Chapter 7
Industry Dynamics and Geographical Concentration

Use a picture. It's worth a thousand words.
(Arthur Brisbane 1911)

Abstract A natural starting point for the descriptive part of this book is to look at the industry as a whole. The results of our initial industry level analysis provide the basis for exploring cooperation activities in the following sections. This chapter is divided into two sections. Section 7.1 focuses on industry dynamics and geographical concentration patterns in the German laser industry. The initial descriptive exploration provides a comparison of industry dynamics, geographical concentration indices and spatial distribution patterns for three types of laser-related organizations – laser source manufacturers (LSMs), laser system providers (LSPs) and laser-related public research organizations (PROs). Section 7.2 focuses on LSMs that constitute the core of the industry due to their central position along the industry value chain. Our analysis reveals some interesting insights by uncovering entry and exit dynamics of LSMs on an annual basis and illustrating the size distribution of firms at the regional and national level. Finally, we take a closer look at the public research landscape in the German laser industry by exploring the structural composition of all PROs in the sample.

7.1 Exploring the German Laser Industry from Various Angles

This section will begin by focusing on industry dynamics[1] and geographical concentration patterns in the German laser industry.

[1] For an in-depth discussion on industry evolution in the German laser industry see Buenstorf (2007). We had to identify all organizational entities under investigation at firm or business unit level to meet the requirements of our study. The consequence is that the following descriptive findings can differ from the industry evolution patterns reported by Buenstorf (2007).

M. Kudic, *Innovation Networks in the German Laser Industry*,
Economic Complexity and Evolution, DOI 10.1007/978-3-319-07935-6_7

7.1.1 *Industry Dynamics – An Overview of the Major Trends*

Figure 7.1 shows the total number of LSPs (black line), PROs (gray line) and LSMs (dotted gray line) in Germany in the past 20 years. It is immediately apparent that the yearly number of LSPs exceeds the number of LSMs and PROs throughout the entire period under observation. The early period between 1990 and 1992 is characterized by a strong growth tendency for LSPs followed by a stagnating period between 1992 and 1996. The following decade is characterized by an almost stable growth trend with minor fluctuations followed by a peak in 2005. The last 5 years are characterized by a slight decrease in numbers. With the exception of some minor differences, the overall LSM trend mirrors the long-term LSP trend for the most part. However unlike the LSPs, the number of LSMs stagnates between 1992 and 1996 and is at a significantly lower level throughout. The number of LSMs decreases slightly after 2005, however in the last 5 year period, there are some notable differences between the LSM curve and the LSP curve. This is highlighted by a short but accentuated increase in LSMs followed by a relatively high number of firm exits in 2008.

The PRO line on the graph shows the total number of laser-related universities and public research organizations per annum. The pronounced increase in PROs between 1990 and 1991 is mainly the result of the integration of former GDR research facilities into the FRG's sectoral laser industry innovation system. In general, there is a less marked increase in PROs than in LSMs and LSPs. After 1991, the number of PROs remains remarkably stable during the entire period under observation.

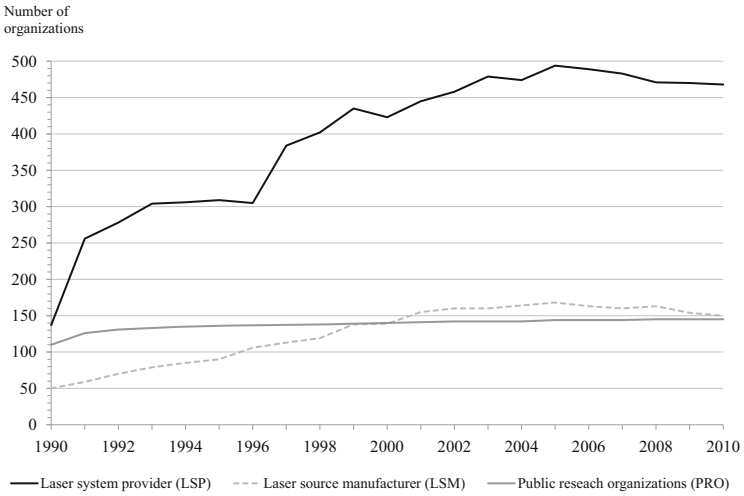

Fig. 7.1 Industry dynamics – overall trends between 1990 and 2010 (Source: Author's own calculations and illustration)

To obtain a more detailed picture of the industry we will now turn our attention to geographical aspects. More precisely, we will explore geographical concentration indices at the industry level and spatial distribution patterns at the state level.

7.1.2 Geographical Concentration

Figure 7.2 illustrates the geographical Herfindahl-Hirschman Indices (HHI-indices) which are calculated on an annual basis and broken down by type of organization (LSP, PRO, LSM).[2]

The graph also includes an average trend line seen here as a dotted black line. It represents the average concentration for all organizations in our sample: LSPs, PROs and LSMs. We can observe a general decrease in concentration which amounts to an increasing geographical dispersion of laser-related organizations in Germany over time. The HHI indicates an overall industry concentration of 0.062 index points at the beginning of the observation period in 1990. Average concentration decreases until 2003 after which the trend remains stable at around 0.04 index points.

