investments are essential for evaluation purposes. Efforts could thus focus on collecting data on related investments that are necessary for space programmes and on doing impact estimations of the main effects of space investments. These improvements make for stronger evaluations by providing the necessary inputs for the SCBA-plus methodology, by assessing more effects in the SCBA-part of the methodology and by providing more information on which to base scores of MCA-criteria.

Space sector data

A very important limitation is the absence of an explicit space sector in economic data. Also, the input-output relations between sectors are only available at an aggregated level. This makes it hard to measure direct and indirect impacts of space programmes. Societal and environmental effects are hardly known. Given these data limitations, we see two viable roads of assessing the impacts of space programmes which are close to markets:

- Research into the direct effects of space investments in specific industries. Such research should then collect its own data, complementing the (well-known) characteristics of the investments with e.g. surveys.
- Research into wider economic effects. This would necessarily be rather aggregated, looking at broad economic sectors and the whole economy.

Also, efforts to obtain better data which describe more explicitly the space sector and its relations with other economic sectors may be in order. This could consist of contacting Eurostat and other statistics bureaus (preferably together with OECD and other users of such data) about possibilities to compile 'tailor-made' data. Furthermore, it is advisable to collect societal and environmental data, which could start with exploratory studies by knowledgable consultants. Finally, ESA collects a lot of relevant data for administrative purposes and for decision-making. These data can also be used to improve ex post evaluation of space investments.

First step

The first step, however, is to apply the SCBA-plus methodology to ESA programmes. In this way, the method can be tested and experience can be gained, leading towards a better assessment of the value of space activities.

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Appendix A Data Gathering techniques

Relevant for evaluation of methodologies	Irrelevant for evaluation of methodologies
Experimental Methods • Time series • Non equivalent groups (benchmarking)	**Experimental Methods** • Post-test control group • Pre-test post-test control group • Solomon four group • Factorial
Survey Methods • Face to face interviews • Focus groups / expert panels • Questionnaire surveys • Crowd sourcing	**Survey Methods** • Mapping techniques • Criterion tests
Field study/social anthropology methods • Case studies	**Field study/social anthropology methods** • Observation(participant/non participant) • Protocol/ critical incidents analysis • Ethnographic techniques • Physical trace analysis • Case studies
Modelling • Economic modelling • Systems analysis (network analysis)	**Modelling** • Game simulation
	Interpretative • Content Analysis • Oral history
	Critical • Discourse Analysis • Critical ethnography
	Participatory • Action research

Source: SEO Economic Research based mostly on European Commission (2002).

Appendix B Criteria for comparing methodologies

Completeness

1. Does the methodology provide the opportunity to distinguish the relevant actors?
2. Does the methodology distinguish direct, indirect and external effects?
3. Does the methodology incorporate quantifiable and unquantifiable effects?
4. Are effects measured comprehensively, does the methodology cover the entire range?
5. How are redundancies avoided, is there a way to make sure that effects are not double counted or falsely included?

Feasibility

6. What dimensions are used or required when incorporating (quantitative) effects, like volume, prices, value, consumption and quality improvement?
7. What kind of data are required, and to which detail, in order to measure the impact in a stable and reliable way?
8. What data are available from public sources, and at what cost?
9. Which steps should be taken to gather or acquire reliable data, and at what cost?

Objectivity

10. Does the methodology provide for means to specify and test a statistical or causal link between space programme activities and investments to effects? Can the critical contribution of space related activities be assessed?
11. Does the application of the methodology lead to a fair view, without double-counting or skewed information?
12. Under what conditions do existing methodologies yield reliable results? Which assumptions are made implicitly or are to be made explicitly? How sensitive are the methodologies when these conditions and assumptions are violated?
13. Are the methodologies static or dynamic: do they provide ‘snap-shot’ information, or can they detect longitudinal impacts and structural changes?

Clarity of calculations

14. Are the calculations easy to understand for non-experts? Or are they a *black box*?
15. Can the results be presented in a clear and concise way?

