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Markups and Concentration in the Context of Digitization: Evidence from German Manufacturing Industries*

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Abstract: Recent empirical studies suggest that there is a rising trend of market power across sectors in advanced economies. We contribute to this line of research by providing industry-specific evidence for German manufacturing industries, based on representative high-quality firm level data from official statistics that cover firms from all size classes with more than 20 employees (2005–2013). We compare firm-specific markups and industry concentration as market power indicators and discuss the role of digitization. Our results do not suggest an overall average increase in market power in German manufacturing. However, if we look at changes in individual industries, then we do find increasing markups and an increasing concentration in many industries. We also demonstrate the ambiguous relationship between the two indicators and find no clear evidence that digital transformation and market power go hand in hand.

JEL Classification: D4, L1, L4, L5, L6

Keywords: Market power, business concentration, markups, digitalization, manufacturing, Germany

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1 Introduction

A series of recent empirical studies have suggested that there is an increasing trend of companies' market power in economies worldwide. These results have triggered an international debate among researchers and policy makers, which focuses on the reasons and implications of an intersectoral rise of market power and also the validity of the empirical findings.[1] We contribute to this line of research and also the debate among policy makers by providing industry-specific evidence for German manufacturing industries. We also focus on the role a digital transformation plays for markup and concentration developments.

In general, studies of an increasing intersectoral market power are of particular relevance because they may provide a reason for other macroeconomic developments, such as declining productivity growth, declining labor share, increasing income inequality, and declining technology diffusion. They touch the essential question of a proper functioning of the overall resource allocation and the economies' respective competition regimes.[2] From a sociopolitical perspective, a potential concentration of economic power must also be seen against the background of potential anti-democratic developments.[3] In particular, in Germany the implementation of the competition regime after the Second World War was, among other things, motivated by efforts to prevent a concentration of economic power that may not be compatible with a democratic regime (e.g., Murach-Brand, 2004; Wu, 2018).

Special emphasis must be laid on the validity of the increasing market power trend, due to the far-reaching implications for academia and economic policy. However, the available studies are insufficient to speak of a stylized fact. This is especially true for economies other than the US economy because most research has been based

[1] See, for example, the background paper of the OECD (2018) in the context of an expert hearing in 2018 and a critique of the validity of the used indicators in Ohlhausen (2016), Traina (2018), and Berry et al. (2019).

[2] For an investigation of the implications of a rising intersectoral market power, see, among others, Van Reenen (2018), Syverson (2019), De Loecker and Eeckhout (2017), Barkai (2016), Autor et al. (2017), Decker et al. (2017), Bartelsman et al. (2013), CEA (2016), Ennis et al. (2017), Díez et al. (2018), Ponattu et al. (2018). For a discussion of results with a focus on Germany, see Wambach and Weche (2020).

[3] For the identification of current anti-democratic developments, see, among others, Shafik (2018), Hartmann (2018), and Mounk (2018).

on US data. For the US economy, for example, Grullon et al. (2016) find that the industry concentration among publicly listed firms, as an indicator for market power, increased in 75 percent of all 3-digit NAICS industries since 2000. They also find that the absolute number of publicly traded firms in the US has since shrank by almost 50 percent. Autor et al. (2017) also find an increasing industry concentration in several sectors over the period 1980–2010. De Loecker and Eeckhout (2017), as well as Dixon and Lim (2018) use firm-level markups as another indicator for market power and they find significantly increasing average markups over the last few decades in the United States.

A recent study by Bajgar et al. (2019) presents evidence for a rising intersectoral average industry concentration also in European countries between 2000 and 2014, although the increase is less pronounced than in the North American economies of the United States and Canada. A similar pattern can be observed when looking at the development of average firm-level markups. Here, the evidence suggests a drop in average markups for Europe during, and immediately after, the 2008 economic and financial crisis, which was followed by a sharp increase, just as in the United States (Weche and Wambach, 2018). However, the magnitude of this post-crisis increase of market power appears to be lower in Europe than in the United States.[4] This also applies to the increase of market power over a longer time span, as Díez et al. (2018) demonstrate. In a global comparison, the trend of increasing average markups can be observed primarily in advanced economies, for which Díez et al. (2018) estimate an average increase of almost 40 percent for the period between 1980 and 2016. Calligaris et al. (2018) also find increasing markups across 26 OECD countries for the period 2001–2014. They find that this increase is driven by firms at the top of the markup distribution. For developing and emerging countries, a comparable increase in average markups is not prevalent (Díez et al., 2018). However, another study by De Loecker and Eeckhout (2018) that was conducted for firms in 134 countries suggests a globally increasing average markup from 1980 to 2016, but again this increase is driven by developments in North America and Europe.

[4] In the study by Weche and Wambach (2018), the average markup for European countries did not even reach the pre-crisis level in 2015.

There seem not only to be heterogeneous developments of market power indicators across broad country categories but also across individual countries. Country specific studies are still scarce. However, Weche and Wambach (2018) report results for individual European economies and find significant differences. For some countries, the results even point to a declining average market power after the 2008 financial and economic crisis.[5] Another country-specific study by the Netherlands Bureau for Economic Policy Analysis (Van Heuvelen et al., 2019) reports no overall rise of the average markup in the Netherlands over the period 2006–2016. However, there is evidence for increasing markups for firms at the upper end of the markup distribution, although the authors conclude that the increase is far below the magnitude found in other studies. Moreover, De Loecker et al. (2018) show for Belgium that the average markup increased during the period 1985–1995, but—apart from cyclical fluctuations—they developed rather constantly thereafter.

For Germany, which is the focus of the present study, market power indicators point in different directions. From a market structure perspective, no intersectoral trend of an increasing industry concentration can be observed over the years 2007–2015 (Monopolkommission, 2018). Although the cyclical drop that started with the global financial and economic crisis in 2008, and particularly hit European economies, had the potential for a significant impact on the competitive environment through restructuring processes at the firm and industry level.[6] A constant average concentration development is supported by a study by Ponattu et al. (2018), although they identify individual industries in the services sector that show an increasing business concentration.[7] In addition, the German Central Bank found no intersectoral increase in German concentration figures but they did find an increase in the manufacturing sector (Deutsche Bundesbank, 2017). In contrast to the development of industry concentration, the level of the average firm-level markup appears to have increased over the same period. This increase was larger than the European average (Monopolkommission, 2018; Weche and Wambach, 2018). The German Monopolies

[5] These countries are Estonia, Hungary, Romania, Slovenia and Sweden.

[6] For restructuring processes during the crisis, see Duval et al. (2017) and Foster et al. (2016).

[7] These industries are trade, research and development, and public administration.

Commission, which has the legal mandate to report on the business concentration in Germany, concluded that there may be an indication of an increasing market power in Germany, although it appears to be much less dramatic than in the United States (Monopolkommission, 2018).

There is a strong motivation for sector-specific studies on the market power development because the review of empirical studies suggests clear differences. For example, concentration indices for non-financial services in North American economies show a steeper increase as compared to manufacturing industries (Bajgar et al., 2019). However, for European economies, there does not seem to be such a difference (ibid.).[8] When looking at markups in the Netherlands, the average markup level does appear to be higher in services industries than in manufacturing industries and declining markups appear to play a more important role in services industries than in manufacturing (Van Heuvelen et al., 2019).

The review of empirical studies on the development of market power indicators leads to the insight that the results are not transferable across regions, countries, or sectors. This gives a strong motivation for conducting country- and sector-specific studies. Consequently, the present study primarily contributes to the academic and policy debate by providing the first evidence for the markup development in German manufacturing industries. Another—more technical, but not less important—contribution is the use of administrative firm-level survey data that is statistically representative for firms with more than 20 employees and which offers a high quality of the reported values because firms are legally obliged to respond to these surveys. This is an important advantage compared to other studies that use accounting data from private data providers, which either cover only publicly traded firms or only a fraction of the entire firm population without using a proper sampling method or both. Hence, in the present study we are able to consider not only smaller and medium sized firms, as well as private firms, but we are also able to build our conclusions on representative survey data, which is of particular importance for reaching stylized facts. A third contribution is an investigation of the role of the digital transformation

[8] A possible explanation of this difference is stronger language barriers within Europe, which may hinder economic agglomeration processes in the services industries.

for the development of markups and concentration, as it is widely discussed as an important reason for increasing market power.

Our results do not suggest an overall average increase in market power in German manufacturing between 2005 and 2013 in terms of markups. However, average industry concentration in German manufacturing has increased during this period, although this increase does not appear to be dramatic. If we look at average changes in individual industries, we do find both increasing markups and increasing concentration in many industries. We also demonstrate the ambiguous relationship between industry concentration and markups, suggesting their complementary use. Furthermore, we consider the role of digital transformation processes for competition, but find no clear evidence that digitalization and market power go hand in hand. Our results even suggest a negative correlation between market power and research as well as software expenses. This finding does not support the hypothesis that rising markups may be caused by rising fixed costs due to an increasing importance of investments in intangible assets because of a digital transformation (e.g., Berry et al. 2019).

