Geppert, Kurt; Neumann, Anne

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DIW Berlin
German Institute for Economic Research
Mohrenstr. 58
10117 Berlin

Tel. +49 (30) 897 89-0
Fax +49 (30) 897 89-200
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Regional Patterns of Intangible Capital, Agglomeration Effects and Localised Spillovers in Germany

Kurt Geppert* and Anne Neumann**

*German Institute for Economic Research (DIW Berlin)

**University of Potsdam and German Institute for Economic Research (DIW Berlin)

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Abstract

We use a large micro-dataset to assess the importance of intangible capital - organisation, R&D and ICT capital – for the economic performance of establishments and regions in Germany. In 2003 self-produced intangible capital accounted for more than one fifth of the total capital stock of establishments. More than half of the intangible capital is R&D capital. This high proportion is mainly due to a relatively strong and research-intensive manufacturing sector in Germany. At the regional level, we find descriptive evidence for a positive relationship between intangible capital and the economic performance of regions. This is true both for the level of economic activities and for growth. The results of cross-sectional regressions for the years from 1999 to 2003 indicate that doubling the intangible capital intensity of establishments increases the average wage levels by one percent. Regarding the regional economic environment of establishments, we find that the substantial net advantages of agglomeration have more to do with broad knowledge and diversity than with regional clustering and specialisation. Separate regressions for the wage levels of *non-intangible* workers show very similar results. These workers can share the rents of the activities of *intangible* workers. Thus, intangible capital generates positive externalities not only at the regional level, but also at the level of establishments.

JEL classification: J24, M40, O33, R30

Keywords: Firm productivity, intangible capital, agglomeration, local spillovers

1 Introduction

Investment in intangible assets has been shown to be – in addition to tangible assets - an important factor in economic growth. The issue is being investigated both at the macro level of nations (Corrado, Hulten, Sichel 2006; Marrano, Haskel 2006; Belhocine 2009) and at the micro level of firms (e.g. Lev, Radhakrishnan 2005). At the macro level, intangible investments have reached the same magnitude as tangible investments. Ignoring intangibles in national accounts implies an underestimation of labour productivity growth by 10 to 20 percent.[1] At the micro level, organisational capital, as a major part of intangibles, contributes significantly to the market value of firms, even though the value of organisation capital is not fully priced at the stock market (Lev, Radhakrishnan 2005).

The present paper claims that our understanding of the role of intangible capital can be enhanced by adopting a regional (or spatial) perspective. In terms of empirical analysis, two different aspects can be distinguished:

- regionalisation of data can provide additional information on the character and the dynamics of the growth and innovation process,
- incorporating the industrial environment of firms in the analysis is likely to unveil localised spillovers (social returns) of firms' investments in intangible capital.

Intangible capital essentially arises from the various forms of organisational and technological knowledge. Therefore, taking a regional perspective on intangibles is equivalent to looking at the spatial distribution of knowledge-intensive activities. Advantages of co-location induce these activities to agglomerate in space (Malecki 2010), and as a consequence wages and productivity are substantially higher in dense areas than in non-agglomerated regions (e.g. Glaeser, Maré 2001; Combes, Duranton, Gobillon 2004; Head and Mayer 2004; Rosenthal and Strange 2004). Agglomeration economies can be categorised as the result of sharing, matching and learning processes (Combes, Duranton and Overman 2005). The learning channel in the transmission of agglomeration effects is important because intellectual assets are not the exclusive property of their original holders, rather they partly spill over to other – nearby – firms and workers (Jaffe et al. 1993; Audretsch, Feldman 1996). This leads to increasing returns on intellectual assets at regional and national levels (Rauch 1993; Glaeser, Mare 2001; Moretti 2004; Berry, Glaeser 2005; Yankow 2006). To the extent that geographical proximity, clustering and agglomeration contribute to innovation and produc-

[1] To some degree, intangible investments are already included in the official systems of national accounts. This applies, for instance, to software, licences and property rights. But these components represent only a small fraction of all intangible assets accumulated in a firm or a whole economy (Corrado, Hulten, Sichel 2006, 40).

tivity, the locational patterns of the economy may be seen as one of the strategic factors in promoting growth, employment and competitiveness of the European Union. In this sense, agglomeration is itself part of the intangible capital of an economy. In fact, there appears to be a strong positive connection between the degree of urbanisation and the income level of countries (Bertinelli, Strobl 2007; Glaeser, Gottlieb 2009, 1016), even though this relationship might be non-linear (Brülhart, Sbergami 2009).