Clear advice

16. Does the methodology yield unambiguous recommendations for policy makers?

Acceptability

17. Is the methodology accepted by the scientific community?
18. Do policy makers find the methodology attractive?

Appendix C Economic Activities and Statistics

Investments lead to economic activity. In this section a typology of space (related) economic activities is presented. Second a typology of sectors is given to which each of these economic activities belongs. Economic activities can be categorized in many different ways. Various classifications of economic activities exist. This section first gives a brief overview of the most important classifications. Space (related) economic activities are identified thereafter.

Classifications of economic activities

ISIC

The *International Standard Industrial Classification of All Economic Activities* (ISIC) is the international reference classification of productive activities. Over 150 countries currently use classifications of economic activities based on ISIC. In order to attain international comparability, countries are requested to adopt the same general principles and definitions in their industrial classification schemes (United Nations, 2008).

NACE

Within the European Union the mandatory *European Classification of Economic Activities* (NACE) is used (European Commission, 2008b). This system is based on ISIC, ensuring comparability at the European and world level.

NAICS

The *North American Industry Classification System* (NAICS) was developed in the mid-1990s to provide common industry definitions for Canada, Mexico, and the United States. NAICS is developed on the basis of a production-oriented conceptual framework and classifies units, not activities. As a result, the structures of ISIC/NACE and NAICS are substantially different. However, statistical data collected according to NAICS can be aggregated into the two-digit divisions of ISIC/NACE, ensuring comparability of data. In many cases, more detailed links are possible.[42]

Structure

Classification systems are characterised by a finer and finer partition of categories, which makes it possible to collect and present the information at various levels of aggregation. ISIC and NACE for instance have a hierarchical structure with four levels.

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42 A detailed concordance between NAICS and ISIC is published on the NAICS website (USA: *www.census.gov/naics,* Canada: *www.statcan.ca/).*

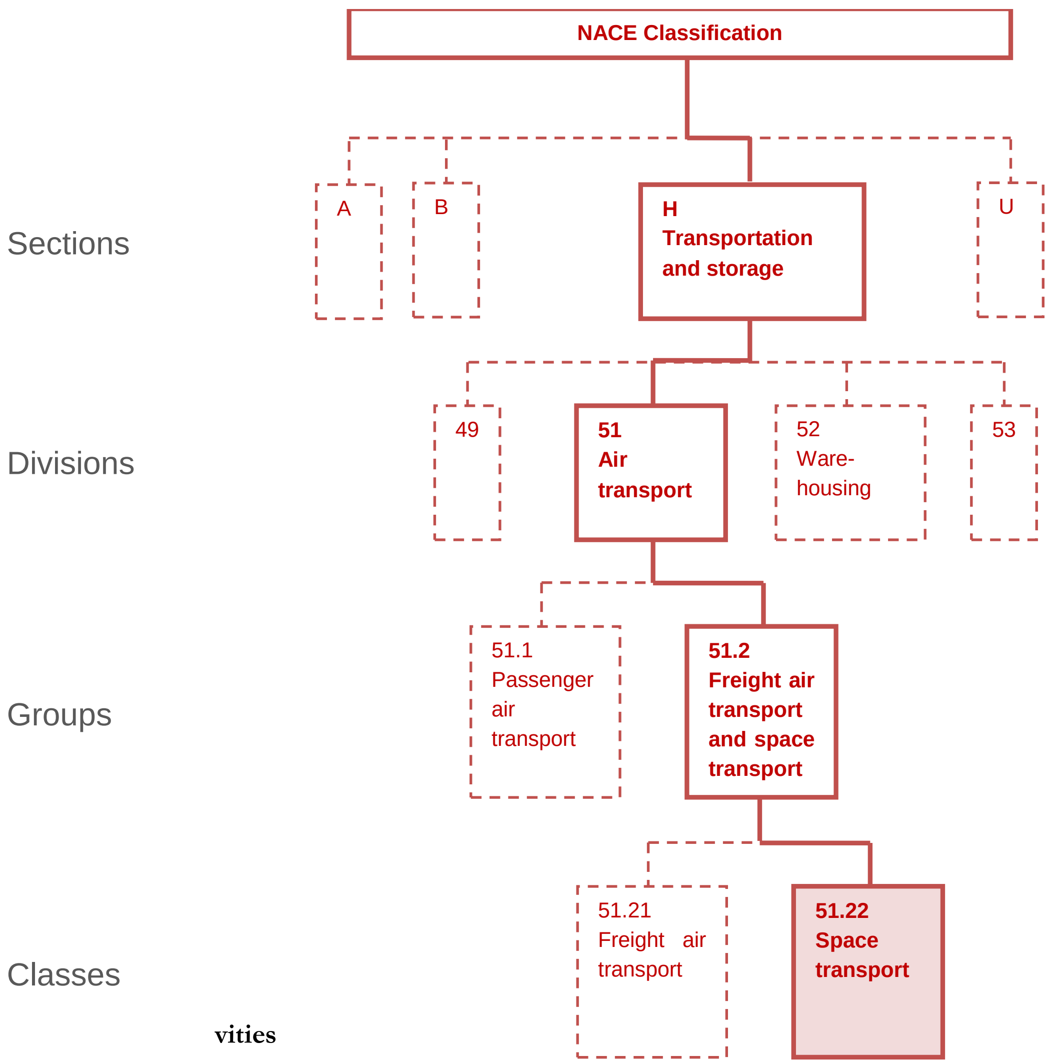
The structure of NACE is described in the NACE Regulation as follows (European Commission, 2006):