The rest of the paper is structured as follows. In Section 2, the methods to measure market power are explained and general limitations of measures of competitive pressure in interindustry studies are discussed. Section 3 provides a description of the administrative micro data used. The results are presented and discussed in Section 4. Finally, in Section 5, we discuss the implications of our results and give an outlook.

2 Measuring competition

The measurement of an individual firm's market power or the competition intensity of an entire market poses a demanding task for empiricists. This is true for specific cases, such as in merger control proceedings where it is possible to undertake comprehensive inquiries, and information on product prices and quantities is usually available. It is even more true for inter-industry studies, where neither product-level data nor an appropriate market definition are available.

Traditionally, competition intensity in inter-industry studies has been proxied by a measure of industry concentration, such as concentration ratios (CR_n) or the Herfindahl-Hirschman-Index (HHI), which can be calculated as the sum of the squared market shares s^2 of all firms i in a market j:

$$HHI_{jt} = \sum_{i \in j,t} s_{it}^2. \tag{1}$$

Current empirical studies still use this measure due to a lack of alternatives. The underlying assumption for these structural measures to be valid indicators of competition intensity is that the more concentrated markets are, the more market power firms have in these markets. Apart from the fact that markets can be characterized by a high degree of competition, precisely because they are concentrated and suppliers benefit from economies of scale (e.g., Schmalensee, 1989 and Demsetz 1973), the use of concentration figures does have technical shortcomings. Among the most important is that figures of (sales) concentration usually neither consider imports nor exports, and thus may dramatically over- or underestimate market concentration. In addition, concentration figures are usually calculated according to statistical industry classifications that do not reflect proper market definitions.[9]

Due to the limitations of structural measures for market power, profit-oriented firm-level indicators that are based on the idea of measuring excess profits over marginal cost are generally preferred. These measures are less susceptible to the market definition and they try to directly measure the price-setting behavior of firms.[10] In the subsequent analysis, we apply the approach proposed by De Loecker (2011) and De Loecker and Warzynski (2012) to approximate firm-level markups that indicate prices over marginal cost and can be derived from production data.[11] The underlying idea is that market power manifests itself in prices P above marginal costs λ ($\frac{P_{it}}{\lambda_{it}} > 1$) and, hence, markups μ above unity.

The identification of markups, as the ratio of an input's output elasticity and

[9] For a brief discussion of the limitations of concentration statistics in general and for Germany in particular, see Heidorn and Weche (2020).

[10] The extent to which structural and market outcome measures are correlated will be examined in Section 4.3.

[11] For a discussion and comparison of different approaches to estimate firm-level markups via production functions, see e.g. Van Heuvelen et al. (2019).

the revenue share of its costs, is based on the insight that the output elasticity of a variable input factor without adjustment costs equals its revenue share when both price and marginal cost are equal under perfect competition. Thus, in a situation of optimal input demand, the firm-level markup μ_{it} can be defined as a function of output elasticity $\theta_{it}^{X^V}$ and the corresponding variable input factor's X_{it}^V revenue share:[12]

$$\mu_{it} = \theta_{it}^{X^V} \left(\frac{P_{it}^{X^V} X_{it}^V}{P_{it} Q_{it}} \right)^{-1} . \tag{2}$$

Although firm-level markups appear to be more suitable to measure market power than structural measures, their interpretation requires particular care. When a firm is able to generate excess profits and has pricing power, this may also be due to high fixed costs or an efficiency advantage due to superior technology that may result from past investments, which have to be amortized.[13] Hence, a high markup may both indicate a high market power and innovativeness at the same time. While the former must be regarded rather problematic from a policy perspective, the latter must be regarded as being rather positive because it points to technological progress.

3 Data and variables

We use the Cost Structure Surveys from official German business statistics for manufacturing firms with at least 20 employees.[14] This firm-level survey data covers up to 18,000 enterprises per reporting year and is of high quality because firms are obliged to respond and the sample is representative at the industry and size level.[15] Thus, the data is advantageous compared to other studies that either cover only (large) publicly traded firms or lack representativeness.

We begin by analyzing data for the most recent years 2010 and 2011 for which we

[12] For a formal derivation, see De Loecker and Warzynski (2012) and for a description of our estimation strategy to yield output elasticities, see the following section.

[13] In particular, investment in intangible assets may play a significant role for high markups. For a more detailed discussion see, among others, Martins et al. (1996) and Van Reenen (2018).

[14] The firm level data are strictly confidential but are not exclusive. They can be used in the research data centers of the statistical offices, see www.forschungsdatenzentrum.de for details.

[15] For more information on the German Cost Structure Surveys, see Fritsch et al. (2004).

have sufficient enterprise-year observations after calculating all necessary variables (14,631 and 14,347).[16] In a further step, we are able to construct a balanced panel for the period 2005–2013 to track the evolution of average markups within firms. However, because a new sample is drawn every four years, only firms that reported throughout the entire period are covered (23,238 firm-year observations). On the one hand, large firms, which are important for the representativeness of the sample, are more likely to remain in the sample during the entire period. On the other hand, an overrepresentation of large firms and the fact that the panel only covers firms that survived throughout the period may create sample selection effects.

For the estimation of output elasticities to yield markups, we rely on the firm-level variables value added, material cost, capital stock, labor cost and the number of employees (see Table 1 for summary statistics).[17] While material cost and the number of employees can be taken directly from the data, labor cost is calculated as the sum of salaries paid (including social cost), and value added is calculated by subtracting material cost from operating revenue.[18] The capital stock is identified according to Söllner (2017) as the average of tax depreciation over the last three years plus rental and lease expenses.

[Table 1 about here]

To estimate markups according to De Loecker and Warzynski (2012), as discussed in the previous section, we use a restricted production function of the translog type with value added as the dependent variable. We control for unobserved productivity shocks using the control function approach, developed by Ackerberg et al. (2015),

[16] Although our most recent survey year is 2013, 2010 and 2011 are the most recent years with sufficient information to calculate markups. The reason for this choice is that we rely on lag variables of the two previous years to adequately identify the capital stock according to Söllner (2017) and a new sample was drawn for the Cost Structure Survey in 2012. The overall number of available observations decreased slightly due to missing producer price index information for some industries and due to the exclusion of industries that show too few observations for reliable production function estimations (mining and quarrying, manufacture of tobacco as well as coke and refined petroleum products).

[17] All pecuniary variables are deflated by using producer price index data at the 2-digit NACE Rev. 2 level provided by Eurostat.

[18] The operating revenue is calculated by substracting revenue from trading and other activities from the gross production value.

based on Olley and Pakes (1996) and Levinsohn and Petrin (2003).[19] Although price changes over time are accounted for by deflation at the industry-level, price differences across firms in the same industry may impose an omitted price variable bias because a firm's input choice may be correlated with price changes that deviate from the industry mean (Klette and Griliches, 1996). However, De Loecker and Warzynski (2012) conclude that even if this omitted price variable bias affects the level of estimated markups, neither the markups' changes nor their correlation with firm characteristics should be biased. Therefore, we focus on markup changes and differences in our analysis rather than on the absolute magnitude. We use labor as the relevant input factor, which is in line with De Loecker and Warzynski (2012).[20] The results of the markup estimation are presented and discussed in the following.

4 Results

Table 2 shows summary statistics of the estimated markups. The average markup of 1.47 in 2011 is slightly higher than in the previous year and this difference appears to be statistically significant because the t-test supports a rejection of the hypothesis of equal mean values.[21] This fits the picture of a rising average market power in Germany in the aftermath of the crisis, which is found by Weche and Wambach (2018). To check whether this difference holds along the distribution of estimated markups, we use the nonparametric Kolmogorov-Smirnov test that evaluates if all moments of the two cumulative distribution functions for 2010 and 2011 are statistically different from each other (Conover, 1999). The p-value suggests a rejection of the

[19] This approach relies on the assumptions that firms can be pooled together by time-invariant common production technology at the industry level (2-digit in our case) and that the production is Hicks-neutral in productivity, meaning that changes in productivity do not affect the proportion of factor inputs.

[20] When the labor factor is characterized by adjustment costs, other factors without adjustment costs may pose an alternative. However, although labor markets in Germany may be characterized by rigidities, it needs to be kept in mind that we use yearly variations of labor input which must be regarded as much more variable than, for example, monthly variations. Moreover, De Loecker and Warzynski (2012) compare markups based on labor elasticities with markups based on material input elasticities and find very similar results.

[21] This difference also appears if we look at sales weighted mean values which are also reported in Table 2 and are slightly lower than the unweighted mean values.

null hypothesis that the distributions are equal (Table 2). To get a better picture of the distributional differences, Figure 1 offers a graphical comparison of the markup distributions in 2010 and 2011, and shows a slight shift to the right of the 2011 distribution, meaning that more firms in the sample had higher markups.