In the present study we use a large micro dataset for Germany, first, to quantify intangible capital at the level of individual establishments, second, to explore the role of intangible capital for the economic performance of establishments and regions, third, to analyse whether there is indeed a connection between the productivity of individual establishments and the amount of intangible capital in the rest of the regional economy. If the latter were the case it would be an indication of local externalities. Our findings suggest that there are significant positive relationships between intangible capital, firm productivity and regional economic performance and that localised spillovers play a role in these processes.

The rest of the paper is organised as follows: Section 2 describes the data base, the measures of intangible capital, the regional concept and the approach chosen to evaluate the relation between establishments and their industrial environment. Section 3 presents descriptive results on the regional distribution of intangible assets, technology and innovative activities in Germany for the period from 1999 to 2003. Geographical correlations are used to illustrate connections between intangible capital and the economic performance of regions. Section 4 provides estimates of the determining factors of the wage levels of individual establishments and assesses agglomeration effects and localised spillovers. Section 5 summarises.

2 Data, measurement and estimation

The database used for this analysis has been constructed as a combination of LEED data from the employment statistics with Regional Accounts and EUKLEMS data for Germany. The dataset

- offers information on, e.g., employment, wages, tangible and intangible capital, output, value added,
- covers the period from 1999 to 2003,
- comprises around 1.5 million establishments per year with around 20 million employees,
- allocates establishments to three-digit industries (NACE rev.1) and 92 planning regions

While this dataset - at its final stage - is large and rather comprehensive in terms of economic variables (Görzig 2010), there are also some significant limitations. We have data on establishments but not on individual workers and we lack detailed information on the educational or occupational structure of establishments. Furthermore, we would have liked to base the analysis on a longer time series. Our period is not only short, it also goes from a peak to a trough of a business cycle. Therefore, we have to be cautious with regard to cyclical distortions of results.

In their seminal paper, Corrado, Hulten and Sichel (2006, 9) call for a "… *symmetric* treatment of *all* types of capital …", and this symmetry "… requires that most business expenditures aimed at enhancing the value of a firm and improving its products, including human capital development as well as R&D, be accorded the same treatment as tangible capital in national accounting systems." In principle, we follow this expenditure based approach here, but with our micro data we are restricted to own-account intangibles, i.e., we cannot include purchased intangible assets in the analysis (Görzig, Piekkola, Riley 2010). The calculation of stocks of intangible capital is done in three steps: first, we identify employees who – by virtue of their education and occupation – are likely to create intangible assets, second, we calculate labour costs for these employees and other expenditures related to their work, third, we determine cost shares that constitute self-production of intangible assets and then capitalise these assets to receive stocks of capital. As a result we have three categories of intangible capital: organisational (ORG) capital (derived from management and marketing activities), R&D capital and ICT capital. Basic Parameters for the calculation of intangible capital are summarised in Table 1 (for more details see Görzig, Piekkola, Riley 2010, 14-23).

Table 1

Calculation of intangible capital

	ORG	R&D	ICT
Investment share of labour costs[1]	0.20	0.70	0.50
Cost multiplier[2]	1.76	1.55	1.48
Combined multiplier[3]	0.35	1.10	0.70
Depreciation rate	0.25	0.20	0.33

1 Share of labour costs dedicated to the production of intangible assets (e.g., 20 percent of the compensation for skilled organisation workers are assumed to be dedicated to the production of ORG assets)
2 Total production costs associated with particular occupations/skill groups (incl. labour costs, excl. profits) in relation to labour costs
3 Total costs of the production of intangible assets in relation to labour costs (row 1*row 2)
Source: Görzig, Piekkola, Riley 2010

The regional dimension of the analysis is based on the concept of Planning Regions which can be viewed as approximations of self-contained regional labour markets. Germany is subdivided into 97 Planning Regions each of which consists of one or more NUTS-3 units. The three city states Berlin, Hamburg and Bremen have to be integrated with the surrounding regions to receive functional units. This leaves us with 92 regions. On average, these regions have a population of 896 000 and the distribution is spread from 150 000 to a maximum of 5.1 million (Table 2). A possible alternative to this choice of areas of observation are NUTS-2 regions which are much larger than Planning Regions. The advantage would be that additional data on education, human capital and technology from EU statistics which are broken down no further than to the NUTS-2 level could be used in the analysis. But, at least in the German case, this geographical concept is of very limited use for economic analyses. NUTS-2 regions in Germany are purely administrative areas with little relation to socio-economic linkages.