1. Sections. A first level consisting of headings identified by an alphabetical code.
2. Divisions. A second level consisting of headings identified by a two-digit numerical code.
3. Groups. A third level consisting of headings identified by a three-digit numerical code.
4. Classes. A fourth level consisting of headings identified by a four-digit numerical code.

The first four digits of the NACE classification system are the same in all European countries. The fifth digit may vary from country to country and further digits are sometimes placed by suppliers of databases.

The activity "Space transport" for instance is identified by the code 51.22. This activity belongs to the group "Freight air transport and space transport" with code 51.2, which in turn belongs to the division "Air Transport" with code 51, which is part of the section "Transportation and storage" identified by the letter H. Figure C.1 shows this example and the hierarchical structure of the NACE classification graphically.

Figure C.1 Illustration of hierarchical structure of the NACE classification



Besides the activity "Space transport" mentioned above, the classification systems contain many other activities which are more or less related to space. None of the classifications systems assign these activities to a single section, division, group or class. Instead space (related) economic activities are scattered across many different divisions and groups. Table C.2 shows the sections and divisions in the NACE and ISIC classification that contain space (related) activities. It also gives some examples of space (related) activities that belong to each division.

Eurostat and the OECD produce economic statistics based on respectively the NACE and ISIC classification systems. As space (related) activities are scattered across multiple divisions and groups, it is difficult to compile statistics for the space sector as a whole. In Technical Note 2, the report on Work Package 2, we elaborate more on this.

Divisions 26, 28, 30, 51 and 72 contain the actual space activities: the manufacturing, launching and monitoring of spacecraft and scientific activities related to space (upstream). Whereas the other divisions contain the space related activities: services to clients of space industries (downstream). Below in this appendix all 4-digit classification codes are given that contain space (related) activities.

Table C.2 NACE and ISIC sections and divisions containing space (related) activities

Section	**Division**	Division Name	Examples of space (related) activities
C Manufacturing	26	Manufacture of computer, electronic and optical products	Navigation equipments, radars, antenna, GPS devices, lenses, telescopes etc
	28	Manufacture of machinery and equipment	Aircraft launching gear
	30	Manufacture of other transport equipment	Spacecraft and launch vehicles, satellites, planetary probes, orbital stations and shuttles
	33	Repair and installation of machinery and equipment	Repair and maintenance of spacecraft, radars, antenna, GPS devices, lenses, installation of communications equipment etc
F Con-struction	43	Specialised construction activities	Installation of satellite dishes and solar energy collectors
H Transportation and Storage	51	Air transport	Launching of satellites and space vehicles, space transport of freight and passengers
	52	Warehousing and support activities for transportation	Services incidental to space transportation
J Information and communication	60	Programming and broadcasting activities	Radio and television broadcasting via satellite
	61	Telecommunications	Satellite linkups, operating maintaining or providing satellite telecommunications infrastructure, satellite tracking etc

