
This research analyses various questions regarding industry agglomeration. Which development did agglomeration in the manufacturing sectors in Hungary undergo during increasing integration with the EU, first under the Europe agreement and then in the post-accession phase: Did integration reinforce industry agglomeration in the manufacturing sector? Did agglomeration decrease? Were there perhaps phases of both? Was there a turning point, and if so, when was it reached?

Chapter 4 shall approach this part of the research topic by presenting results of empirical calculations. The data shall be treated in a way such that information shall be provided about the actual development of agglomeration in Hungary during the period 1992 to 2008. The results will be commented and put into context of the predictions made by NEG theories (chapter 2.1.2), by previous empirical studies, and, where applicable, by the descriptive empirical analysis of chapter 3.

4.1 Measuring industry agglomeration

Before embarking into the analytic part, the issue of concentration versus specialization shall be set out here clearly.

<table>
<thead>
<tr>
<th>Concentration</th>
<th>looks at the industry, a sector of manufacturing, at the degree of its agglomeration or dispersion in space.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specialization</td>
<td>looks at the region, at the structure of sectoral employment, whether only a few sectors are dominant, or whether a region is highly diversified.</td>
</tr>
</tbody>
</table>

While industry concentration is analysed in this chapter, the topic of regional specialization is reserved for the following Chapter 5.

With respect to concentration, this research looks at the research questions whether manufacturing industry concentration in Hungary has increased or declined in the course of European integration, or whether there were both trends and at which stages of the integration process. It also verifies whether there may have been a turning point in the development up to which there was an increase and after which there was a decline. Such a development would correspond to the predictions made by the selected NEG models (Puga 1999, Ludema & Wooton...
1997, *Livas-Elizondo & Krugman 1996*). The analysis shall also find out whether such a peak point was already reached prior to full EU-membership of Hungary.

Here again, the speciality of my research is that it is based on regional sectoral manufacturing employment data as a basis for calculating industry concentration for the country of Hungary, and not at sectoral country-wide data for a group of countries such as the EU-15 or a set of CEECs, as most previous empirical studies in the field.

The subject of industry agglomeration can best be measured using the tool of concentration indices. The unique contribution of this research is that it applies six different concentration measures to the same set of data, thus allowing for a comparison of them. The period under study is 1992 to 2008, which is the longest available and with reliable data at the time of writing using the Hungarian regional sectoral employment data series of the HCSO.

### 4.2 Overview of indices

Table 19 gives an overview of the six concentration measures used in this research. They were all calculated based on Hungarian regional employment data by manufacturing sectors. The detailed formula of each index will be given in the

<table>
<thead>
<tr>
<th>Table 19</th>
<th>Concentration measures used for measuring agglomeration.</th>
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</thead>
<tbody>
<tr>
<td>1)</td>
<td><strong>Krugman concentration index:</strong> a <em>relative</em> measure of concentration of the industry in space;</td>
</tr>
<tr>
<td>2)</td>
<td><strong>CR3:</strong> an <em>absolute</em> measure (usually used in competition policy); shows the concentration accounted for by the three largest regions in each sector’s country-wide employment;</td>
</tr>
<tr>
<td>3)</td>
<td><strong>Herfindahl index:</strong> measures <em>absolute</em> concentration of the sector; also referred to as HHI (Herfindahl-Hirschman index);</td>
</tr>
<tr>
<td>4)</td>
<td><strong>relative Herfindahl index</strong> (modified form): measures <em>relative</em> concentration of the sector compared to the benchmark of manufacturing employment;</td>
</tr>
<tr>
<td>5)</td>
<td><strong>Hoover-Balassa index:</strong> measures the <em>relative</em> concentration of a specific industry in a region with respect to the average concentration in the country, Hungary;</td>
</tr>
<tr>
<td>6)</td>
<td><strong>Entropy:</strong> measures the degree of dispersion of an industry in space as an absolute number (thus the inverse concept of concentration).</td>
</tr>
</tbody>
</table>

Source: Own selection and formulation.
respective subsections. Some of these indices are absolute measures of concentration, some are relative measures, i.e. in relation to some other benchmark value.

All of these indices were applied to employment data by manufacturing sector and for the 20 Hungarian regions. The idea to calculate values for these indices also based on output, production or value added data was not feasible due to the lack of such data at the regional level; they are not available from HCSO.

Some of the 6 indices were used in previous studies of agglomeration, some of them rather rarely though. These 6 are not the only existing concentration indices, however. Two other indices could not be applied here due to the unfitting set-up of the data. These are the Ellison-Glaeser index (Ellison & Glaeser 1997 and 1999) the calculation of which would require firm-level data; such were not publicly available for Hungary. Another index not applicable here is the so-called spatial separation index (Midelfart-Knarvik et al. 2000); calculations for that index would require regional output data by subsector which are not available for Hungary either; from its conceptual definition, that index cannot be transformed to using employment data, so that this possibility had to be ruled out. Another recent paper by Giacinto & Pagnini (2008) proposed two modified indices measuring industry agglomeration in Italy. These include properties of the economic environment such as regional adjacency. As they also require plant level data, they are not feasible for my research.

The remainder of this chapter is structured as follows: first, industry agglomeration is analyzed by means of the 6 different concentration indices or measures. Each section first presents the index, then the results obtained by its calculation; where applicable, they are put into relation with the results of other empirical studies. A comparative section analyses all 6 concentration indices based on their results for the data set. The final section of this Chapter draws first conclusions with respect to industry concentration in Hungary under the Europe agreement.

### 4.3 The Krugman concentration index

As first index, the Krugman concentration index shall be presented here. As Krugman is one of the founding fathers of the theories of the New Economy Geography regarding the development of industry agglomeration in space (Krugman 1991a), this index is presented first. The Krugman concentration index is a relative measure of the degree of an industry’s agglomeration or dispersion in space. In this form, it was derived from the index proposed by Krugman (1991b).

The index shall be applied here to the 8 manufacturing subsectors and 20 Nuts-3 regions in Hungary based on HCSO employment data, i.e. regional employment
by manufacturing subsector for the 20 Hungarian regions for the years 1992 to 2008.

4.3.1 Formula of the Krugman concentration index

The formula of the index is as follows:

\[ K_i = \sum_{j=1}^{N} (s_{ij} - x_{ij}) \]

\( K_i \) is the numerical value of the Krugman concentration index for industry sector \( i \). In the term on the right hand side, \( s_{ij} \) is the share of industry \( i \)'s employees working in region \( j \) and \( x_{ij} \) is the share of total manufacturing employment in region \( j \); the Krugman index for industry \( i \) takes the absolute value of this term and sums it over all regions \( j=1 \) to \( N (N=20) \) to give the value of the index.

A specific industry \( i \) is considered to be concentrated, if a large part of production is carried out in a small number of regions. The higher is the value of the index, the larger is the degree of concentration of the industry.

4.3.2 Results of the Krugman concentration index

In this section, the results of the calculations of the Krugman concentration index for the 20 Hungarian Nuts-3 regions for the years 1993-2008 shall be presented.

Figure 25 shows the values of the Krugman index for the four manufacturing sectors food, beverages, tobacco, chemicals and chemical products, other non-metallic mineral products, and basic metals and fabricated metal products. At the first glance, the results show strong differences between the degree of concentration of the industries in this sample. While the mineral products industry had values of 0.7416 at the start of the period, the food, beverages and tobacco industry showed much lower concentration levels of around 0.2940 only.

117 Formula according to Traistaru et al. (2002). They applied this index to a (private) database collected under a Phare ACE project, on five Central and East European countries on manufacturing industry and total employment for the years 1990-1999 (even though the initial years 1990, 1991 and to some extent 1992 can be regarded as distorted by the end of communist regimes data collection). In my research, it will be targeted more precisely on manufacturing employment.

118 The data for 1992 were also calculated, but were left out here for clarity, as they seemed to be still under some influences from the strong restructuring recession.
The larger concentration of the former can be attributed to the fact that natural resources rich in minerals are located in only a small number of regions of the country as a location factor, whereas the food, beverages and tobacco industry has a broader resource base which is also easier transportable.

As to the development over the period, the graph shows a clear rise in overall industry concentration levels from 1993 up to a peak in the year 1999; from then onwards, concentration levels were falling; by the year 2004, the date of EU membership of Hungary, they were generally below the start level. For the remainder of the period up to 2008, they were rising again, for mineral products and chemicals a decline set in towards the end of the period.