[Table 2 about here]

[Figure 1 about here]

A comparison of markups across size groups is of special interest in the present context because most studies rely on data for publicly traded firms, which are in general larger than non-traded firms, and operational differences can be expected across size groups. For example, smaller firms may operate more often in niche markets with less competitors and could thus charge higher markups. Contrary to this reasoning, Van Heuvelen et al. (2019) analyze markups in two size categories and find that smaller firms in the Netherlands charge lower markups. Table 3 shows that small firms in German manufacturing (with less than 50 employees) also have a significantly lower average markup than medium sized firms (with between 50 and 250 employees) and that large firms (with at least 250 employees) in turn charge significantly lower markups than medium sized firms.[22] However, this is only the case if we assume a uniform production function across firm size categories. If we allow the production function of firms to differ by size, then we can see the highest average markup for small firms, supporting the hypothesis that smaller firms are more likely to operate in niche markets, where they face less competition (Table 3). However, in both categories of small and large firms, firms with higher markups generate relatively more sales than those with lower markups as can be seen from the higher sales weighted mean averages. The density graph in Figure 2 illustrates these findings and also shows a clear difference between mid-sized and large firms.

[Table 3 about here]

[22] These differences appear to be both economically and statistically significant, as the t-test results in Table 3 suggest. Note that the data that we use covers only firms with more than 20 employees. If we look at sales weighted mean values medium sized firms also yield the highest average markup, but the largest firms show the lowest average markup.

[Figure 2 about here]

Figure 3 shows markup results by 2-digit manufacturing industries. By far the highest average markups can be found in the manufacture of beverages, the manufacture of other transport equipment (e.g., ships, railway locomotives and rolling stock, air and spacecraft, and military fighting vehicles), and the manufacture of other non-metallic mineral products (e.g., glass, cement, and products of cement, concrete, stone, porcelain, and ceramic). Furthermore, there appear to be only exceptions in which the average markup has not increased from 2010 to 2011.

[Figure 3 about here]

An important finding of other studies, which is of importance for policy considerations, is that an increasing average markup over time may be driven by the upper end of the distribution. This can either point to increasing markups of firms that already have high markups or to restructuring processes in which firms at the top of the distribution may be, for example, new entrants. Therefore, a look at the evolution of markups at the upper end of the distribution is of importance in the present context.[23] Figure 3 supports these findings because in the majority of industries in which we observe rising average markups, we observe a rising 90th percentile. However, it needs to be borne in mind that we look at a period of only two years. On the one hand, this means that these changes may only reflect year-to-year fluctuations but, on the other hand, even small year-to-year changes may point to a significant evolution if they are part of a steady development.

4.1 The development of market power over time

In a further step, to track the evolution of average markups over time, we construct a balanced panel for the period 2005–2013.[24] This panel covers pre- and post-crisis years and allows us to evaluate whether or not average market power of firms that

[23] Our analysis has the advantage that there are no outliers excluded from the sample due to the high data quality, which offers an unbiased view on upper percentiles of the markup distribution.

[24] See the earlier data section for a detailed description and a discussion of the trade-off between panel length and representativeness when using Cost Structure Survey data.

were active throughout this period has increased during and after the crisis. Although a panel length of nine years does not enable us to track the market power evolution over several decades, as other studies do, the period that is covered is of particular interest because the 2008 financial and economic crisis could have been the reason for a severe industry restructuring and therefore a significant change in the competitive environment (Duval et al., 2017 and Foster et al., 2016).

The development of the markups in the overall manufacturing sector, presented in Figures 4 and 5, does not suggest an overall average increase. The average markup level in 2013 has not reached the pre-crisis levels from 2005, 2006, and 2007 and the observed increase between 2009 and 2011 rather seems to reflect a return to pre-crisis levels. This conclusion holds if the arithmetic mean is weighted by sales shares to consider the economic weight of individual firms. Moreover, we cannot detect a disproportional development of markups at the upper end of the markup distribution, as other studies do (cf. Sec. 1). These results hold even if we consider small, medium-sized, and large firms separately.[25] Thus, the increase from 2010 to 2011 that we have found in our analysis of the respective cross sections—and which is also apparent in Figure 4—may indicate a recovery process rather than a steady trend of increasing market power. However, it needs to be stressed that we are only able to consider a possible within firm effect in a balanced panel and a between variation cannot be considered.

[Figure 4 about here]

[Figure 5 about here]

If we look at individual manufacturing industries, we get a heterogeneous picture. Table 4 shows industry-specific mean values of individual firms' markup changes between 2005 and 2013 (mean Δ).[26] The results point to a considerable heterogeneity across manufacturing industries in the way that some industries show an average increase and some an average decrease. However, when we look at the number of

[25] The results are not reported for brevity.

[26] Unfortunately, for two industries, the results are not available due to confidentiality reasons, meaning that less industries are considered in the total average in Table 4 than in Figures 4 and 5.

industries showing an average increase or decrease, the picture is less heterogeneous because there is an increase in the great majority of industries. If we calculate the percentage change of excess profits, as the percentage change in prices over marginal cost, the economic significance of the rise in markups in most industries becomes apparent. In the manufacturing of leather and related products, for example, we observe an increase in excess profits of more than 70 percent. In the printing and reproduction of recorded media industries, the wearing apparel industries, and the motor vehicles, trailers and semi-trailers industries we observe an increase of 56, 50, and 34 percent. Overall we observe an average increase of excess profits of almost 15 percent across 2-digit manufacturing sectors.[27]

[Table 4 about here]

An important conclusion from this industry-specific analysis is that the sole consideration of sector-wide or even economy-wide averages bears the potential to mask markup developments in individual industries. In the case of German manufacturing, the result of almost no change of the overall average markup level between 2005 and 2013 masks the fact that an increase has indeed taken place in the majority of 2-digit industries, if we consider firm-specific changes. However, firms with increasing markups do not seem to increase their sales shares significantly.

4.2 Market power and the digital transformation

The digital transformation of industries is a much-discussed potential reason for the rising average market power (see e.g., Andrews et al. (2016) and Calligaris et al. (2018)). Digital technologies, in particular information and communications technologies (ICT), that allow firms to create larger consumer networks and facilitate a fast access to geographical and product markets, as well as the exploitation of scale economies from intangible assets, can significantly help to increase the firms' productivity. Although digitalization can be associated with the potential to increase

[27] This average increase is not visible if we only look at the percentage change between the 2005 and 2013 mean values in Table 4. If we consider the respective sales weighted mean values, reported in Table 9 in the appendix, there is even a total negative average percentage change of 5 percent.

competition (e.g., due to decreasing production costs, easier market entry and internationalization), it may also adversely affect market entry and pricing behavior. The reasons for this can be, among others, that only firms at the innovation frontier may be able to keep pace with the high speed of innovation in a digital context and that intellectual property rights may prevent technology diffusion in a disproportionate manner (e.g., Andrews et al., 2016 and Acemoglu et al., 2012). However, a recent OECD study finds no differences regarding the industries' development of business concentration by digital intensity in European economies (Bajgar et al., 2019). For the United States, the authors even find a significantly less pronounced increase in business concentration for industries with a high digital intensity. On the contrary, Calligaris et al. (2018) find markups to be higher in digital-intensive sectors and that this gap was increasing significantly over the period 2001–2014.

Against the background of the ambiguous theoretical predictions and mixed evidence regarding the role of a digital transformation for market power, we use the OECD taxonomy of sectors according to their degree of digitalization to evaluate the digitalization-competition nexus in German manufacturing.[28] Figure 6 shows industries by digital intensity quartile, where the 1st quartile indicates a low level of digital intensity and the 4th quartile a high level. However, apart from the fact that all industries that do not show an increase in markups have been assigned a low or medium-low level of digitalization, there appears to be no clear evidence for a correlation of digital intensity and markups. The absence of a clear pattern is also supported if we consider average markup changes over time, as reported in Table 4. For example, while among the seven industries with decreasing markups, we find four industries with a low or medium-low digital intensity, we find three with a high or medium-high digital intensity. However, among the 14 industries with increasing markups, we do not find any at a low digitalization level but half only at a medium-low level.

[28] This taxonomy, which was proposed by Calvino et al. (2018), considers various dimensions of the digital transformation, such as the intensity in ICT tangible and intangible investment, the intensity in purchases of ICT intermediate goods and services, the stock of robots per hundreds of employees, the number of ICT specialists over total employment, and the proportion of turnover from online sales. We use the overall summary classification at the 2-digit level, based on data for 2013–2015.