However, a closer look at the geographical concentration tendencies, broken down by organizational type, reveals some interesting insights. LSPs (black line) have the highest geographical concentration at the beginning of the observation period of about 0.13 index points. This is followed by a comparably sharp decrease in concentration over time.

In contrast, the geographical dispersion tendency is less pronounced for LSMs (gray dashed line). The LSM concentration level starts at about 0.08 index points in 1990 and, after decreasing sharply in the first 2 years, they level off at around 0.06 index points in 1996. After some minor fluctuations between 1996 and 2001, the LSM trend stabilizes at about 0.05 index points and remains relatively stable until the end of the observation period.

Finally, a look at the geographical concentration patterns of PROs (gray line) reveals a different picture. In contrast to LSMs and LSPs, PROs display an increasing geographical concentration over time. Between 1990 and 1991 there is a short but pronounced increase in the geographical concentration of PROs. The curve remains relatively stable over the course of the next 19 years showing little fluctuation and remaining at between 0.036 and 0.038 index points.

7.1.3 Spatial Distribution Patterns

Next, we refine our initial findings by changing our analytical perspective and illustrating the location of laser-related organizations within a geographical space. Figure 7.3 shows the spatial distribution of LSPs, LSMs and PROs based on laser

[2] For a detailed description of the calculation procedure, see Sect. 5.3.2.

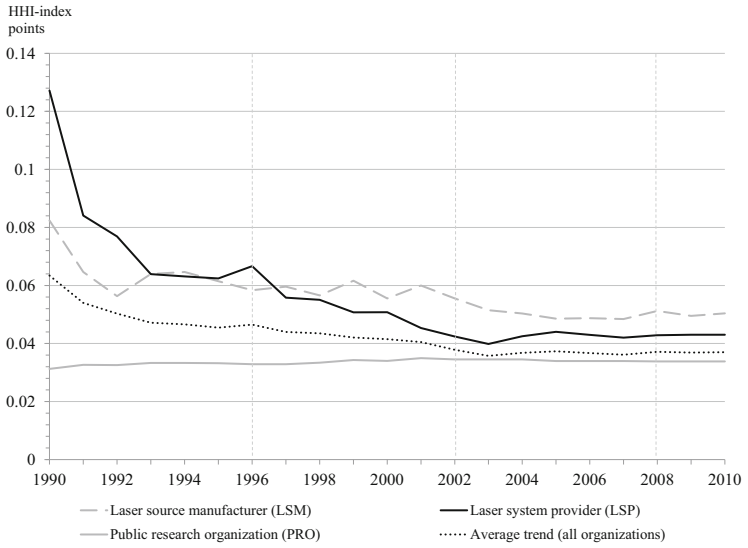

Fig. 7.2 Geographical concentration indices in the German laser industry (Source: Author's own calculations and illustration)

industry maps at four distinct points in time.[3] These maps are divided into 97 *"Raumordnungsregionen"* (i.e. planning regions) in order to provide a fine-grained picture of the organizations' positioning within the geographical space.[4] LSMs and PROs are illustrated by differently shaped and sized elements on the maps whereas the number of LSPs is reflected in the shading of the regions.[5]

The data reveals that the German laser industry included 138 LSPs, 50 LSMs and 110 PROs in 1990. It should be noted that this year saw a relatively high number of LSMs and PROs in three planning regions: Munich (planning region 93: with LSMs = 10, PROs = 7), Berlin (planning region 30: with LSMs = 6, PROs = 8), and Stuttgart (planning region 72: with LSMs = 3, PROs = 7). In addition, Fig. 7.3a indicates that PROs are quite equally dispersed over the geographical space. This confirms our previous findings. However, a look at the spatial distribution of LSPs in this first year provides a somewhat different picture (cf. Fig. 7.3a). The largest number of LSPs was located in Munich with a total of 44 firms (planning region 93). With eleven firms in Starkenburg (planning region 52), 7 firms in Dusseldorf (planning region 42) and 6 firms in the Rhine-Main region (planning region 51), LSPs were concentrated in quite different regions than LSMs and PROs at that point in time.

[3] We chose the years 1990, 1996, 2002 and 2008 based on the findings in Sects. 7.1.1 and 7.1.2 since these yearly snap-shots reflect some remarkable turning points for the organizations under observation.

[4] Appendix 2 provides a complete list of the 97 planning regions as applied in this analysis.

[5] The ESRI ArcMap 10.0 software package was applied to visualize the spatial distribution patterns in the German laser industry. We would like to thank Mr. Michael Barkholz for his support.