Figure 26 illustrates industry concentration for the remaining 4 manufacturing industries for the same period, 1993-2008. At the first glance, the results show noticeable differences between the degree of concentration of the industries in the second sample. The highest concentration at the start was found in the wood, paper and printing, and publishing industry, 0.5290. This is due to the resources
for wood and paper manufacturing and to the concentration of the publishing activity in the Budapest agglomeration. The lowest concentration was found in the machinery and equipment sector at the start and at the end, with a decline over the period, namely 0.3117 in 1993 and 0.2176 in 2008.

As to the development, interestingly, these four industries all show a pronounced hub after 2004, i.e. since the EU membership of Hungary, with the decline setting in from 2007 onwards. The prior period, up to 2004, shows a rather shallow development for these four industries. The only clear line is the textiles industry with a rising concentration up to 2007.

4.3.3 Comparison of the empirical results with NEG

The model by *Livas-Elizondo & Krugman (1996)* for regional integration modelled in the context of international trade described that an (irreversible) agglomeration would form within the country consisting of more than one region. The model by *Puga (1999)* predicted an Ω-shaped relationship between agglomeration and trade costs with proceeding integration. The model by *Ludema & Wooton (1997)* predicted (less than complete) agglomeration to form at some intermediate level of trade costs, followed by dispersion as trade costs decline even further in the course of proceeding integration.
The empirical results based on calculations of the Krugman concentration index for the Hungarian manufacturing industry in the period 1992 to 2008 show the following: for a majority of manufacturing industries, concentration has generally increased up to a point around 1999; afterwards, decreasing concentration set in to lower levels than at the start. The highest value for concentration, i.e. the degree of agglomeration, was reached in 1999, thus prior to EU accession of Hungary. Since 2004 a second rise but to lesser levels than in 1999 set in, which was followed by a new decline by 2007.

With regards to the hypothesis, the empirical results provide an overall confirmation in the sense that agglomeration in the manufacturing industry in Hungary under the Europe agreements, i.e. up to 2004, first increased, before dispersion set in to lower degrees of agglomeration than at the start of the period. The highest concentration was indeed reached prior to EU membership of Hungary, namely in 1999.

It would be interesting to find out whether there were other influences at work than the mere decline in trade costs, especially which might have triggered the turning point in 1999. Trade costs – as important as they may have been – are one factor among various factors which influence an industry’s concentration in space. The Hungarian privatisation regime underwent different phases throughout the period, new sectors and enterprises were opened up to foreign investors gradually, larger scale enterprises which were formerly state owned were put for sale in specific years, and there was also a tendency towards more green field investments rather than the take-over of existing plants or companies in the latter part of the period (Csengodi et al. 2003). These developments could have contributed to the reaching of the turning point and the reversal of the concentration trend in 1999.

Moreover, there was a phase of privatisation and recapitalisation of the national banking system as part of the transition to a market economy, a policy which was also supported by the PHARE programme. Further, the availability of a more stable banking system all over the country rather than only in Budapest and other economic centres around towns could also have been a precondition enabling the spreading out of economic activity from 1999 onwards. Furthermore, the internal policy of the Széchenyi plan with its industrial parks scheme spread out on purpose in the Eastern and Western part of the country and in new sites could have contributed to the turning of the tendency of concentration (see chapter 3, section 3.2.4).

Finally, an external factor in 1999 which took place in Hungary’s main export market, the EU, was that 1999 was the start year of the Euro in the majority of EU
member states, which were Hungary’s main trading partner already at that point. As the Euro brought with it more stability and better planning for foreign investors, these could have been incited to locate their investments more spread out over the country. Indeed, the following year 2000 saw the largest single FDI inflow over the almost two decades analysed in this study. Whether FDI had a significant influence on manufacturing industry concentration and on regional specialization will be analysed by econometric analysis in Chapter 6. To sum up, apart from falling trade costs and the predictions of the NEG models regarding a turning point of industry concentration during proceeding integration, various other factors were also potentially influencing the development of manufacturing concentration in Hungary around the turn of the millennium.

4.3.4 Comparison of concentration ranks

In this subsection, the values of the Krugman concentration index for the 8 industries shall be ranked according to their degree of agglomeration and be compared. Table 20 compares ranks for the start and end years 1993 and 2008 respectively.

Table 20: Ranks of manufacturing industry concentration in Hungary, 1993 and 2008 in comparison; Krugman concentration index based on employment data

<table>
<thead>
<tr>
<th>Manufacturing industry</th>
<th>Rank in 1993</th>
<th>Rank in 2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>food, beverages, tobacco</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>textiles, wearing apparel, leather and fur products</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>wood, paper and printing, publishing</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>chemicals and chemical products</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>other non-metallic mineral products</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>basic metals and fabricated metal products</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>machinery and equipment (n.e.c., electrical and optical equipment, transport equip.)</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>other manufacturing industries, recycling</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

Source: Own calculations; own presentation.
Source of data: HCSO, Regional Statistical Yearbook of Hungary, subsequent years, Budapest.
As Table 20 with the comparison of concentration levels in 1993 and 2008 demonstrates, the highest concentration level prevailed in the mineral products industry. This high absolute concentration level of the industry is due to the natural resources in minerals being found in only a few regions over the country, and due to the difficulty to transport them, creating a strong reason for firms of the industry to locate near them. The chemicals industry was still highly agglomerated in 2008, ranking third instead of second. This industry is one in which economies of scale in production play an important role, according to the OECD (1994). Industries with low concentration were machinery and equipment, as well as food, beverages and tobacco, with ranks 8 and 6 respectively. The most marked change in concentration ranks was undergone by the textiles industry, from rank 6 to second rank, a sign for the ongoing consolidation of that industry.

**Figure 27: Employment in the textiles sector in Hungary, number of employees, 1993-2008**

Source: Own illustration.
Source of data: HCSO, Statistical Yearbook of Hungary, subsequent years, Budapest.

For the various manufacturing sectors, very different conditions prevailed and played a role in shaping the developments of the industry and the degree of concentration. In the following, a closer look at the Hungarian textiles industry shall be taken, one of the specialities of Hungary during the CMEA division of production, which also played a specific role during the early phases of integration with the EU under the Europe agreement. The industry was in strong decline during the period 1992 to 2008 - as in most European countries in the 1990s and around the turn of the millennium - due to increased competition in a
context of global trade liberalisation, producers in the Far Eastern countries, mainly India, Bangladesh, and China took increasing shares of the market. Thus, globalisation had its effects on the textiles industry in Hungary, too.

**Figure 27** shows the development of employment in the textiles industry in Hungary from 1993 to 2008. The number of employees in the textiles sector in Hungary declined from 138,140 at the start of the period to 44,565 in 2008, thus only 32% of the start level. Looking at the graph, however, it can be seen that there was an initial slight decline until about the year 1995, then a rise to a peak in 1999, and the steep decline followed only after this 1999 peak. Thus, there must have been some other influence apart from globalisation and sticky firm restructuring explaining this shape.

While employment was in decline, the output of the textiles, wearing apparel, leather and fur products sector - corrected by the producer price index for manufacturing\(^{120}\), remained more or less at the 1993 level until 2003, when the decline in output to 91,500 million HUF in 2008 set in. For the output development in the textiles industry, please see **Figure 28**.

**Figure 28: Output in the textiles sector 1992-2008 (million HUF), corrected by producer price index for manufacturing**

Source: Own calculations; own illustration.

Source of data: HCSO, Budapest.

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120 As that index is published by HCSO with previous year =100, it was converted here to an index holding the prices of 1992 constant and =100.
Given that the number of employees in the sector declined to 32% of the 1992 workforce by 2008, these figures point to an increase in productivity per employee. Measured in HUF and using the output figures corrected by the producer price index, this increase was from 990,100 HUF per employee in 1993 to 2,052,400 HUF per employee in 2008, i.e. more than the double.\footnote{Output corrected by the producer price index with base year 1992; see footnote \ref{footnote102} for the methodology.}

How can the hub in output of the sector around the years 2000 to 2003 and the preceding increase in employees of the sector in the years 1997 to 2000 be explained? Were there any special phenomena going on which could explain this development? \citet{Sdogati et al. (2002)\footnote{Chapter 5 in \textit{Sdogati et al. (2002)} entitled “Moving to Central-Eastern Europe: International Fragmentation of Production and Competitiveness of the European Textile and Apparel Industry”}} analysed the competitiveness of the textiles industry in two founding EU member states, Germany and Italy, in relation to eight CEECs, including Hungary, using customs data provided by textile and apparel firms for the years 1988 to 1997. Those data allowed for a distinction between final versus temporary imports and exports. That analysis revealed that German and Italian firms responded to the global cost pressure due to the competition from Far Eastern producers in the mid-1990s by means of outward processing trade (OPT) to the CEECs. That strategy enabled them to benefit from the lower labour costs in CEECs, yet selling the final product under the high-quality, high-prestige labels “made in Italy” or “made in Germany”, as the majority of value added was still generated in those countries.