[Figure 6 about here]

To further evaluate the relation between digitization and markups at the firm level, we correlate firms' expenses for intangible assets with their individual markups. The role of intangible assets has significantly increased over the last decades and may pose a crucial factor for firms' digital transformation. Therefore, it is argued that a growing need for intangibles in the production process leads to higher markups to bear the additional fixed costs (cf. Section 2). Thus, rising markups may be a result of a growing need to invest in intangibles instead of indicating rising market power. Within the category of intangible asset investment, we also look specifically at software expenses, as we regard software as an important component of business digitalization. Moreover we consider research activities of firms as another important component of intangible assets.

Figure 7 shows that the firms in our balanced sample report an only slightly increasing average intensity of research efforts as well as for software and other intangible investment. To evaluate the partial correlation of these variables with markups, we estimate OLS regressions for the representative pooled sample and the balanced sample and control for industries (3-digit level), years, and a non-linear role of firm size in terms of the number of employees. If intangible asset investment is indeed an explanatory factor for markups—either because they affect the competitive pressure or merely the need to cover additional fixed costs—we allow this effect to happen with a delay and estimate both a static and a dynamic specification. In the dynamic specification we consider the intangible and research intensity from the previous period.

[Figure 7 about here]

Tables 5 and 6 show a negative partial correlation between markups and both research intensity and software intensity. This negative correlation can be observed in both samples and in both static and dynamic specifications. However, if we include a firm fixed effect to control for unobserved time-invariant heterogeneity (FE-OLS), the correlation with software intensity appears to be statistically significant only in the dynamic specification. The results suggest that, once we control for industry, size, and unobserved heterogeneity, an increase in research/software intensity by one percentage point in t comes along with a markup decrease by 0.002/0.01 in $t+1$ (in the case of research intensity also in t). This magnitude appears to be relevant for software intensity, but rather small for research intensity. [29]

[Table 5 about here]

[Table 6 about here]

This finding does not support the hypothesis that rising markups may be caused by rising fixed costs (instead of market power) due to an increasing importance of investments in intangible assets because of a digital transformation. If firms with a higher research and software intensity would be the more digitalized, the results also do not support the hypothesis that digitalization enables firms to exert more market power. Instead, the results could, for example, point to an increased competitive pressure in research and software intensive industries.

4.3 The concentration-markup nexus

A positive link between market concentration and a firm's individual pricing power is often wrongly regarded a stylized fact.[30] In the context of a structure-conduct-performance (SCP) paradigm, the explanation for such a relation is that high relative market shares cause monopolistic or rather oligopolistic behavior leading to excess profits (e.g., Bain, 1951). However, today it seems clear that neither a positive correlation between market structure and outcome nor a one-way causal relation can be taken for granted (cf. e.g., Schmalensee, 1989). Instead, the two parameters may not be correlated at all or, for example, a positive correlation may point to the exploitation of scale economies that deter a concentrated market structure. We investigate the correlation between industry concentration and individual markups in German manufacturing in the following section. Our primary purpose is to evaluate

[29] If we add other intangible expenses, such as for patents, licenses and concessions, to the software expenses, the estimated coefficients turn insignificant. The results are not reported for brevity.

[30] Earlier empirical studies, investigating the link between concentration and profit margins can be found, for example, in Weiss (1974), Ravenscraft (1983), and Salinger (1990).

whether or not the two indicators for market power point in the same directions and may thus be used alternatively. We do not try to evaluate a potential causal relationship between market structure and outcome.

Figure 8 shows the development of the 4-digit industry concentration from the pre-crisis year 2007 to the post-crisis year 2015.[31] Similar to the development of the average markup, the average HHI neither suggests a soaring trend.[32] Nevertheless, if we take a closer look at the development of mean values by changeing the scale in Figure 9, we can see an increase of the average HHI as well as the CR6, which is an alternative concentration measure that measures the top 6 firms industry's sales share.[33] However, the weighted means are increasing more because either highly concentrated industries become relatively larger in terms of their sales shares or large industries get more concentrated. Table 7 offers an overview of the concentration development by 2-digit industry from 2007 to 2013 analogous to Table 4. Again, the industry-specific perspective offers a heterogeneous picture regarding the direction of the change. Industry concentration has been increasing on average in most of the 2-digit industries in German manufacturing.

[Figure 8 about here]

[Figure 9 about here]

[Table 7 about here]

Figure 10 illustrates the relationship between an industry's average HHI (calculated at the 4-digit level) and its average firm-specific markup at the 2- and 3-digit level. In both cases, the linear trend points slightly upwards.[34] However, if we calculate Pearson correlation coefficients, we only observe a positive correlation

[31] The data can be obtained from the German Monopolies Commission (*Monopolkommission*) upon request. See Heidorn and Weche (2020) for details.

[32] For an explanation and discussion of concentration measures and the HHI in particular, see Section 2.

[33] This finding is in line with an analysis of the German Federal Bank that also observed an increasing concentration in manufacturing industries (Deutsche Bundesbank, 2017).

[34] For our correlation analysis, we have excluded some outliers because the correlation coefficient could otherwise be biased. In particular, we have excluded HHI values above 4,000 and average markup values below zero and above three (at the 3-digit level).

coefficient in slightly more than half of the manufacturing industries and the highest coefficient is 0.3 (Table 8). If we move from a cross-section correlation in levels to a correlation between markup changes and HHI changes over time (both 2005–2013), using the balanced panel, then we observe a positive correlation coefficient of up to 0.3 in about three quarters of manufacturing industries. Overall, the results are in line with other analyses of the concentration-markup relation in manufacturing industries (e.g., Fedderke et al., 2018 and Mishra, 2008) and seem to demonstrate the ambiguous relation between market concentration and outcome, suggesting that the two indicators should not be used alternatively.

[Figure 10 about here]

[Table 8 about here]

5 Concluding remarks and outlook

A number of recent empirical studies have suggested that there is a rising trend of market power across economies and sectors. We contribute to this line of research and the debate among policy makers by providing industry-specific evidence for German manufacturing industries. We compare firm-specific markups and industry concentration as market power indicators and we use administrative data from official German business statistics.

Our results do not suggest an overall average increase in market power in the German manufacturing between 2005 and 2013, although concentration is moderately rising. However, if we look at average changes in individual industries, we do find increasing markups and an increasing concentration in many industries. We also demonstrate the ambiguous relationship between market concentration and markups, suggesting their complementary use. Furthermore, we consider the role of digital transformation processes for competition but we find no clear evidence that digitalization and market power go hand in hand.

These results demonstrate that an overall rise of markups and concentration, as dramatic as it is found in other studies, cannot inevitably assumed for German manufacturing. Nevertheless, markups and concentration seem to be rising in many German manufacturing industries, indicating a rising market power. However, the underlying reasons remain unclear and should be subject to future research. For example, firms may be able to charge higher prices due to their innovativeness and for financing fixed costs and investments in intangible assets. This would lead to different policy implications than if firms were able to charge higher prices merely because of their market power while innovativeness is stagnating. However, our first evidence from a partial correlation analysis suggests a negative correlation between markups and research as well as software expenses. This does not support the hypothesis of rising markups through rising fixed costs due to digitalization-related investments in intangible assets.

Since we do not observe a disproportional rise of markups within firms at the top of the markup distribution in overall manufacturing, there is no evidence for a selective technological progress in the sense of a lack of technology diffusion from more innovative firms. However, this may be bad news from an industrial policy perspective because it could point to the fact that there is simply a lack of disproportionately innovative firms in German manufacturing. Nevertheless, the result of rising market power indicators in many manufacturing industries should be kept in mind, especially against the background of the growing demand for a more active industrial policy to prevent severe negative long-term implications for innovativeness, efficiency, and consumer welfare.

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Tables and Figures

Table 1: Summary statistics of production function variables

	2010		2011	
	Mean	Std. dev.	Mean	Std. dev.
Value added*	27.46	256.22	28.60	260.14
Material cost*	34.88	476.25	38.83	532.38
Capital stock*	3.16	39.18	3.09	37.67
Labor cost*	13.32	133.47	13.69	141.86
Employees	248	1820	255	1876