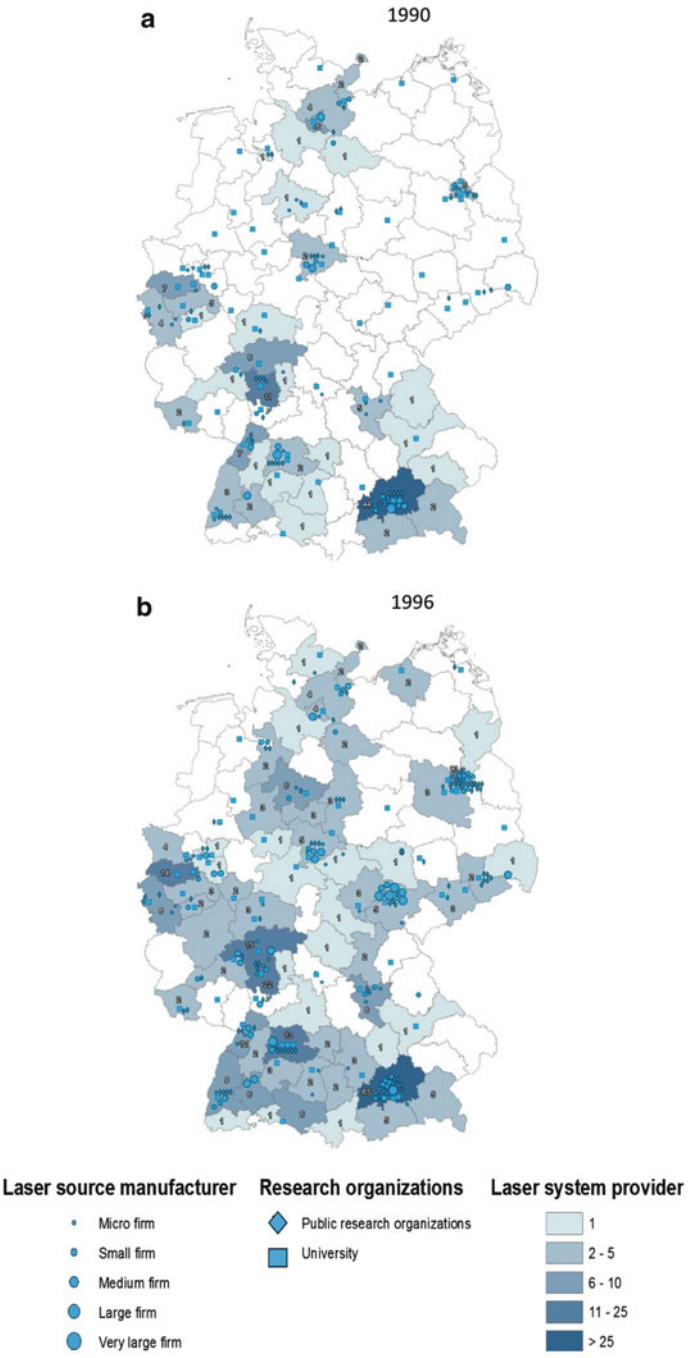

Fig. 7.3 (continued)

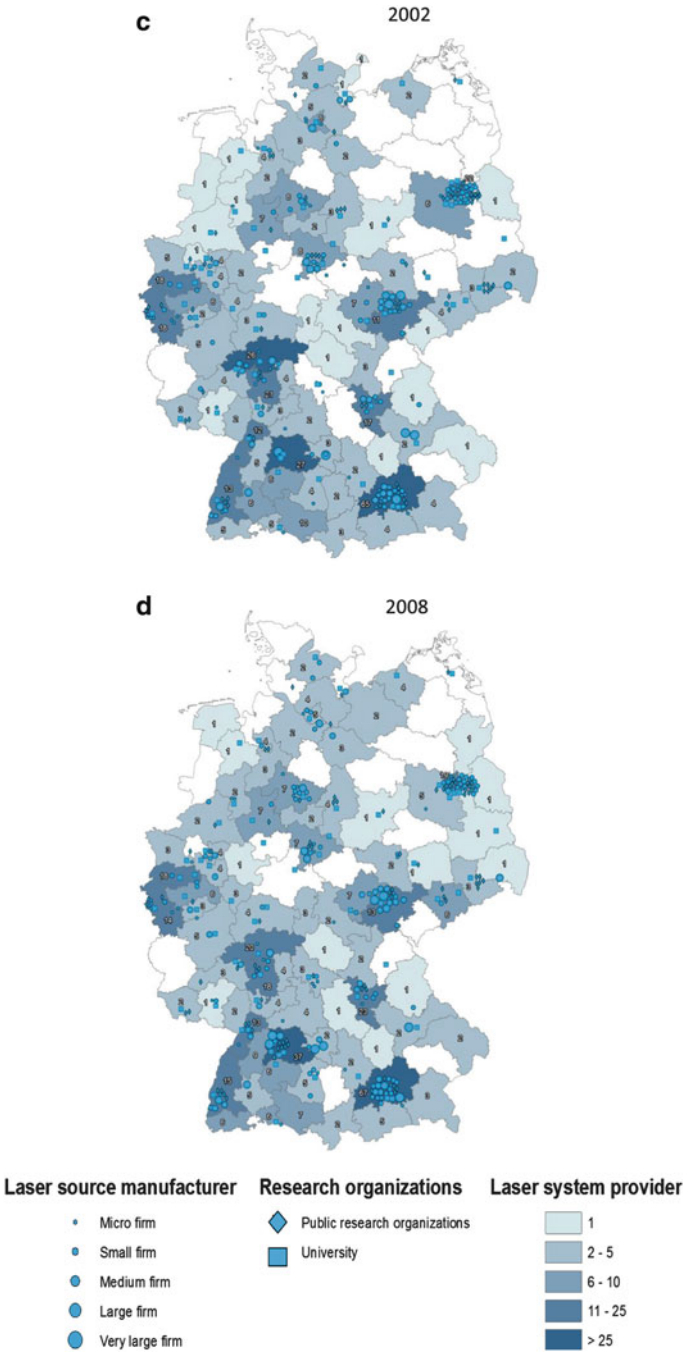

Fig. 7.3 Spatial distribution of LSPs, PROs and LSMs (Source: Author's own calculations and illustration)