This international division of labour was made possible through provisions specially included in the Europe agreements with CEECs making the arrangements ruling over OPT even more favourable. The authors concluded by estimating the cost savings realized by German firms through OPT with CEECs in the order of 50\% and for Italy in the order of 40\% to 50\% in the period analyzed.

As relative and real production costs in Hungary and other CEECs increased over the years though, especially in the late 1990s and early 2000s, Hungary and other CEECs gradually lost their cost advantage. The firms in the EU-15 responded by delocating their outward processing trade to Far Eastern production sites instead. This could explain the observed hub in employment in the Hungarian textiles industry in the late 1990s and the hub-shaped increase in output around the year 2000 as well as the steep drop in output from 2003 onwards, which only happened in the textiles sector and was not observed in any of the other 7 manufacturing sectors examined in this research.
4.3.5 Comparison of the results with previous studies and for other countries

Coming back to the results of my calculations of the Krugman concentration index based on employment for the 8 Hungarian manufacturing industries, this section shall put them into context with previous empirical research.

There is study on economic geography in five CEECs edited by Traistaru et al. (2003) which analysed several aspects of the general economic set-up in those countries for the years 1990 to 1999. Yet data for the first years of this period have certainly been under a distorting influence from the communist era and from the severe restructuring recession. For Hungary, Mafioli (2003) calculated a concentration measure called the dissimilarity index for industry. The results obtained there have to be treated with caution, however, as they refer to total employment, whereas my study is to a great extent more focussed by using as a benchmark manufacturing employment only. Additionally, the categories of the industries have been agglomerated to fit the scheme of the overall five country study, leaving a certain element of error. Finally, the results are shown giving merely two digits after the decimal, which is not as accurate in the analysis of changes of agglomeration, as often there is no visible change this way from one year to the next. Thus, that study is only vaguely and in part comparable with the results of my calculations.

As a trial, the numerical values presented by Mafioli (2003) - based on total employment - and the results of my calculations - based on manufacturing employment - have been plotted in graphs together by industry.\(^{123}\) The picture was such that the lines for the concentration found by Mafioli were generally above those obtained in my calculations; and further, they showed a different direction of development of concentration. Most importantly, they end at the point where my calculations become most interesting, i.e. with the year 1999, which is a great disadvantage of that study to my mind, as that peak became a turning point prior to the EU accession of Hungary.

In a comparative summary of five CEECs, Traistaru et al. (2003) showed average concentration for manufacturing as a whole (not individual industries) for 1990 to 1999, based on the data and method just described for Mafioli (2003). In comparison with other countries, Hungary had a relatively low overall concentration in manufacturing, which kept rising until about 1997, then falling in 1999, the last year of that study, below the start level. Higher average concentration was observed in Bulgaria, Slovenia (a country with 2 million inhabitants and thus too

\(^{123}\) As this would methodologically not be accurate, it is not shown here.
small to conduct such a study in my view), and the highest in Romania. To give a range of values to put that into perspective, the average manufacturing concentration for Hungary was shown in the range of 0.45 to 0.48, falling to 0.43 in 1999; the average for Romania was in the range of 0.61 to 0.66, falling to 0.64 in 1999. Those results have to be taken with caution, as was explained before.

4.4 Concentration rate $CR_3$

After these first results on the actual development of industry agglomeration in Hungary as measured by the values provided by the Krugman concentration index, it is interesting to see which results the other measures will provide. In this section, the measure $CR_3$ shall be introduced. $CR_3$ stands for the market concentration share made up by the 3 largest entities. $CR_3$ is a concept used primarily in competition policy by the competition authorities to determine market power held by firms. It is applied here to the market share of an industry country-wide contributed by regions instead of firms.

4.4.1 Formula of the $CR_3$ measure

The employment share of the 3 largest regions in total Hungary-wide employment of an industry sector $i$ is denoted as follows:

$$CR_{3i} = \sum_{j=1}^{3} s_{ij}$$

where the index $i$ refers to the manufacturing industry sector (8 manufacturing sectors), $j$ to regions (20 Nuts-3 regions). The values of the three regions contributing the largest share of country-wide employment of the industry are summed up to give the value of $CR_3$ for industry $i$.\textsuperscript{124}

This concentration index is perhaps the most intuitive measure of industry agglomeration. To interpret the values of this measure using an example from competition policy, $CR_3 = 0.60$ would mean that the sum of the market shares of the three largest firms is 60% of the total market. A disadvantage of the measure is that the relative market share of the 3 largest entities is not taken into consideration; i.e. a $CR_3 = 0.60$ could have been made up either of 3 entities with a

\textsuperscript{124} Formula according to \textit{Aiginger \& Pfaffermayr (2004)}; they apply this to 99 NACE 3-digit industries and 14 EU-countries, for 3 years 1985, 1992, 1998, in context of analyzing Single Market effects.
share of 0.20 each, or of one large entity with a share of 0.50 and two small ones with a share of 0.05.  

4.4.2 Results of the concentration rate CR$_3$ for Hungary

The results of the calculation of CR$_3$ for industry concentration are shown in Table 21 for the 20 regions in Hungary based on the HCSO employment data. Firstly, the results of CR$_3$ calculations in Table 21 allow an identification of industries with an overall high, medium and low concentration. A comparatively high concentration, with a market share of over 40 to more than 50% in three regions, is prevailing in the chemicals, basic metals and the wood, paper and printing industries. Medium level concentration, below 40 to more than 30%, characterises the mineral products, machinery and equipment and other manufacturing sectors. Low concentration levels, with less than 30% market share, are found in the food, beverages and tobacco as well as the textiles sectors.

As for the development of industry concentration, the last column of Table 21 shows the overall trend prevailing over the entire period, 2008 compared to the start year 1992. Concentration had risen in 4 sectors, declined in 3 sectors, and remained more or less at the start level in one sector, that of chemical products. Comparing this with the share in manufacturing employment of each sector, 3 sectors with a low employment share had become more concentrated and only one with a high employment share did so, the food, beverages and tobacco industry. Among those with a falling concentration was one with a high employment share, the machinery and equipment sector, the other had rather low shares. The more or less constant concentration industry, chemicals, had an intermediate employment share in overall manufacturing employment. Therefore, no generalisation about the trend in concentration and the employment share of the industry is possible from these data.

In the subperiods, however, the development of CR$_3$ concentration was different from the overall result. From 1992 compared to 1999, the value of CR$_3$ had risen for 6 out of the 8 sectors, when a peak was reached. These industries were food, beverages and tobacco, textiles, wood and paper, chemicals, machinery and equipment and other manufacturing industries. From 1999 to 2004, concentration has fallen for five of these industries (except for the food, beverages and tobacco sector). For the two remaining sectors, concentration has either remained more or less constant - for the mineral products sector, or it has kept falling until 2004:

125  www.mikrooekonomie.de on 20th Sept. 2007 „Messung der Anbieterkonzentration“.
126  The textiles industry which had a high employment at the start and a low employment share at the end of the period, was classified here with its end of period employment.
Table 21: CR₃ concentration rate per industry based on regional manufacturing employment data, selected years

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>food, beverages, tobacco</td>
<td>0.2747</td>
<td>0.3089</td>
<td>0.3228</td>
<td>0.3715</td>
<td>↑</td>
</tr>
<tr>
<td>textiles, wearing apparel, leather and fur products</td>
<td>0.2999</td>
<td>0.3462</td>
<td>0.2572</td>
<td>0.3754</td>
<td>↑</td>
</tr>
<tr>
<td>wood, paper and printing, publishing</td>
<td>0.4494</td>
<td>0.5267</td>
<td>0.4333</td>
<td>0.4809</td>
<td>↑</td>
</tr>
<tr>
<td>chemicals and chemical products</td>
<td>0.5201</td>
<td>0.5978</td>
<td>0.4685</td>
<td>0.5099</td>
<td>≈</td>
</tr>
<tr>
<td>other non-metallic mineral products</td>
<td>0.3571</td>
<td>0.3529</td>
<td>0.3314</td>
<td>0.4480</td>
<td>↑</td>
</tr>
<tr>
<td>basic metals and fabricated metal products</td>
<td>0.5057</td>
<td>0.4353</td>
<td>0.3671</td>
<td>0.4105</td>
<td>↓</td>
</tr>
<tr>
<td>machinery and equipment (n.e.c., electrical and optical equipment, transport equip.)</td>
<td>0.4495</td>
<td>0.4573</td>
<td>0.3361</td>
<td>0.4104</td>
<td>↓</td>
</tr>
<tr>
<td>other manufacturing industries, recycling</td>
<td>0.3989</td>
<td>0.4067</td>
<td>0.3281</td>
<td>0.3795</td>
<td>↓</td>
</tr>
</tbody>
</table>

Source: Own calculations; own presentation.
Source of data: HCSO, Regional Statistical Yearbook of Hungary, subsequent years, Budapest.

