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Research Report

Quantitative analysis of economic performance in the European space industry: Part of the project "Analysis of the European Space Industry" mandated by the European Space Agency - Directorate of Technical and Quality Management

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Quantitative Analysis of Economic Performance in the European Space Industry

Project “Analysis of the European Space Industry” mandated by the
European Space Agency – Directorate of Technical and Quality Management

Spyros Arvanitis and Martin Wörter
With the cooperation of Arlette Frener, Tim Veseli and Tobias Stucki

ETH Zurich, KOF Swiss Economic Institute,
Section Innovation Economics

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Zurich, April 2014

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1. Introduction

This study is part of the project “Analysis of the European Space Industry” mandated by the European Space Agency (ESA) and refers to the quantitative analysis of the data that were collected in 2011 by a postal survey based on a questionnaire that has been developed earlier and was completed with additional questions for the purpose of the 2011 survey. The survey was addressed to 432 actors (enterprises and institutions) that are related to ESA and was conducted by ESA.

In chapter 2 we discuss the data collection, the data controls that warranted validity and reliability of the data and the construction of the datasets based on the survey2011 that covers the period 2008-2010. In addition, a dataset was constructed based on the results of an earlier survey that referred to the period 2003-2007 (historical data).

The conceptional background of our quantitative approach and some basic methodical remarks are presented in chapter 3. In sum, we distinguish (a) the innovation process that links innovation inputs with innovation outputs and (b) the production process that links production inputs and production outputs.

In chapter 4 we discuss information on the innovation process in the space industry as it appears in the available data of the actors. We distinguish innovation inputs and innovation outputs and discuss also the relationship between them.

The production process is analyzed descriptively in chapter 5 and econometrically in chapter 7. The econometric analysis is the central part of the study and refers to the drivers of productivity, an important indicator of economic performance.

The factors that may hamper innovation (R&D) activities are discussed in chapter 6.

In chapter 8 the time dimension is taken into account through the consideration of the historical data. Chapter 9 concludes.

2. Data

2.1 Data collection, data controls and construction of datasets

For the quantitative analysis we used two sources of data. First, the data on firm (institution) level that were collected in the course of a survey in 2011 and, second, historical data for the period 2003-2007 from an earlier survey of space firms and institutions that were made available to us by ESA.

The survey 2011 was based on an expanded version of the questionnaire used in an earlier survey and covered the period 2008-2010. The additional questions of the questionnaire 2011 referred to knowledge acquisition means and strategies (use of various external knowledge sources; R&D cooperation; extramural (contract) R&D); innovation performance (product and process innovations; patents; licenses); and possible obstacles of innovative activities. This new part of the questionnaire was designed in accordance with the newest (European) Community Innovation Survey (CIS).

Most questions had to be answered separately for each year. In this chapter we present basic statistics of these two data sets that refer to the composition of the datasets by *country* and *type of actor*.

The raw data of the questionnaires were recoded according to a detailed scheme that transformed these data to formats that were appropriate for descriptive and econometric analysis. To this end, we first read all recoded data in an Excel matrix with so many lines as years and responding firms (maximum 3 lines per actor) and hundreds of columns for the detailed information for every question in the questionnaire. In a further step, this Excel-file was transformed to a SAS-dataset for the descriptive analysis (chapter 4 to 6) and to a STATA-dataset for the econometric analysis and the description of the development of the space industry (chapter 7 and 8). The software packages SAS and STATA were then used for quantitative analysis. In last step, plausibility and consistency tests were performed for the variables used in the quantitative analysis based mostly on ratio variables such as turnover per employee or space turnover divided by total turnover, etc.

The data from the original Excel-file provided by the ESA were recoded and read in an Excel-file as described above, so that the variable formats were the same as far a possible. SAS and STATA datasets were also constructed; also a STATA dataset containing selected variables for the analysis of the long period 2003-2010.

2.2 Response rates of the survey 2011

We distinguish three types of actors: large firms (250 and more employees and more than 50 mio. Euro turnover); small- and medium-sized firms (SMEs) (less than 250 employees and less than 50 mio. Euro turnover); research institutions (universities, public and private

research organizations, etc.); and ‘others (incl. government agencies and other public institutions). Table 2.1 shows the composition of the sample of actors to which the questionnaire was sent. The questionnaire was sent to total 432 firms and institutions. About 54% of them are SMEs, most of them rather highly specialized providers of equipment and services. About 28% are larger firms with a wider spectrum of products and services and about 8% are research institutions. The largest country contingents come from France (74), Germany (43) and UK (34); these are also the countries with a strong industrial presence in the space sector.¹

The Tables 2.2a, 2.3a and 2.4a show the composition by country and type of actor of the received answers for the years 2008, 2009 and 2010. The Tables 2.1b, 2.2b and 2.3b contain the corresponding response rates by country and type of actor. Not every actor has sent back answers for each year. The response rates with respect to the type of actor do not differ much from total response rate. Large firms are rather over-represented (response rate of about 49% in 2008). There are significant differences among the countries, but most countries are represented by at least 5 actors.² Austria, Denmark, Finland, Spain and the Netherlands are rather over-represented, Ireland, Greece and Switzerland rather under-represented. The UK shows almost the average overall response rate, Germany and France lie beneath the average. The overall response rate varied between 34.5% (2009) and 36.1% (2008). Given the complexity of the questionnaire the overall response of about 35% can be considered as satisfactory, also as compared with other complex surveys (for example the (European) Community Innovation Survey). Also the representativeness of the responses with respect to the criteria ‘country of origin’ and ‘type of actor’ (large firms; SMEs; research institutions) are considered to be satisfactory.

¹ The Czech Republic, which is also represented in the sample by a high number of actors, is as new member of ESA a special case.

² For Luxembourg we received 2 out of 5 questionnaires sent, for Canada 3 out of 3 questionnaires sent.

Table 2.1: Composition of the sample of actors to which questionnaires were sent

Countries	SME (incl. Small + private research centres)	Large	Public research, Universities, Assoc. & consortium	Others (incl. Government Agencies & other public inst.)	All
Austria	7	3	4	2	16
Belgium	11	9	6	4	30
Canada	1	2	0	0	3
Czech Rep.	26	11	6	2	45
Denmark	5	1	1	0	7
Finland	5	2	0	0	7
France	36	26	1	11	74
Germany	19	15	1	8	43
Greece	16	1	1	1	19
Ireland	25	0	1	0	26
Italy	10	13	2	0	25
Luxembourg	1	4	0	0	5
Netherlands	18	2	4	4	28
Norway	7	2	0	2	11
Portugal	8	2	1	1	12
Spain	9	9	2	4	24
Sweden	7	4	0	0	11
Switzerland	6	2	2	2	12
UK	18	13	1	2	34
Total	235	121	33	43	432

Table 2.2a: Composition of the sample of received answers 2008

Countries	SME (incl. Small + private research centres)	Large	Public research, Universities, Assoc. & consortium	Others (incl. Government Agencies & other public inst.)	All
Austria	5	3	3	1	12
Belgium	4	3	2	2	11
Canada	0	2	0	0	2
Czech Rep.	2	4	2	1	9
Denmark	3	0	1	1	5
Finland	4	1	0	0	5
France	9	13	1	3	26
Germany	6	4	0	2	12
Greece	4	0	0	0	4
Ireland	2	0	0	0	2
Italy	4	6	0	0	10
Luxembourg	0	2	0	0	2
Netherlands	10	1	2	1	14
Norway	3	1	0	0	4
Portugal	2	1	0	1	4
Spain	8	6	0	0	14
Sweden	2	3	0	0	5
Switzerland	1	2	0	0	3
UK	3	7	0	2	12
Total	72	59	11	14	156

Table 2.2b: Composition of the sample of received answers 2008; response rate in %

Countries	SME (incl. Small + private research centres)	Large	Public research, Universities, Assoc. & consortium	Others (incl. Government Agencies & other public inst.)	All
Austria	71.4	100.0	75.0	50.0	75.0
Belgium	36.4	33.3	33.3	50.0	36.7
Canada	0.0	100.0	0.0	0.0	66.7
Czech Rep.	7.7	36.4	33.3	50.0	20.0
Denmark	60.0	0.0	100.0	0.0	71.4
Finland	80.0	50.0	0.0	0.0	71.4
France	25.0	50.0	100.0	27.3	35.1
Germany	31.6	26.7	0.0	25.0	27.9
Greece	25.0	0.0	0.0	0.0	21.1
Ireland	8.0	0.0	0.0	0.0	7.7
Italy	40.0	46.2	0.0	0.0	40.0
Luxembourg	0.0	50.0	0.0	0.0	40.0
Netherlands	55.6	50.0	50.0	25.0	50.0
Norway	42.9	50.0	0.0	0.0	36.4
Portugal	25.0	50.0	0.0	100.0	33.3
Spain	88.9	66.7	0.0	0.0	58.3
Sweden	28.6	75.0	0.0	0.0	45.5
Switzerland	16.7	100.0	0.0	0.0	25.0
UK	16.7	53.8	0.0	100.0	35.3
Total	30.6	48.8	33.3	32.6	36.1

Table 2.3a: Composition of the sample of received answers 2009

Countries	SME (incl. Small + private research centres)	Large	Public research, Universities, Assoc. & consortium	Others (incl. Government Agencies & other public inst.)	All
Austria	4	3	3	1	11
Belgium	4	3	2	2	11
Canada	0	2	0	0	2
Czech Rep.	2	4	2	1	9
Denmark	3	0	1	1	5
Finland	3	1	0	1	5
France	8	12	0	3	23
Germany	6	4	0	2	12
Greece	4	0	0	0	4
Ireland	1	0	0	0	1
Italy	4	5	0	0	9
Luxembourg	0	2	0	0	2
Netherlands	8	2	2	2	14
Norway	3	1	0	0	4
Portugal	2	1	0	1	4
Spain	7	6	0	0	13
Sweden	2	3	0	0	5
Switzerland	1	2	0	0	3
UK	3	7	0	2	12
Total	65	58	10	16	149

Table 2.3b: Composition of the sample of received answers 2009; response rate in %

Countries	SME (incl. Small + private research centres)	Large	Public research, Universities, Assoc. & consortium	Others (incl. Government Agencies & other public inst.)	All
Austria	57.1	100.0	75.0	50.0	68.8
Belgium	36.4	33.3	33.3	50.0	36.7
Canada	0.0	100.0	0.0	0.0	66.7
Czech Rep.	7.7	36.4	33.3	50.0	20.0
Denmark	60.0	0.0	100.0	0.0	71.4
Finland	60.0	50.0	0.0	0.0	71.4
France	22.2	46.2	0.0	27.3	31.1
Germany	31.6	26.7	0.0	25.0	27.9
Greece	25.0	0.0	0.0	0.0	21.1
Ireland	4.0	0.0	0.0	0.0	3.8
Italy	40.0	38.5	0.0	0.0	36.0
Luxembourg	0.0	50.0	0.0	0.0	40.0
Netherlands	44.4	100.0	50.0	50.0	50.0
Norway	42.9	50.0	0.0	0.0	36.4
Portugal	25.0	50.0	0.0	100.0	33.3
Spain	77.8	66.7	0.0	0.0	54.2
Sweden	28.6	75.0	0.0	0.0	45.5
Switzerland	16.7	100.0	0.0	0.0	25.0
UK	16.7	53.8	0.0	100.0	35.3
Total	27.7	47.9	30.3	37.2	34.5

Table 2.4a: Composition of the sample of received answers 2010

Countries	SME (incl. Small + private research centres)	Large	Public research, Universities, Assoc. & consortium	Others (incl. Government Agencies & other public inst.)	All
Austria	4	3	3	1	11
Belgium	4	4	1	3	12
Canada	0	2	0	0	2
Czech Rep.	2	3	2	2	9
Denmark	3	0	1	1	5
Finland	3	1	0	1	5
France	8	14	1	2	25
Germany	6	4	0	2	12
Greece	4	0	0	0	4
Ireland	1	0	0	0	1
Italy	3	6	0	0	9
Luxembourg	0	2	0	0	2
Netherlands	8	2	2	3	15
Norway	3	1	0	0	4
Portugal	2	1	0	1	4
Spain	8	6	0	0	14
Sweden	1	3	0	0	4
Switzerland	1	2	0	0	3
UK	2	7	0	2	11
Total	63	62	10	17	152

Table 2.4b: Composition of the sample of received answers 2010; response rate in %

Countries	SME (incl. Small + private research centres)	Large	Public research, Universities, Assoc. & consortium	Others (incl. Government Agencies & other public inst.)	All
Austria	57.1	100.0	75.0	50.0	68.8
Belgium	36.4	44.4	16.7	75.0	40.0
Canada	0.0	100.0	0.0	0.0	66.7
Czech Rep.	7.7	27.3	33.3	100.0	20.0
Denmark	60.0	0.0	100.0	0.0	71.4
Finland	60.0	50.0	0.0	0.0	71.4
France	22.2	53.8	100.0	18.2	33.8
Germany	31.6	26.7	0.0	25.0	27.9
Greece	25.0	0.0	0.0	0.0	21.1
Ireland	4.0	0.0	0.0	0.0	3.8
Italy	30.0	46.2	0.0	0.0	36.0
Luxembourg	0.0	50.0	0.0	0.0	40.0
Netherlands	44.4	150.0	50.0	75.0	53.6
Norway	42.9	50.0	0.0	0.0	36.4
Portugal	25.0	50.0	0.0	100.0	33.3
Spain	88.9	66.7	0.0	0.0	58.3
Sweden	14.3	75.0	0.0	0.0	36.4
Switzerland	16.7	100.0	0.0	0.0	25.0
UK	11.1	53.8	0.0	100.0	32.4
Total	26.8	51.2	30.3	39.5	35.2

2.3 Historical data 2003-2007

Table 2.5 gives an overview about the response pattern in the historical data (2003-2007). It shows the number of observations per country and year. In total and at a maximum we have 315 observations – 63 observations per year. Spain, UK, Netherlands, and France show the greatest number of observations and Austria, Finland, Norway, Sweden, Switzerland and Luxembourg the lowest figures.

Table 2.5: Number of observations per country

Country	2003	2004	2005	2006	2007	Total
Austria	1	1	1	1	1	5
Belgium	5	5	5	5	5	25
Canada	2	2	2	2	2	10
Denmark	2	2	2	2	2	10
Finland	1	1	1	1	1	5
France	8	8	8	8	8	40
Germany	6	6	6	6	6	30
Italy	4	4	4	4	4	20
Netherlands	8	8	8	8	8	40
Norway	1	1	1	1	1	5
Portugal	3	3	3	3	3	15
Spain	10	10	10	10	10	50
Sweden	1	1	1	1	1	5
Switzerland	1	1	1	1	1	5
United Kingdom	9	9	9	9	9	45
Luxembourg	1	1	1	1	1	5
Total	63	63	63	63	63	315

3. Concept of analysis and methodical remarks

We use the concept of an *augmented production function* that links production inputs to outputs in order to structure both our descriptive (chapters 3 to 6) and econometric analysis (chapter 7). In the simplest version of the *production process* of a firm, inputs such as labour, physical capital and knowledge capital (proxied, e.g., by R&D investment or more exactly, by cumulated 'R&D capital') are combined via production techniques to products (goods and services). Augmented is this production process as compared to the more traditional version that takes only labour and physical capital into consideration because of the use of knowledge capital (see Griliches 1979; 1998).

A further useful conceptual element refers to the generation of knowledge in the *innovation process* of the firm as described in the *knowledge production function* that links innovation inputs (e.g., external innovation-relevant knowledge, R&D investment, R&D personnel) to innovation outputs (patents, new products, new processes) (see Pakes and Griliches 1984; also Crèpon et al. 1998).

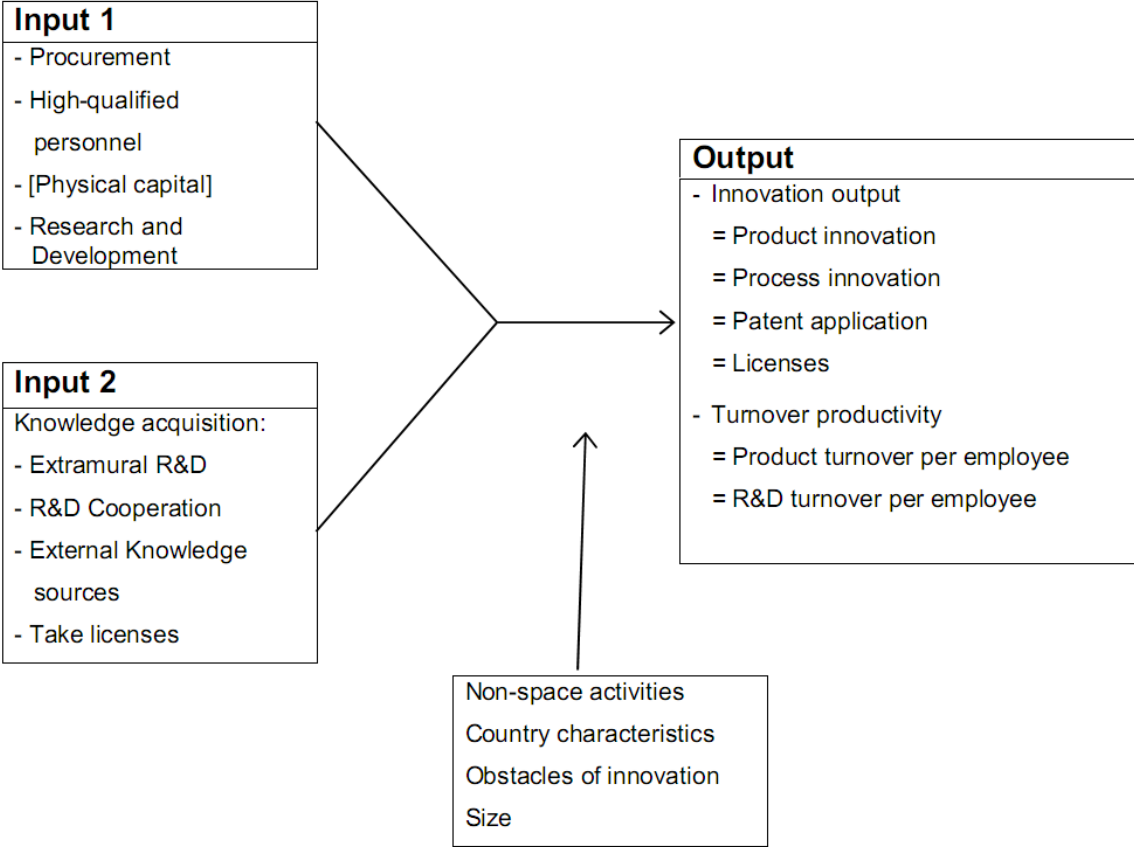
Most microeconomic theory is developed based on the concept of the *representative (average) agent*. In industrial partial analysis (i.e. without consideration of the effects of a specific industry on the rest of the economy and the effects of the rest of the economy on a specific industry, respectively) the concepts at the firm level can be transferred to the industry level (see Scherer and Ross 1990).