Table 2

Regional units of observation

Type of regions	Number of regions	Population 2001 (1 000)		
		mean	minimum	maximum
Planning Regions	92	896	149	5 099
NUTS-2 regions	39	2 112	512	5 255

DIW Berlin 2010

In order to control for the settlement structure of locations in the econometric analysis, we characterize the Planning Regions by employment density (per sqkm) and classify them according to their settlement type:

- (1) large metro areas with core cities > 500 000 inhabitants
- (2) small metro areas with core cities of 200 000 – 500 000 inhabitants
- (3) intermediate regions with population density > 150 per sqkm
- (4) rural regions with population density <= 150 per sqkm[2]

[2] Urban theory and empirical evidence suggest that productivity and wages are positively related to the density of regions (Ciccone, Hall 1996). But apart from density the size of the core city is also very important (Glaeser, Maré 2001). Therefore we classify our settlement types by city size (large and small metro areas) and population density (intermediate and rural regions).

In our attempt to assess local externalities, we use average wages of establishments as dependent variable and establishment, industry and regional characteristics as independent variables. We estimate the equation

$$\ln w_i = a \ln X_i + b \ln R_{ij} + Ind + [F_{ij}] + e_{ij}$$

where the X_i are establishment features (employment, intangible and tangible capital intensity), the R_{ij} describe the industrial environment of establishments (same-industry number of establishments and same-industry intangible capital in the region, other-industry intangible capital, industrial diversity, employment density and settlement type of the region), *Ind* are three-digit industry*year dummies and F_{ij}, in additional fixed- and random-effects regressions, are establishment/location unobserved characteristics. Some more details, estimation issues and limitations of the analysis are discussed together with the presentation of results in section 4.

3 Regional distribution of intangible capital and its components

In this section, we first describe the distribution of own-account intangible capital across establishments, industries and regions. Even if the focus in this paper is on the regional perspective, information on establishments and industries is helpful in interpreting the results. Second, we show how intangible capital correlates with economic performance of regions.

Establishments

On average, the share of own-account intangible capital in total capital of establishments was more than 20 percent in 2003. But the distribution is very uneven. More than half of the establishments have no intangible capital at all, and just under 30 percent of the establishments show shares of up to 25 percent (Figure 1).

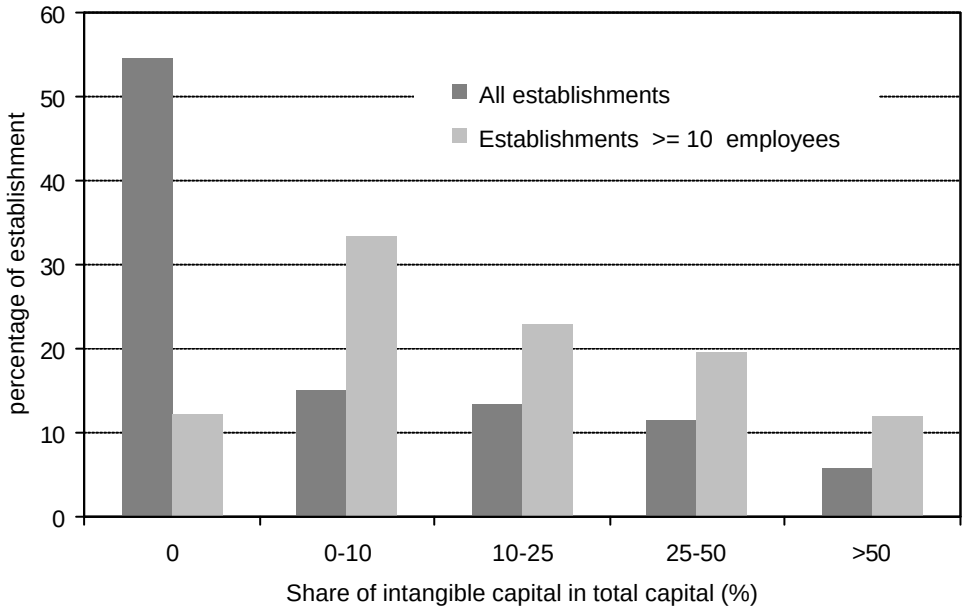
These figures are based on the entirety of around 1.5 million German establishments with at least one employee who was subject to social insurance in 2003.[3] When we restrict the analysis to larger establishments - with 10 and more employees - the pattern changes drastically. The majority of these establishments range with their shares of intangible capital between zero and 25 percent. Obviously, there is a significant size effect in the distribution of own-account intangible capital. But this does not necessarily mean that the *use* of intangibles is distributed in the same way. For many small