In 1996, the total number of organizations increased among all types of organizations to a total of 306 LSPs, 137 PROs and 106 LSMs. The spatial distribution of PROs remained nearly unchanged over the entire observation period aside from a few notable exceptions (cf. Fig. 7.3, a–d). However, a comparison of the geographical locations of PROs in 1990 and 1996 reveals some interesting patterns. Data indicates that about 50 % of the total increase in PROs between 1990 and 1996 took place in only three planning regions – the Upper Elbe Valley (planning region 58: from 3 to 7 PROs), East Thuringia (planning region 56: from 1 to 4 PROs) and Berlin (planning region 30: from 8 to 13 PROs). All of these regions are located in the eastern part of Germany (cf. Fig. 7.3b). In 1996, the number of PROs in Munich remained just as high as in the years before. A closer look at the geographical distribution of LSMs between 1990 and 1996 shows that these firms entered the scene in 15 additional planning regions. In other words, in 1996, we can find at least one LSM in 39 out of every 97 planning regions. Once again Munich has the highest number of LSMs in a given year with a total of 15 firms. The sharp increase in LSMs in Berlin (from 6 to 12 LSMs) and East Thuringia (from 0 to 10 firms) by 1996 is quite remarkable. Finally, this period is marked by the emergence of LSPs throughout the entire landscape with the highest increases in LSPs in the western and the southern parts of Germany (cf. Fig. 7.3b). This is reflected in the doubling of LSPs in the Rhine-Main area (planning region 51), Dusseldorf (planning region 42), and Starkenburg (planning region 52). The number of LSPs in Stuttgart (planning region 72) rose considerably (from 2 LSPs in 1990 to 13 LSPs in 1996). Not surprisingly, the Munich region shows the highest presence of system providers (a total of 65 LSPs) at that time.

By 2002, the total number of organizations had again increased throughout all three categories. Data for this year shows there were 458 LSPs, 160 LSMs and 142 PROs. A comparison of 1996 and 2002 reveals some remarkable patterns. We will start by looking at LSMs (cf. Fig. 7.3c). Compared to 1996, the number of firms in the dominant southern regions increased on average by about 30 % – Stuttgart (planning region 72: by 33 %), Southern Upper Rhine (planning region 77: by 25 %), and Munich (planning region 93: by 33 %). In contrast, the eastern regions present a rather heterogeneous picture between 1996 and 2002. The total number of LSMs increased at quite a different rate. For instance, Berlin (planning region 30) shows a pronounced increase of 83 % to a level of 22 LSMs in 2002. By contrast, data for East Thuringia (planning region 56) indicates a moderate increase of 20 % to a level of 12 LSMs in 2002. Neither the number nor the positioning of the PROs in the geographical space changed substantially compared to the situation in 1996. A closer look at the PROs reveals that research facilities in the regions of the Upper Elbe Valley (planning region 58: with 7 PROs), East Thuringia (planning region 56: with 4 PROs), Berlin (planning region 30: with 15 PROs) and Munich (planning region 93: with 7 PROs) clearly dominated the scene. Figure 7.3c illustrates the increasing dispersion of LSPs throughout the planning regions. Unlike in the previous years, the number of LSPs in the western regions of Germany increased at a significantly lower rate. The number of LSPs in Dusseldorf (planning region 42) increased slightly to a level of 18 firms in 2002 whereas Starkenburg (planning region 52) lost about 4.5 % of its LSPs compared to previous years. The same is true

for some southern regions like Munich where the number of LSPs remained constant at 65 firms. Surprisingly, the industrial region of Central Franconia (planning region 86) exhibited a remarkable growth tendency in the last 6 years with LSPs increasing from 8 to 17 firms. Finally, two regions in the eastern part of Germany made significant gains in terms of LSP presence in 2002. The number of laser source providers in East Thuringia (planning region 56) and Berlin (planning region 30) nearly doubled over the course of 6 years.

We can identify a total of 472 LSPs, 163 LSMs and 145 PROs for 2008. A comparison between 2002 and 2008 reveals no great surprises in terms of geographical concentration for either PROs or for LSMs. In 2008 the number of PROs in the regions of the Upper Elbe Valley (planning region 58), East Thuringia (planning region 56), Berlin (planning region 30) and Munich (planning region 93) was at the same level as 6 years previously. In Central Franconia (planning region 86) one new public research facility entered the scene. 2008 saw an increase of at least one or more LSMs in 52 % of the planning regions. The number of LSMs in the dominant regions did not change considerably over the course of 6 years. During this period the dispersion of LSPs increased slightly. Figure 7.3d illustrates the increasing emergence of LSPs in regions around Berlin (planning region 30), East Thuringia (planning region 56), Munich (planning region 93), Stuttgart (planning region 72) and Central Franconia (planning region 86).