Figure 3.1 illustrates the underlying concepts of production function and knowledge production function for the case of space industry as mirrored in the data and described in the next chapters. The first group of inputs (Input 1) refers to procurement; high-qualified personnel, R&D inputs and physical capital, for which unfortunately not enough data are available. The second input group (Input 2) contains types of knowledge acquisition: use of external knowledge sources (e.g. from clients, suppliers, universities, etc.); extramural (contract) R&D; R&D cooperation (R&D joint ventures; technology exchange agreements, etc.); and licenses. The innovation inputs are combined in the innovation process to generate patents and licenses (in a first stage); new products and new processes (in a later stage). The production inputs are combined in the production process to products and services. In case of the space industry we expect that non-space activities, country characteristics, and the size of the actors would have an influence on the transformation of inputs to outputs. Finally, both the innovation and the production process may be hampered by innovation obstacles (e.g. lack of funds, lack of qualified personnel, lack of information, etc.).

Our quantitative analysis in the chapters 4 to 7 is based on the data of the survey 2011. The available data allow only partially the specification of a production function (see chapter 7) that can be econometrically estimated. For this reason we constrain ourselves in the next

chapters to a descriptive analysis of inputs and outputs of the *innovation process* (chapter 4) and the *production process* (chapter 5), respectively. For the descriptive analysis we use only the data for 2010 (the last available year for which data are available) and not the means of the three years because the number of available observations varies strongly between years, so that differences between years cannot be clearly identified.³ This is particularly the case for monetary variables as well as for the information on the presence of the firms in the procurement and sales markets. For this reason we prefer to present the data, e.g., for turnover or employment, not in absolute numbers but rather in relative terms as shares or intervals of values, thus emphasizing the *structural nature* of the underlying information. On the other hand, the data on innovation activities are reported only for the entire 3-year-period 2008-2010.

Figure 3.1: Concept of analysis



³ For this reason we use in chapter 8 on the evolution of the space sector not the means of turnover variables but quantile or median variables.

4. Innovation process

4.1 Innovation inputs

R&D investment is the most important innovation input – of course in combination with the R&D personnel, whose high qualification is a precondition for the success of R&D. Table 4.1 shows the *R&D intensity* (R&D investment divided by total turnover) of the actors in our sample. 27.8% of firms, most of them SMEs, reported no R&D investment, which is rather astonishing for this kind of business. About 39% of firms had a R&D intensity of 5%, 25% had an intensity that is higher than 5% but less than 20%, and about 8% reported intensity values higher than 20%. Most large firms (60%) reported values of R&D intensity up to 5%. As compared to other industries the R&D intensity of the firms in our sample is clearly above-average.

The knowledge that is generated in the firms' R&D departments is based to a considerable extent on external knowledge that may come from different sources (e.g. clients, suppliers, competitors, universities, etc.; see, e.g., Clevorick et al. 1995), from licensing of external knowledge, R&D cooperation projects, and contract R&D (see, e.g., Cassiman and Veugelers 2006). The firms in our sample reported on a five-point Likert scale how important has been for them each of the external sources listed in Table 4.2. In accordance with information for other industries 'clients' are the most important information source (75% of firms reporting 4 or 5 on the five-point scale). Knowledge from universities and other higher education institutions is the second most important source, publicly available information from conferences, trade fairs and exhibitions is the third most important source (about 49%). The high percentage of firms using intensively university information as well as information from public research institutions is a specific characteristic of the space sector.

Table 4.3 contains information on the likelihood of the knowledge acquisition strategies 'R&D cooperation', 'extramural R&D' and 'take licenses'. The most frequently used strategy is R&D cooperation (about 64% of firms), next to it extramural R&D (about 37%). Only about 13% of the firms use licensed knowledge. Extramural R&D and licensing are more frequently used by larger firm than SMEs. Not astonishingly, research institutions tend to use almost exclusively R&D cooperation as acquisition strategy.

Particularly interesting for the actors in space sector is the presence in different technological fields that are closely related to space activities. Our questionnaire contained a comprehensive list of such technologies. Table 4.4b documents in detail how many firms reported activities in a certain technological area (firms could report more than one technological field). On the whole we identified 385 such 'market presence counts', i.e. on average 2.5 per actor (firm or institution). This is a hint that *technological diversification* is on average rather low, which is not astonishing given the large number of SMEs in our

sample (about 54%). Table 4.4a presents a summary of the information in Table 4.4b. The technological areas with the four highest shares of ‘market presence counts’ are: ‘space system software’ (17.7%); ‘mechanisms and tribology’ (8.3%); ‘system design & verification’ (7.5%) and ‘structures and pyrotechnics’ (7.0%). These four technological areas amount to about 40% of all counts. The four lowest shares were found for ‘ECLS and ISRU’, ‘Aero-dynamics’, ‘automation-telepresence robotics’ and ‘quality, dependability & safety’ (all four shares are less than 1.3%).

Table 4.1: *Internal space R&D investment* as percentage of total turnover (R&D intensity)

		0	Up to 5%	5%-20%	> 20%
All	N	22	31	20	6
	%	27.8	39.3	25.3	7.6
Large firms	N	6	18	5	1
	%	20.0	60.0	16.7	3.3
SME	N	13	9	13	5
	%	32.5	22.5	32.5	12.5

Table 4.2: External innovation-relevant knowledge sources

Sources	Importance: percentage of firms reporting 4 or 5 on a five-point Likert scale
<i>Market sources</i>	
Clients	75.0
Suppliers	37.5
Competitors	40.2
Consultants, commercial labs, private R&D institutes	32.1
<i>Institutional sources</i>	
Universities, other higher education institutions	55.4
Governmental, other public research institutions	48.2
<i>Publicly available sources</i>	
Conferences, trade fairs, exhibitions	49.1
Scientific journals, trade / technical publications	46.4
Professional and industry associations	28.6

Table 4.3: Knowledge acquisition strategies; percentages of firms using a certain strategy

		R&D cooperation	Extramural R&D	Take Licenses
All	N	71	39	14
	%	63.9	37.1	13.5
Large firms	N	27	19	9
	%	64.3	45.2	23.1
SME	N	26	11	4
	%	56.5	26.2	8.9
Research institutes	N	5	1	0
	%	83.3	25.0	0.0

Firms could report more than one strategy.

Table 4.4a: Summary: Number of firms that are active in a *technological area* (N= 154); firms can be active in more than one technological area

Technological Area	Number of firms	Percentage
<i>Areas with the four highest shares</i>		
Space system software	68	17.7
Mechanisms and tribology	32	8.3
System design & verification	29	7.5
Structures and pyrotechnics	27	7.0
<i>Areas with the four lowest shares</i>		
ECLS and ISRU	2	0.5
Aero-thermodynamics	3	0.8
Automation-Telepresence robotics	4	1.0
Quality, dependability & safety	5	1.3

Table 4.4b: Number of firms that are active in a technological area (N=154); firms can be active in more than one technological area

Technological Area	Number of firms	Percentage
On-board data system	23	6.0
Payload data processing	13	3.4
On-board data management	10	2.6
Space system software	68	17.7
Advanced software technologies	10	2.6
Space segment software	10	2.6
Ground segment software	19	4.9
Ground data processing	14	3.6
EO and payload data exploitation	15	3.9
Spacecraft electrical power	6	1.6
Power system architecture	0	0.0
Power generation technologies	3	0.8
Energy storage technologies	0	0.0
Power conditioning and distribution	3	0.8
Spacecraft environment & effects	12	3.1
Space environment	5	1.3
Environment effects	3	0.8
Space weather	4	1.0
Space system control	18	4.7
Space system architecture & autonomy	5	1.3
Space segment guidance, navigation & control (GNC)	13	3.4
RF payload and systems	22	5.7
Telecommunication subsystems	3	0.8
Radio navigation subsystems	4	1.0
TT&C subsystems	3	0.8
RF payloads	6	1.6
Microwave & millimetre wave technologies & equipment	6	1.6
Electromagnetic technologies & techniques	12	3.1
Antennas	9	2.3
Wave interaction and propagation	0	0.0
EMC-RFC-ESD	3	0.8
System design & verification	29	7.5
Mission and system specification	8	2.1
Collaborative and concurrent engineering	3	0.8
System analysis and design	7	1.8
Verification and AIT	11	2.8
Mission control & operations	22	5.7
Mission operations	8	2.1
Mission control systems (MCS)	14	3.6
Flight dynamics and precise navigation	10	2.6
Flight dynamics	8	2.1
Precise navigation	2	0.5

continued

Space debris	10	2.6
Measurements	2	0.5
Modelling, databases and risk analysis	6	1.6
Hyper-velocity impact and protection	2	0.5
Mitigation	0	0.0
Ground station system & networking	13	3.4
Ground station system	7	1.8
Ground communications networking	6	1.6
Automation-Telepresence robotics	4	1.0
Applications and concepts	0	0.0
Automation and robotics systems	3	0.8
Automation/robotics components & technologies	1	0.2
Life and physical sciences	11	2.9
Instrumentation in support of life sciences	3	0.8
Instrumentation supporting physical sciences	5	1.3
Applied life science technologies	3	0.8
Applied physical science technologies	0	0.0
Optics	14	3.6
Optical system engineering	7	1.8
Optical component technology & materials	1	0.2
Optical equipment & instrument technology	6	1.6
Optoelectronics	8	2.1
Laser technologies	3	0.8
Detector technologies	4	1.0
Photonics	1	0.2
Aero-thermodynamics	3	0.8
Computational tools	1	0.2
Ground based facilities	0	0.0
Flight testing	1	0.2
Multidisciplinary tools	1	0.2
Propulsion	6	1.6
Chemical propulsion technologies	1	0.2
Electric propulsion technologies	2	0.5
Advanced propulsion	1	0.2
Supporting propulsion technologies & tools	2	0.5
Structures and pyrotechnics	27	7.0
Inflatable and deployable structures	2	0.5
High stability & high precision spacecraft structures	5	1.3
Structural design & verification methods & tools	3	0.8
Hot structures	1	0.2
Active/adaptive structures	0	0.0
Damage tolerance and health monitoring	2	0.5
Launchers, re-entry vehicles, planetary vehicles	5	1.3
Crew habitation, safe haven and EVA suits	1	0.2
Meteorite and debris shield design and analysis	2	0.5
Advanced structural concepts and materials	6	1.6

continued

Pyrotechnics technologies	0	0.0
Thermal	16	4.2
Heat transport technologies	4	1.0
Cryogenics and refrigeration	3	0.8
Thermal protection	6	1.6
Heat storage and rejection	1	0.2
Thermal analysis tools	2	0.5
ECLS and ISRU	2	0.5
Environmental control and life support (ECLS)	1	0.2
in-situ resources utilisation (ISRU)	1	0.2
EEE components and quality	6	1.6
Methods and processes for radiation hardness assurance	2	0.5
EEE components technologies	4	1.0
Materials and processes	6	1.6
Novel materials	2	0.5
Materials processes	3	0.8
Cleanliness and sterilisation	1	0.2
Quality, dependability & safety	5	1.3
System dependability and safety Software quality	5	1.3
Mechanisms and tribology	32	8.3
Mechanisms core technologies	7	1.8
Non-explosive release technologies	5	1.3
Exploration tool technologies	3	0.8
Control electronics technologies	4	1.0
MEMS technologies	0	0.0
Tribology technologies	4	1.0
Mechanism engineering	9	2.3

4.2 Innovation outputs

We distinguish four kinds of innovation outputs: patent (applications) that can be considered as ‘intermediates’ to new products and processes; licenses that are based on existing patents; and product and process innovation that are ‘new to market’. Table 4.5 presents information on such outcomes for the space sector that were reported by the actors in our sample for the period 2008-2010.

The space sector shows a high propensity to introduce products that are ‘new to market’. About 70% of all firms reported the introduction of such innovative products. This percentage is considerably higher than the respective percentage, for example, in the most innovative German manufacturing industries (chemical industry: 45%; electrical machinery: 38%; machinery: 32%; automobile industry: 34%; this information refers to 2010; see Rammer et al. 2012). The share of innovative firms is about 85% for large firms and considerably lower for the SMEs (about 52%).

The share of firms introducing processes that are ‘new to market’ is about 45%. Large firms tend to introduce more often such new processes than SMEs (54% versus 33%). Also for this kind of innovations shows the space sector a remarkable high share of innovating firms as compared, for example, with German innovative industries (for 2010: electrical machinery: 39%; chemical industry: 35%; machinery: 34%; automobile industry: 34%; see Rammer et al. 2012).

Also the propensity to patent is exceptionally high in the space sector: about 40% of all firms reported at least 1 patent application in the period 2008-2010. For example, the respective shares for innovative Swiss industries for the period 2006-2008 are considerably lower: chemical industry: about 28%; electronics/instruments: about 33%; machinery: about 30%; see Arvanitis et al. 2010). As expected the patenting propensity is considerably higher for large firms than for SMEs: 61% versus 18%).

Finally, about 15% of all firms license their new knowledge to other firms. In this case the differences between large firms and SMEs are small.

Table 4.5: Space innovation output

		Product innovation: new to market	Process innovation: new to market	Patent applications	Give Licenses ^(*)
All	N	69	41	42	16
	%	69.7	45.6	40.0	15.2
Large firms	N	35	20	24	5
	%	85.4	54.1	61.5	13.2
SME	N	21	12	8	5
	%	52.5	33.3	17.8	10.9
Research institutes	N	2	1	1	0
	%	66.7	33.3	25.0	0.0

(*): The share of 'All' is larger than the respective shares for 'Large firms' and 'SME' because 3 of the 4 firms of the category 'other' that has not been considered explicitly in the above table have also licenses.

4.3 Correlations: innovation output and knowledge acquisition strategies

The available data did not allow the estimation of a knowledge production function. As a (weak) substitute we provide some information on the *correlations* between innovation inputs and innovation outputs (Table 4.6). The existence of intramural and extramural R&D activities correlate positively with patenting activities but, rather unexpected, not with introduction of product or process innovations. Further, rather astonishingly, R&D cooperation and the knowledge acquisition from other firms or institutions via licenses correlate negatively with product and process innovation (only licensing). A possible explanation for the negative correlations between product and process innovations and R&D, R&D cooperation and licenses might be that product and process innovations were reported for the entire firm (i.e. including non-space activities) thus covering a wider spectrum of novelties, while R&D inputs are measured only for the space department. Then it is possible that firms that have only or mainly space activities may show a lower innovation propensity than firms with stronger diversified activities.

Table 4.6: Correlations between innovation outputs and innovation inputs

		Product innovation: new to market	Process innovation: new to market	Patent applications	Give Licenses
Intramural R&D	R	-0.136	-0.208	0.283**	-0.006
	N	58	52	62	61
Extramural R&D	R	0.007	-0.054	0.453***	0.075
	N	93	83	99	100
R&D cooperation	r	-0.252**	-0.097	0.252	0.025
	N	95	86	103	102
Take Licenses	r	-0.221**	-0.350***	0.091	0.361***
	N	92	83	100	103

All variables are binary variables; ***, ** and * denote statistical significance at the 1%, 5% and 10% test level, respectively.

4.4 Summary

The technological areas with the four highest shares of ‘market presence counts’ are: ‘space system software’ (17.7%); ‘mechanisms and tribology’ (8.3%); ‘system design & verification’ (7.5%) and ‘structures and pyrotechnics’ (7.0%). These four technological areas amount to about 40% of all counts. On the whole we identified 385 such ‘market presence counts’, i.e. on average 2.5 per actor (firm or institution). This is a hint that *technological diversification* is on average rather low, which is not astonishing given the large number of SMEs in our sample (about 54%).

About 39% of firms had a *R&D intensity* of 5%, 25% an intensity that is higher than 5% but less than 20%, and about 8% reported intensity values higher than 20%. Most large firms (60%) reported values of R&D intensity up to 5%. As compared to other industries the R&D intensity of the firms in our sample is clearly above-average.

With respect to *external innovation-relevant knowledge sources*, the high percentage of firms using intensively university information as well as information from public research institutions is a specific characteristic of the space sector.