[3] Agriculture, mining, public administration, education and household activities are not included in the analysis.

firms, the only own-account intangible capital is that represented by the owners.[4] But whenever specific knowledge is needed, these firms can purchase intangible assets on the market, in particular if "thick" local markets and networks exist (Bellandi 1989; Markusen 1996). And in the case of multi-plant firms, small subsidiaries can often resort to the resources of larger units or to corporate headquarters (Duranton, Puga 2005; Aarland et al. 2006). Altogether, own-account intangible capital constitutes a considerable part of total capital at the micro-level, even though its relative importance does not reach the weight found for intangibles at the macro-level (Corrado, Hulten, Sichel 2006).

Figure 1

Share of own-account intangible capital in total capital 2003



Sources: Employment statistics of the Federal Agency for Labour; Regional Accounts; EU KLEMS; own calculations.

DIW Berlin 2010

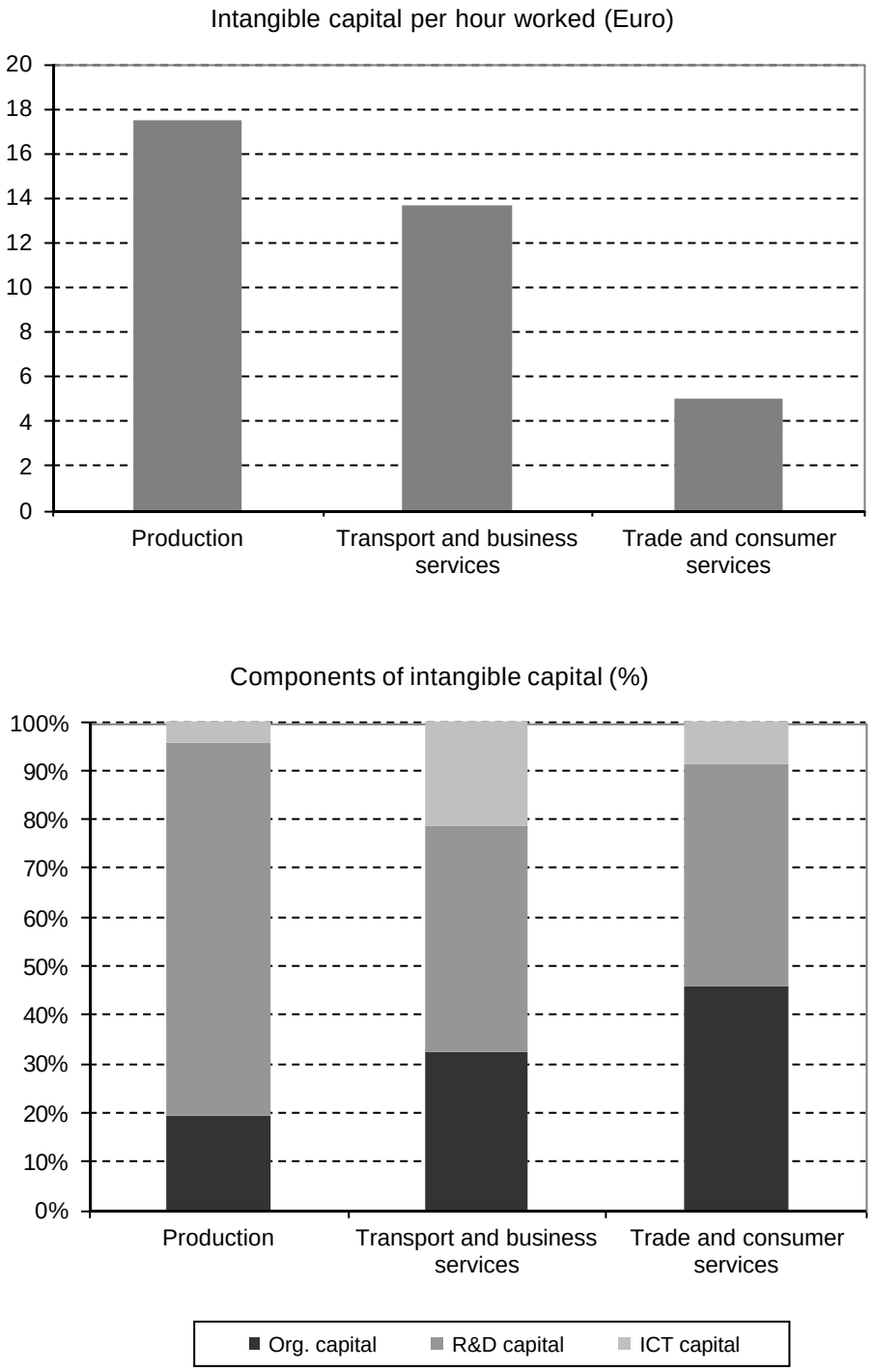
Industries

The role of intangibles differs substantially between the various sectors of the economy. With 18 Euros per hour worked, the intangible capital intensity is highest in the *goods-producing* sector (manufacturing, energy and water supply, construction). This is largely due to the R&D activities in this sector, in particular manufacturing. R&D capital accounts for more than three quarters of total intangible capital in the production sector (Figure 2).

[4] Intangible assets that might be generated by active owners of firms are not considered here.

Figure 2

Sectoral distribution of intangible capital and its components 2003



Production sector: NACE D-F; Transport and business services: NACE I-K (excl. 70);
Trade and consumer services: NACE G, H, N, O.
Sources: Employment statistics of the Federal Agency for Labour; Regional Accounts; EU KLEMS; own calculations.