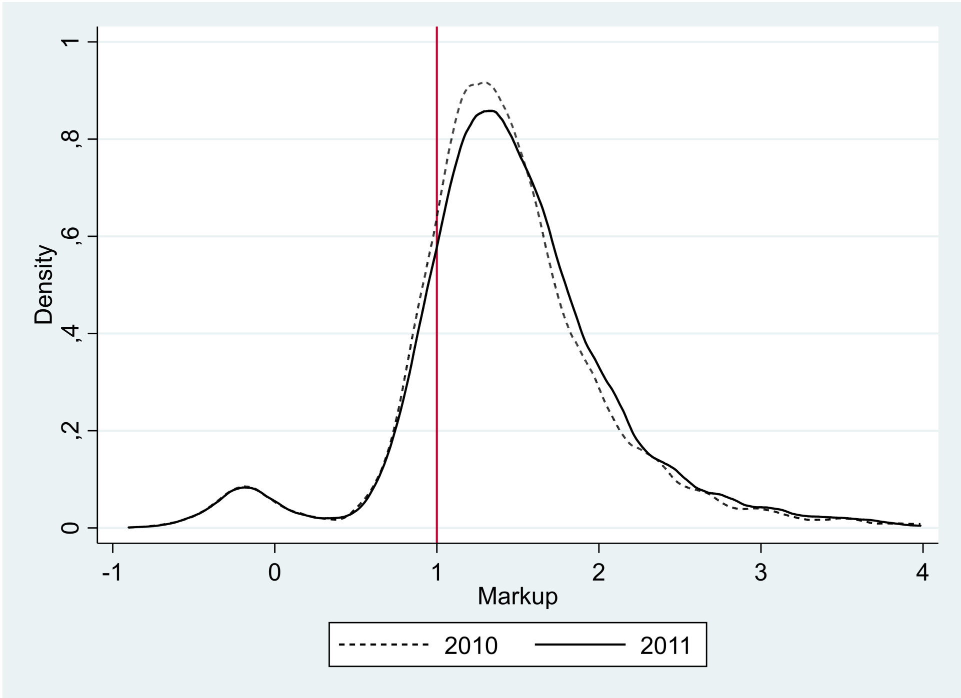
Note: The number of observations for 2010 (2011) is 14,631 (14,347). *In Mio. EUR, deflated by Eurostat PPI. The reporting of single values, such as minimum and maximum values, is not possible due to the confidentiality of the data.

Table 2: Summary statistics of markups

Year	Mean	WMean	Std. dev.	Percentile					
				1	25	50	75	90	99
2010	1.42	1.30	0.67	-0.33	1.10	1.37	1.70	2.15	3.51
2011	1.47	1.35	0.69	-0.32	1.12	1.41	1.77	2.21	3.56
t-test unequal mean (p-value)									0.000
Kolmogorov-Smirnov test of equality of distributions (p-value)									0.000

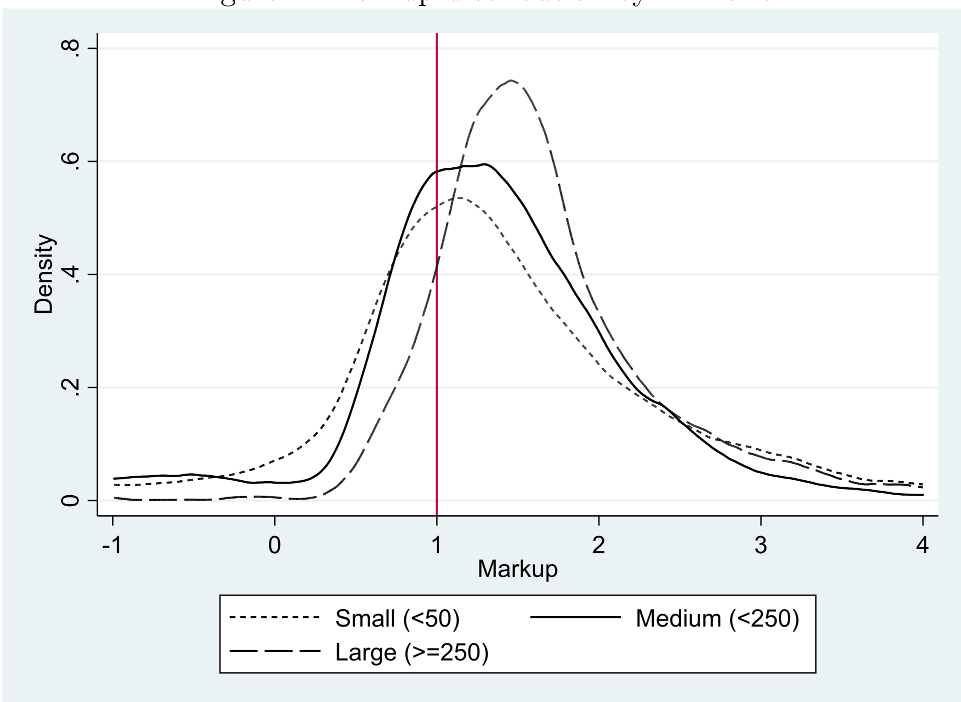
Note: The number of observations for 2010 (2011) is 14,591 (14,307). The reporting of single values, such as minimum and maximum, is not possible due to the confidentiality of the data. Weighting according to sales shares.

Figure 1: Markup distribution



Note: Kernel density estimation according to Epanechnikov function. Restricted range.

Figure 2: Markup distribution by firm size

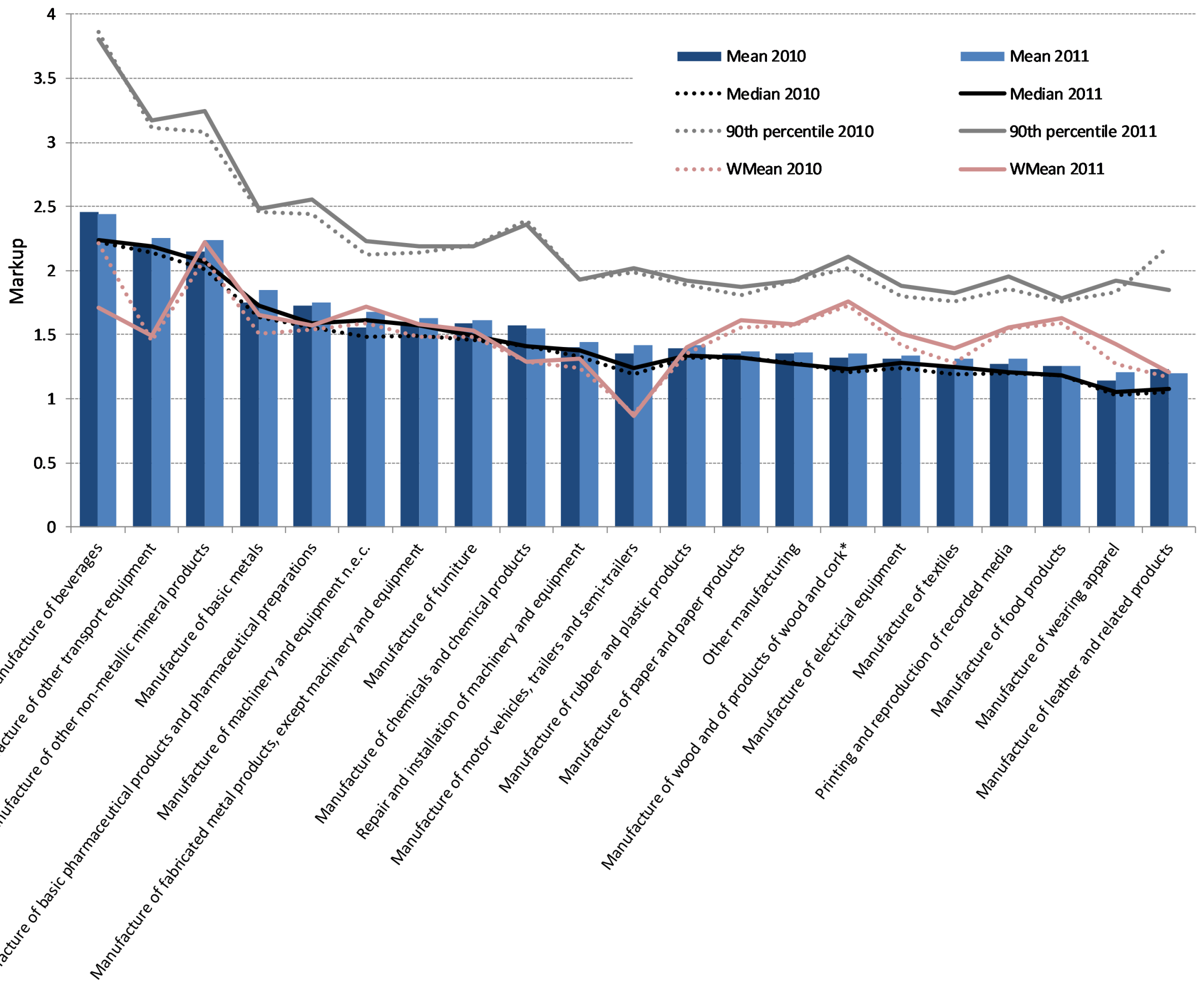


Note: Kernel density estimation according to Epanechnikov function. Restricted range. Markup estimation assuming different production functions by size category.