This was the case for the metal products sector where a marked decrease took place, implying a fall in market share for the 3 largest regions from 50.6% to 36.7%. For the remainder of the period since the EU accession of Hungary, all industries showed an increase in CR₃ concentration levels, yet the end levels in 2008 were generally below the 1999 peak.

4.4.3 Regional composition of industry concentration CR₃

The concentration measure CR₃ allows for a detailed analysis of the regional setup of industry agglomeration. More precisely, it is possible to see in which regions held the largest centres of each industry in employment terms. As the greatest shifts are expected over the longest period possible, the years 1992 and 2008 are compared in Table 22.
The comparison in Table 22 shows that for two industries, namely the food, beverages and tobacco, and chemicals and chemical products, the agglomeration centres have not changed for 1992 and 2008 respectively, i.e. the main concentration was still located in the same three regions. For the remaining six industries, there was a change in the top three regarding one region - although for some of these industries, the position of the regions with respect to the start year changed.

Table 22: Regions making up the largest shares in Hungarian manufacturing employment per industry in 1992 and 2008, based on the CR₃ concentration rate

<table>
<thead>
<tr>
<th>Manufacturing of</th>
<th>3 largest regions in 1992</th>
<th>3 largest regions in 2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>food, beverages, tobacco</td>
<td>Budapest, Bacs, Pest</td>
<td>Budapest, Pest, Bacs</td>
</tr>
<tr>
<td>textiles, wearing apparel, leather and fur products</td>
<td>Budapest, Győr, Vas</td>
<td>Budapest, Vas, Szolnok</td>
</tr>
<tr>
<td>wood, paper and printing, publishing</td>
<td>Budapest, Szabolcs, Bacs</td>
<td>Budapest, Pest, Szabolcs</td>
</tr>
<tr>
<td>chemicals and chemical products</td>
<td>Budapest, Borsod, Pest</td>
<td>Budapest, Borsod, Pest</td>
</tr>
<tr>
<td>other non-metallic mineral products</td>
<td>Borsod, Budapest, Veszprem</td>
<td>Budapest, Pest, Veszprem</td>
</tr>
<tr>
<td>basic metals and fabricated metal products</td>
<td>Budapest, Borsod, Fejer</td>
<td>Budapest, Pest, Fejer</td>
</tr>
<tr>
<td>machinery and equipment (n.e.c., electrical and optical equipment, transport equip.)</td>
<td>Budapest, Pest, Fejer</td>
<td>Budapest, Pest, Komarom</td>
</tr>
<tr>
<td>other manufacturing industries, recycling</td>
<td>Budapest, Zala, Csongrad</td>
<td>Budapest, Vas, Zala</td>
</tr>
</tbody>
</table>

Source: Own calculations; own presentation.
Source of data: HCSO, Regional Statistical Yearbook of Hungary, subsequent years, Budapest.

Budapest region was among the three regions contributing the largest shares in industry employment for all manufacturing sectors in the years 1992 and 2008. For the mineral products industry, however, Budapest was not the largest concentration area overall. The prominent position of Budapest is not unusual when taking into account that about one fifth of Hungary’s workforce live in Budapest, namely 19.6% of manufacturing employment in 2008, and 20.9% for the year 1992 respectively.
Pest region advanced from being 3 times among the largest three production sites to being 6 times among the top 3. This shows an increasing economic importance of this region surrounding Budapest, located in Central Hungary. As the analysis of internal net migration in Chapter 3.5.1 showed, Pest region was also the region with the largest positive internal net migration of the period, with +248,000 persons over the period.

4.4.4 Comparison of the results with theory

The overall evolution of manufacturing industry concentration in Hungary as measured by the CR$_3$ concentration index is broadly comparable to the predictions made by NEG theory for agglomeration in the course of integration processes. The model by *Livas-Elizondo & Krugman (1996)* for regional integration modelled in the context of international trade described that an (irreversible) agglomeration would form within the country consisting of more than one region. More in particular, the model by *Puga (1999)* which predicts first a rise to a peak, then a fall in concentration levels, called Ω-shaped evolution, is confirmed by the data from my own calculations. The model by *Ludema & Wooton (1997)* predicted for some intermediate level of trade costs between regions of a country agglomeration (less than complete) to form, followed by industry dispersion as trade costs decline even further in the course of proceeding integration. There were such phases in the manufacturing sectors in Hungary during the observation period, even though the second rise of concentration after EU accession could not fully be explained. Trade costs would be presumed to have fallen more since 2004 due to Hungary being part of the Single Market and all regulations then in force; apparently, however, what could have happened is that international trade costs increased due to a surge in NTBs applied to a stronger degree or newly to products “made in Hungary” upon full EU membership.

4.4.5 Evaluation of the results by means of other empirical studies

The results of this research are not directly comparable to those of other empirical studies, as the industry scope and country coverage as well as data sources are different. One study working explicitly with the CR$_3$ concentration measure is the one by *Aiginger & Pfaffermayr (2004)*, which analysed concentration effects in 14 EU member states for selected years from 1985 to 1998 in order to identify concentration effects entailed by the European Single Market programme. The authors based their calculations on Eurostat data of value added for 99 3-digit industries. First of all, they found an overall increase of CR$_3$ concentration of the 3 largest of these 14 old EU countries from 64.6% to 65.0% (unweighted average) from 1985 to 1992, then a decrease by 2.1% to 63.7% in 1998. Overall, they observed a decrease in industry concentration measured by CR$_3$ by 1.5%
from 1998 - post Single Market - over the year 1985 - prior to the political decision for the Single Market programme. Compared with their results, the changes of industry concentration observed in Hungary by this research during the almost two decades were much stronger. They ranged between +13% and -19% of the initial CR3 concentration levels for 2008 compared to the 1992 start level.

Calculation of such unweighted averages - equivalent to the method used in Aiginger & Pfaffermayr (2004) - on my results based on Hungarian manufacturing employment data for the years 1992, and 1999, as well as 2004 and 2008, gave the figures presented in Table 23.

Table 23: Unweighted averages in CR3 concentration in Hungarian manufacturing industry based on employment, selected years, and percentage change

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.4069</td>
<td>0.4290</td>
<td>0.3556</td>
<td>0.4233</td>
<td>+11.2%</td>
<td>-11.8%</td>
<td>+4.0%</td>
</tr>
</tbody>
</table>

Source: Own calculations.
Source of data: HCSO, Regional Statistical Yearbook of Hungary, subsequent years, Budapest.

The overall concentration level measured by CR3 of the three largest regions in terms of manufacturing employment was 40.69% in 1992, rose to 42.90% in 1999, fell to 35.56% in 2004, and finally rose to 42.33% in 2008. Comparing the percentage change, this meant a rise of 11.2% in the first period, and a decline of -11.8% for the entire period of the Europe agreement, 2004 compared to 1992. Overall, concentration measured by CR3 rose by +4.0% in 2008 relative to the 1992 start level.

This shape of the development of industry agglomeration goes broadly in line with the trend observed by Aiginger & Pfaffermayr (2004) in their EU-14 Single Market analysis, first a rise, then a fall offsetting the initial rise and making up for an overall fall when comparing the end to the start year of the analysis. This leaves the question whether perhaps similar processes might have set in among the Hungarian industry on the regional level under the influence of the Single Market Action plan.

A comparison of the level of CR3 of Aiginger & Pfaffermayr (2004) and my data shows much lower figures for the Hungarian regions than for the country-based EU-14 study. While these average CR3 concentration levels for the manufacturing
industries in Hungary ranged around 40%, for the country level in the EU-14 they were shown to be around 60%. This could be due to the vast differences in the database of the two studies and also due to the much larger size of at least 5 of the countries of the EU-14.