In summary, the comparably sharp increase in PROs between 1990 and 1996 can be explained to a large extent by the fact that former GDR research facilities were being integrated into the German laser industry innovation system after the reunification. The spatial distribution of PROs in subsequent time periods remained nearly unchanged. The pronounced increase in LSMs in Thuringia during the early 1990s was largely driven by the reorganization and integration of former state-owned companies such as VEB Carl Zeiss Jenoptik into the German sectoral innovation system. In other words, spin-offs are strongly influenced by the dominate actors in the region. In 1996 about 40 % of all laser source manufactures were located in only five of the 97 planning regions. Berlin had an especially high number of LSM entries during that time. The following decade was characterized by industry growth and geographical dispersion tendencies. After a short but pronounced increase in LSPs in West Germany this trend slowed down in 2002.

In summary, our analysis shows that the laser organizations were concentrated quite early on in the regions of Munich, Thuringia, Berlin, and in and around Stuttgart. These geographical areas still constitute the centers of the German Laser Industry.

7.2 A Closer Look at the Core of the Industry

In this section we focus on LSMs and PROs for the following reasons. As outlined before, LSMs constitute the core of the German laser industry due to their central position along the industry value chain. Thus this section explores the entry and exit dynamics as well as size distribution patterns for the entire population of LSMs between 1990 and 2010. Breaking up the data into entries and exits reveals some

details that would otherwise go undetected. Because focus is on innovation networks, the technological dimension of the industry has to be taken into particular consideration. Consequently, we provide some descriptive statistics and give an overview of all laser-related public research organizations active in the period between 1990 and 2010.

7.2.1 Exploration of LSM Entry and Exit Dynamics

The upper half of Fig. 7.4 illustrates the number of actively operating LSMs on an annual basis (cf. Buenstorf 2007; Kudic et al. 2011). Starting with a total of 50 active LSMs in 1990 we observed a total of 183 entries and 83 exits resulting in a total number of 233 firms throughout the entire observation period. The lower half of Fig. 7.4 illustrates firm entries (darkly shaded bars) and firm exits (lightly shaded bars).

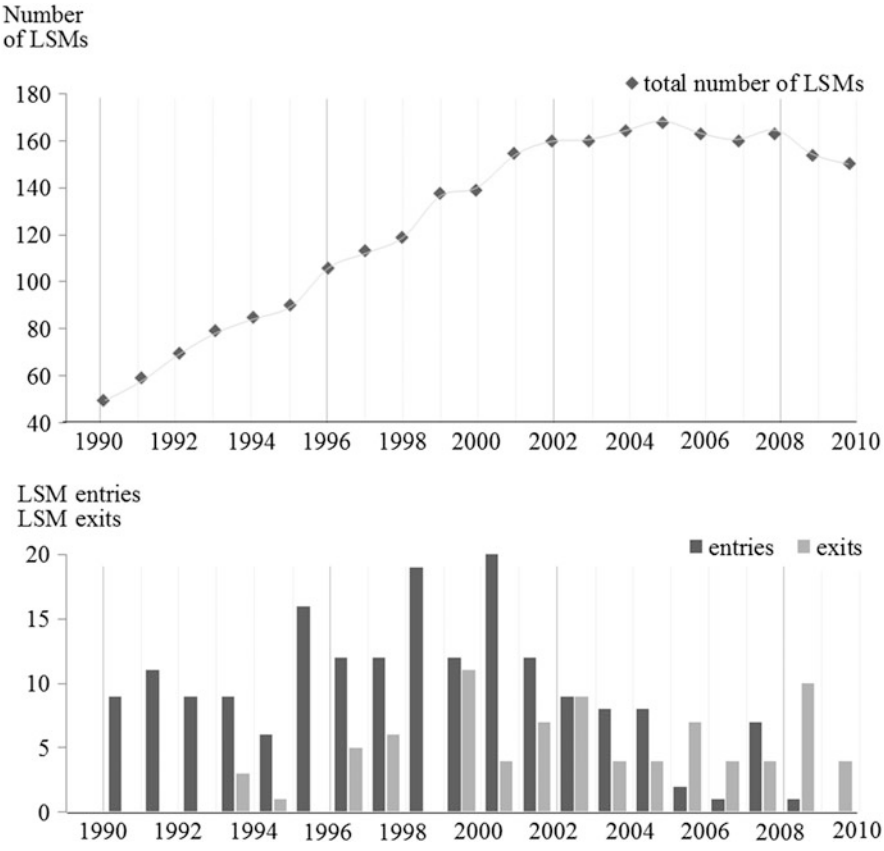

Fig. 7.4 Industry dynamics – LSM entries and exits (Source: Author's own calculations and illustration)

The overall trend indicates a 3.4-fold increase in firms over the course of just 15 years peaking in 2005 at 168 firms. This is followed by an overall decrease to 150 LSMs in 2010. Our data indicates the highest number of firm entries in the years 1995, 1999 and 2001 with firm entries peaking in 2001. In contrast, both 1990 and 2010 are characterized by no firm entries at all. However, a relatively high number of firm exits in 2001 resulted in the steepest net increase in LSMs having occurred in 1999. No LSMs left the industry from 1991 to 1993, nor did any leave in 1996 or 1999. The total number of firm exits peaked in 2000 with eleven LSMs leaving the industry. However, due to twelve firm entries, the overall industry growth trend remained unbroken resulting in a marginal increase for this year. Three years later there is another case of a high fluctuation of entries and exits that are not reflected in the overall industry growth trend. More precisely, both the number of LSM entries as well as the number of LSM exits amounts to a total of nine firms in 2003. Unlike in previous years, firm exits significantly exceeded firm entries in 2006 and 2007. After an increase in the total number of firms in 2008 we can observe a slightly increased number of exits at the end of the observation period.