M Professional, scientific and technical activities	71	Architectural and engineering activities; technical testing and analysis	Subsurface surveying activities
	72	Scientific research and development	Research and experimental development on natural science and engineering
	74	Other professional, scientific and technical activities	Aerial photography, weather forecasting and environmental consulting
O Public administration and defence; compulsory social security	84	Public administration and defence; compulsory social security	Communications, intelligence and space defence

Note: List compiled by the research team

Relation with sectors

In chapter 2 definitions were given for the space sector, related sectors and other sectors. The space sector is made up of those companies and organisations whose main activities belong to the space activities described above (divisions 26, 28, 30, 51 or 72). The space related sector is made up by organisations whose main activities belong to any of the other divisions in Table C.3. All other companies and organisations whose main activities belong to divisions other than those in Table C.3 are considered to belong to 'Other sectors'.

Table C.3 Space activities

NACE	ISIC	Description	This includes the manufacture of:
26.3	263	Manufacture of communication equipment	data communications equipment, such as bridges, routers, and gateways. transmitting and receiving antenna. mobile communication equipment.
26.51	2651	Manufacture of instruments and appliances for measuring, testing and navigation	aircraft engine instruments. meteorological instruments. radiation detection and monitoring instruments. search, detection, navigation, aeronautical, and nautical equipment, including sonobuoys. radar equipment. GPS devices. radars. laboratory analytical instruments.
26.7	267	Manufacture of optical instruments and photographic equipment	optical positioning equipment. optical measuring and checking devices and instruments. lenses, optical microscopes, binoculars and telescopes. laser assemblies.
28.99	2829	Manufacture of other special-purpose machinery n.e.c.	aircraft launching gear, aircraft carrier catapults and related equipment.
30.3	303	Manufacture of air and spacecraft and related machinery	spacecraft and launch vehicles, satellites, planetary probes, orbital stations, shuttles.
51.22	5120	Space transport	launching of satellites and space vehicles space transport of freight and passengers
72.19	7210	Other research and experimental development on natural sciences and engineering	research and experimental development on natural science and engineering other than biotechnological research and experimental development.

Note: List compiled by the research team

Table C.4 Space related activities

NACE	ISIC	Description	This includes:
33.13	3313	Repair of electronic and optical equipment	the repair and maintenance of goods produced in groups 26.5, 26.6 and 26.7, except those that are considered household goods.
33.16	3315	Repair and maintenance of aircraft and spacecraft	the repair and maintenance of aircraft and spacecraft.
33.2	332	Installation of industrial machinery and equipment	the installation of communications equipment
43.21	4321	Electrical installation	The installation of: telecommunications wiring satellite dishes electric solar energy collectors
52.23	5223	Service activities incidental to air transportation	services incidental to space transportation
60.1	601	Radio broadcasting	activities of radio networks, i.e. assembling and transmitting aural programming to the affiliates or subscribers via over-the-air broadcasts, cable or satellite
60.2	602	Television programming and broadcasting activities	the broadcasting of a television programme by cable companies or satellite television providers.
61.1	611	Wired telecommunications activities	operating and maintaining switching and transmission facilities to provide point-to-point communications via landlines, microwave or a combination of landlines and satellite linkups
61.3	613	Satellite telecommunications activities	operating, maintaining or providing access to facilities for the transmission of voice, data, text, sound and video using a satellite telecommunications infrastructure delivery of visual, aural or textual programming received from cable networks, local television stations or radio networks to consumers via direct-to-home satellite systems. provision of Internet access by the operator of the satellite infrastructure
61.9	619	Other telecommunications activities	provision of specialised telecommunications applications, such as satellite tracking, communications telemetry, and radar station operations operation of satellite terminal stations and associated facilities operationally connected with one or more terrestrial communications systems and capable of transmitting telecommunications to or receiving telecommunications from satellite systems
71.12	7110	Engineering activities and related technical consultancy	Geodetic surveying activities, such as: subsurface surveying activities cartographic and spatial information activities
74.2	742	Photographic activities	aerial photography.
74.9	749	Other professional, scientific and technical activities n.e.c.	weather forecasting activities. environmental consulting.
84.22	8422	Defence activities	administration, supervision and operation of military defence affairs and land, sea, air and space defence forces such as engineering, transport, communications, intelligence, material, personnel and other non-combat forces and commands.