The most frequently used *strategy of knowledge acquisition* is R&D cooperation (about 64% of firms), next to it extramural R&D (about 37%). Only about 13% of the firms use licensed knowledge.

The space sector shows a high propensity to introduce *products and processes that are ‘new to market’*. About 70% of all firms reported the introduction of such innovative products. This percentage is considerably higher than the respective percentage, for example, for such innovative industries as chemicals, automobile and machinery for Germany. About 45% of firms introduced new processes.

Also the *propensity to patent* is exceptionally high in the space sector, also as compared to such Swiss innovative industries as chemicals, electronics/instruments and machinery: about 40% of all firms reported at least 1 patent application in the period 2008-2010.

The correlations between innovation inputs and innovation outputs do not allow clear-cut conclusions about the efficacy of inputs.

5. Production process

5.1 Production inputs

5.1.1 Procurement markets

Our questionnaire contained a comprehensive list of procurement markets or market segments. Table 5.1a contains information about the main procurement markets, in which the actors in our sample have been active in 2010. Table 5.1b documents in detail how many firms reported activities in a certain market segment (firms could report more than one market segment). On the whole we identified 123 such ‘market presence counts’, i.e. on average 0.8 per actor (firm or institution). Procurement activities were focussed on the market segment ‘spacecraft’ (about 70% all ‘market presence counts’). About 41% of all ‘market presence counts’ referred to the sub-segment of ‘spacecraft components and materials’. Procurement activities in ‘ground systems and activities’ were reported in about 18% of all cases, activities in ‘launchers’ in about 12% of all cases.

Table 5.1a: Summary: Number of firms that are active in a *procurement market* (N = 154); firms can be active in more than one procurement market

Procurement markets	Number of firms	Percentage
SPACECRAFT	86	69.9
Spacecraft systems	0	0.0
Spacecraft subsystems	0	0.0
Spacecraft equipments	20	16.2
Spacecraft components and materials	51	41.5
Spacecraft engineering services	15	12.2
GROUND SYSTEMS AND ACTIVITIES	22	17.9
LAUNCHERS	15	12.2

Table 5.1b: In detail: Number of firms that are active in a *procurement market* ($N_{\text{tot}} = 154$); firms can be active in more than one procurement market

Procurement markets	Number of firms	Percentage
SPACECRAFT	86	69.9
Spacecraft systems	0	0.0
Communication / Navigation Satellites	0	0.0
EO/meteorology satellites	0	0.0
Science satellites	0	0.0
Space exploration probes	0	0.0
Unmanned space infrastructure	0	0.0
Manned space infrastructure	0	0.0
Spacecraft subsystems	0	0.0
Satellite buses	0	0.0
Telecom payloads (BSS, FSS, MSS, broadband...)	0	0.0
Navigation payloads	0	0.0
Optical instruments	0	0.0
Radar instruments	0	0.0
Other instruments	0	0.0
Microgravity payloads	0	0.0
Robotic exploration payloads	0	0.9
Spacecraft equipments	20	16.2
<i>Spacecraft – structures / tanks / mechanisms</i>	<i>0</i>	<i>0.0</i>
Primary structures	0	0.0
Secondary structures	0	0.0
Pressurized tanks	0	0.0
Un-pressurized tanks	0	0.0
Cryogenic tanks	0	0.0
Pointing / positioning mechanisms	0	0.0
Storage / deployment mechanisms	0	0.0
Special mechanisms	0	0.0
Robotics (manipulators, effectors)	0	0.9
<i>Spacecraft - electrical power</i>	<i>6</i>	<i>4.9</i>
Solar arrays	2	1.6
PCU/PDU	0	0.0
BAPTAs	0	0.0
Batteries	2	1.6
Harnesses	2	1.6
Power electronics	0	0.0
<i>Spacecraft - thermal control equipment</i>	<i>3</i>	<i>2.4</i>
Active devices	3	2.4
Passive devices	0	0.0

Continued

<i>Spacecraft - TT&C</i>	2	1.6
Sensors	1	0.8
Actuators	0	0.0
Atomic clocks	0	0.0
Flight dynamics O/B software	1	0.8
<i>Spacecraft – propulsion</i>	3	2.4
Apogee booster motors	0	0.0
Chemical thrusters	0	0.0
Cold gas thrusters	2	1.6
Electrical thrusters	1	0.8
<i>Spacecraft - data / signal handling / processing</i>	2	1.6
Digital electronics	0	0.0
Analog signal electronics	2	1.6
Microwave electronics	0	0.0
O/B software	0	0.0
<i>Spacecraft - antenna systems</i>	4	3.3
Antennas	0	0.0
Waveguides/Feeds	4	3.3
Spacecraft components and materials	51	41.5
Valves, tubes, fittings	6	4.9
Electromechanical parts for mechanisms	3	2.4
Mechanical components for mechanisms	4	3.3
Cables, connectors, relays, PCBs	1	0.8
Transducers	4	3.3
Electronic components passive	7	5.7
Electronic components active	3	2.4
Electronic components programmable	0	0.0
Solar cells	1	0.8
TWT	3	2.4
Metal forms	3	2.4
Carbon fibres	4	3.3
Chemical products (resins, paints, glues, ...)	2	1.6
Optical components	2	1.6
Optical materials (laser crystals, non-linear, ...)	0	0.0
Pyrotechnical devices	0	0.0
Propellant	4	3.3
Other components	4	3.3

Spacecraft engineering services	15	12.2
Software development	3	2.4
Test and space qualification	3	2.4
Engineering analysis support	0	0.0
System/Mission analysis support	0	0.0
Custom semiconductor development	1	0.8
Quality assurance support	0	0.0
Independent verification and validation	2	1.6
Mechanical machining / processing	1	0.8
Central procurement	2	1.6
Other services	3	2.4
GROUND SYSTEMS AND ACTIVITIES	22	17.9
Ground systems and activities	3	2.4
Systems of systems	3	2.4
Ground segment systems	5	4.0
Spacecraft Control centers	3	2.4
Mission/payload operation centers	0	0.0
Ground stations	2	1.6
Ground Equipment / components / software / services	14	11.4
Antenna systems	2	1.6
RF transmit / receive equipment	1	0.8
Baseband equipment and software	1	0.8
In-orbit calibration & testing equipment	0	0.0
Control center software	1	0.8
Flight dynamics software	0	0.0
Spacecraft and payload simulators	0	0.0
Mission analysis software	0	0.0
Payload operation SW applications	0	0.0
Networking equipment & software	2	1.6
Ground support equipment	0	0.0
Spacecraft operational support services	0	0.0
Launch operational support services	2	1.6
Ground systems maintenance	0	0.0
CAE software development	0	0.0
Other equipment	0	0.0
Propellant	2	1.6
Other components	3	2.4

LAUNCHERS	15	12.2
Launcher system	5	4.0
Mission analysis	0	0.0
Launch system engineering	0	0.0
Guidance Navigation Control	0	0.0
Software	3	2.4
Avionics	0	0.0
Health monitoring systems	2	1.6
Lox/H2 propulsion	4	3.2
Propulsion system engineering	0	0.0
Turbopumps	1	0.8
Combustion components	1	0.8
Nozzles	1	0.8
Equipment	1	0.8
Storable propulsion	1	0.8
Propulsion system engineering	0	0.0
Tubopumps	0	0.0
Combustion components	0	0.0
Nozzles	0	0.0
Equipment	1	0.8
Solid propulsion	1	0.8
Propulsion system engineering	0	0.0
Bare motor case	0	0.0
Thermal protection	0	0.0
Propellant grain	0	0.0
Nozzles	0	0.0
Igniters	1	0.8
Lox/HC propulsion	3	2.4
Propulsion system engineering	0	0.0
Tubopumps (fuel)	0	0.0
Combustion components	0	0.0
Nozzles	0	0.0
Equipment	3	2.4
Launchers - stage and equipment	1	0.8
Stage system engineering	0	0.0
Stage propulsion engineering	1	0.8
Stage structures	0	0.0
Payload adapters	0	0.0
Fairings	0	0.0
Propellant tanks	0	0.0
High pressure tanks	0	0.0
Equipment	0	0.0
TPS and hot structures	0	0.0

5.1.2 Human capital endowment

Table 5.2 shows information on the (total) employment share of *space R&D personnel* by type of actors. About 55% of all firms reported employment shares of space R&D personnel higher than 20%, which is an extraordinarily high percentage as compared with other industries. About 31% of all firms reported employment shares that are larger than 40%. There are considerable differences between large firms and SMEs, but they refer to the two categories ‘5%-20%’ and ‘20%-40%’. Both groups of firms show comparable large percentage of firms with space R&D personnel shares larger than 40%. A comparison with the figures for R&D investment in Table 4.1 shows that the R&D process in space sector is highly personnel-intensive. For the vast majority of firms space R&D investments amount to less than 20% of total turnover, while most of them have a much higher percentage of total employment in space R&D activities.

According to the information in Table 5.3 about 20% of all firms have an employment share of *space engineering and design personnel* of more than 40%. The differences between large firms and SMEs with respect to this personnel category are small.

Table 5.4 contains information on the employment shares of a further category of high-qualified personnel, namely personnel for the *development and production of software*. About 24% of all firms reported employment shares for this personnel category of more than 40%. Also in this case the differences between large firms and SMEs are relatively small.

On the whole, space actors seem to be well-equipped with high-qualified personnel in R&D, engineering and design as well as software development.

Table 5.2: Employment share of space *R&D* personnel

		0	Up to 5%	5%-20%	20%-40%	> 40%
All	N	4	12	22	21	27
	%	4.7	14.0	25.5	24.4	31.4
Large firms	N	1	5	12	5	9
	%	3.1	15.6	37.6	15.6	28.1
SME	N	2	6	7	13	13
	%	4.9	14.6	17.1	31.7	31.7
Research institutions	N	0	1	1	1	2
	%	0.0	20.0	20.0	20.0	40.0

Table 5.3: Employment share of space *engineering and design* personnel

		0	Up to 5%	5%-20%	20%-40%	> 40%
All	N	18	4	17	11	12
	%	29.0	6.5	27.4	17.7	19.4
Large firms	N	5	2	9	4	5
	%	20.0	8.0	36.0	16.0	20.0
SME	N	11	2	7	4	5
	%	38.0	6.9	24.1	13.8	17.2

Table 5.4: Employment share of space *software development and production* personnel

		0	Up to 5%	5%-20%	20%-40%	> 40%
All	N	22	11	14	6	17
	%	31.4	15.7	20.0	8.6	24.3
Large firms	N	8	4	6	2	8
	%	28.6	14.3	21.4	7.1	28.6
SME	N	11	7	5	2	8
	%	33.3	21.2	15.2	6.1	24.2

5.2 Production outputs

5.2.1 Turnover

Total turnover and non-space turnover

Table 5.5 shows the distribution of firms and institutions in our sample in 8 intervals of turnover values. About 67% of all actors (mostly firms) had a total turnover in 2010 of less than 50 mio. Euro. About 14% of all firms are very small having a turnover of less than 1 mio. Euro, about 10% had a turnover of more than 500 mio. Euro. These figures reflect the *size distribution* of the actors in the sample, but say nothing about the weight and significance of space activities of these actors. This information is found in Table 5.8. Of course the firm (or institution) size reflects an overall potential of resources that could have also an influence on activities in the space sector (see chapter 7).

Before turning to the space-specific information we present some information about the main sectors of activities other than space. Many of the actors are active not only in space sector but also in one or more other sectors. The respective information is presented in Table 5.6. The three most important fields of activities besides space as measured by the share of turnover in such activities are '*telecommunication and information*', '*energy / utilities*' and '*aeronautics*'. More than 55% of all firms have a turnover share between 10% and 50% in one of these three important fields. The defence activities with the exception of aeronautics are of minor importance for most firms. For the development of the space sector is important to investigate the relevance of *synergy effects* between the activities in

space sector and the activities in other fields of the same firm (or institution). This investigation is presented in chapter 7.

Then actors reported also *expected trends* in the various fields of activities (including space) on a three-level scale (decrease; no change; increase). The actor assessments are found in Table 5.7. The expectations with respect to *space* seem to be at best. About 40% expected in 2010 an increase of activities, about the same percentage expected no change and only about 18% reported pessimistic expectations. In all other fields of activities most actors (at lowest in ‘aeronautics’ (61%), at highest in ‘defence: missiles’ (96%)) expected stagnation of activities.

Table 5.5: Total turnover T

T	N	%
T up to 1 M€	18	14.3
1 M€ < T ≤ 5 M€	20	15.9
5 M€ < T ≤ 10 M€	11	8.7
10 M€ < T ≤ 50 M€	35	27.7
50 M€ < T ≤ 100 M€	15	11.9
100 M€ < T ≤ 500 M€	14	11.1
500 M€ < T ≤ 1000 M€	7	5.6
> 1000 M€	6	4.8

N = 126; 2010

Table 5.6: Main sectors of activities other than space; percentage of total turnover

		0%	Up to 10%	10%-50%	> 50%
Aeronautics	N	15	12	10	3
	%	37.5	30.0	25.0	7.5
Transportation	N	19	8	4	1
	%	59.4	25.0	12.5	3.1
Energy / utilities	N	15	12	14	2
	%	34.8	27.9	32.6	4.7
Telecommunications and information	%	14	10	15	8
	N	29.8	21.3	31.9	17.0
Science	N	15	6	10	4
	%	42.9	17.1	28.6	11.4
Defence: aeronautics	N	14	10	8	2
	%	41.2	29.4	23.5	5.9
Defence: missiles	N	19	8	0	1
	%	67.8	28.6	0.0	3.6
Defence: telecommunications	N	18	11	5	1
	%	51.4	31.4	14.3	2.9

Table 5.7: Trends in *space* and *non-space* activities 2010

Sectors	Abnahme			Keine Änderung	Zunahme
	N				
Space	N	12	29	27	
	%	17.7	42.6	39.7	
Aeronautics	N	4	20	9	
	%	12.1	60.6	27.3	
Telecommunications & Information	N	5	22	6	
	%	18.2	66.7	15.2	
Transportation	N	1	21	5	
	%	3.7	77.8	18.5	
Energy utilities	N	5	22	7	
	%	14.7	64.7	20.6	
Life sciences	N	0	20	3	
	%	0.0	87.0	13.0	
Science	N	0	24	7	
	%	0.0	77.4	22.6	
Defence: aeronautics	N	2	20	8	
	%	6.7	66.7	26.6	
Defence: missiles	N	1	24	0	
	%	4.0	96.0	0.0	
Defence: telecom	N	3	26	0	
	%	10.3	89.7	0	

Turnover related to space activities

Table 5.8 presents information on the turnover share of *total space activities*. 45% of all actors had a space share that was larger than 75%. This share amounted to about 50% for large firms, to about 40% for SMEs and to about 43% for research institutions. *More than 50% of large firms and SMEs had a space share of more than 50%*. For these firms the space sector is the *main activity sector*. One third of all firms belonged to the group of firms, for which space activities was only a minor field of activities (space share up to 25%).

We distinguish two types of space turnover, namely *product* space turnover (products for final users; RTL >6) and *R&D* space turnover (R&D outputs; RTL ≤ 6). Most of the firms had 2010 a space *product* share (of total space turnover) of more than 50% (large firms: 75%; SMEs: 58%; Table 5.9). The respective figures for space R&D turnover are considerably smaller: 24% of all firms had a share larger than 50% (large firms: 11%; SMEs: 35%; Table 5.10).

Table 5.8: Space *total* turnover as a percentage of total turnover

		up to 25%	26%-50%	51%-75%	76%-100%
All	N	40	14	13	54
	%	33.1	11.6	10.7	44.6
Large firms	N	20	2	3	26
	%	9.2	3.9	5.9	51.0
SME	N	14	9	10	21
	%	25.9	16.7	18.5	38.9
Research organizations	N	3	1	0	3
	%	42.8	14.3	0.0	42.8

Table 5.9: Space *product* turnover as a percentage of total space turnover

		0%	up to 25%	26%-50%	51%-75%	76%-100%
All	N	9	5	10	10	62
	%	9.4	5.2	10.4	10.4	64.6
Large firms	N	0	2	4	5	33
	%	0.0	4.5	9.0	11.4	75.1
SME	N	6	3	6	3	25
	%	14.0	7.0	14.0	7.0	58.0

Table 5.10: Space *R&D* turnover as a percentage of total space turnover

		0%	Up to 10%	10%-50%	> 50%
All	N	14	30	29	23
	%	14.6	31.2	30.2	24.0
Large firms	N	6	20	13	5
	%	13.6	45.5	29.5	11.4
SME	N	6	8	14	15
	%	14.0	18.6	32.6	34.8

Exports

The *export intensity* (exports divided by turnover) of the European space sector is an indicator for the *international competitiveness* of this sector. About 36% of all firms reported exports outside Europe (Table 5.11). 58% of them had an export share up to 25%, 27% a share between 26% and 50%, and 16% a share of more than 50%. The main export market was the USA, next to it Asia, some firms exported space products to Russia.

Table 5.11: Exports outside Europe as a percentage of space *product* turnover

		up to 25%	26%-50%	51%-100%
Outside Europe	N	26	12	7
	%	57.8	26.7	15.5
USA-share (of sales outside Europe)	N	5	10	15
	%	16.7	33.3	50.0
ASIA-share (of sales outside Europe)	N	12	7	9
	%	42.9	25.0	32.1
Russia (of sales outside Europe)	N	9	1	0
		90.0	10.0	0.0

ESA R&D turnover

Table 5.12 contains information on the share of space activities that is directed to ESA (contracts, assignments, etc.). About 50% of all firms (53% of large firms; 50% of SMEs) had an ESA space share of more than 75%. For these firms ESA was their *main client*. Therefore, it is important for this study to investigate the influence of the EAS contribution to the performance of space firms (see chapter 7).