7.2.2 Size Distribution of LSMs at the National Level

Figure 7.5 illustrates the size distribution of German LSMs at the national level. The bar graph at the top of Fig. 7.5 shows the absolute number of LSMs divided into five distinct size categories. The line graph at the bottom of Fig. 7.5 shows the changes in size distribution by presenting the relative terms for each size category. Firm size categories are based on the number of employees in a firm. Smaller firms are represented by lighter colored bars and lines while darker shades symbolize larger firms. To enhance visibility, micro firms are represented by black-hashed bars and the dotted black line. As before, the period under observation lasted from 1990 to 2010.

We start our analysis by looking at the absolute figures displayed in the bar graph. To start with, the comparably high number of micro firms and small-sized firms is striking. At the beginning, more than half of all firms are micro firms. After a short increase in the number of micro firms in the early 1990s the absolute number of LSMs remained roughly constant for nearly a decade at around 45–55 firms before starting to decline after 2005. We can also observe an increase in the number of small-sized firms over time. Starting with twelve firms in 1990 the number increases five-fold over the course of 20 years to 59 LSMs. The trend is nearly the same for medium-sized firms, even though the total number of medium-sized firms is roughly one half the number of small-sized firms. Accordingly, we can observe a 4.5-fold rise in the number of medium-sized firms, from six firms in 1990 to 27 firms in 2010. Finally, large and very large firms only begin to play a significant quantitative role after 1994. At the beginning of the observation period data indicates there were three large and two very large firms. In both cases the absolute number of firms quadrupled over the course of 20 years.

The relative values enable us to get a clearer picture of the firm size distribution within the industry. The line graph provides the relative terms for all five firm size

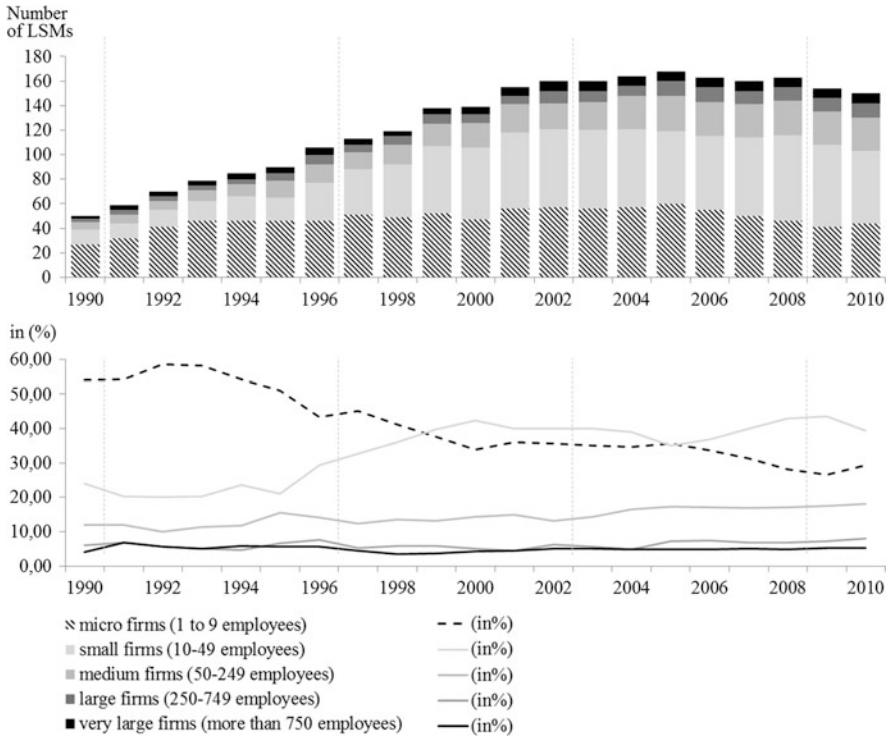

Fig. 7.5 Size distribution of LSMs at the national level (Source: Author's own calculations and illustration)

categories. The black dotted line represents the micro firms in the sample. It becomes obvious that micro firms dominated the industry at the onset of the observation period, not only in absolute terms but also in relative terms. However, the decreasing trend indicates a diminishing relevance over time of micro firms in comparison to larger firms. A closer look at small firms reveals a completely different picture. The line graph clearly indicates a rise in the significance of small-sized firms compared to other firms in the sample. The same is true for medium-sized firms in terms of relative figures. In other words, both small and medium-sized firms gain in importance over time. Finally, the proportion of large firms and very large firms remains remarkably stable over the entire observation period.

In summary, our descriptive analysis reveals that micro firms, in particular, lost ground in the German laser industry over time. One possible explanation is that micro firms outgrow their infancy and, in time, turn into small firms. Small firms show the highest average growth rates, followed by medium, large and very large firms. At the end of the observation period small firms dominate the scene. It should also be stated that due to the moderate but continuous growth of medium-sized LSMs (by about 20 % up until 2010) there is a clear increase in the presence of both small and medium-sized LSMs in the German laser industry during the observation period. Next we explore the size distribution of LSMs at the regional level.