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In the *transport and business services* sector (transport and communication, finance, renting and business activities, consulting) the intangible capital intensity was 14 Euros in 2003.[5] The relative importance of R&D capital is much lower here than in the production sector, but with a share of 46 percent it is still the dominant component of intangible capital. ICT capital amounts to more than one fifth of total intangible capital in transport and business services; this is a much higher proportion than in the two other sectors. Quite a number of industries in transport and business services are highly innovative and R&D intensive, e.g., telecommunications, software development, engineering. In some cases production personnel is made up of almost one hundred percent R&D workers (software development is done by software developers). Firms in these industries provide new technological solutions for their customers, i.e., they create intangible assets not only for their own use but also – and primarily – for other firms and industries. The same applies to consultancy firms that develop and sell new organisational and ICT solutions.[6]

Intangible capital intensity in the sector *trade and consumer services* (wholesale and retail trade, hotels and restaurants, health and social work, other service activities) is only a small fraction of the values for the two other sectors (5 Euros). Similar to transport and business services, but quantitatively less important, some industries in trade and consumer services provide organisational or ICT advice to customers which we cannot clearly separate from own-account investment in ORG or ICT capital in these industries. Examples are business and membership organisations.

Regions

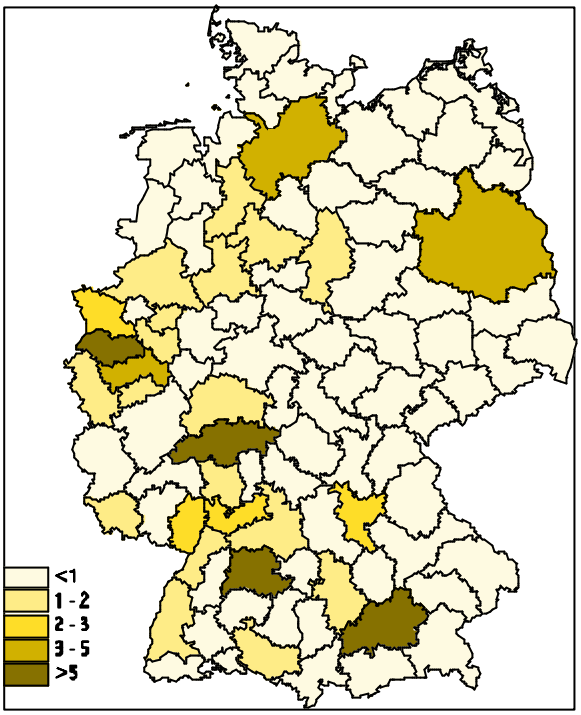
Intangible capital is highly concentrated in a few centres. The two maps show the geographical structure of the German economy. More than one quarter of the whole intangible capital is being accumulated by establishments in just four metropolitan areas in the South and West of the country (Map 1). Two other large metropolitan areas – Hamburg in the North and Berlin in the East - also hold relatively high shares in national intangible capital. These areas are more or less specialised economically. Two extreme cases are Stuttgart as a centre of technology-intensive manufacturing (and thus R&D capital) and Berlin with a focus on consumer services (and thus ORG capital).