Table 5.12: *ESA R&D* turnover as a percentage of space R&D turnover

		0%	up to 25%	26%-50%	51%-75%	76%-100%
All	N	8	10	11	11	35
	%	10.7	13.3	14.7	14.7	46.6
Large firms	N	3	1	3	7	16
	%	10.0	3.3	10.0	23.3	53.4
SME	N	5	5	4	3	17
	%	14.7	14.7	11.8	8.8	50.0
Research organizations	N	0	3	2	0	0
	%	0.0	60.0	40.0	0.0	0.0

5.2.2 Sales markets

Our questionnaire contained a comprehensive list of sales markets or market segments (which is identical with that for procurement markets). Table 5.13a contains information about the main sales markets, in which the actors in our sample have been active in 2010. Table 5.13b documents in detail how many firms reported activities in a certain market segment (firms could report more than one market segment). On the whole we identified 235 such ‘market presence counts’, i.e. on average 1.5 per actor. This is a hint to a rather low diversification. Sales activities were focussed on the market segment ‘spacecraft’ (about 53% all ‘market presence counts’). About 18% of all ‘market presence counts’ referred to the sub-segment of ‘spacecraft equipments’. Sales activities in ‘ground systems and activities’ were reported in about 37% of all cases, most of them in the sub-segment ‘ground equipment / components / software / services’. Finally, activities in ‘launchers’ were reported in about 10% of all cases.

Table 5.13a: Summary: Number of firms that are active in a *product market* (N = 154); firms can be active in more than one product market

Product markets	Number of firms	Percentage
SPACECRAFT	124	52.7
Spacecraft systems	5	2.1
Spacecraft subsystems	17	7.2
Spacecraft equipments	43	18.3
Spacecraft components and materials	25	10.6
Spacecraft engineering services	34	14.4
GROUND SYSTEMS AND ACTIVITIES	88	37.4
Ground systems and activities	5	2.1
Ground segment systems	12	5.1
Ground Equipment / components / software / services	71	30.2
LAUNCHERS	23	9.8

Table 5.13b: Number of firms that are active in a *product market* ($N_t = 154$); firms can be active in more than one product market

Product markets	Number of firms	Percentage
SPACECRAFT	124	52.7
Spacecraft systems	5	2.1
Communication / Navigation Satellites	0	0.0
EO/meteorology satellites	2	0.8
Science satellites	0	0.0
Space exploration probes	2	0.8
Unmanned space infrastructure	0	0.0
Manned space infrastructure	1	0.4
Spacecraft subsystems	17	7.2
Satellite buses	0	0.0
Telecom payloads (BSS, FSS, MSS, broadband...)	0	0.0
Navigation payloads	0	0.0
Optical instruments	5	2.1
Radar instruments	1	0.4
Other instruments	4	1.7
Microgravity payloads	4	1.7
Robotic exploration payloads	3	1.3
Spacecraft equipments	43	18.3
<i>Spacecraft – structures / tanks / mechanisms</i>	<i>12</i>	<i>5.1</i>
Primary structures	3	1.3
Secondary structures	0	0.0
Pressurized tanks	0	0.0
Un-pressurized tanks	0	0.0
Cryogenic tanks	3	1.3
Pointing / positioning mechanisms	2	0.8
Storage / deployment mechanisms	2	0.8
Special mechanisms	1	0.4
Robotics (manipulators, effectors)	1	0.4
<i>Spacecraft - electrical power</i>	<i>6</i>	<i>2.5</i>
Solar arrays	2	0.8
PCU/PDU	0	0.0
BAPTAs	0	0.0
Batteries	0	0.0
Harnesses	3	1.3
Power electronics	1	0.4
<i>Spacecraft - thermal control equipment</i>	<i>3</i>	<i>1.3</i>
Active devices	2	0.8
Passive devices	1	0.4

Continued

<i>Spacecraft - TT&C</i>	4	1.7
Sensors	1	0.4
Actuators	2	0.8
Atomic clocks	1	0.4
Flight dynamics O/B software	0	0.0
<i>Spacecraft – propulsion</i>	4	1.7
Apogee booster motors	0	0.0
Chemical thrusters	1	0.4
Cold gas thrusters	3	1.3
Electrical thrusters	0	0.0
<i>Spacecraft - data / signal handling / processing</i>	10	4.3
Digital electronics	3	1.3
Analog signal electronics	3	1.3
Microwave electronics	3	1.3
O/B software	1	0.4
<i>Spacecraft - antenna systems</i>	4	1.7
Antennas	2	0.8
Waveguides/Feeds	2	0.8
Spacecraft components and materials	25	10.6
Valves, tubes, fittings	0	0.0
Electromechanical parts for mechanisms	1	0.4
Mechanical components for mechanisms	1	0.4
Cables, connectors, relays, PCBs	3	1.3
Transducers	4	1.7
Electronic components passive	2	0.8
Electronic components active	1	0.4
Electronic components programmable	0	0.0
Solar cells	0	0.0
TWT	0	0.0
Metal forms	1	0.4
Carbon fibres	0	0.0
Chemical products (resins, paints, glues, ...)	4	1.7
Optical components	0	0.0
Optical materials (laser crystals, non-linear, ...)	0	0.0
Pyrotechnical devices	0	0.0
Propellant	3	1.3
Other components	5	2.1

Spacecraft engineering services	34	14.4
Software development	6	2.5
Test and space qualification	4	1.7
Engineering analysis support	2	0.8
System/Mission analysis support	0	0.0
Custom semiconductor development	3	1.3
Quality assurance support	6	2.5
Independent verification and validation	0	0.0
Mechanical machining / processing	1	0.4
Central procurement	8	3.4
Other services	4	1.7
GROUND SYSTEMS AND ACTIVITIES	88	37.4
Ground systems and activities	5	2.1
Systems of systems	5	2.1
Ground segment systems	12	5.1
Spacecraft Control centers	5	2.1
Mission/payload operation centers	2	0.8
Ground stations	5	2.1
Ground Equipment / components / software / services	71	30.2
Antenna systems	2	0.8
RF transmit / receive equipment	3	1.3
Baseband equipment and software	4	1.7
In-orbit calibration & testing equipment	7	3.0
Control center software	4	1.7
Flight dynamics software	6	2.5
Spacecraft and payload simulators	6	2.5
Mission analysis software	7	3.0
Payload operation SW applications	3	1.3
Networking equipment & software	5	2.1
Ground support equipment	4	1.7
Spacecraft operational support services	3	1.3
Launch operational support services	9	3.8
Ground systems maintenance	1	0.4
CAE software development	1	0.4
Other equipment	1	0.4
Propellant	3	1.3
Other components	2	0.8

LAUNCHERS	23	9.8
Launcher system	10	4.2
Mission analysis	0	0.0
Launch system engineering	1	0.4
Guidance Navigation Control	2	0.8
Software	4	1.7
Avionics	1	0.4
Health monitoring systems	2	0.8
Lox/H2 propulsion	1	0.4
Propulsion system engineering	0	0.0
Turbopumps	0	0.0
Combustion components	0	0.0
Nozzles	0	0.0
Equipment	1	0.4
Storable propulsion	1	0.4
Propulsion system engineering	0	0.0
Tubopumps	0	0.0
Combustion components	0	0.0
Nozzles	0	0.0
Equipment	1	0.4
Solid propulsion	1	0.4
Propulsion system engineering	0	0.0
Bare motor case	0	0.0
Thermal protection	0	0.0
Propellant grain	0	0.0
Nozzles	0	0.0
Igniters	1	0.4
Lox/HC propulsion	3	1.3
Propulsion system engineering	0	0.0
Tubopumps (fuel)	0	0.0
Combustion components	0	0.0
Nozzles	0	0.0
Equipment	3	1.3
Launchers - stage and equipment	7	3.0
Stage system engineering	1	0.4
Stage propulsion engineering	4	1.7
Stage structures	1	0.4
Payload adapters	1	0.4
Fairings	0	0.0
Propellant tanks	0	0.0
High pressure tanks	0	0.0
Equipment	0	0.0
TPS and hot structures	0	0.0

5.3 Summary

Procurement activities were focussed on the market segment 'spacecraft' (about 70% all 'market presence counts'). About 41% of all 'market presence counts' referred to the sub-segment of 'spacecraft components and materials'. Procurement activities in 'ground systems and activities' were reported in about 18% of all cases, activities in 'launchers in about 12% of all cases.

On the whole, space actors seem to be well-equipped with high-qualified personnel in R&D, engineering and design as well as software development.

About 67% of all actors (mostly firms) had a total turnover in 2010 of less than 50 mio. Euro. About 14% of all firms are very small having a turnover of less than 1 mio. Euro, About 10% had a turnover of more than 500 mio. Euro.

Many of the actors are active not only in space sector but also in one or more other sectors. The three most important fields of activities besides space as measured by the share of turnover in such activities are '*telecommunication and information*', '*energy / utilities*' and '*aeronautics*'. More than 55% of all firms have a turnover share between 10% and 50% in one of these three important fields.

45% of all actors had a space share that was larger than 75%. This share amounted to about 50% for large firms, to about 40% for SMEs and to about 43% for research institutions. *More than 50% of large firms and SMEs had a space share of more than 50%.*

About 36% of all firms reported exports outside Europe. 58% of them had an export share up to 25%, 27% a share between 26% and 50%, and 16% a share of more than 50%. The main export market was the USA, next to it Asia, some firms exported space products to Russia.

Sales activities were focussed on the market segment 'spacecraft' (about 53% all 'market presence counts'). About 18% of all 'market presence counts' referred to the sub-segment of 'spacecraft equipments'. Sales activities in 'ground systems and activities' were reported in about 37% of all cases, most of them in the sub-segment 'ground equipment / components / software / services'. Finally, activities in 'launchers' were reported in about 10% of all cases. On the whole we identified 235 such 'market presence counts', i.e. on average 1.5 per actor. This is a hint to a rather low diversification.

About 50% of all firms (53% of large firms; 50% of SMEs) had an ESA space share of more than 75%. For these firms ESA was their *main client*.

6. Factors hampering R&D activities

Actors were asked to assess the importance of 11 different obstacles of innovative (R&D) activities on a five-point Likert scale. Table 6.1 shows the percentage of actors that reported 4 or 5 on the five-point scale.

Cost factors seem to be the main obstacle for all actors. Particularly, 72% of all factors reported the lack of *external* funds as a relevant hindrance. 59% found that the lack of internal funds was an important hampering factor. It is interesting that there no discernible differences between large firms and SMEs as to the assessment of these two obstacles. Significance differences between these two groups of firms exist with respect to the assessment of innovation costs as an innovation obstacle. Not astonishingly, SMEs firms seem to perceive innovation costs as a significantly more important hindrance than large firms (66% versus 33%). On the whole, actors in the space sector appear to perceive cost factors much more intensive as a problem than manufacturing firms in other sectors, for example in Switzerland or even on average in the European Union (see Arvanitis et al. 2010, section 4.3, 4.5 and 5.5, respectively). Many of the space activities are performed on behalf of public agencies (including ESA), so that most funding comes from these public institutions. Given that public funding is in general restricted, the capital market would be the place to get additional funds. The fact that space firms reported such severe problems in financing their innovation activities raises the question, whether their access to capital markets is insufficient, and if yes, for which reasons.⁴

Lack of qualified personnel and *lack of protection of the property rights* of innovative outcomes are a problem only for a relatively small percentage of the actors in the sample. Further, *knowledge factors* do not seem to hamper severely the activities of the vast majority of actors. Lack of technology-relevant information is a problem only for few actors, reflecting the high level of technological knowledge and personnel qualification in the space sector. However, 23% of all actors reported lack of *information on markets*. SMEs perceive this obstacle stronger than large firms as a problem (26% versus 21%).

Market factors are also quite important for most actors. 45% of them reported *demand uncertainty* as a relevant obstacle, which is not astonishing given the fiscal problems in most European countries and the overall economic stagnation in the reference period. It is understandable that SMEs suffered more severely from demand uncertainty than large firms (61% versus 36%)

55% of all actors saw a problem in the *dominance of established (presumably large) firms*. SMEs gave considerably more emphasis to this obstacle than large firms (66% versus 50%). This raises the question of the role of the market structure and the functioning of competition in the space sector.

⁴ Of course, we cannot exclude that some of the actors behave strategically and exaggerate financing problems in order to persuade public funding agencies to increase funds.

In sum, the main difficulties that actors reported refer to *funding and costs*, whereas SMEs seem to suffer much more than large firms from the burden of too high innovation costs, but also from the dominance of established firms.

Table 6.1: Factors hampering R&D activities; percentage of firms reporting 4 or 5 on a five-point Likert scale measuring the importance of hampering factors (N=112)

Hampering factors	All	Large Firms	SME	Research institutes
	%	%	%	%
<i>Cost factors</i>				
Lack of <i>internal</i> funds	59.2	59.5	58.5	50.0
Lack of <i>external</i> funds	71.8	73.8	70.7	100.0
Innovation costs too high	47.6	33.3	65.9	50.0
Easiness to copy innovations	13.6	16.7	14.6	25.0
Lack of qualified personnel	19.4	16.7	24.4	
<i>Knowledge factors</i>				
Lack of information on technology	9.7	2.4	14.6	25.0
Lack of knowledge on markets	23.3	21.4	26.8	25.0
Difficulty in finding cooperation partners for R&D	17.5	16.7	22.0	25.0
<i>Market factors</i>				
Market dominated by established enterprises	55.3	50.0	65.9	50.0
Uncertain demand for innovative goods / services	44.7	35.7	61.0	25.0

7. Econometric analysis: models of productivity

7.1 Model specification and method

In the econometric analysis we investigate the main factors driving *average labour productivity* of space-related firms. Labour productivity is considered as an important indicator of *economic performance*. Further, productivity is – given the level of labour costs and exchange rate (for countries outside the euro area), both factors that are not determined at firm level – the main determinant of *unit labour costs*, thus of the international competitiveness of a firm (industry or country).

Our conceptual background is the production function framework as discussed in chapter 3. Such type of analysis enables us to identify the relevance of firm characteristics, market characteristics, country affiliation, etc. for firms' productivity in their space and non-space activities.

We pooled the data of the three years 2008, 2009 and 2010 and applied a standard multivariate regression method, namely the OLS (ordinary least square) estimation procedure, in order to identify significant effects. The errors of the models are assumed to be normal distributed with a zero mean; standard errors are heteroscedasticity robust. Because of the large number of missing values for several relevant variables and the fact that most variables are contemporaneous, we could not apply more advanced methods (panel estimators; consideration of endogeneity issues).⁵ As a consequence, we consider our data as a cross-section, even if they contain data from different years. Thus, the results do not identify “causal effects”, they have to be considered as multivariate correlations. However they bring out some robust “regularities” than can be interpreted as indicating causal effects.

As *dependent variables* serve several *measures of productivity*:⁶

- *Total turnover* per employee;
- *Production* turnover per employee;
- *R&D* turnover per employee;
- *Space product* turnover per employee;
- *Space R&D* turnover per employee.

Table 7.1 gives an overview of variables used in the models and Table 7.2 provides some descriptive information about those variables. Description is based on the number of

⁵ Calling firms after having received the filled questionnaire in order to substitute for missing values was not the appropriate remedy because in this ways consistence of the data could not be warranted.

⁶ Value added per employees would be a more appropriate measure of productivity but unfortunately no value added data were available. Also not available was information on intermediate inputs that would serve as control variable in the turnover productivity equations.

observations used in the econometric models. All quantitative variables (except employment) are expressed in Euros 1000. The data allows us to investigate the following characteristics that may impact firm productivity and as a consequence would serve as *independent* variables in our econometric model:⁷

- the relevance of *firm size* (as measured by the number of employees);
- the relevance of *product diversification* (or the other way around *product specialization*);
- the relevance of the extent of *space activities* (as measure of space specialization);
- the relevance of the extent *activities in other than the space industry* (e.g. civil aeronautics) (as measure of non-space specialization)
- the relevance of *R&D investments* (as important innovation input);
- the relevance of *external knowledge sources* (as measure for the extent and direction of used external knowledge);
- the relevance of *knowledge acquisition strategies* (such as R&D cooperation; contract R&D; licensing of external know-how);
- the relevance of *innovation obstacles*;
- the relevance of *ESA contracts* and contracts with *other civil public institution* ;
- the relevance of the country of origin of a firm (country effect);
- the relevance of the status of the country of origin of a firm with respect to pay-off of a country's contribution to ESA (not-under-returned members; under-returned members; new members)

⁷ We do not dispose data on physical capital. However, some control for capital is given by firm size and the various field of activities that are included in our model.