4.5 The Herfindahl index

The development of agglomeration of the manufacturing industries in Hungary shall now be measured using the Herfindahl index, sometimes called Herfindahl-Hirschman index. In its original form, this index results in an absolute measure of industry concentration. In another context, when applied to export data of countries, the Herfindahl-Hirschman index can measure the degree of export concentration of a country’s exports, as in Guerson et al. (2007) for Argentina. Back to the context of spatial industry concentration where it is used here, the Herfindahl index is sometimes called a comprehensive concept as it includes information about the whole distribution, unlike the CR$_3$ measure (see section 4.4.1). The comprehensiveness of the Herfindahl index also has a disadvantage to it, however, as the very largest shares tend to dominate the results. A modified form of the Herfindahl index, then resulting in a relative concentration measure, shall therefore be presented in section 4.6 of this chapter.

4.5.1 Formula of the Herfindahl index

The formula of the Herfindahl concentration index in its absolute form can be denoted as follows:

\[
H_i = \sum_{j=1}^{N} (s_{ij})^2
\]

where the index $i$ refers to the industry sector (8 manufacturing sectors), and $j$ to the regions (20 Nuts-3 regions).\textsuperscript{127} Thus the Herfindahl index for industry sector $i$ takes the value of the sum of the squared regional employment shares of industry $i$ for all 20 regions $j$. The result can take values between 0 and 1. The higher the value, the more concentrated is the industry.

\textsuperscript{127} Formula according to Aiginger & Pfaffermayr (2004).
4.5.2 Results of the Herfindahl index

The Herfindahl index has been calculated for the 8 manufacturing sectors based on regional employment data for selected years: 1992, 1995, 1999, 2004 and 2008. Figure 29 presents the results for the 4 sectors with the higher absolute concentration values, while Figure 30 will present the remaining sectors.

**Figure 29: Absolute Herfindahl index based on employment data, 4 manufacturing sectors, selected years**

The chemicals sector shows the steepest rise in concentration levels of the four sectors in Figure 29, from the start in 1992 at 0.1236 to a high of over 0.2057 in 1999, whereafter it falls below the start level. This is a rise by more than 66%. The wood, paper and printing sector also shows a rise to a peak in 1999, then a fall below start levels. This corresponds to 22% beneath the start level. The recycling and other manufacturing industries also follow the trend with a peak in 1999, then fall below start levels. Finally, the machinery and equipment sector initially falls from the start in 1992 until 1995, then rises to an intermediary peak in 1999, then keeps on falling to an absolute level of 0.0714 in 2004. That concentration for the machinery and equipment sector is over 40% lower than the
start level. Finally, for the post-accession period, a rise in concentration levels set in for all four industries, but to lesser levels than in 1999.

**Figure 30: Absolute Herfindahl index based on employment data, remaining 4 manufacturing sectors, selected years**

![Graph showing the Herfindahl index for different sectors over years]

Source: Own calculations; own graphical illustration.
Source of data: HCSO, Regional Statistical Yearbook of Hungary, subsequent years, Budapest.

**Figure 30** shows the results of the Herfindahl index calculated for the remaining sectors. These sectors tend to have lower concentration levels than those in Figure 29. The mineral products sector shows a fall in concentration from the start to the year 2004, the concentration level was 30% lower in 2004 than in 1992. Two sectors show a rise to a peak in 1999, the textiles sector as well as food, beverages and tobacco. All of these four sectors show a rise of concentration from 2004 to 2008, most pronounced for the mineral products sector.

### 4.5.3 Comparison of the results with theory

The development regarding agglomeration of the 8 manufacturing sectors in Hungary during the period 1992 to 2008 as measured by the Herfindahl concentration index is overall in line with models from NEG. The model by *Livas-Elizondo & Krugman (1996)* for regional integration modelled in the context of international trade described that an (irreversible) agglomeration would form within the country consisting of more than one region. More concretely, the
predictions made for agglomeration in the course of integration processes of the model by *Puga (1999)* are verified by my results. They notably predicted first a rise in manufacturing industry concentration up to a peak, thereafter a fall in concentration levels - called Ω-shaped evolution; that shape is confirmed by the graphs and data of my calculations. The model by *Ludema & Wooton (1997)* predicted (less than complete) agglomeration to form at some intermediate level of trade costs, followed by dispersion as trade costs decline even further in the course of proceeding integration. For the period under the Europe agreement, this was also the case in Hungarian manufacturing industries.

There are few empirical papers using the Herfindahl index on EU data. One paper is that by *Giannetti (2002)* who, based on a modified new growth model, conducted an analysis based on income data for 10 EU countries from 1980-86, and from 1986-92 in which she used the Herfindahl index for country employment concentrated in one of the three macro-sectors of the economy as a control variable (that paper was interested in isolating the role of technological spill-overs for regional growth). This was done to control for the exceptionally good performance of regions which derive their wealth from being political centres of major importance, such as Paris and Brussels, and to account for other regions with higher levels of public sector employment, such as in Italy, and finally, to account for regions endowed with natural resources (such as Nordrhein-Westfalen in Germany) where performance is likely to depend on national endowments rather than on a mechanism of technological transmission.

### 4.6 The relative Herfindahl index

The next index to be presented in this effort to measure the development of manufacturing industries' agglomeration in Hungary in the course of European integration is the relative Herfindahl index, a modified form of the Herfindahl index. This index measures sectoral geographic concentration with respect to a benchmark, which is the overall geographic concentration of the manufacturing sector.

#### 4.6.1 Formula of the relative Herfindahl index

The formula of the relative Herfindahl index is as follows:

$$HR_{ri} = \sum_{j=1}^{N} \left( s_{ij} - x_{ij} \right)^2$$
where $s_{ij}$ is the share of industry $i$'s employees working in region $j$ and $x_{ij}$ is the share of total manufacturing employment in region $j$. The index for industry $i$ then takes the sum of these differences squared over all 20 Hungarian regions $j$. The index can take values between 0 and 1. The higher the value, the more concentrated is the industry.

### 4.6.2 Results of the relative Herfindahl index for Hungary

The relative Herfindahl index has a different nature than the other indices presented so far due to the fact that it measures an industry’s concentration relative to a benchmark. The benchmark chosen is total manufacturing employment in a given region as a share of country-wide manufacturing employment. It then puts the

**Figure 31:** Relative Herfindahl concentration index for 8 manufacturing sectors based on employment data, years 1992 and 2008 in comparison

![Graph showing relative Herfindahl concentration index for 8 manufacturing sectors, years 1992 and 2008.](image)

**Source:** Own calculations; own graphical illustration.

Source of data: HCSO, Regional Statistical Yearbook of Hungary, subsequent years, Budapest.

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128 The Formula is spelt according to Giacinto & Pagnini (2008) and an earlier version of that paper. They used this index on Italian data from 103 industrial subsectors for the year 1996, census data from the Italian National Institute of Statistics.
industry i’s agglomeration measured in employment terms in relation to overall manufacturing employment. The values of this relative Herfindahl index could be ranging from 0 to 2. The index would take on a value of zero when a specific sector’s employment was distributed across regions in the same way as total manufacturing employment. The results of the calculations are shown in Figure 31.

**Figure 31** presents the results of the relative Herfindahl concentration index for the 8 manufacturing sectors in Hungary for the years 1992 and 2008, the start and the end year of the observation period. For most sectors, concentration as measured by the relative Herfindahl index fell over the period. This decline was by more than half the initial concentration value for wood and paper, and mineral products, and by about a third for basic metals and other manufacturing industries. The strongest decline was observed in the machinery and equipment sector, to less than one fifth of the original concentration, thus a strong relative dispersion of this sector as measured by the relative Herfindahl index. Exceptions to this falling tendency were the (shrinking) textiles and wearing apparel sector (see section 4.3.5), and food, beverages and tobacco, which remained almost the same.

A word of caution should be added when evaluating the results of the relative Herfindahl index: as the comparison of indices in section 4.9 demonstrates, the relative Herfindahl shows the rise and fall in concentration in the strongest way of the 6 concentration measures. Thus, also such extreme values as the result for the manufacturing and equipment sector should be viewed in this light.

To put these figures in perspective, a look should be taken at the development of Hungarian manufacturing employment in absolute terms. Overall manufacturing employment in Hungary decreased over the period from 854,913 in 1992 to 648,454 in 2008, that is by almost 25%. The graph in **Figure 32** shows the 8 sectors’ manufacturing employment in Hungary for the years 1992 until 2008. On the one hand, the machinery and equipment sector increased from 24% to 39.5% over the observation period. In absolute terms, employment increased from 148,000 in 1995 to 256,500 in 2008. This went along with the relative dispersion or strong fall in relative Herfindahl concentration just described for the results shown in Figure 31.

On the other hand, the food, beverages and tobacco sector went from a share in manufacturing employment of 21% in 1992 down to 14% in 2008. This corresponded to a decline in absolute employment figures, from 184,000 in 1992 to 91,800 in 2008.