Table 3: Markups by size (2011)

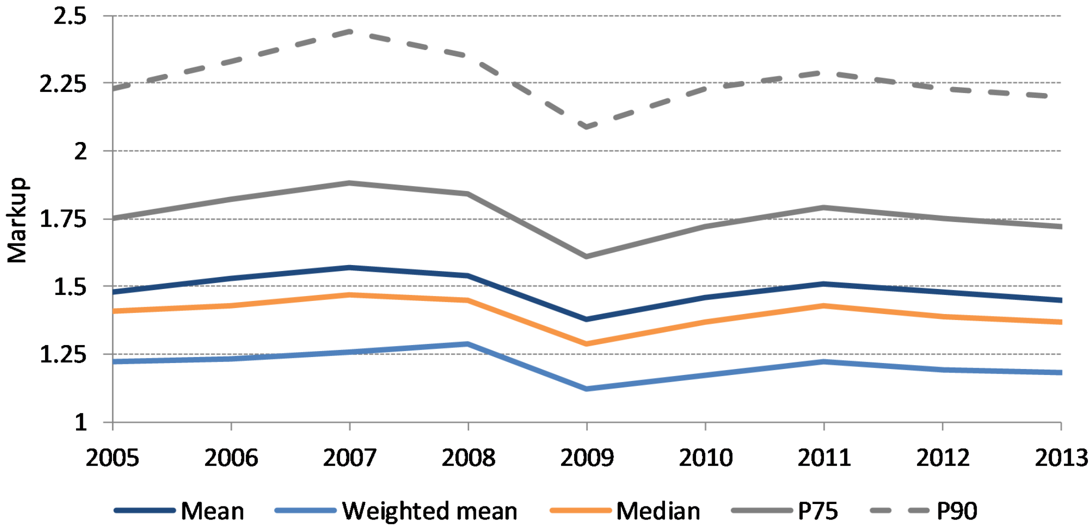
No. of employees	N	Mean	WMean	Std. dev.	Percentiles					
					1	25	50	75	90	99
Uniform production function										
<50 (small)	4152	1.43	1.76	0.75	-0.49	1.07	1.37	1.74	2.21	3.75
>=50 & <250 (medium)	7344	1.50	1.77	0.71	-0.23	1.14	1.44	1.82	2.27	3.59
>=250 (large)	2811	1.46	1.25	0.55	0.12	1.15	1.42	1.72	2.07	3.11
		t-test unequal mean (*p*-value)			Kolmogorov-Smirnov test of equality of distributions (*p*-value)					
Small vs. medium		0.000			0.000					
Small vs. large		0.084			0.000					
Medium vs. large		0.001			0.000					
Different production functions by size category										
<50 (small)	4152	1.42	1.80	1.43	-2.51	0.81	1.28	1.92	2.84	6.03
>=50 & <250 (medium)	7344	1.32	1.32	1.08	-1.81	0.89	1.31	1.80	2.38	4.28
>=250 (large)	2811	1.27	1.82	2.61	-11.47	1.17	1.52	1.94	2.67	5.83
		t-test unequal mean (*p*-value)			Kolmogorov-Smirnov test of equality of distributions (*p*-value)					
Small vs. medium		0.000			0.000					
Small vs. large		0.003			0.000					
Medium vs. large		0.317			0.000					

Figure 3: Markups by 2-digit manufacturing industries



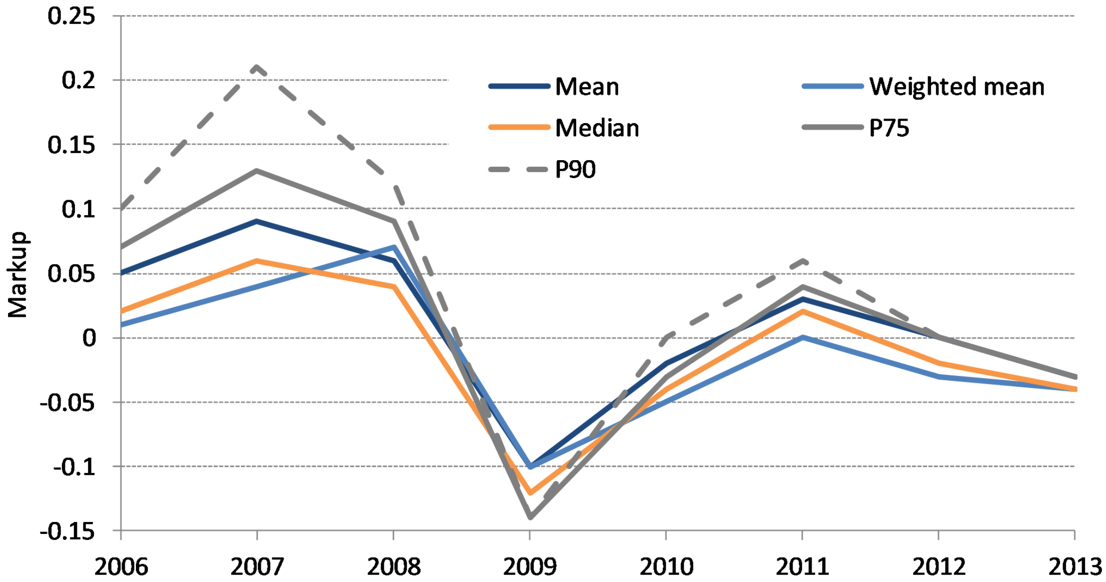
Note: Insufficient observations were available for the manufacture of tobacco products (12) and the manufacture of coke and refined petroleum products (19). The manufacture of computer, electronic and optical products (26) is not reported, because values are below 0. *Except furniture and manufactures of articles of straw and plaiting materials.

Figure 4: Markup development (2005–2013)



Note: Balanced panel of 23,238 firm-year observations (n = 2,582). Weighting according to sales shares.

Figure 5: Markup changes since initial year (2005)



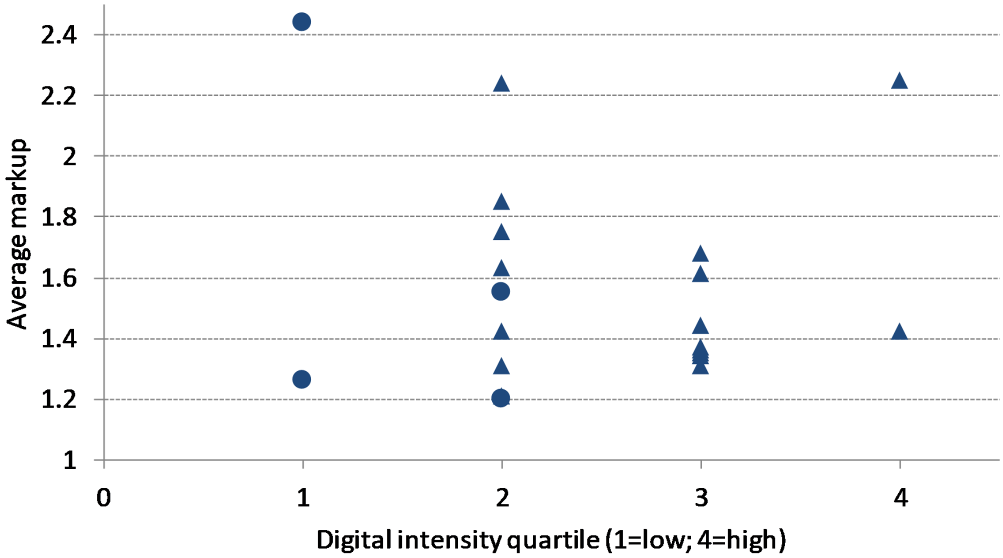
Note: Balanced panel of 23,238 firm-year observations (n = 2,582). Weighting according to sales shares.

Table 4: Markup changes by industry (2005–2013)

Manufacture of ...	Mean 2005	Mean 2013	Mean Δ	% change of excess profit	Digital intensity
10 food products	1.35	x	-0.06	-17.14	low
11 beverages	3.28	3.27	x	-0.44 *	low
13 textiles	1.26	1.28	-0.03	-11.54	med.-low
14 wearing apparel	1.14	1.05	0.07	50.00	med.-low
15 leather and related products	1.21	1.06	0.15	71.43	med.-low
16 wood and of products of wood and cork**	1.65	1.47	0.18	27.69	med.-high
17 paper and paper products	1.51	1.42	0.09	17.65	med.-high
18 Printing and reproduction of recorded media	1.68	1.3	0.38	55.88	med.-high
20 chemicals and chemical prod.	1.51	1.42	0.08	15.69	med.-low
21 basic pharmaceutical prod. and pharmaceutical preparations	1.68	1.66	0.08	11.76	med.-low
22 rubber and plastic products	1.28	1.31	-0.02	-7.14	med.-low
23 other non-metallic mineral products	2.13	2.02	0.11	9.73	med.-low
24 basic metals	1.69	1.62	0.08	11.59	med.-low
25 fabricated metal products, except machinery and equipment	1.43	1.38	0.05	11.63	med.-low
26 computer, electronic and optical products	0.06	0.11	-0.04	4.26	med.-high
27 electrical equipment	1.29	1.27	0.03	10.34	med.-high
28 machinery and equipment n.e.c.	1.66	1.6	0.04	6.06	med.-high
29 motor vehicles, trailers and semi-trailers	1.32	1.26	0.11	34.38	high
30 other transport equipment	1.99	2.11	-0.13	-13.13	high
31 furniture	1.46	1.51	-0.05	-10.87	med.-high
32 Other manufacturing	1.36	1.35	x	-2.78 *	med.-high
Total average	1.52	1.47	0.06	14.48	