Table 7.1: Definition of model variables; metric variables are used in logarithmic form

Variables	Definition
<i>Dependent variables</i>	
Total turnover	Value of total turnover divided by the total number of employees
Total product turnover per employee	Value of total product turnover divided by the total number of employees
Total R&D turnover per employee	Value of R&D total turnover divided by the total number of employees
Space product turnover per employee	Value of space product turnover divided by the number of employees in space segment
Space R&D turnover per employee	Value of space R&D turnover divided by the space number of employees in space segment
<i>Independent variables</i>	
ESA share of space R&D turnover	Value of space R&D turnover that is related to ESA divided by space R&D turnover
ESA R&D turnover per employee	Value of space R&D turnover that is related to ESA divided by the number of employees in space segment
Civil agencies share of space R&D turnover	Value of space R&D turnover that is related to space civil agencies (incl. ESA) divided by space R&D turnover
Civil agencies R&D turnover per employee	Space R&D turnover that is related to space civil agencies (incl. ESA) divided by the number of employees in space segment
Space intramural R&D investment per employee	Sum of the values of capitalized R&D, R&D expenses and R&D infrastructure divided by the number of employees in space segment
Product diversification	Number of product markets, in which a firm reports sales
Space share of total turnover	Value of space product and R&D turnover divided by total turnover
<i>External knowledge sources:</i>	
Internal	Five-level ordinal variable
<i>Market sources</i>	
Clients	Five-level ordinal variable
Suppliers	Five-level ordinal variable
Competitors	Five-level ordinal variable
Consultants, commercial labs, private R&D/institutes	Five-level ordinal variable
<i>Institutional sources</i>	
Universities, other higher education institutions	Five-level ordinal variable
Government, public research institutes	Five-level ordinal variable
<i>Publicly available sources</i>	
Conferences, trade fairs, exhibitions	Five-level ordinal variable
Scientific journals, trade / technical publications	Five-level ordinal variable
Professional and industry associations	Five-level ordinal variable

Continued

<p><i>Knowledge acquisition strategies:</i></p> <p>'Make' only</p> <p>'Coop' only</p> <p>'Buy' only</p> <p>Mixed 'Coop'/'Buy'</p>	<p>Firms / Institutions that have <i>only</i> internal R&D</p> <p>Firms / Institutions that have <i>only</i> R&D collaborations with other firms / institutions (besides own R&D)</p> <p>Firms / Institutions that have <i>only</i> external (contracted) R&D (besides own R&D)</p> <p>Firms / institutions that have R&D cooperation <i>and</i> external R&D (besides own R&D)</p>
<p><i>Innovation obstacles:</i></p> <p><i>Cost factors</i></p> <p>Lack of <i>internal</i> funds</p> <p>Lack of <i>external</i> funds</p> <p>Innovation costs too high</p> <p>Easiness to copy innovations</p> <p>Lack of qualified personnel</p> <p><i>Knowledge factors</i></p> <p>Lack of information on technology</p> <p>Lack of knowledge on markets</p> <p>Difficulty in finding cooperation partners for R&D</p> <p><i>Market factors</i></p> <p>Market dominated by established enterprises</p> <p>Uncertain demand for innovative goods/services</p>	<p>Five-level ordinal variable</p> <p>Five-level ordinal variable</p> <p>Five-level ordinal variable</p> <p>Five-level ordinal variable</p> <p>Five-level ordinal variable</p> <p>Five-level ordinal variable</p> <p>Five-level ordinal variable</p> <p>Five-level ordinal variable</p> <p>Five-level ordinal variable</p> <p>Five-level ordinal variable</p> <p>Five-level ordinal variable</p> <p>Five-level ordinal variable</p>
<p><i>Firm / institution size</i></p>	
<p>Number of employees total; space</p> <p>Number of employees squared total; space</p>	
<p><i>Share of turnover of non-space sectors:</i></p> <p>Civil aeronautics</p> <p>Transportation</p> <p>Energy / utilities</p> <p>Civil telecommunication & information</p> <p>Life sciences</p> <p>Science</p> <p>Other (e.g., scientific equipment)</p> <p>Defence</p>	<p>Percentage</p> <p>Percentage</p> <p>Percentage</p> <p>Percentage</p> <p>Percentage</p> <p>Percentage</p> <p>Percentage</p> <p>Percentage</p>
<p><i>Countries:</i></p> <p>Not-under-returned⁽¹⁾</p> <p>Under-returned⁽²⁾</p> <p>New members⁽³⁾</p>	<p>Dummy-(0,1)-Variable</p> <p>Dummy-(0,1)-Variable</p> <p>Dummy-(0,1)-Variable</p>
<p>Austria</p> <p>Belgium</p> <p>Denmark</p> <p>Finland</p> <p>France</p> <p>Greece</p> <p>Italy</p> <p>Netherlands</p> <p>Norway</p> <p>Portugal</p> <p>Spain</p>	<p>Dummy-(0,1)-Variable</p> <p>Dummy-(0,1)-Variable</p> <p>Dummy-(0,1)-Variable</p> <p>Dummy-(0,1)-Variable</p> <p>Dummy-(0,1)-Variable</p> <p>Dummy-(0,1)-Variable</p> <p>Dummy-(0,1)-Variable</p> <p>Dummy-(0,1)-Variable</p> <p>Dummy-(0,1)-Variable</p> <p>Dummy-(0,1)-Variable</p> <p>Dummy-(0,1)-Variable</p>

Continued

Sweden	Dummy-(0,1)-Variable
Switzerland	Dummy-(0,1)-Variable
United Kingdom	Dummy-(0,1)-Variable

Note: (1): Belgium, France, Germany, Italy, Netherlands, Spain, United Kingdom, Canada; (2): Austria, Denmark, Finland, Ireland, Norway, Sweden, Switzerland; (3): Czech Republic, Greece, Portugal, Romania. All values are measured in M€ All five-level ordinal variables are measured on a Likert scale (1: 'no importance'; 5: very high importance').

Table 7.2: Description of variables used in the models

Variable	Obs	Mean	Std. Dev.	Min	Max
Total turnover per employee (log)	311	4.500	1.237	-1.344	8.654
Product turnover per employee (log)	257	4.458	1.532	-1.344	11.522
R&D turnover per employee (log)	244	2.750	1.917	-4.369	10.191
Space product turnover per employee (log)	195	4.573	1.305	1.099	11.538
Space R&D turnover per employee (log)	211	2.877	1.782	0.000	10.191
Number of employees (log)	311	4.829	1.974	0.000	10.597
ESA share of space R&D turnover (log)	177	-0.581	0.850	-4.500	0.000
ESA R&D turnover per employee (log)	171	2.650	1.753	-4.369	9.383
Civil agencies share of space R&D turnover (log)	196	-1.408	2.304	-6.908	0.001
Civil agencies R&D turnover per empl. (log)	166	3.881	1.589	-2.066	10.964
<i>Markets</i>					
Space share of total turnover (TTO)	311	0.489	0.407	0.000	1.000
Defence share of total turnover	311	0.023	0.048	0.000	0.285
Civil aeronautics share of total turnover	311	0.026	0.093	0.000	1.000
Transportation share of total turnover	311	0.015	0.061	0.000	0.560
Energy/utilities share of total turnover	311	0.042	0.147	0.000	1.000
Civil telecommunication & information share of TTO	311	0.067	0.167	0.000	1.000
Life science share of total turnover	311	0.009	0.078	0.000	0.800
Science share of total turnover	311	0.042	0.151	0.000	1.000
Other (e.g. scientific equipment) share of TTO	311	0.145	0.278	0.000	1.000
<i>Obstacles (space sector)</i>					
Lack of internal funds	223	3.587	1.266	1.000	5.000
Lack of external funds	223	3.933	1.143	1.000	5.000
Innovation costs are too high	223	3.305	1.165	1.000	5.000
Easiness to copy innovations	223	2.139	0.988	1.000	4.000
Lack of qualified personnel	225	2.489	1.065	1.000	5.000
Lack of information on technology	223	2.103	0.872	1.000	4.000
Lack of knowledge on markets	223	2.525	1.086	1.000	5.000
Difficulty in finding cooperation partners for R&D	223	2.430	1.108	1.000	5.000
Market dominated by established enterprises	223	3.220	1.326	1.000	5.000
Uncertainty demand for innovative goods/services	220	3.155	1.280	1.000	5.000
<i>External knowledge sources</i>					
Group internal	229	4.087	1.005	1.000	5.000
Clients	232	3.996	1.000	1.000	5.000
Suppliers	229	3.135	0.971	1.000	5.000
Competitors	229	3.105	1.054	1.000	5.000
Consultants, commercial labs, private R&D inst.	227	2.828	1.194	1.000	5.000
Universities, other higher education institutions	229	3.498	1.107	1.000	5.000
Government, public research institutes	229	3.485	1.091	1.000	5.000
Conferences, trade fairs, exhibitions	232	3.427	1.083	1.000	5.000
Scientific journals, trade/technical publications	229	3.367	0.971	2.000	5.000
Professional and industry associations	229	2.817	1.085	1.000	5.000
<i>Countries</i>					
Austria	311	0.087	0.282	0.000	1.000
Belgium	311	0.084	0.277	0.000	1.000
Denmark	311	0.035	0.185	0.000	1.000
Finland	311	0.026	0.159	0.000	1.000
France	311	0.132	0.339	0.000	1.000
Greece	311	0.039	0.193	0.000	1.000

Ireland	311	0.010	0.098	0.000	1.000
Italy	311	0.071	0.257	0.000	1.000
Netherlands	311	0.080	0.272	0.000	1.000
Norway	311	0.019	0.138	0.000	1.000
Portugal	311	0.026	0.159	0.000	1.000
Spain	311	0.103	0.304	0.000	1.000
Sweden	311	0.026	0.159	0.000	1.000
Switzerland	311	0.019	0.138	0.000	1.000
United Kingdom	311	0.084	0.277	0.000	1.000

Note: all quantitative variables are expressed in Euros 1000; log: natural logarithm.

7.2 Results

7.2.1 Estimates for total turnover productivity, product turnover productivity and R&D turnover productivity

Table 7.3a and Table 7.3b provide a summary of the main results of the econometric estimation. The detailed estimates are found in the Tables 7.4 to 7.9.

In Table 7.3a we look at the driving factors for total turnover per employee, product turnover per employee, and R&D turnover per employee. A first important result refers to the variable '*space share of total turnover*' that measures the extent of space activities or the space specialization of a firm). This variable correlates *negatively* with all three productivity variables in Table 7.3a. This means that high *shares* of space activities show negative effects not only on total turnover productivity but also on product turnover and R&D turnover productivity. This means that a high space specialization does not contribute to overall productivity of the firm, presumably because of the specificity of inputs and technologies in the space activities that require a proportionately too high share of firm resources.

A second relevant result refers to the productivity effects of the contribution of ESA and other civil public agencies to space R&D turnover. '*ESA share of space R&D turnover*' is *negatively* correlated with the three productivity variables indicating that an increase in '*ESA share of space R&D turnover*' decreases the total productivity, production turnover productivity and the R&D turnover productivity. However, if we look at the '*ESA R&D turnover per employee*' we find a significantly *positive* sign for production turnover productivity and R&D turnover productivity. Taking together these results they show that larger ESA space shares are lowering the productivity, while the degree of efficiency of conducting ESA contract work (as measured by the '*ESA R&D turnover per employee*') reflects quite well the overall efficiency of a firm. In other words, productivity (efficiency) gains in conducting ESA contracts positively affect the turnover productivity of a firm.

This result is in line also with the findings for '*civil agencies share of space R&D turnover*' and '*civil agencies space R&D turnover per employee*'; here we also see a significant *negative* sign for the former variable and a significant *positive* sign for the latter in the equations for total turnover and product turnover.

The results for the shares for ESA space turnover and civil agencies turnover are in accordance with the findings for the share of total space turnover. Consequently, not only ESA space contracts are lowering firm productivity, space contracts in total seem to have a degree of complexity that requires a firm to invest greater resources compared to non-space activities.

Looking at the productivity effects of firms' activities in other than the space sector the findings show that activities in the '*civil aeronautics*' market are *positively* related with

productivity for all three productivity measures. Further, firms active in *'life sciences'* show a *positive* effect on R&D turnover per employee. Activities in all other markets are negatively or unrelated with the three productivity measures in Table 7.3a. On the whole, it seems that the 'activity portfolios' of the firms in the sample are not optimal with respect to economic performance as measured by the three productivity variables.

As expected and also found in other industries, the *'space intramural R&D investments per employee'* are *positively* related with product turnover productivity and R&D turnover productivity. Hence, higher R&D expenditures per employees in the space department foster productivity. However, the negative sign of this variable in the equation for total turnover productivity cannot be easily explained; given that total turnover is the sum of product turnover and R&D turnover, it cannot be excluded that this negative effect is a statistical artefact.

In all models we have *size* controls, which indicate a *non-linear relationship* between firm size and total turnover productivity, *i.e. the relationship is positive starting with smaller firm sizes and gets negative for already very large firms*. The relationship between size and R&D turnover per employee is *negative*.

It is also likely that the *home country* of a firm influences their productivity, e.g., through special funding schemes, good infrastructure, beneficial market structures. Our control variables for the country of origin of firms confirm such effects. Germany is the 'benchmark' (reference country) in our vector of country controls. Firms from Austria are on a mean level less productive and firms from Belgium are more productive in terms of total turnover productivity. Positive results we see also for Ireland, Sweden, and Switzerland. Concerning product turnover productivity we see positive signs for Denmark, Italy, and Switzerland. Firms in Belgium, Spain, and Sweden have also on average a greater R&D turnover productivity compared to Germany. We could not find statistically significant differences between France and Germany in any of the productivity equations in Table 7.3a.

By separating *not-under-returned* countries from *under-returned* countries and *new member* states we find that there are not any differences between not-under-returned and under-returned countries in terms of total turnover per employee and production turnover per employee. However, not-under-returned countries seem to have a higher R&D turnover productivity as compared to under-returned countries. Firms in new member states are on average less productive (with respect to product turnover and R&D turnover productivity) as compared to firms in under-returned countries.

7.2.2 Estimates for space product turnover productivity and space R&D turnover productivity

In Table 7.2b we show the estimates for the two productivity measures referring to *space activities* of firms, i.e. the ‘space product turnover per employee’ and ‘space R&D turnover per employee’. The results for ‘ESA share of space R&D turnover’, ‘ESA R&D turnover per employee’, ‘civil agencies share of space R&D turnover’, and ‘civil agencies R&D turnover per employee’ are similar to the respective results in Table 7.2a. A larger share of ESA space contracts and/or civil agencies contracts is also in this case *negatively* correlated with *space productivity*. However, the efficiency with which such contracts are carried out is *positively* related with the overall space productivity.

‘Space intramural R&D investments per employee’ are as expected *positively* related with the space productivity measures.

A further remarkable result refers to the influence of the degree of *diversification of non-space activities* pursued by a firm (as measured by the number of non-space fields, in which a firm is active; or the other way around, the degree of *specialization* of a firm) on *space productivity*. The *higher* the degree of *specialization* (the *lower* the degree of *diversification*) of a firm, the higher is the space productivity of a firm. Specialization increases space productivity. Consequently, there are not any significant productivity gains for the space sector from activities in other markets (e.g. Defence, Transportation). This does not mean that activities in the space sector do not show positive spillovers on other markets.

Space activities are *knowledge-intensive*. Hence, it is important to investigate the influence of external knowledge sources on such activities. Concerning space product turnover productivity we see that knowledge from ‘*clients*’ and knowledge from ‘*governments, public research institutes*’ and knowledge from ‘*professional and industry associations*’ show significantly *positive* effects. Concerning space R&D turnover productivity, knowledge from ‘*competitors*’ and ‘*consultants, commercial labs, private R&D institutes*’ are relevant.

In general, firms can pursue different *strategies to acquire knowledge* for their space activities. In Table 7.3b we distinguish between four strategies: ‘make only’ (only in-house R&D activities), ‘buy only’ (in-house R&D activities and buying R&D results from other firms or institutions), ‘coop only’ (in-house R&D activities and R&D cooperation), and ‘mixed’ (in-house R&D activities, buying R&D results, and cooperating in R&D). In Table 7.3b we see a significantly positive sign for all strategies for space R&D turnover productivity. In order to look at the differences among those strategies we have to consult the more detailed results (see Table 7.9). There we see that external strategies (mixed, coop, buy) show a significantly *stronger positive effect* than the ‘make’ strategy. Moreover, we

could not find any significant differences between ‘mixed’ and ‘coop’ and ‘mixed’ and ‘buy’. However, the ‘buy’ strategy is more ‘R&D productive’ than a purely ‘coop’ strategy.

We do not see any significant positive effects for *activities in other than space markets* for our space-related performance indicators; most of them are insignificant.

Also the *country effects* show few significant productivity deviations from reference country Germany. Firms from Belgium, Denmark, Spain, Sweden, and Switzerland show on average *higher* space product turnover productivity than Germany, while Portugal shows *lower* productivity than Germany. Concerning space R&D turnover productivity we find a *positive* sign for Denmark, Sweden, and Switzerland; Portugal and UK show a *negative* effect.

Finally, we see that also in this case *not-under-returned* countries are doing *better* than *under-returned* countries and firms from *new member* states are doing *worse* than *under-returned countries* in terms of the two space productivity measures in Table 7.3b.

Most important for policy making are the relationships between different *obstacles of innovation (R&D) activities* and space R&D turnover productivity. Table 7.3b shows that space R&D productivity is mainly hindered (*negative* signs of the variables) through the obstacles ‘innovation costs are too high’ and ‘difficulties in finding cooperation partners for R&D’. For some other obstacles we find a significantly *positive* sign indicating that such obstacles are relevant for firms with a relatively high level of space R&D turnover productivity. The positive sign indicates that firms became aware of such obstacles with increasing productivity. Such obstacles are: ‘lack of external funds’, ‘lack of information on technology’, ‘lack of knowledge on markets’, and ‘market dominated by established enterprises’.