Note: List compiled by the research team

Appendix D Ex ante en ex post SCBA

A distinction is usually made between ex ante evaluations and ex post evaluations of policy changes or investments. If an ex ante evaluation (before the policy change) concerns a completely new policy, like a new investment, it becomes very difficult to produce real empirical evidence. There will always be some kind of conjecture about what the effect will be, without proof that the effect is actually there. Still one can strive to make the evidence base for the estimation of the effects as large as possible, e.g. by collecting information on similar policy changes elsewhere. Ex post evaluations (after the policy change) have the advantage that one should be able to investigate what has happened in reality.

Alternatives

Alternatives can be relatively minor alterations of the same investment, or other investments that intend to have the same goal. In the first form, the question is what is the optimal form of a given type of investment (size, timing, duration, ...). In the second form, the question is if there are other types of investments that may reach the same goal. Defining alternatives is especially relevant in ex ante evaluations, so when the investment decision still has to be made.

Base case

The base case is of importance because SCBA calculates costs and effects relative to the base case. The base case is the state of the world without the investment under consideration and includes behaviour of actors in the absence of that investment. Defining the base case differs between ex ante evaluations and ex post evaluations. In ex ante evaluations of investments, the base case has to be defined before effects can be calculated. The base case involves projections of what the world looks like in the future. Since the future is uncertain, usually different scenarios (different projections of future states of the world) are set up and the costs and effects of an investment are calculated in each of these scenarios[43]. So, in ex ante evaluations, it is necessary to first define the future state(s) of the world, without investment, and then to calculate the effects of the investment given the (assumed) future state(s).

In ex post evaluations, with enough data, we know what the world was like in the past, but we do not know what it would have been like without the investment. The base case is not a first step, but the result of confronting the observed state of the world with the estimated effects. If we would know the base case up front, we could calculate the effects as the difference between the two states (with and without the investment).

[43] In ex ante evaluations, the base case cannot include an investment that is an alternative to the investment that is being evaluated, since the effects of alternative investments should be calculated relative to the base case and then compared to each other.

Box . Ex ante and ex post SCBA and the base case: a road.

Ex ante:
the investment to be evaluated is the building of an additional road. We know that the road will lead to lower travel times and other changes in travel behaviour between A and B. Before we estimate this effect, however, we need to think how travel time would develop without the road. If many more people will buy cars, or if more trade takes place, travel times will probably go up more than if people will not buy more cars or if trade stays like it is now. We could make up two scenarios: 1=many more cars and lorries on the road and 2=the same as now. Next, we estimate the effect of the investment on travel time in each of these scenarios[44].
Ex post:
the investment to be evaluated is the building of an additional road. We may know the travel times in the past, but without further investigation, we do not know by how much travel times have dropped because of the road. Simply comparing travel times before and after the building of the new road is not good enough, if only because traffic flows would have changed without the road as well. If we would know travel times and traffic flows in the hypothetical situation without the road, we could simply calculate the drop in travel times and changes in traffic flows. Knowing the base case is knowing the effects relative to the state of the world that has actually taken place[45].

Programmes of investments
In ex post analysis, one chooses which investments one would like to evaluate. In ex ante analysis, there may not only be a choice as to the precise nature of the investment (alternatives), but also which investments are going to be combined. This increases the complexity in ex ante analysis, for it requires estimating cross-effects between (combinations of) investments. This complexity is only present in ex post analysis if the effects of isolated investments within a programme are to be estimated, for this requires, again, estimations of cross-effects.