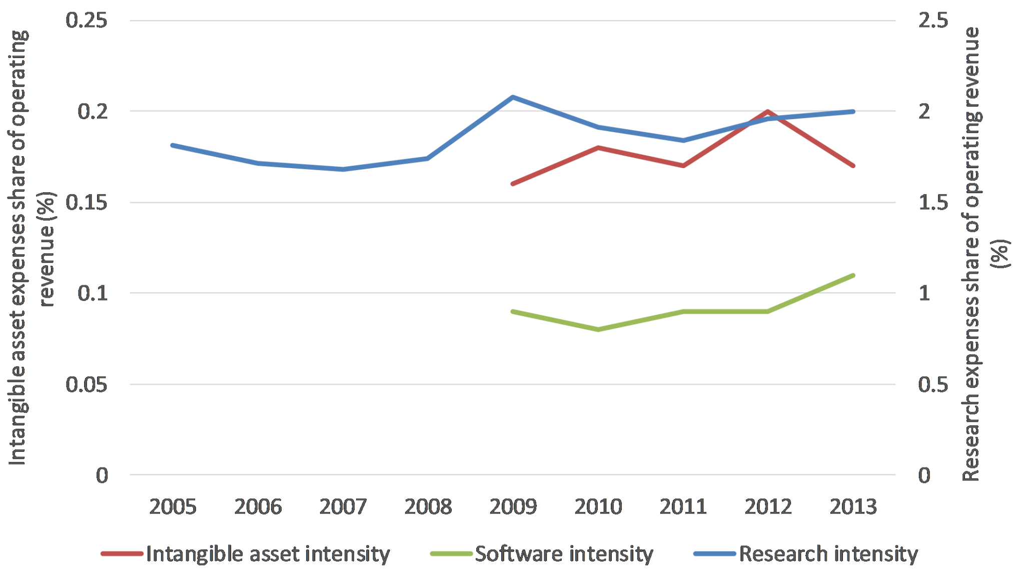
Note: Balanced panel of 23,238 firm-year observations (n = 2,582). No observations available in 2005 in Repair and installation of machinery and equipment (33). *Percentage change between industry mean values (no individual delta values available due to confidentiality reasons). **Except furniture; and manufacture of articles of straw and plaiting materials. x indicates values that were blocked by the RDC. Digital intensity classification according to Calvino et al. (2018) for the years 2013–2015.

Figure 6: Industries by markup and digital intensity



Note: Triangles represent industries with increasing average markups and dots represent industries with stable or decreasing average markups (compared to previous year). The manufacture of computer, electronic and optical products (26) is not reported, because values are below 0. Digital intensity classification according to Calvino et al. (2018) for the years 2013–2015.

Figure 7: Development of intangible asset and research expenses



Note: Reported are arithmetic mean values for firms in the balanced panel. The category of intangible assets covers software expenses as well as expenses for patents, licences, concessions, etc. Expenses for intangibles are not surveyed before 2009.

Table 5: Research intensity and markups

Sample	2010 and 2011 pooled		Balanced panel 2005–2013			
	OLS (1)	*OLS (2)*	*OLS (3)*	*OLS (4)*	*FE-OLS (5)*	*FE-OLS (6)*
Research	-0.01***	-	-0.01***	-	-0.002**	-
	(6.08)		(6.30)		(1.96)	
Research$_{t-1}$	-	-0.01***	-	-0.01***	-	-0.002*
		(6.38)		(6.79)		(1.75)
Employees	-0.00003***	-0.00003***	-0.00003***	-0.00002***	0.00006***	0.00007***
	(5.75)	(6.17)	(4.99)	(5.10)	(3.46)	(3.17)
Employees^2	1.70e-10***	1.74e-10***	1.52e-10***	1.56e-10***	-2.55e-10***	-3.88e-10***
	(4.71)	(5.02)	(4.21)	(4.32)	(3.36)	(3.73)
R^2 (within)	-	-	-	-	0.063	0.074
R^2 (overall)	0.437	0.434	0.461	0.462	0.001	0.001
n	28,898	18,543	23,238	20,656	23,238	20,656

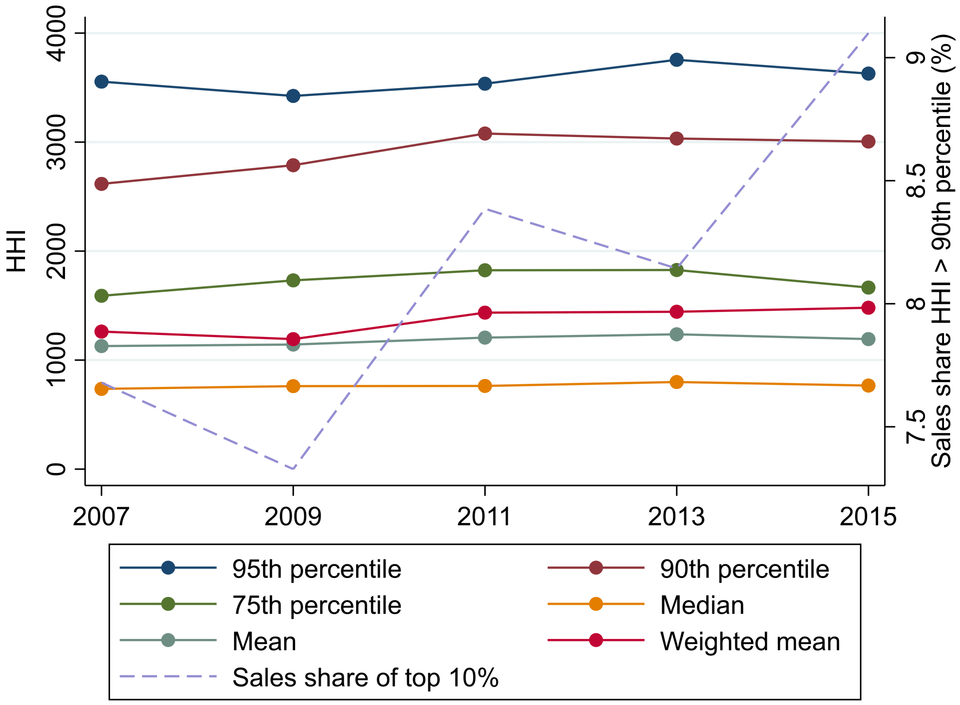
Note: Reported are estimated coefficients for markups with |t-values| in parentheses. Research intensity is measured as the operating revenue share of research expenditures. Significance at the 10% (*), 5% (**) and 1% (***) level. All specifications include industry dummies at the 3-digit NACE level, year dummies, and a constant. Standard errors are adjusted for firm clusters.

Table 6: Software intensity and markups

Sample	2010 and 2011 pooled		Balanced panel 2009–2013			
	OLS (1)	*OLS (2)*	*OLS (3)*	*OLS (4)*	*FE-OLS (5)*	*FE-OLS (6)*
Software	-0.06***	-	-0.08***	-	-0.01	-
	(3.58)		(3.67)		(1.59)	
Software$_{t-1}$	-	-0.05***	-	-0.07***	-	-0.01**
		(4.11)		(2.97)		(2.16)
Employees	-0.00003***	-0.00003***	-0.00003***	-0.00003***	-0.0001***	0.0001***
	(7.00)	(7.33)	(6.25)	(6.24)	(2.75)	(2.75)
Employees^2	2.21e-10***	2.17e-10***	1.98e-10***	1.97e-10***	-3.9e-10***	-3.9e-10***
	(5.46)	(5.68)	(5.04)	(5.04)	(3.01)	(3.01)
R^2 (within)	-	-	-	-	0.056	0.056
R^2 (overall)	0.436	0.432	0.452	0.452	0.004	0.004
n	28,898	18,543	12,909	12,910	12,909	12,910