7.3 Summary and implications

The results of the econometric analysis can be summarized as follows:

- A high *space specialization* does not contribute to overall productivity of the firm, presumably because of the specificity of inputs and technologies in the space activities that require a proportionately too high share of firm resources.
- The econometric analysis shows that *ESA contracts* and *contracts with other civil public institutions* matter for the productivity level of firms. Measures that enable a firm to carry out such contracts more efficiently would significantly increase the productivity on several levels. Such measures could be related to the contractual procedure but also to the specification of the content of the contract.
- *R&D investments* (per employee) are positively related with the space related performance of a firm. Measures that help to increase R&D investments also

increase firm performance as measured by productivity. The analysis shows that lack of external funds, difficulties to find cooperation partners or the dominance of well-established firms influence negatively space R&D turnover productivity. Measure to attenuate such hindrances would also increase the readiness to invest in R&D, since we know from other sectors that R&D is mainly funded by internal financial means. On the other hand, productivity increases the availability of internal funds and hence contributes to the increase of R&D investments.

- High *specialization* is positively related with space (products and R&D) turnover productivity. Measures that help firms to specialize in market segments are likely to increase productivity. On the other hand, high specialization, particularly high technological specialization, can lead in the long-run to 'lock-in' situations, which make the change to new technological paths extremely costly.
- "Openness" of a firm is positively related to space R&D turnover productivity in several ways. Firstly, we saw that access to *external knowledge sources* increase space productivity. Secondly, we saw that external knowledge acquisition strategies also positively contribute to space R&D productivity. Consequently, measures to promote the "openness" also foster space productivity. From the results concerning the *innovation obstacles* we saw that firms have problems to find cooperation partners for R&D; easing collaborations, e.g., through information exchange platforms would increase "openness".
- *Country affiliation* plays also a role for the firm performance in the space as well as in the overall turnover productivity. "Best-practice" measures to create a space-friendly economic environment for firms could be formulated by looking at not-under-performed countries.

Table 7.3a: Summary of the results of econometric analysis I

	Performance Indicators		
	Total turnover per employee	Product turnover per employee	R&D turnover per employee
<i>Drivers</i>			
ESA share of space R&D turnover	-	-	-
ESA R&D turnover per employee	ns	+	+
Civil agencies share of space R&D turnover	-	-	/
Civil agencies space R&D turnover per employee	ns	+	/
Space intramural R&D investment per employee	-	+	+
Space share of total turnover	-	-	ns
<i>Firm / institution size</i>			
Number of employees total	+	ns	-
Number of employees total squared	-	-	/
<i>Share of turnover of non-space sectors:</i>			
Civil aeronautics	+	+	+
Transportation	ns	ns	ns
Energy / utilities	ns	ns	ns
Civil telecommunication & information	-	-	ns
Life sciences	-	-	+
Science	-	-	ns
Other (e.g., scientific equipment)	-	-	-
Defence	-	-	ns
<i>Countries:</i>			
Not-under-returned members	ns	ns	+
New members	ns	-	-
Austria	-	ns	ns
Belgium	+	ns	+
Denmark	ns	+	ns
Finland	ns	ns	-
France	ns	ns	ns
Greece	-	-	-
Ireland	+	/	-
Italy	ns	+	ns
Netherlands	-	ns	ns
Norway	ns	ns	ns
Portugal	-	-	-
Spain	ns	+	+
Sweden	+	ns	+
Switzerland	+	+	ns
United Kingdom	ns	ns	-

Note: Results of 19 separate OLS estimations; + (-): positive (negative) effect; statistically significant at least at the 10% test level; ns: statistically insignificant; /: not considered; reference country: Germany; reference for not-under-returned and new members: under-returned members.

Table 7.3b: Summary of the results of econometric analysis II

	Performance Indicators	
	Space product turnover per employee	Space R&D turnover per employee
Drivers		
ESA share of space R&D turnover	-	-
ESA R&D turnover per employee	+	+
Civil agencies share of space R&D turnover	-	/
Civil agencies R&D turnover per employee	+	/
Space intramural R&D investment per employee	+	+
Product diversification	-	-
<i>External knowledge sources:</i>		
Internal	ns	ns
<i>Market sources</i>		
Clients	+	-
Suppliers	ns	ns
Competitors	ns	+
Consultants, commercial labs, private R&D institutes	ns	+
<i>Institutional sources</i>		
Universities, other higher education institutions	ns	-
Government, public research institutes	+	-
<i>Publicly available sources</i>		
Conferences, trade fairs, exhibitions	-	ns
Scientific journals, trade / technical publications	ns	ns
Professional and industry associations	+	-
<i>Knowledge acquisition strategies:</i>		
'Make only'	/	+
'Coop' only	/	+
'Buy' only	/	+
Mixed 'Coop'/'Buy'	/	+
<i>Innovation obstacles:</i>		
<i>Cost factors</i>		
Lack of <i>internal</i> funds	/	ns
Lack of <i>external</i> funds	/	+
Innovation costs too high	/	-
Easiness to copy innovations	/	ns
Lack of qualified personnel	/	ns
<i>Knowledge factors</i>		
Lack of information on technology	/	+
Lack of knowledge on markets	/	+
Difficulty in finding cooperation partners for R&D	/	-
<i>Market factors</i>		
Market dominated by established enterprises	/	+
Uncertain demand for innovative goods / services	/	ns

Continued

<i>Firm / institution size</i>		
Number of employees total space	+	-
Number of employees total space squared	-	/
<i>Share of turnover of non-space sectors:</i>		
Civil aeronautics	ns	ns
Transportation	ns	ns
Energy / utilities	ns	ns
Civil telecommunication & information	ns	-
Life sciences	ns	ns
Science	-	ns
Other (e.g., scientific equipment)	ns	-
Defence	ns	ns
<i>Countries:</i>		
Not-under-returned members	+	+
New members	-	-
Austria	ns	ns
Belgium	+	ns
Denmark	+	+
Finland	ns	ns
France	ns	ns
Greece	ns	ns
Italy	ns	ns
Netherlands	ns	ns
Norway	ns	ns
Portugal	-	-
Spain	+	ns
Sweden	+	+
Switzerland	+	+
United Kingdom	ns	-

Note: Results of 17 separate OLS estimations; + (-): positive (negative) effect; statistically significant at least at the 10% test level; ns: statistically insignificant; /: not considered; reference country: Germany; reference for over- / under-returned countries: new members; reference strategy: 'make' only.

Table 7.4: Drivers of *total turnover per employee*; pooled OLS estimates

Drivers	(1)	(2)	(3)	(4)	(5)	(6)	(7)
ESA share of space R&D turnover		-0.242** (0.109)					
ESA R&D turnover per employee			-0.044 (0.043)				
Civil agencies share of space R&D turnover				-0.096** (0.047)			
Civil agencies R&D turnover per employee					0.028 (0.057)		
Space intramural R&D investment per employee						-0.167** (0.074)	
Space share of total turnover	-0.657** (0.296)	-0.020 (0.205)	-0.123 (0.225)	-0.157 (0.285)	-0.176 (0.221)	-0.310 (0.514)	-0.496 (0.404)
<i>Firm / institution size</i>							
Number of employees total	0.220** (0.114)	0.454** (0.232)	0.444* (0.254)	0.006 (0.310)	0.745** (0.329)	-0.168 (0.268)	0.115 (0.129)
Number of employees total squared	-0.028*** (0.011)	-0.050*** (0.018)	-0.051** (0.021)	-0.013 (0.029)	-0.071** (0.030)	-0.002 (0.022)	-0.016 (0.013)
<i>Share of turnover of non-space sectors:</i>							
Civil aeronautics	3.021*** (1.008)						
Transportation	0.697 (0.861)						
Energy / utilities	-0.098 (0.380)						
Civil telecommunication & information	1.016** (0.423)						
Life sciences	-30.039*** (10.031)						

Continued

Science	-0.975** (0.479)	
Other (e.g., scientific equipment)	-1.442*** (0.394)	
Defence	-3.050** (1.296)	
<i>Countries:</i>		
Not-under-returned		0.169 (0.187)
New members		-0.181 (0.223)
Austria	-0.669* (0.389)	
Belgium	0.769*** (0.284)	
Denmark	0.050 (0.244)	
Finland	-0.496 (0.627)	
France	-0.147 (0.216)	
Greece	-0.797*** (0.209)	
Ireland	21.403*** (7.895)	
Italy	0.273 (0.211)	
Netherlands	-0.464** (0.235)	

Continued

Norway	-0.574 (0.378)						
Portugal	-1.023*** (0.172)						
Spain	-0.111 (0.179)						
Sweden	0.469*** (0.169)						
Switzerland	0.576*** (0.173)						
United Kingdom	0.103 (0.212)						
N	311	177	171	196	166	214	311
F	20.8***	23.9***	17.3***	23.2***		424.7***	11.2***
R-squared	0.400	0.513	0.492	0.622	0.702	0.498	0.233
Root MSE	1.001	0.874	0.901	0.833	0.680	1.036	1.107

Note: Heteroscedasticity-robust standard errors in brackets under the coefficients; ***, ** and * denote statistical significance for the 1%, 5% and 10% test level, respectively. Equations (2) to (6) contain controls for non-space sectors and countries (reference country: Germany); equation (7) contains only controls for non-space sectors; test for difference if the coefficients of ‘not-under-returned’ and ‘new members’ (reference group: ‘under-returned members’): $F=4.23^{**}$; intercepts are not shown.

Table 7.5: Drivers of *total product turnover per employee*; pooled OLS estimates

Drivers	(1)	(2)	(3)	(4)	(5)	(6)	(7)
ESA share of space R&D turnover		-0.656** (0.259)					
ESA R&D turnover per employee			0.287* (0.151)				
Civil agencies share of space R&D turnover				-0.086* (0.053)			
Civil agencies R&D turnover per employee					0.493*** (0.118)		
Space intramural R&D investment per employee						0.389*** (0.134)	
Space share of total turnover	-0.890** (0.421)	-0.219 (0.284)	-0.579 (0.542)	-0.041 (0.377)	-0.142 (0.396)	-1.025 (0.800)	-0.709* (0.411)
<i>Firm / institution size</i>							
Number of employees total	0.268 (0.178)	1.006** (0.458)	1.439*** (0.435)	-0.055 (0.382)	0.863* (0.490)	0.242 (0.328)	0.349** (0.167)
Number of employees total squared	-0.035** (0.016)	-0.088** (0.038)	-0.120*** (0.035)	-0.010 (0.036)	-0.081* (0.046)	-0.027 (0.028)	-0.038** (0.015)
<i>Share of turnover of non-space sectors:</i>							
Civil aeronautics	2.774** (0.903)						
Transportation	0.173 (1.510)						
Energy / utilities	-0.152 (0.651)						
Civil telecommunication & information	-1.237* (0.654)						
Life sciences	-56.415*** (4.345)						

Continued

Science	-3.026*** (0.890)	
Other (e.g., scientific equipment)	-1.470*** (0.531)	
Defence	-5.148*** (1.902)	
<i>Countries:</i>		
Not-under-returned		0.068 (0.237)
New members		-0.584* (0.321)
Austria	0.156 (0.577)	
Belgium	0.315 (0.355)	
Denmark	0.718** (0.324)	
Finland	0.441 (0.399)	
France	0.084 (0.303)	
Greece	-1.424*** (0.437)	
Ireland		
Italy	0.533* (0.304)	
Netherlands	0.076 (0.291)	

Continued

Norway	-0.907 (0.617)						
Portugal	-0.936*** (0.338)						
Spain	1.030** (0.486)						
Sweden	-0.247 (0.296)						
Switzerland	0.760*** (0.266)						
United Kingdom	0.426 (0.302)						
N	247	137	133	195	165	186	259
F	16.1***			22.1***		18.7***	26.9***
R-squared	0.382	0.461	0.475	0.472	0.684	0.539	0.299
Root MSE	1.263	1.343	1.338	1.217	0.920	1.240	1.312

Note: Heteroscedasticity-robust standard errors in brackets under the coefficients; ***, ** and * denote statistical significance for the 1%, 5% and 10% test level, respectively. Equations (2) to (6) contain controls for non-space sectors and countries (reference country: Germany); equation (7) contains only controls for non-space sectors; test for difference if the coefficients of ‘not-under-returned’ and ‘new members’ (reference group: ‘under-returned members’): $F=6.8^{***}$; intercepts are not shown.

Table 7.6 : Drivers of total R&D turnover per employee; pooled OLS estimates

Drivers	(1)	(2)	(3)	(4)	(5)
ESA share of space R&D turnover		-0.774*** (0.127)			
ESA R&D turnover per employee			0.657*** (0.077)		
Space intramural R&D investment per employee				0.306** (0.147)	
Space share of total turnover	0.281 (0.740)	0.911 (1.038)	0.833 (0.779)	0.471 (1.180)	0.342 (0.802)
<i>Firm / institution size</i>					
Number of employees total	-0.498*** (0.073)	-0.547*** (0.090)	-0.401*** (0.126)	-0.596*** (0.089)	-0.423*** (0.070)
Number of employees total squared					
<i>Share of turnover of non-space sectors:</i>					
Civil aeronautics	1.662* (0.907)				
Transportation	-1.052 (1.990)				
Energy / utilities	1.046 (0.831)				
Civil telecommunication & information	-0.568 (0.839)				
Life sciences	-18.339** (5.203)				
Science	0.933 (0.873)				
Other (e.g., scientific equipment)	-1.278 (0.884)				

Continued

Defence	1.141 (3.365)	
<i>Countries:</i>		
Not-under-returned		0.497* (0.274)
New members		-0.948*** (0.331)
Austria	-0.548 (0.394)	
Belgium	0.891* (0.472)	
Denmark	-0.173 (0.464)	
Finland	-0.874* (0.508)	
France	0.093 (0.439)	
Greece	-1.048*** (0.455)	
Ireland	-16.279*** (4.173)	
Italy	0.293 (0.384)	
Netherlands	0.125 (0.353)	
Norway	-0.371 (0.365)	
Portugal	-2.281*** (0.563)	

Continued

Spain	1.006*				
	(0.590)				
Sweden	1.441***				
	(0.373)				
Switzerland	0.508				
	(0.404)				
United Kingdom	-1.262*				
	(0.765)				
N	251	173	162	179	251
F	15.2***	14.7***	53.8***	32.3***	7.0***
R-squared	0.350	0.475	0.710	0.522	0.237
Root MSE	1.705	1.635	1.232	1.619	1.797

Note: Heteroscedasticity-robust standard errors in brackets under the coefficients; ***, ** and * denote statistical significance for the 1%, 5% and 10% test level, respectively. Equations (2) to (6) contain controls for non-space sectors and countries (reference country: Germany); equation (7) contains only controls for non-space sectors; test for difference if the coefficients Of 'not-under-returned' and 'new members' (reference group: 'under-returned members'): $F=15.4^{***}$; intercepts are not shown.

Table 7.7: Drivers of *space product turnover per employee*; pooled OLS estimates

Drivers	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ESA share of space R&D turnover		-0.294* (0.156)						
ESA R&D turnover per employee			0.454*** (0.107)					
Civil agencies share of space R&D turnover				-0.116*** (0.049)				
Civil agencies R&D turnover per employee					0.577*** (0.089)			
Space intramural R&D investment per employee						0.461*** (0.118)	0.510*** (0.110)	
<i>External knowledge sources:</i>								
Internal								0.047 (0.076)
<i>Market sources</i>								
Clients								0.161* (0.095)
Suppliers								-0.000 (0.084)
Competitors								-0.044 (0.133)
Consultants, commercial labs, private R&D institutes								0.035 (0.072)
<i>Institutional sources</i>								
Universities, other higher education institutions								-0.328 (0.254)
Government, public research institutes								0.831*** (0.259)

Continued

<i>Publicly available sources</i>								
Conferences, trade fairs, exhibitions								-0.749*** (0.220)
Scientific journals, trade / technical publications								-0.101 (0.217)
Professional and industry associations								0.546** (0.270)
<i>Firm / institution size</i>								
Number of employees space	0.650*** (0.262)	0.681* (0.401)	0.818*** (0.311)	0.762*** (0.304)	-0.139** (0.071)	1.301*** (0.376)	0.980*** (0.276)	0.461 (0.31)
Number of employees space squared	-0.078** (0.033)	-0.070 (0.048)	-0.064* (0.036)	-0.106*** (0.037)		-0.131*** (0.039)	-0.091*** (0.030)	-0.059 (0.039)
<i>Product diversification</i>								
						-0.159*** (0.044)		
<i>Share of turnover of non-space sectors:</i>								
Civil aeronautics	0.979 (0.994)							
Transportation	-2.586 (1.889)							
Energy / utilities	1.731 (1.111)							
Civil telecommunication & information	-0.335 (0.461)							
Life sciences	-3.699 (3.429)							
Science	-2.784*** (0.455)							
Other (e.g., scientific equipment)	-0.196 (0.370)							

Continued

Defence	1.279 (1.544)	
<i>Countries:</i>		
Not-under-returned		0.413** (0.198)
New members		-1.295*** (0.288)
Austria	-0.256 (0.378)	
Belgium	0.491** (0.247)	
Denmark	0.847** (0.405)	
Finland	0.215 (0.262)	
France	0.466 (0.331)	
Greece	-0.696 (0.714)	
Ireland		
Italy	0.668* (0.363)	
Netherlands	0.128 (0.267)	
Norway	-0.155 (0.428)	
Portugal	-1.184*** (0.291)	

Continued

Spain	0.954** (0.451)							
Sweden	0.627*** (0.219)							
Switzerland	1.035*** (0.236)							
United Kingdom	0.264 (0.264)							
N	200	155	155	153	131	179	179	162
F	15.4****	14.7***	24.9***	23.6***		7.9***	9.4***	
R-squared	0.315	0.375	0.619	0.387	0.753	0.456	0.501	0.381
Root MSE	1.139	1.140	0.890	1.060	0.698	1.030	0.971	0.891

Note: Heteroscedasticity-robust standard errors in brackets under the coefficients; ***, ** and * denote statistical significance for the 1%, 5% and 10% test level, respectively. Equations (2) to (5) contain controls for non-space sectors and countries (reference country: Germany); equation (6) and equation (8) contain only controls for countries; equation (7) contains only controls for non-space sectors; test for difference if the coefficients of 'not-under-returned' and 'new members': $F=47.8$; intercepts are not shown.