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129 Data source for these figures: HCSO, Regional Statistical Yearbook of Hungary series.
This went along with relative dispersion also, as measured by the Herfindahl index (see Figure 31). Thus, while the absolute employment figures provide some information, they can by no means provide an indication about the direction of spatial concentration or dispersion tendencies in the manufacturing industry in Hungary. Only the calculation of concentration indices based on sectoral regional employment data can.

### 4.6.3 Results of other empirical studies

The specific form of a relative Herfindahl index has not been applied to Central and East European data so far. Di Giacinto & Pagnini (2008) conducted a plant location study for 103 industrial sectors and regions in Italy, for a single year based on Italian census data from Italian National Institute of Statistics, based on employment and for the year 1996 for 95 administrative provinces and 20 regions.
It is therefore judged not meaningful to compare those results here in any way with the calculations made for Hungary in this study.

4.7 The Hoover-Balassa index

The one before last measure to be presented in this analysis of agglomeration of the Hungarian manufacturing industries is the Hoover-Balassa index, a relative measure of concentration. This concept has been selected as Bela Balassa, a Hungarian, did breaking research in the context of European integration regarding the integration indicator trade, creating Balassa indices to measure comparative advantage of countries and intra-industry trade specialization. As for this research, the effects of integration on Hungarian regions and industry agglomeration under the Europe agreement and beyond are of interest, which liberalised trade in manufacturing goods, this researcher’s contribution should not be left out.

The Hoover-Balassa index is a relative measure of concentration. It is applied here in a modified form in order to adjust for differences in regional sizes, in accordance with Haaland et al. (1999).

4.7.1 Formula of the Hoover-Balassa index

The formula of the Hoover-Balassa index as used here is as follows:

\[ CONC_i = \sqrt{\frac{1}{j} \sum_j \left[ \frac{x_{ij}}{\sum_j x_{ij}} - \frac{\sum_i x_{ij}}{\sum_i \sum_j x_{ij}} \right]^2} \]

where the index i refers to the industry sector (8 manufacturing sectors), j to regions (20 Nuts-3 regions). The term in brackets is the share of industry i’s employees in region j, minus region j’s share in total manufacturing employment in Hungary, squared; summed over all regions, times 1/20 (0.05) for the 20 Nuts-3 regions in Hungary, taken the square root of, equals the Hoover-Balassa index for the industry sector i.\(^{130}\)

The Hoover-Balassa index is a relative concentration indicator as it measures the difference of an industry’s spread of employment to the average spread of employment in Hungary.

\(^{130}\) The Formula is given according to Hildebrand & Wörz (2004). They applied this index to 10 countries in Central and Eastern Europe, to output and employment data for 11 industries from 1993 to 2000 (wiiw database).
employment. Thus, an industry is relatively concentrated if its employment is more concentrated than total manufacturing employment in Hungary is.

4.7.2 Results of the Hoover-Balassa index

The results of the calculation of the Hoover-Balassa concentration index based on regional sectoral employment data for Hungary are presented in form of a bar chart in Figure 33.

Figure 33 shows the percentage changes in industry concentration measured by the Hoover-Balassa index for the 8 manufacturing sectors. The first bar for each industry shows the percentage change in relative concentration in 1999 over the start year 1992, the second bar shows the percentage change in concentration in 2008 over the start year 1992. For the chemicals and chemical products industry, the rise in concentration to a peak in 1999 is most marked, a rise by 70%.

Figure 33: Hoover-Balassa concentration index based on employment data, percentage change per sector, 1999 and 2008 relative to 1992

Source: Own calculations; own graphical illustration.
Source of data: HCSO, Regional Statistical Yearbook of Hungary, subsequent years, Budapest.

The textiles industry also shows a rise in 1999 over 1992, by 18%, mineral products by 12%, and the food, beverages and tobacco sector by 5%. For the other
four sectors, relative concentration as measured by the Hoover-Balassa index fell in 1999 compared to 1992, by between 5% for the wood, paper and printing industry and 22% for machinery and equipment.

Looking at the end year 2008 compared to 1992, three industries show an overall decline in concentration. The strongest decline as measured by the Hoover-Balassa index was in the machinery and equipment industry, by almost 40%, followed by the mineral products industry. The other five industries showed a rise as compared to the start year, most pronounced for the textiles and second the chemicals industry. In general, the rise was less than for 1999 compared to 1992 - with the exception of the shrinking textiles industry.

4.7.3 Comparison of the results with theory

The Hoover-Balassa index does not show the hub-shaped development in such a clear way as other concentration indices calculated in previous sections of this research do, thus this index is only a relatively weak confirmation of the predictions by the Puga (1999) model. The weaker form of the hub-pattern for this index could be due to the formula and the smaller absolute values which the Hoover-Balassa index takes for each year and industry. The values range from 0.0147 for the machinery and equipment sector in 2008 to a high of 0.0482 for the chemicals industry in 1999, thus overall roughly one decimal smaller than for the four indices presented up to this point. The results of the Hoover-Balassa index for Hungary do confirm, however, the decrease in concentration overall, as NEG theory predicts in multi-country models in context with economic integration, such as Livas-Elizondo & Krugman (1996).

4.7.4 Evaluation in the light of other empirical studies

The results obtained for relative manufacturing industry agglomeration in Hungary using the Hoover-Balassa index for the years 1992 to 2008 shall now be put in context with other empirical studies. In the study by Hildebrandt & Wörz (2004), the Hoover-Balassa index is applied to production data and employment data of 11 industries from 10 countries in Central and Eastern Europe for the years 1993 and 2000 using a database of their institute, the wiwi. Please note that the authors take as a whole the sum of these 10 countries and as components per-country data, whereas I take Hungary as a whole and the sectoral data for the 20 Hungarian Nuts-3 regions as components.

Hildebrandt & Wörz (2004) found that relative concentration had risen for 7 sectors in 2000 as compared to 1993 and fallen for 4 sectors. The chemicals sector - which had the strongest rise in 1999 over 1992 in my Hungarian calcu-
lations - remained almost constant in their data set. The machinery and equipment sector, which was split in two sectors, showed a rise in 2000 for electrical and optical equipment and a slight decline for machinery and equipment n.e.c.. The overall order of magnitude of the values taken by the Hoover-Balassa index is between 0.0124 and 0.0407 for the start year 1993 (Hildebrandt & Wörz 2004). This corresponds more or less with that of the year 1992 Hungarian data of my calculations where values range from 0.0222 to 0.0409, as a plausibility verification of the results. As the scope of that study is very different from mine, though, the results cannot be compared in any detail.

In an analysis of Single Market effects in the EU-15, Haaland et al. (1999) used the Hoover-Balassa index in a simplified form for country-based data of 13 EU countries and 35 ISIC sectors of the OECD STAN data base. The results for the years 1985 and 1992 serve as input into a more complex econometric model. A table in the annex nevertheless presents these in a 3-digit precision such that several sectors come out equal or same rank. The industries are not directly comparable with the 8 Hungarian manufacturing sectors. The 3-digit presentation of that study is judged too raw for my analysis of Hungarian concentration based on regions, which is why 4-digit precision was chosen throughout this study.

### 4.8 Entropy

The final measure is the entropy, which shall now be applied to the Hungarian data in order to measure manufacturing industries agglomeration under the Europe agreement and beyond. Entropy is a concept stemming from physics where it is used to describe the difference between the start and the end extension of a gas in space. Entropy gives an absolute number for the degree of dispersion in space, thus this is the inverse idea of concentration in a way. As in this research, the main idea is to analyze agglomeration or dispersion tendencies in manufacturing industries in Hungary due to European integration, this concept is suitable for application in this analysis when transposed to the extension or dispersion of an industry in space.

#### 4.8.1 Formula of the entropy

The formula for calculating the entropy is as follows:

$$ E_i = \sum_{j=1}^{J} s_{ij} \times \ln s_{ij} $$
where the index i refers to the industry sector (8 manufacturing sectors), j to regions (20 Nuts-3 regions), and $s_{ij}$ is the employment share of industry i in region j (expressed as %), times the logarithm of the share of industry i in region j (expressed as %), then summed up over all regions to give the entropy figure for industry i.\footnote{131}

To evaluate the results of entropy, it should be said that due to this formula, the effect of a dominance of large regions is mitigated by multiplying shares and log shares. Therefore, the entropy has the advantage that it gives the role of large regions a fair but not dominant share.