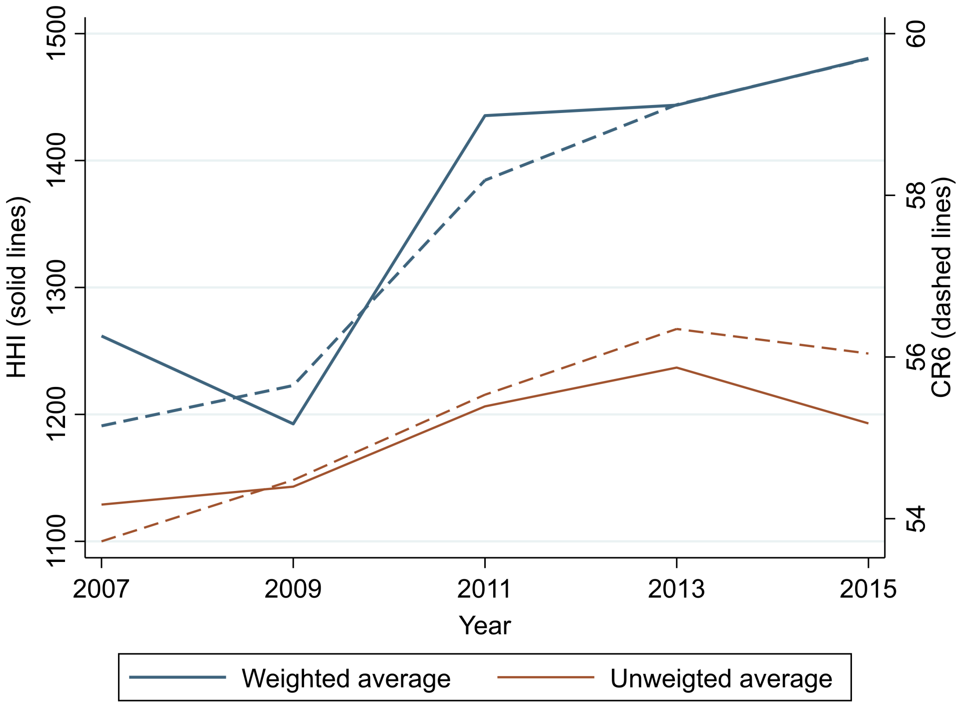
Note: Reported are estimated coefficients for markups with |t-values| in parentheses. Software intensity is measured as the operating revenue share of software expenditures. Significance at the 10% (*), 5% (**) and 1% (***) level. All specifications include industry dummies at the 3-digit NACE level, year dummies, and a constant. Standard errors are adjusted for firm clusters.

Figure 8: Development of concentration (in 4-digit industries)



Note: Weighting according to sales share.

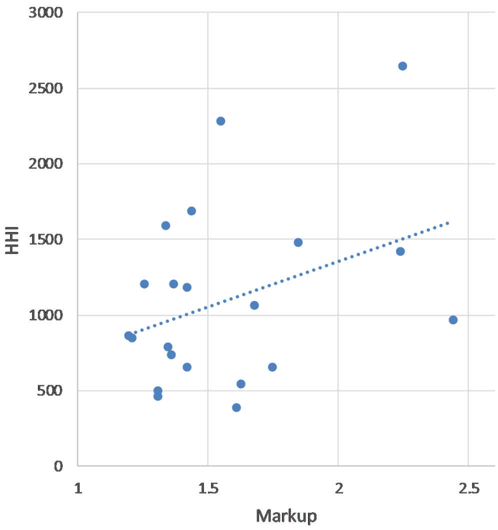
Figure 9: Development of mean concentration (in 4-digit industries)



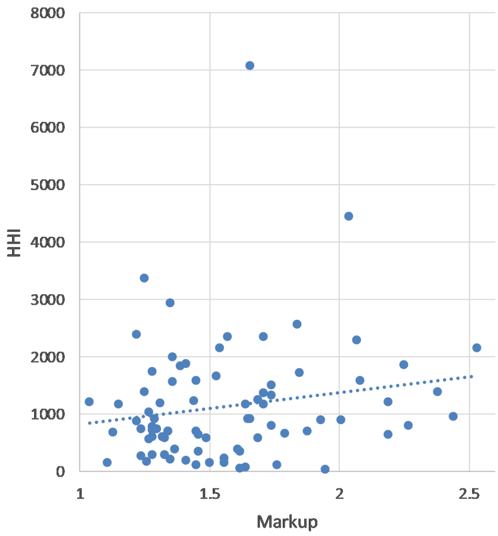
Note: Weighting according to sales share.

Figure 10: Average markup and concentration (2011)

a) by 2-digit industries



b) by 3-digit industries



Note: Line describes the linear trend. The Pearson correlation coefficient can be biased in the presence of outliers, therefore, average markup values below 0 and above 3 have been excluded (at the 3-digit level).

Table 7: Concentration changes by industry (2007–2013)

Manufacture of ...	Mean 2007	Mean Δ	% change
10 food products	1,269	-45	-3.55
11 beverages	915	61	6.67
13 textiles	569	-29	-5.10
14 wearing apparel	604	399	66.06
15 leather and related products	1,099	-4	-0.36
16 wood and of products of wood and cork*	648	380	58.64
17 paper and paper products	1,154	-125	-10.83
18 Printing and reproduction of recorded media	354	184	51.98
20 chemicals and chemical prod.	1,775	-36	-2.03
21 basic pharmaceutical prod. and pharmaceutical preparations	704	-16	-2.27
22 rubber and plastic products	572	97	16.96
23 other non-metallic mineral products	1,360	132	9.71
24 basic metals	1,459	104	7.13
25 fabricated metal products, except machinery and equipment	513	26	5.07
26 computer, electronic and optical products	1,446	-91	-6.29
27 electrical equipment	1,508	255	16.91
28 machinery and equipment n.e.c.	877	223	25.43
29 motor vehicles, trailers and semi-trailers	941	248	26.35
30 other transport equipment	2,072	845	40.78
31 furniture	534	-145	-27.15
32 Other manufacturing	500	397	79.40
Total average	994	136	16.83

Note: Mean Δ describes the mean over all 4-digit industry changes within 2-digit industry. *Except furniture; and manufacture of articles of straw and plaiting materials.

Table 8: Correlation of firm-level markups and 4-digit concentration by industry

Manufacture of ...	Markups and HHI in 2011	Δ markup and Δ HHI in balanced panel*
10 food products	0.074	0.097
11 beverages	0.285	0.151
13 textiles	-0.030	-0.023
14 wearing apparel	-0.139	-0.049
15 leather and related products	-0.054	0.047
16 wood and of products of wood and cork**	0.146	0.044
17 paper and paper products	0.177	0.198
18 Printing and reproduction of recorded media	0.056	-0.409
20 chemicals and chemical prod.	0.061	-0.129
21 basic pharmaceutical prod.	0.163	-0.231
22 rubber and plastic products	-0.012	0.191
23 other non-metallic mineral products	-0.044	0.123
24 basic metals	0.157	0.105
25 fabricated metal products, except machinery and equipment	-0.042	0.162
26 computer, electronic and optical products	-0.076	0.076
27 electrical equipment	-0.081	0.144
28 machinery and equipment n.e.c.	-0.008	0.150
29 motor vehicles, trailers and semi-trailers	0.022	0.317
30 other transport equipment	0.159	0.149
31 furniture	0.028	-0.037
32 Other manufacturing	0.091	0.168

Note: The Pearson correlation coefficient can be biased in the presence of outliers, therefore, observations with an HHI or markup value greater than the 99th percentile or below the 1st percentile were excluded. The correlation coefficient of the entire sample (not by industry) is -0.005 (13,521 observations) for the 2011 cross section and 0.069 for the Δ-values in the balanced panel (7,432 observations). *Biannual changes (2005–2013). **Except furniture; and manufacture of articles of straw and plaiting materials.

Appendix

Table 9: Changes of weighted average markups by industry (2005–2013)

Manufacture of ...	WMean 2005	WMean 2013	% change
10 food products	1.61	x	
11 beverages	2.49	2.58	3.61
13 textiles	1.25	1.34	7.20
14 wearing apparel	1.24	1.02	-17.74
15 leather and related products	1.19	1.01	-15.13
16 wood and of products of wood and cork*	2.01	1.71	-14.93
17 paper and paper products	1.67	1.54	-7.78
18 Printing and reproduction of recorded media	2.02	1.52	-24.75
20 chemicals and chemical prod.	1.19	1.13	-5.04
21 basic pharmaceutical prod. and pharmaceutical preparations	1.49	1.51	1.34
22 rubber and plastic products	1.24	1.33	7.26
23 other non-metallic mineral products	2.08	2.01	-3.37
24 basic metals	1.4	1.41	0.71
25 fabricated metal products, except machinery and equipment	1.33	1.29	-3.01
26 computer, electronic and optical products	0.68	0.44	-35.29
27 electrical equipment	1.41	1.37	-2.84
28 machinery and equipment n.e.c.	1.62	1.52	-6.17
29 motor vehicles, trailers and semi-trailers	0.88	0.77	-12.50
30 other transport equipment	1.16	1.38	18.97
31 furniture	1.27	1.31	3.15
32 Other manufacturing	1.53	1.53	0.00
Total average	1.46	1.39	-5.32

Note: Balanced panel of 23,238 firm-year observations (n = 2,582). Weighting according to sales shares within industry. No observations available in 2005 in Repair and installation of machinery and equipment (33). *Except furniture; and manufacture of articles of straw and plaiting materials. x indicates values that were blocked by the RDC.

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