7.2.3 Size Distribution of LSMs at the Regional Level

Figure 7.6 shows the size distribution of LSMs in a geographical space.[6] The level of analysis is the state level ("Bundesländer"). The vertical axis in the bar graph represents the number of firms whereas the horizontal axis represents time. For the sake of clarity, the annual number of firms per region is grouped into 3-year time intervals.

To start with, we look at the federal states of Bavaria and Baden-Wurttemberg, both located in the southern part of Germany. Bavaria shows the highest absolute number of LSMs throughout the entire period of observation. Looking more closely at firm size distribution reveals that the high number of small and medium-sized firms is responsible for the above-average presence of LSMs in Bavaria.

In contrast, the majority of large and very large firms are located in Baden-Wurttemberg. Baden-Wurttemberg also shows a relatively stable trend in firm growth throughout the entire period of observation. The federal state of Thuringia, located in the eastern part of Germany, reveals a very similar picture to that of Bavaria. In both cases we see a pronounced growth phase in the early 90s followed by a shakeout at the end of the observation window. Even though the total number of firms in Thuringia is lower than in both southern states, we can again observe a relatively high number of very large firms. Moreover, in all three federal states – Bavaria, Baden-Wuerttemberg and Thuringia – micro firms lose ground over time whereas small firms and medium-sized firms are on the rise. In summary, firm size distribution in these three states follows very similar patterns with only minor exceptions.

The situation looks somewhat different in Lower Saxony since no very large firms are located in this state. Nonetheless, the relatively high number of micro firms, small firms and exceptionally the presence of some large firms highlights the importance of Lower Saxony as a location for LSMs in Germany. The situation in Berlin is characterized by a comparatively high number of both micro and small firms. The most plausible explanation for this seems to be the comparably high number of PRO spin-offs in Berlin. Medium, large and very large firms are completely missing here.[7] This is important to note since otherwise there is a danger of overemphasizing Berlin in terms of LSM presence. At first glance, the situation in North Rhine-Westphalia looks quite similar to that of Berlin. However, the main difference is the existence of a solid stock of medium-sized firms throughout the entire observation period. Finally, we look at the federal states of Hesse and Hamburg. The comparatively low presence of LSMs conceals the fact that a small number of highly relevant actors are located in these regions. As we will see later the same is true for the federal state of Rhineland Palatinate. The remaining federal states had a very low number of LSMs throughout the 21 year period. Saarland shows no LSM presence at all.

[6] A similar analysis was previously conducted by Kudic et al. (2011).

[7] A contemporary study that focuses on the laser industry in Berlin-Brandenburg confirms this finding. It found that 94 % of all firms studied have less than 50 employees (TSB 2010, p. 9).