\section*{4.8.2 Results of the entropy for Hungary}

The results of my calculations of the entropy applied to the sectoral regional employment data of HCSO are presented in the two following graphs, each for a set of 4 industry sectors.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{entropy_graph.png}
\caption{Entropy based on employment data, 4 manufacturing sectors, selected years}
\end{figure}

\textbf{Source: Own calculations.}
Source of data: \textit{HCSO}, Regional Statistical Yearbook of Hungary, subsequent years, Budapest.

\footnote{131 Formula according to \textit{Aiginger \& Pfaffermayr} (2004). They applied the entropy to 99 NACE 3-digit industries and 14 EU-countries, for 3 years 1985, 1992, 1998 in order to measure concentration tendencies due to the EU Single Market programme.}
Figure 34 shows the results of my calculations of the entropy applied to the sectoral regional employment data for 4 of the 8 manufacturing industries in Hungary for the years 1992, 1995, 1999, 2004 and 2008. For the chemicals industry, the graph shows a steep rise from 1992 to 1999, even a rise from 1992 to 1995 already, with a peak in 1999; from 1999 to 2004, concentration falls to about the 1995-level. For the wood, paper and printing sector, there is a rise in entropy from 1992 with a peak in 1999, followed by a decline. For the food, beverages and tobacco sector, entropy also rises to 1999, thereafter remains at the new level. Only for the mineral products sector, entropy does not show a peak in 1999, but remains at about the start level, then falling slightly to 2004. For the post-accession period, entropy rises for the four sectors up to 2008.

**Figure 35: Entropy based on employment data, remaining 4 sectors, selected years**

![Graph showing entropy for remaining 4 sectors](image)

Source: Own calculations; own graphical illustration.
Source of data: HCSO, Regional Statistical Yearbook of Hungary, subsequent years, Budapest.

Figure 35 shows the results of the entropy calculations for the remaining 4 sectors. Three sectors of these show a rise to a peak in 1999, after an initial slight decline from 1992 to 1995; these are the machinery and equipment, textiles as well as the other manufacturing industries and recycling sectors. After this peak, concentration declines up to 2004, for all industries below the start level.
Finally, the measure shows a rise up to 2008 again for all the 4 sectors. Table 24 analyses in more detail the percentage changes in entropy for the peak year and the year 2004 compared to the start.

Table 24: Percentage changes in entropy for the 8 manufacturing sectors based on employment data, selected years

<table>
<thead>
<tr>
<th>Manufacturing of</th>
<th>Percentage change 1999/92</th>
<th>Percentage change 2004/1992</th>
</tr>
</thead>
<tbody>
<tr>
<td>food, beverages, tobacco</td>
<td>1.4%</td>
<td>1.7%</td>
</tr>
<tr>
<td>textiles, wearing apparel, leather and fur products</td>
<td>2.4%</td>
<td>-0.8%</td>
</tr>
<tr>
<td>wood, paper and printing, publishing</td>
<td>3.2%</td>
<td>-4.1%</td>
</tr>
<tr>
<td>chemicals and chemical products</td>
<td>24.6%</td>
<td>11.5%</td>
</tr>
<tr>
<td>other non-metallic mineral products</td>
<td>-0.1%</td>
<td>-3.1%</td>
</tr>
<tr>
<td>basic metals and fabricated metal products</td>
<td>-5.9%</td>
<td>-8.7%</td>
</tr>
<tr>
<td>machinery and equipment (n.e.c., electrical and optical equipment, transport equip.)</td>
<td>-0.7%</td>
<td>-7.9%</td>
</tr>
<tr>
<td>other manufacturing industries, recycling</td>
<td>2.2%</td>
<td>-4.7%</td>
</tr>
</tbody>
</table>

Source: Own calculations; own presentation.
Source of data: HCSO, Regional Statistical Yearbook of Hungary, subsequent years, Budapest.

Table 24 presents the percentage change in the entropy in the expected peak year, 1999, over the start year 1992, and 2004 over 1992. There is a strong increase in concentration by almost 25% in the chemicals and chemical products industry for 1999/1992. For 4 other industries, there is a moderate increase by between 1.4% and 3.2%.

As to the comparison of the year 2004 to 1992, for 6 industries the overall agglomeration measured by entropy is lower than in 1992. Only for the chemicals industry, concentration has increased by 11.5%, and for food, beverages and tobacco, it has slightly increased by 1.7%. This overall decline of concentration for most industries over the period of validity of the Europe agreement - 1992 to 2004 - is more or less in line with the results for the other concentration indices used in this analysis.
4.8.3 Comparison of the results with theory and other empirical studies

The overall development of manufacturing industry concentration in Hungary as measured by the entropy is comparable to the predictions made by NEG theory for agglomeration in the course of integration processes. The model by Livas-Elizondo & Krugman (1996) for regional integration modelled in the context of international trade described that an (irreversible) agglomeration would form within the country consisting of more than one region. More precisely, the model by Puga (1999) which predicts first a rise to a peak, then a fall in concentration levels, called Ω-shaped development, is confirmed by the data from my own calculations. The case 5 of the model by Ludema & Wooton (1997), agglomeration at intermediate levels of trade costs which disperses during even further integration, is also broadly confirmed by the present results under the Europe agreement.

The entropy as a measure of industry agglomeration has not been applied to Central and East European data in published literature so far.132 Brühlhart & Traeger (2003) applied entropy indices to 7 broad economic sectors across 17 West European countries over the period 1975 to 2000. They found that manufacturing has become gradually more concentrated, although the locational bias towards central regions has become weaker over the period. Concentration measured at the regional level rose for 2 manufacturing sectors for Hungary over the period 1992 to 2004, and declined for the others.

In an effort to measure concentration effects due to the Single Market programme in the EU-15 (14 countries used), Aiginger & Pfaffermayr (2004) applied the entropy measure to Eurostat data of value added for 99 NACE 3-digit industries. They found a decrease in concentration for 40% of all industries for the year 1992 - the target year of the Single Market programme - as compared to 1985, one year prior to the Single Market decision. Beyond 1992, they found further dispersion effects up to 1998, with overall decreases of entropy for 66% of all industries. When comparing the end year 1998 to the start year 1985 of that analysis, they found decreases of concentration for 58% of all industries; thus concentration measured by entropy increased for 42% of the industries in that study. Those data are not in line with the publicly perceived wave of mergers and acquisitions sparked by the Single Market programme which are deemed to have fostered concentration processes. Perhaps the broad selection of industries in the study by Aiginger & Pfaffermayr (2004) was such that this did not allow for a specific

132 At the time of writing, May 2009.
analysis of the sectors which were subject to explicit and early liberalisation policies under the EU Single Market programme.

4.9 Comparison of concentration indices

In the preceding sections of this Chapter 4, concentration indices have been used to measure manufacturing industries agglomeration. One of the specialities of this research is that it applies 6 different concentration indices to the same data set. Most empirical studies use a single index, or at the most three to four indices. Another main difference is that in this research, regional sectoral data are used, whereas most other studies rely on per-country industry data of a set of several countries. In this section, the six concentration indices shall be compared.

4.9.1 Comparison of results of the 6 concentration measures

The comparison shall be done by taking a "cross section" of all six indices for one industry at a time. First, the chemicals and chemical products industry has been

Figure 36: Comparison of 5 concentration indices and entropy for chemicals and chemical products, value 1992=100; selected years

Source: Own calculations; own graphical illustration.
Source of data: HCSO, Regional Statistical Yearbook of Hungary, subsequent years, Budapest.

chosen, as this industry in general showed the most pronounced rise to a peak in 1999, followed by a decline in concentration. Second, the machinery and equipment industry has been chosen, as this industry contributed most to Hungary’s rising exports to the EU, with a share in exports of 66.3% in 2008, and rose to have the largest share in manufacturing output of Hungary, 51.5% in 2008.

**Figure 36** shows the development of concentration of the chemicals and chemical products sector based on regional sectoral employment for the years 1992, 1995, 1999, 2004, and 2008. The value for the year 1992 has been set equal to 100, the other values were calculated as an index relative to the base year. This results in the same scale of measurement for all 6 concentration measures which have different numerical values.

The graph shows for the five concentration indices a rise to a peak in 1999, followed by a decline in concentration levels up to 2004. The strongest rise is shown by the Hoover-Balassa index, a relative concentration index, followed by the absolute Herfindahl index, while the Krugman concentration index shows a modest rise. After the peak, concentration of the chemicals index fell rather steeply, to levels below the start level. From 2004 to the 2008 point, concentration

**Figure 37:** Comparison of 5 concentration indices and entropy for the machinery and equipment sector, value 1992=100; selected years

![Graph showing concentration indices](image)

Source: Own calculations; own graphical illustration.