Table 7.8: Drivers of *space R&D turnover per employee*; pooled OLS estimates I

Drivers	(1)	(2)	(3)	(4)	(5)	(6)
ESA share of space R&D turnover		-0.546*** (0.117)				
ESA R&D turnover per employee			0.775*** (0.054)			
Space intramural R&D investment per employee				0.499*** (0.139)	0.518*** (0.127)	0.545*** (0.113)
<i>Firm / institution size</i>						
Number of employees space	-0.281*** (0.086)	-0.431*** (0.079)	-0.008 (0.047)	0.960*** (0.418)	1.162*** (0.444)	0.489* (0.297)
Number of employees space squared				-0.126*** (0.045)	-0.138*** (0.047)	-0.060** (0.035)
<i>Product diversification</i>					-0.181** (0.086)	
<i>Share of turnover of non-space sectors:</i>						
Civil aeronautics	-1.838 (1.316)					
Transportation	1.633 (3.583)					
Energy / utilities	0.815 (1.262)					
Civil telecommunication & information	-0.863** (0.439)					
Life sciences	-0.244 (1.175)					
Science	-0.787 (0.626)					
Other (e.g., scientific equipment)	-1.665*** (0.545)					

Continued

Defence	2.863 (2.621)	
Countries:		-0.365
Not-under-returned		(0.267)
		-1.726***
New members		(0.366)
Austria	0.270 (0.434)	
Belgium	0.762 (0.571)	
Denmark	1.115** (0.467)	
Finland	0.187 (0.650)	
France	0.263 (0.579)	
Greece	-0.012 (0.591)	
Ireland		
Italy	-0.391 (0.537)	
Netherlands	-0.398 (0.503)	
Norway	0.310 (0.544)	
Portugal	-1.766*** (0.375)	

Continued

Spain	0.616 (0.666)					
Sweden	1.617*** (0.353)					
Switzerland	0.852** (0.354)					
United Kingdom	-1.088** (0.479)					
N	221	173	173	192	192	192
F	11.4***	16.4***	25.9***	6.2***	8.9***	8.3***
R-squared	0.199	0.297	0.794	0.346	0.297	0.303
Root MSE	1.812	1.513	0.819	1.731	1.758	1.725

Note: Heteroscedasticity-robust standard errors in brackets under the coefficients; ***, ** and * denote statistical significance for the 1%, 5% and 10% test level, respectively. Equations (2) to (4) contain controls for non-space sectors and countries (reference country: Germany); equation (5) only controls for countries; equation (6) contains only controls for non-space sectors; test for difference of the coefficients of 'not-under-returned' and 'new members': $F=14.7^{***}$; intercepts are not shown.

Table 7.9: Drivers of *space R&D turnover per employee*; pooled OLS estimates II

Drivers	(1)	(2)	(3)
<i>External knowledge sources:</i>			
Internal	-0.068 (0.129)		
<i>Market sources</i>			
Clients	-0.345** (0.164)		
Suppliers	-0.142 (0.204)		
Competitors	0.601*** (0.229)		
Consultants, commercial labs, private R&D institutes	0.341** (0.149)		
<i>Institutional sources</i>			
Universities, other higher education institutions	-0.715** (0.332)		
Government, public research institutes	-0.684* (0.385)		
<i>Publicly available sources</i>			
Conferences, trade fairs, exhibitions	0.206 (0.308)		
Scientific journals, trade / technical publications	0.569 (0.366)		
Professional and industry associations	-1.167*** (0.361)		
<i>Knowledge acquisition strategies:</i>			
'Make' only		2.871*** (0.806)	

Continued

'Coop' only	3.942***	
	(0.712)	
'Buy' only	5.577***	
	(0.774)	
Mixed 'Coop'/'Buy'	4.423***	
	(0.606)	
<i>Innovation obstacles:</i>		
<i>Cost factors</i>		
Lack of <i>internal</i> funds		-0.160
		(0.147)
Lack of <i>external</i> funds		0.658***
		(0.120)
Innovation costs too high		-0.661***
		(0.125)
Easiness to copy innovations		0.095
		(0.131)
Lack of qualified personnel		0.097
		(0.102)
<i>Knowledge factors</i>		
Lack of information on technology		0.330*
		(0.184)
Lack of knowledge on markets		0.390***
		(0.113)
Difficulty in finding cooperation partners for R&D		-0.629***
		(0.139)
<i>Market factors</i>		
Market dominated by established enterprises		0.423***
		(0.141)
Uncertain demand for innovative goods / services		-0.136
		(0.115)

Continued

<i>Firm / institution size</i>			
Number of employees space	0.494 (0.348)	-0.238* (0.134)	-0.410*** (0.067)
Number of employees space squared	-0.098*** (0.038)		
N	177	135	168
F	42.4****	502.6***	49.9***
R-squared	0.383	0.818	0.577
Root MSE	1.500	1.428	1.133

Note: Heteroscedasticity-robust standard errors in brackets under the coefficients; ***, ** and * denote statistical significance for the 1%, 5% and 10% test level, respectively. Equations (1) to (3) contain controls only for countries (reference country: Germany); the coefficients of the four knowledge acquisition strategies are significantly different with one exception: 'coop only' / 'mixed' and 'buy only' / 'mixed' (two-tailed t test); equation (3) was estimated without intercept; otherwise intercepts are not shown.

8. Evolution of the space industry 2003-2010

8.1 Introduction

This chapter gives a broad overview of the evolution of the industry based on the data for the period 2003 to 2010 (see chapter 2). Given data limitations due to missing values and lack of comparability it was not possible to estimate an econometric model of factors that drive the evolution. However, the data base is sufficient large to depict some main trends of important performance variables in a descriptive way. We can trace across time the following important indicators:

- Total turnover productivity (total turnover per employee)
- Space turnover productivity (space turnover per space employee)
- Space turnover due to civil public institutions (ESA, national agencies) per space employee
- Space turnover from commercial markets per space employee
- Space R&D investments per space employee
- Share of space employment on total employment
- Share of space R&D employment on space employment

In most case we do not use the means of these indicators because extreme values (outliers) are likely to deter the analysis. Instead, we show the performance on different *quantiles* of the performance distribution: the 25th quantile, the median value, and the 75th quantile. This helps to identify differences between well-performing firms (75th quantile) and poor-performing firms (25th quantile). Given the experience from other sectors it is likely that poor performing firms show some resilience towards further performance losses, since a further deterioration of the performance could cause market exit. They also have difficulties to benefit from a more prospering economic environment, since they are likely to lack resources to absorb new market opportunities.

However due to missing values in single variables the number of observations for analysis is much lower (see Table 8.1). So we have 208 observations for ‘total turnover productivity’ and 140 observations for ‘space R&D investments per employee’. The data show an average of total turnover productivity of 178’000 Euros, with a maximum of 699’000 Euros per employee. Space turnover productivity is of similar magnitude, with a means value of 167’000 Euros per employee. Space turnover due to commercial markets per space employee is lower than space turnover due to civilian public institutions per space employee; however, their maximum values are very similar. This indicates the great importance of civil institutions for the sector as a whole; but we can also see that some

firms earn significant parts of their profits on commercial markets. Thus, some *synergies* between commercial space markets and civil public markets are slightly indicated.

Table 8.1: Summary statistics 2003-2007 (observations, mean values, etc.)

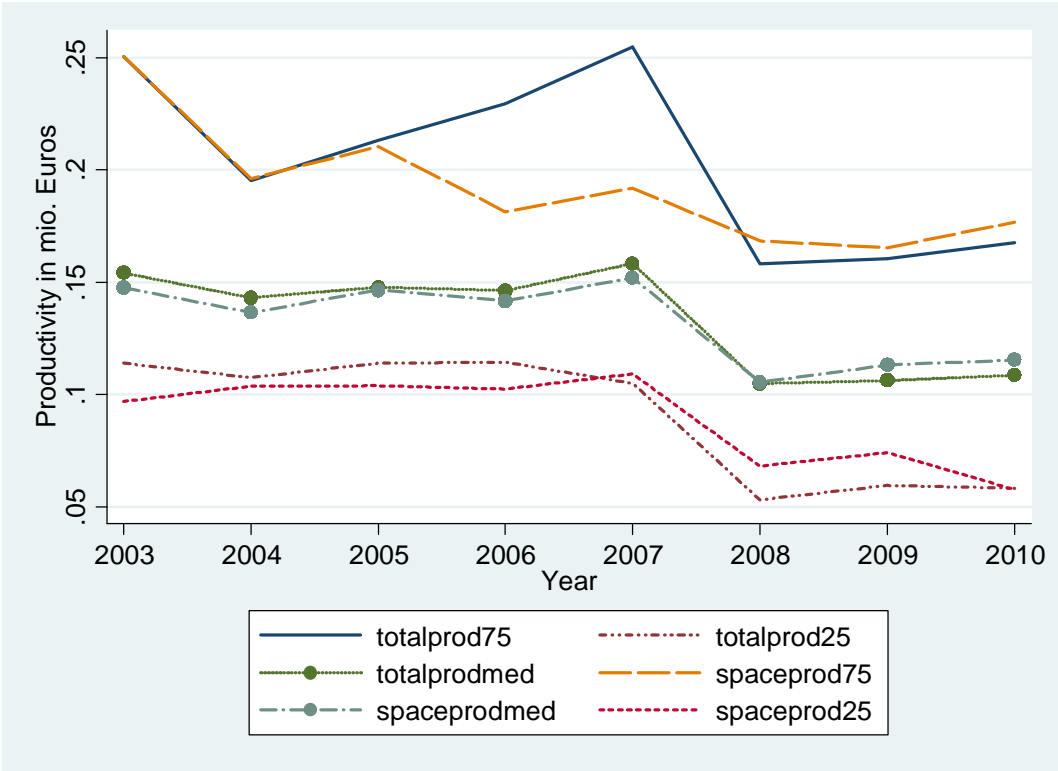
Variable	Obs	Mean	Std. Dev.	Min	Max
Total turnover productivity	208	0.178	0.095	0.038	0.699
Space turnover productivity	217	0.167	0.092	0.000	0.699
Space turnover due to civil institutions per space employee	216	0.093	0.054	0.000	0.265
Space turnover due to commercial markets per space employee	216	0.049	0.055	0.000	0.268
Employment share of space R&D investment	140	0.029	0.034	0.001	0.219
Space employment share on total employment	218	0.623	0.406	0.002	1.000
Space R&D employment share on space employment	144	0.236	0.241	0.018	1.000

8.2 Development of total productivity and total productivity

8.2.1 Total productivity and space productivity

Figure 8.1 shows the development of total turnover productivity (totalprod) and space turnover productivity (spaceprod) for different moments of the distribution, i.e. the median, the 25th quantile and the 75th quantile. Comparing total turnover productivity with space turnover productivity we see a parallel *slightly downward* development for the low performing firms (25th quantile; totalprod25, spaceprod25) and medium performing firms (50th quantile; totalprodmed, spaceprodmed). Concerning the well-performing firms we see a divergent development between total turnover productivity (totalprod75) and space turnover productivity (spaceprod75) beginning with 2005 and ending in the year 2008. In 2006 and 2007 totalprod75 clearly increases, while spaceprod75 is constantly decreasing. Totalprod75 and spaceprod75 are similar again from 2008 onwards. Remarkable and in line with the overall economic development we see a sharp decrease at all productivity levels in 2008; since then industry is recovering rather slowly.

Figure 8.1: Evolution of total productivity and space productivity



8.2.2 Space turnover in the civil/institutional space markets and commercial space markets per employee

Figure 8.2 shows the development of the space turnover due to contracts with public civil/institutional markets (ESA, national agencies) per space employee. The figures show also in this case a *slightly downward trend* over the time with a sharper decrease in 2008 independent whether a firm operates at the 25th quantile, the median, or the 75th quantile. It is also indicated that better-performing firms are likely to recover faster from drop in 2008 compared to firms in the 25th quantile; however the differences are minor. In sum, the trend – given the economic turbulences – over time is remarkably stable.

Figure 8.2: Space turnover per space employee civil/institutional markets

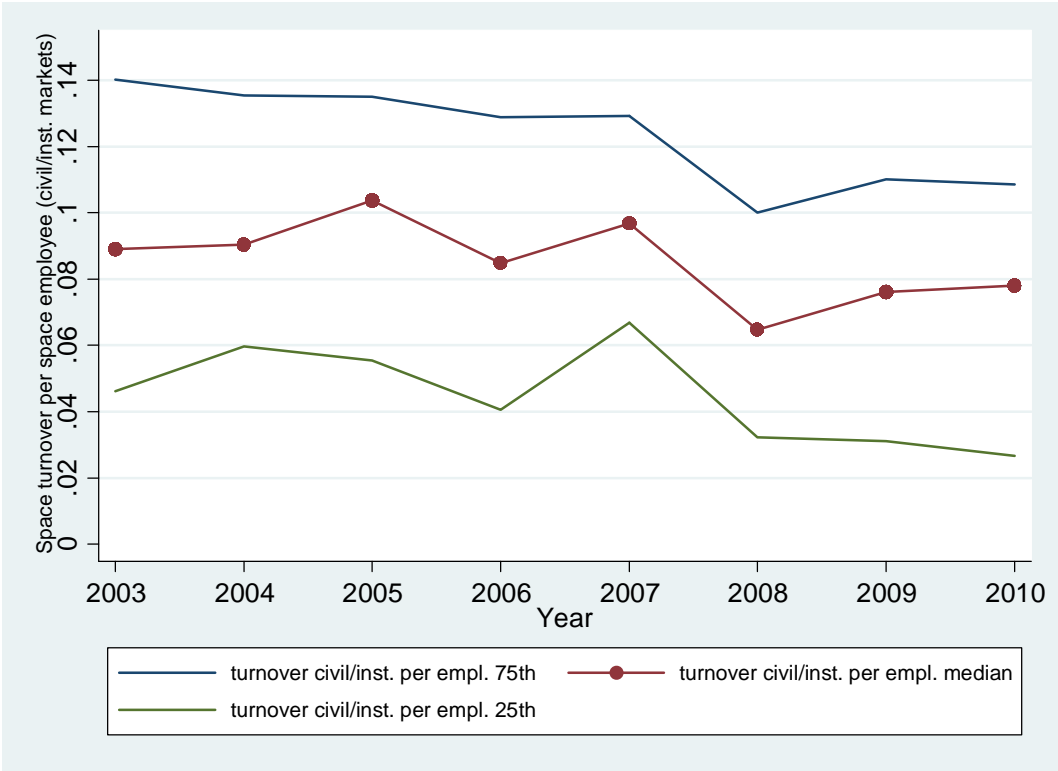
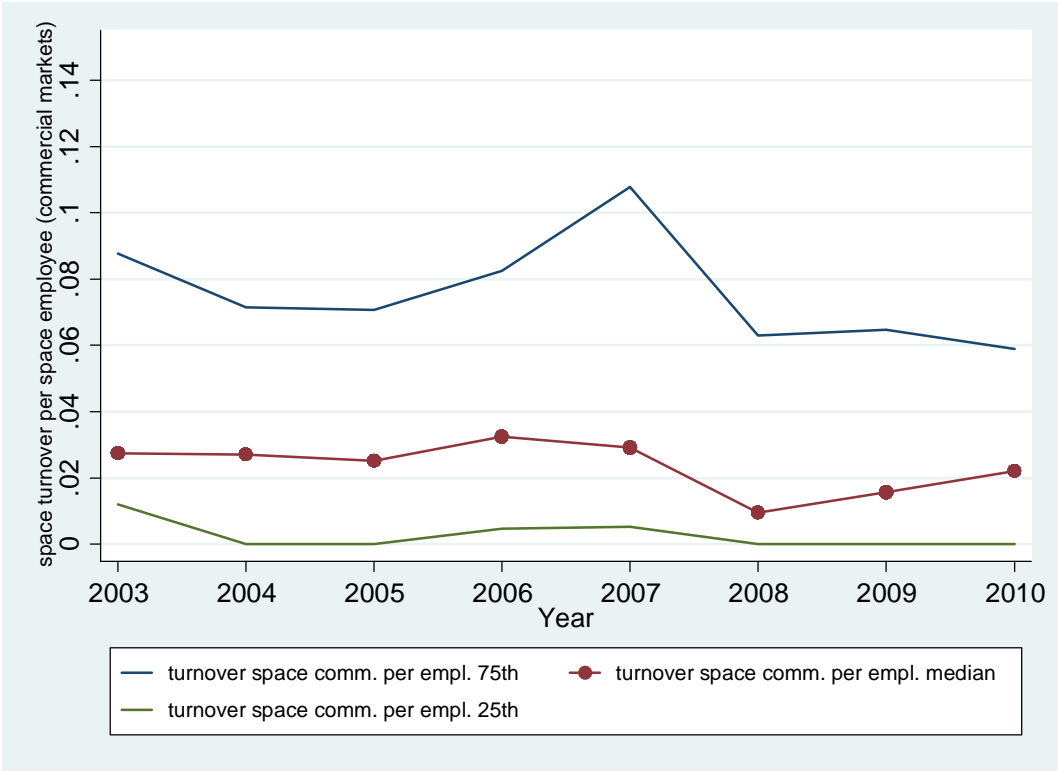


Figure 8.3 shows the evolution of the space turnover in commercial markets per space employee. The figures are not only on a much lower level compared to the civil/institutional markets, they also show some stronger fluctuations at least in the upper quantile; the drop in the 75th quantile is stronger and the recovery basically does not take place. Only the median firms show some slightly upward movement after 2008. Taking together the findings in Figure 8.2 and 8.3 it is likely that public civil/institutional space markets provided stability to the space sector during the crisis especially for well-performing firms (75th quantile).