Discounting
Discounting is used in ex ante analyses because future costs and effects are worth less today. This is because if the investment would not be carried out, the money would be spent on other policies or projects, which would generate an alternative return. Choosing the right discount rate, including risk premia, can be quite complicated. In ex post analysis, a market derived, risk free discount rate can be applied, and costs and effects can (still) be discounted to the first year of investment. In any case, we advise always to apply sensitivity analysis to the discount rate.

How ESA establishes an investment programme
Space systems in general take many years from the drawing board to actual flight. Consider for instance the development of the Vega launcher, the Galileo satellite navigation system or a science mission like Bepi-Colombo. Planning for these missions started many years ago and has stepped through a number of distinct phases and associated decision making milestones, allowing for the re-direction and alignment of funds and activities.

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44 Assuming that the states of the world are exogenous: the building of the road does not change the propensity to buy cars, trade, etc.

45 Assuming, again, that the building of the road does not change the propensity to buy cars, trade, etc.

ESA's space science programme, for instance, is one of the main building blocks of European co-operation in space. In 1984 ESA's Horizon 2000 long-term plan for space science was established, followed by Horizon 2000+ in 1997. Starting in 2004 with an open call for science themes of the future, ESA's Cosmic Vision 2020 plan was established. The aim of this plan is not so much to identify specific missions but rather to bring about the identification of main research themes (and thereby key technological targets) for the next twenty years. The Cosmic Vision plan identifies today's major scientific questions to be addressed by ESA's future space science missions. The open call resulted in more than 150 ideas and proposals for future missions from the European scientific community. These ideas and proposals were evaluated, considering for instance the critical scientific and technological hurdles that must be taken away, and the expected scientific return.

At regular intervals (typically five years), ESA issues a call for proposals for new space missions in line with the Cosmic Vision long-term plan. A distinction is made between "Cornerstone" missions which are the bigger missions, and "Flexi" missions, which are smaller. Typically around 100 submissions from industrial and academic groups are received, ranging from single page outlines to complete proposal documents. ESA's various scientific committees of experts then evaluate the proposals. These committees include for instance the Astronomy Working Group, the Solar System Working Group, the Fundamental Physics Working Group, the Space Science Advisory Committee and the Science Programme Committee. ESTEC staff members take an initial look at the feasibility of the missions from a technical perspective, providing also a first look at the critical technological hurdles that need to be resolved for individual missions.

From this effort, three or four candidates for each mission slot are chosen to enter an assessment phase. An ESA study scientist and study manager are assigned to each proposal and a one-year feasibility study is undertaken. This is when they will identify any new technology that will be needed. The conclusions of these studies are presented to ESA's scientific committees and other scientists, in two meetings usually held at ESA headquarters in Paris. The committees then make choices about which missions should proceed to 'Phase A'. Phase A involves industrial partners and results in a number of preliminary designs for the spacecraft. These are presented again to the relevant committees, and a final decision on which proposal will be selected for each mission is made.

Furthermore, the identified critical technologies (also for missions that have not made it to Phase A) are input towards ESA's various research & development programmes. ESA's strategy for establishing the content of these programmes is to harmonize its own R&D activities with those of other European and Member State organisations. This strategy is at the base of the European Technology Harmonisation Process which tracks current technology needs and strategic gaps and then works to fulfil them by coordinating European R&D around shared development roadmaps. These roadmaps include agreed objectives, processes and interfaces – and break down the different steps required to attain success into individual 'building blocks', capable of being worked on in parallel and in sequence by the various partners. A European Space Technology Master Plan, compiled annually by ESA provides the overview of the R&D landscape of the continent.

The iterative process as described above for ESA's Science Programme is to a large extent also valid for ESA's other investment programmes.

Once a programme has been agreed by the ESA Member States and funding has been allocated, Invitations to Tender for individual projects are released as scheduled and project activities are started. ESA reports back to the Member States on the status of ongoing programmes and projects, and a certain level of adjustment of programme goals – or even addition of new ones – may be agreed with the participating states.