Source of data: *HCSO, Regional Statistical Yearbook of Hungary, subsequent years, Budapest.*
rose to about an intermediate level as that of 1995. The entropy line runs in analogy, but opposite direction as the five concentration measures, as it shows the degree of dispersion in space.

**Figure 37** presents the results of the 6 concentration indices for the machinery and equipment sector based on regional sectoral employment data. All indices show a decline in concentration from 1992 to 1995, and an overall decline in concentration from 1992 to 2004. Three indices show an intermediary rise to a peak in 1999, the absolute Herfindahl index, the CR₃ Concentration rate, and the Krugman concentration index. The decline in concentration is shown, however, to quite different degrees by the different indices. From 2004 to 2008, concentration rose as measured by 3 of the 5 concentration indices. Entropy, the degree of industry dispersion, shows a very slight double hub mirroring the development of the five concentration indices.

**Figure 38:** Comparison of concentration indices and entropy for the machinery and equipment sector in a trend diagram, value 1992 = 100; selected years

![Bar chart showing concentration indices over time](image)

Source: Own calculations; own graphical illustration.
Source of data: HCSO, Regional Statistical Yearbook of Hungary, subsequent years, Budapest.

Here again, the Krugman concentration index gives intermediary values, as already for the results of the chemicals and chemicals products sector, i.e. in between those indices with a moderate decline and the index with a strong decline. The Krugman concentration index can therefore be called a “conservative” concentration index. This justifies also why it is later used as the concentration index in the regression analysis (see chapter 6).
Finally, the bar trend diagram in Figure 38 shows the declining trend in concentration for all concentration indices for data of the machinery and equipment industry for 5 selected years based on employment figures. The year 1992 value was set equal to 100 to make values by the indices comparable. The thin line shows the year 1999-value, the peak in concentration. The relative Herfindahl index shows the strongest decline, followed by the Krugman and Hoover Balassa indices. Entropy shows a rise in the industry’s degree of dispersion in space. Here again, the Krugman concentration index is in an intermediate position - as a “conservative” concentration measure.

4.9.2 Concentration indices in other empirical studies

Most empirical studies use only one or two concentration indices to analyse industry agglomeration at the country level based on per-country data for several countries. Of the few studies which use several indices, the one by Aiginger & Pfaffermayr (2004) - EU Single Market analysis, EU-14 countries, 99 industries, years 1985, 1992, and 1998 - used the absolute Herfindahl index, CR₃ concentration rate and entropy. Of these three, the authors called entropy their preferred indicator, as in their view, it gives the role of large countries a fair but not dominant share.

In their analysis of 10 CEECs based on a private data base from 1990-1999, Traistaru et al. (2003) used two concentration indices, the absolute Herfindahl index and the Krugman index which they called dissimilarity index, as well as a Gini index which only indirectly measures concentration when transposed under a curve. As the country chapters of the book were written by different authors, there is no evaluation contained about which index they preferred.

In their study based on plant level data at the subregional level for Italy, Di Giacinto & Pagnini (2008) discuss various concentration indices which require - apart from the Herfindahl index - plant level data. As their analysis is interested in the question whether economic agglomeration spaces ignore regional borders or can form despite them into different areas, they preferred indices taking into account plant level data - which were not available to me for the study of Hungarian agglomeration at the regional level. They also took into account a plant-level index developed by Devereux et al. (1999) from their study of the geographic distribution of production in the UK. Di Giacinto & Pagnini preferred an Ellison-Glaeser type index to that index which they complemented by some own data in order to take into account spatial autocorrelation measures given by the Moran’s I index.
Finally, in their study on 13 manufacturing industries based on per-country output data of 10 CEECs, Hildebrandt & Wörz (2004) chose the Hoover-Balassa index as their preferred index, as it measures relative concentration and adjusts for differences in country sizes. To me, the Krugman index is the preferred index as it provides “conservative” estimates for the Hungarian regional sectoral employment data, which should be judged to be the most realistic and reliable.

4.10 Conclusions regarding industry concentration in Hungary and the 6 concentration indices

In order to measure manufacturing industry agglomeration in Hungary, this chapter has described various concentration indices as a tool for obtaining concrete information about the actual developments. Six concentration indices have been selected for the purpose of this analysis, three of them providing an information about the absolute level of industry concentration, three of them relative concentration indices, referring to manufacturing employment as a benchmark.

These six concentration indices have been applied to regional sectoral manufacturing employment data from the HCSO for the period 1992-2008 or selection years. The resulting concentration for 8 manufacturing sectors in Hungary showed that there was a general rise of concentration from 1992 or 1993 to 1999, followed by a decline up to the year 2004. Since the EU membership of Hungary, a new rise in concentration levels set in, but with the end levels in 2008 less high than for the 1999 peak.

For the Krugman concentration index, it was shown that this tendency started to be reversed by 2007 already, when a new decline set in. Furthermore, while the levels in 2004 had in general been below the start levels, the end-levels in 2008 were almost equal to those at the start of the period due to the new rise of concentration since EU accession. That double hub pattern first of agglomeration and then of dispersion, and of newly rising concentration since 2004 was the case for all industries with the exception of the shrinking textiles and apparel industry. Moreover, the changes in the degree of concentration of industries found in Hungary over the period exceeded those observed in the EU during the Single Market process (e.g. Aiginger & Pfaffermayr 2004).

The overall degree of concentration - based on the results of CR₃ - differed greatly between manufacturing sectors in Hungary. The most concentrated manufacturing sector was the non-metallic mineral products sector, which was attributed to the fact of this sector depending on a resource which is located in only a few regions
and costly to transport. The chemicals and chemical products sector was second most concentrated, but in this case this was due to the existence of high economies of scale in production prevailing in that industry (as stated in the standard classification by the OECD (1994). Lower concentration levels prevailed in the food, beverages and tobacco as well as the textiles industry, which are both low-wage and rather labour-intensive industries with easily transportable and readily available inputs. The manufacturing industry was rather concentrated at the start of the period and rather dispersed over the country by the end of the period. This was attributed to the large growth in manufacturing output, exports and the large inflow of FDI mainly into this sector. It was also policy-driven to some extent by the Hungarian industrial parks and customs-free zones policies. Moreover, the sector was the main beneficiary of the provisions under the Europe agreement.

The fact that the six concentration measures were applied here to the same set of data allowed for a comparison of indices. This comparison showed that both the Krugman concentration index as well as the entropy provided objective values for the development of actual industry agglomeration. The Krugman concentration index has been singled out as the most “conservative” concentration index to be used later for the purpose of econometric analysis in chapter 6.

The actual development of agglomeration in Hungary’s manufacturing industries during the observation period confirms a part of the hypothesis of this research: That there was first a rise in agglomeration up to a point, followed by a decline; and that the peak was reached prior to full membership of Hungary in the EU, namely in 1999 already. Yet interestingly, and despite falling trade costs which should be associated with full EU-membership due to full participation in the Single Market, a second more modest wave of concentration set in among Hungarian manufacturing industries since 2004.

The results are broadly in line with the predictions made by NEG theories for industry agglomeration in the course of economic integration. The model by Livas-Elizondo & Krugman (1996) for regional integration modelled in the context of international trade described that an (irreversible) agglomeration would form within the country consisting of more than one region. More in particular, the predictions by Puga (1999) about an Ω-shaped relationship between industry agglomeration and declining transport costs during integration have been confirmed by this region-based concentration analysis for Hungarian manufacturing employment data in 1992 to 2008. Further, case 5 of the model by Ludema & Wooton (1997) predicted (less than complete) agglomeration to form at some intermediate level of trade costs, followed by dispersion, as trade costs between
regions within the country decline even further in the course of proceeding integration. This has also been the case for Hungary.

The evaluation of the results in the light of previous empirical studies has confirmed the special character of this research, namely that it relies on regional data to calculate country-level concentration per industry. Most other studies used country-level data of a set of various CEECs to calculate industry agglomeration for the whole of Central and Eastern Europe. Of the few studies that use regional data, comparability is restricted by the fact that these either relied on output, production or value added; or that they used different concentration indices; or that they rely on total employment as a benchmark instead of manufacturing employment, which has been chosen as the focus of this study for the reason that the Europe agreement with Hungary, the main pre-accession policy, comprised almost exclusively the manufacturing sectors in its trade provisions.

As industry concentration and regional specialization are two concepts which are linked in that they rely on the same or similar data sets, and that both can be put in context with spatial developments in the course of regional integration, the following chapter 5 shall analyse the actual development of regional specialization in Hungary in the pre- and post-accession phase.