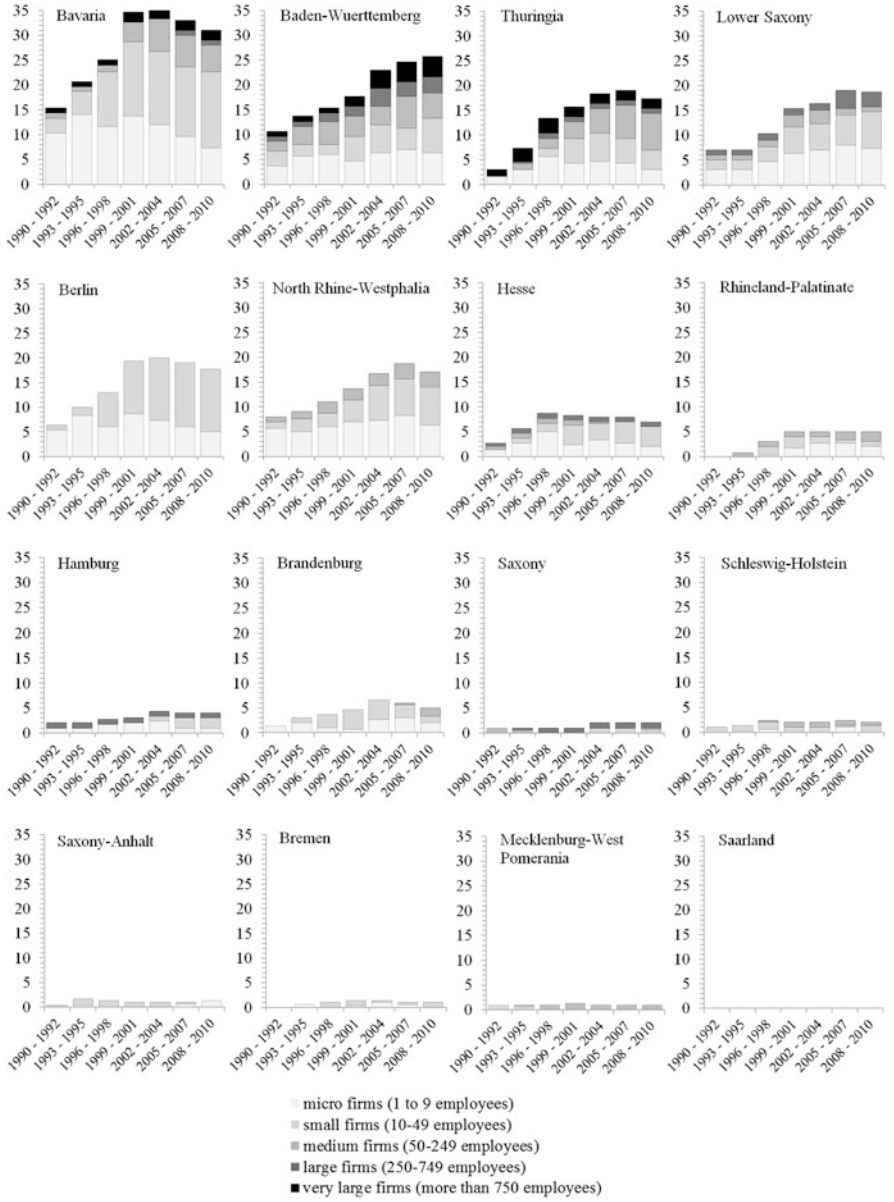

Fig. 7.6 Size distribution of LSMs at the state level (Source: Author's own calculations and illustration)

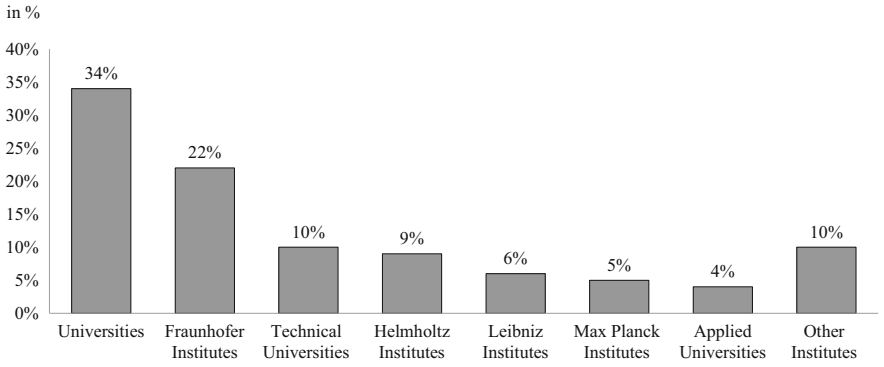

Fig. 7.7 Composition of laser-related PROs in Germany (Source: Author's own calculations and illustration)

7.2.4 Laser-Related Public Research Organizations in Germany

Figure 7.7 illustrates the composition of public laser-related research facilities in Germany. Average values are reported since only minor changes occurred to the composition of the research landscape during the observation period.

Public research organizations (PROs) in Germany that are actively operating in the field of laser research can be grouped into eight categories. Universities are divided into three categories – technical universities, universities (in general), and universities of applied science – and make up about half of all laser-related PROs in Germany. Laser-related research activities were identified at the chair level and thereafter aggregated at the overall university level. In total, the proportion of technical universities, universities and universities of applied science was 10 %, 34 %, and 4 % respectively. Data reveals hardly any fluctuation in terms of population entries or exits among these organizations over the entire observation period. Next we turn to non-university research facilities. The German research landscape is characterized by four large non-university research societies. To start with, Max Planck Society is a publicly funded, non-governmental and non-profit organization. Its 80-plus institutes conduct fundamental research in the areas of natural sciences, life sciences, social sciences and the humanities.[8] The proportion of Max Planck Institutes active in the field of laser research amounts to 5 % on average. The Helmholtz Association is a community of 18 scientific-technical and bio-medical research centers which conduct research in the fields of energy, earth and environment, health, key technologies, structure of matter, aeronautics, space and transport.[9] Our data shows that about 9 % of the laser-related research facilities

[8] Information from: http://www.mpg.de (Accessed: February 2012).

[9] Information from: http://www.helmholtz.de (Accessed: February 2012).

identified belong to the Helmholtz Association. The Leibniz Association comprises 86 scientifically and organizationally independent research institutions that conduct research in the areas of natural science, engineering, environmental science, economics, social science, infrastructure research and the humanities.[10] Our data shows a sharp increase in Leibniz Institutes at the beginning of the observation period. Between 1990 and 1993 the number of institutes active in the field of laser research nearly quadrupled. This can be explained to a large extent by the integration of former GDR research facilities into the FRG science landscape. Leibniz Institutes make up, on average, about 6 % of all PROs in the sample.

The last group of institutes is organized under the umbrella of the Fraunhofer Society. The Fraunhofer Society is Germany's largest application-oriented research organization which is made up of around 60 institutes. These institutes primarily conduct applied research in the fields of health, security, communication, energy and the environment.[11]

Our data reveals two interesting facts. Firstly, at the beginning of the observation period we can again witness a steep increase in population entries. Between 1990 and 1991 we registered a rise by over 50 %; thereafter there was hardly any change in terms of population entries or exits. The explanation for this is similar to that of the Leibniz Institutes. Secondly, Fraunhofer Institutes make up the largest percentage of non-university research organizations in our sample at about 22 %. Finally, about 10 % of the overall population, a notable percentage of laser-related PROs, do not belong to one of the four large German research societies.

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[10] Information from: http://www.wgl.de (Accessed: February 2012).

[11] Information from: http://www.fraunhofer.de (Accessed: February 2012).