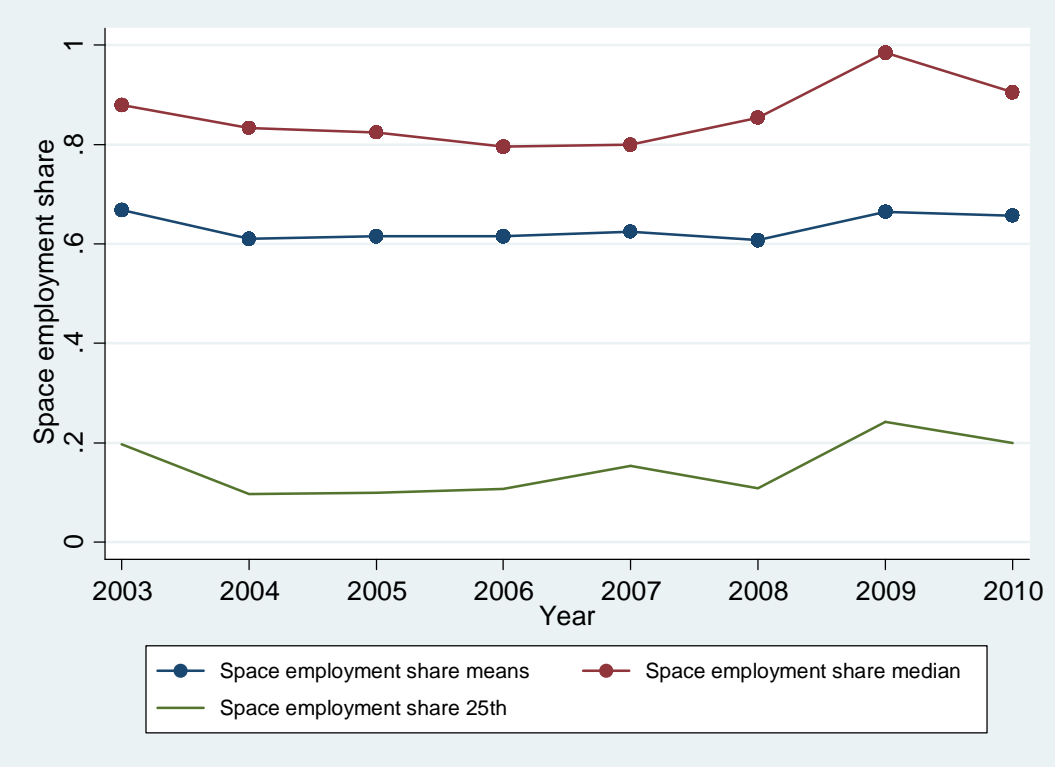
Figure 8.3: Space turnover per space employee commercial markets



8.3 Development of total employment and space employment

Figure 8.4 shows a rather stable development of the share of space employment on total employment until 2008. Quite interestingly, the space employment share increases for median firms as well as for firms with a lower performance level (25th quantile) between 2008 and 2009, although the sector was obviously considerably hit by the crisis. This result indicates that employment in the space departments of firms was reduced (if at all) to a lesser extent than in the non-space departments. It appears that firms were focussing more on their core competences in times of crisis. Moreover, we see that (survey) firms are highly specialized in space activities; in every year the median firm has a space employment rate of more than 80%. Given that the share of space turnover due to commercial markets is relatively low (on average over all years: 26%), firms' space turnover depends heavily on civil public/institutional space contracts (ESA and other national agencies). Such contracts gain in importance in economic downturns and might be the reason for the increasing specialization in the space sector in 2008/2009.

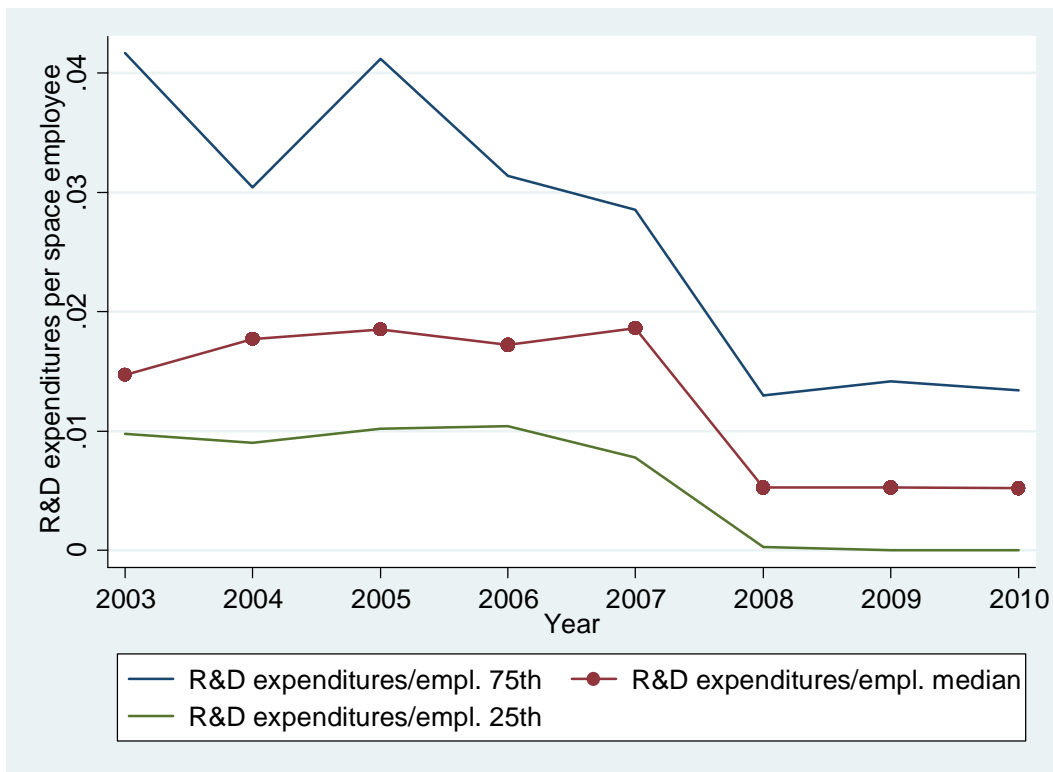
Figure 8.4: Evolution of space employment share on total employment



8.4 Development of space R&D investment and space R&D personnel

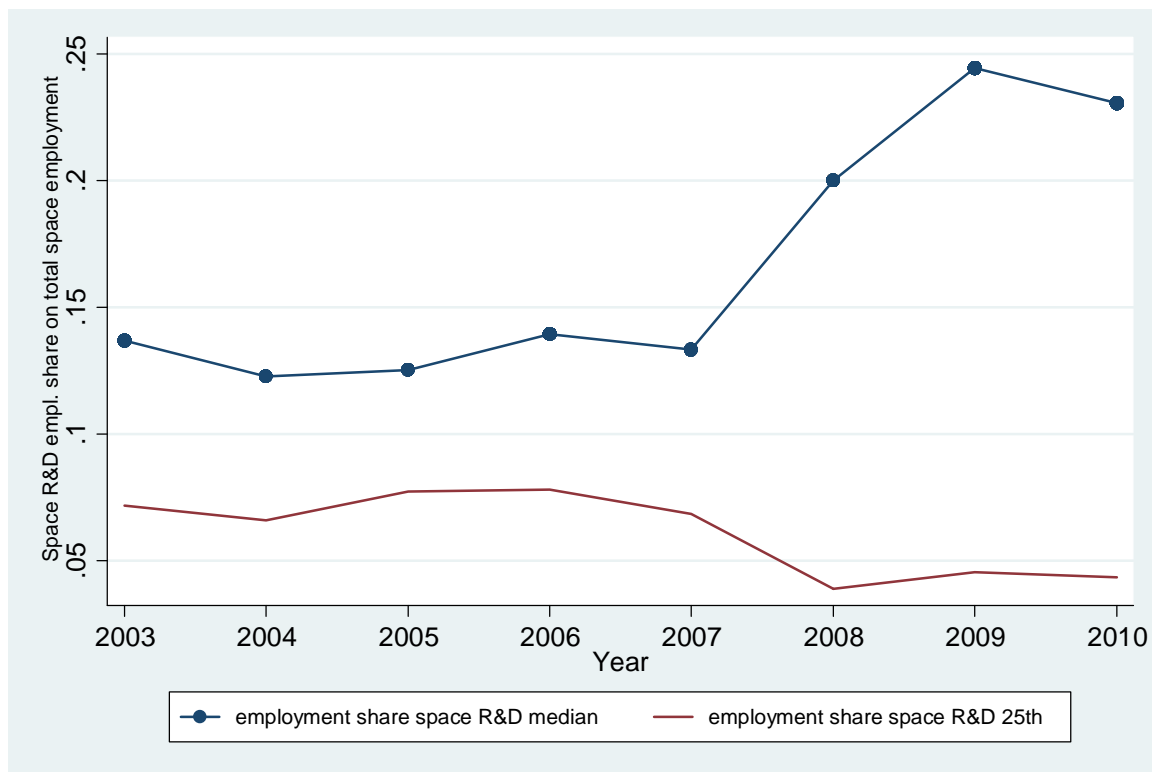
Figure 8.5 shows the development of R&D investments per employee in space for the 25th quantile, the median, and the 75th quantile, respectively. The figures show a *clearly downward trend* over time with a significant drop between 2007 and 2008 for firms with relatively high R&D investment per space employee. In contrast, the trend was rather stable for median firms and firms at the 25th quantile between 2003 and 2007; however, they also experienced a sharp drop between 2007 and 2008.

Figure 8.5: Space R&D investments per space employee



This picture gets clearer if we look at the space R&D employment share on total space employment. Figure 8.6 shows that median firms sharply increased their space R&D employment share between 2007 and 2009, while firms with an already low space R&D employment share further decreased the respective share. This indicates that median firms tried to keep their R&D competences (that are incorporated in the highly qualified R&D personnel) also in economically difficult times, knowing that once lost, it would be difficult to regain competences and (tacit) knowledge when markets prosper again. Less R&D-intensive firms also reduced employment in their space R&D departments.

Figure 8.6: Space R&D employment share on total space employment



Taking together the results in Figure 8.5 and Figure 8.6 it is indicated that at least the R&D-intensive firms reduced R&D expenditures but they hardly reduced their R&D staff in their space activities during the crisis. This way, they could keep their specialized know-how.

8.5 Summary

The descriptive analysis of the evolution of the space industry emphasises four important points:

- Also the evolution of the space industry was strongly affected by the crisis in 2008.
- Space R&D employment is an exception to the overall development. Firms tried to secure their core competences and kept their know-how in space related R&D
- Civil/institutional markets acted as a kind of stabilizing factor to ameliorate the negative effects of economic fluctuations.
- It is likely that the loss in space know-how would be more accentuated without the stabilizing role of civil/institutional markets (ESA, national agencies).

9. Summary and conclusions

Innovation process in the space industry

The technological areas with the four highest shares of ‘market presence counts’ are: ‘space system software’ (17.7%); ‘mechanisms and tribology’ (8.3%); ‘system design & verification’ (7.5%) and ‘structures and pyrotechnics’ (7.0%). These four technological areas amount to about 40% of all counts. On the whole we identified 385 such ‘market presence counts’, i.e. on average 2.5 per actor (firm or institution). This is a hint that *technological diversification* is on average rather low, which is not astonishing given the large number of SMEs in our sample (about 54%).

About 39% of firms had a *R&D intensity* of 5%, 25% an intensity that is higher than 5% but less than 20%, and about 8% reported intensity values higher than 20%. Most large firms (60%) reported values of R&D intensity up to 5%. As compared to other industries the R&D intensity of the firms in our sample is clearly above-average.

With respect to *external innovation-relevant knowledge sources*, the high percentage of firms using intensively university information as well as information from public research institutions is a specific characteristic of the space sector.

The most frequently used *strategy of knowledge acquisition* is R&D cooperation (about 64% of firms), next to it extramural R&D (about 37%). Only about 13% of the firms use licensed knowledge.

The space sector shows a high propensity to introduce *products and processes that are ‘new to market’*. About 70% of all firms reported the introduction of such innovative products. This percentage is considerably higher than the respective percentage, for example, for such German innovative industries as chemicals, automobile and machinery. About 45% of firms introduced new processes.

Also the *propensity to patent* is exceptionally high in the space sector, also as compared to such Swiss innovative industries as chemicals, electronics/instruments and machinery: about 40% of all firms reported at least 1 patent application in the period 2008-2010.

The correlations between innovation inputs and innovation outputs do not allow clear-cut conclusions about the efficacy of inputs.

Production process in the space industry

Procurement activities were focussed on the market segment ‘spacecraft’ (about 70% all ‘market presence counts’). About 41% of all ‘market presence counts’ referred to the sub-segment of ‘spacecraft components and materials’. Procurement activities in ‘ground systems and activities’ were reported in about 18% of all cases, activities in ‘launchers’ in about 12% of all cases.

On the whole, space actors seem to be well-equipped with high-qualified personnel in R&D, engineering and design as well as software development.

About 67% of all actors (mostly firms) had a total turnover in 2010 of less than 50 mio. Euro. About 14% of all firms are very small having a turnover of less than 1 mio. Euro, About 10% had a turnover of more than 500 mio. Euro.

Many of the actors are active not only in space sector but also in one or more other sectors. The three most important fields of activities besides space as measured by the share of turnover in such activities are '*telecommunication and information*', '*energy / utilities*' and '*aeronautics*'. More than 55% of all firms have a turnover share between 10% and 50% in one of these three important fields.

45% of all actors had a space share that was larger than 75%. This share amounted to about 50% for large firms, to about 40% for SMEs and to about 43% for research institutions. *More than 50% of large firms and SMEs had a space share of more than 50%.*

About 36% of all firms reported exports outside Europe. 58% of them had an export share up to 25%, 27% a share between 26% and 50%, and 16% a share of more than 50%. The main export market was the USA, next to it Asia, some firms exported space products to Russia.

Sales activities were focussed on the market segment 'spacecraft' (about 53% all 'market presence counts'). About 18% of all 'market presence counts' referred to the sub-segment of 'spacecraft equipments'. Sales activities in 'ground systems and activities' were reported in about 37% of all cases, most of them in the sub-segment 'ground equipment / components / software / services'. Finally, activities in 'launchers' were reported in about 10% of all cases. On the whole we identified 235 such 'market presence counts', i.e. on average 1.5 per actor. This is a hint to a rather low diversification.

About 50% of all firms (53% of large firms; 50% of SMEs) had an ESA space share of more than 75%. For these firms ESA was their *main client*.

Drivers of productivity in the space industry 2008-2010

The results of the econometric analysis can be summarized as follows:

- A high *space specialization* does not contribute to overall productivity of the firm, presumably because of the specificity of inputs and technologies in the space activities that require a proportionately too high share of firm resources.
- The econometric analysis shows that *ESA contracts* and *contracts with other civil public institutions* matter for the productivity level of firms. Measures that enable a firm to carry out such contracts more efficiently would significantly increase the productivity on several levels. Such measures could be related to the contractual procedure but also to the specification of the content of the contract.

- *R&D investments* (per employee) are positive related with the space related performance of a firm. Measures that help to increase R&D investments also increase firm performance as measured by productivity. The analysis shows that lack of external funds, difficulties to find cooperation partners or the dominance of well-established firms influence negatively space R&D turnover productivity. Measure to attenuate such hindrances would also increase the readiness to invest in R&D, since we know from other sectors that R&D is mainly funded by internal financial means. On the other hand, productivity increases the availability of internal funds and hence contributes to the increase of R&D investments.
- High *specialization* is positively related with space (products and R&D) turnover productivity. Measures that help firms to specialize in market segments are likely to increase productivity. On the other hand, high specialization, particularly high technological specialization, can lead in the long-run to ‘lock-in’ situations, which make the change to new technological paths extremely costly.
- “Openness” of a firm is positively related to space R&D turnover productivity in several ways. Firstly, we saw that access to *external knowledge sources* increase space productivity. Secondly, we saw that external knowledge acquisition strategies also positively contribute to space R&D productivity. Consequently, measures to promote the “openness” also foster space productivity. From the results concerning the *innovation obstacles* we saw that firms have problems to find cooperation partners for R&D; easing collaborations, e.g., through information exchange platforms would increase “openness”.
- *Country affiliation* plays also a role for the firm performance in the space as well as in the overall turnover productivity. “Best-practice” measures to create a space-friendly economic environment for firms could be formulated by looking at not-under-performed countries.

Evolution of the space industry 2003-2010

The descriptive analysis of the evolution of the space industry emphasises four important points:

- Also the evolution of the space industry was strongly affected by the crisis in 2008.
- Space R&D employment is an exception to the overall development. Firms tried to secure their core competences and kept their know-how in space related R&D

- Civil/institutional markets acted as a kind of stabilizing factor to ameliorate the negative effects of economic fluctuations.
- It is likely that the loss in space know-how would be more accentuated without the stabilizing role of civil/institutional markets (ESA, national agencies).

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