[5] Real estate activities are excluded from the analysis.

[6] Since we cannot distinguish statistically between the two purposes of use, we have to accept a certain inconsistency in our analysis. Generally, we capture own-account intangible investment of establishments, but for some industries we cannot completely separate expenditures for own-account investment from expenditures for the development of new ideas and concepts for customers. In the econometric analysis in section 4, we check the sensitivity of results to this inconsistency.

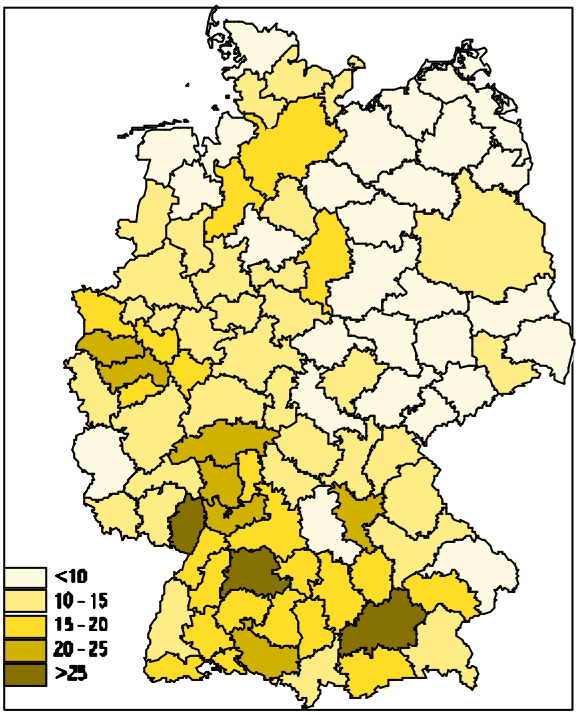
Map 1

Shares of regions in national intangible capital 2003 (%)



Map 2

Intangible capital per hour worked 2003 (Euro)



Regions with high absolute stocks of intangible capital also tend to show high intangible capital intensities, but the spatial hierarchy of intensities is less clear (Map 2). Many small metro areas and intermediate regions have been able to attract relatively high amounts of ICT and R&D capital. Most of these regions feature at least one of the following characteristics: headquarters and large-scale production in technology-based manufacturing, a high-level technical university and good accessibility. Overall, there exists a considerable positive relation between intangible capital intensity and employment density of regions (with R^2=0.38).

One of the most striking characteristics of the spatial distribution of intangible capital in Germany is the gap between the West and the East. Even twenty years after unification and transition to a market economy, almost all eastern regions lag far behind the western regions in terms of intangible capital intensity. The only exceptions are Berlin and Dresden, and even these two regions are below the German average. One reason for the deficit of intangible capital in eastern Germany is the low share of (technology-intensive) manufacturing there. After the massive deindustrialisation in the 1990s, the eastern manufacturing sector has been expanding, but its weight is still relatively low compared to the West. Another factor lies in the structure of economic activities. Many establishments in East Germany are mere assembling operations or subsidiaries. Such units normally do not accumulate much intangible capital, they rather rely on the resources of corporate headquarters (see sub-section "Establishments").

Geographical correlations

The regional distributions of the different kinds of intangible capital are not independent of each other. Regions that attract one component of intangible capital tend to concomitantly attract other components. This geographical correlation is highest between ORG capital intensity and ICT capital intensity (R^2=0.79) but also significant between ORG capital and R&D capital (R^2=0.58) and between ICT and R&D (R^2=0.52).[7] The regional coincidence of different types of intangibles is consistent with the pattern of spatial concentration of intangible capital. As a whole, intangible capital is significantly more concentrated than tangible capital, and ORG and ICT capital are more concentrated than R&D capital.[8]

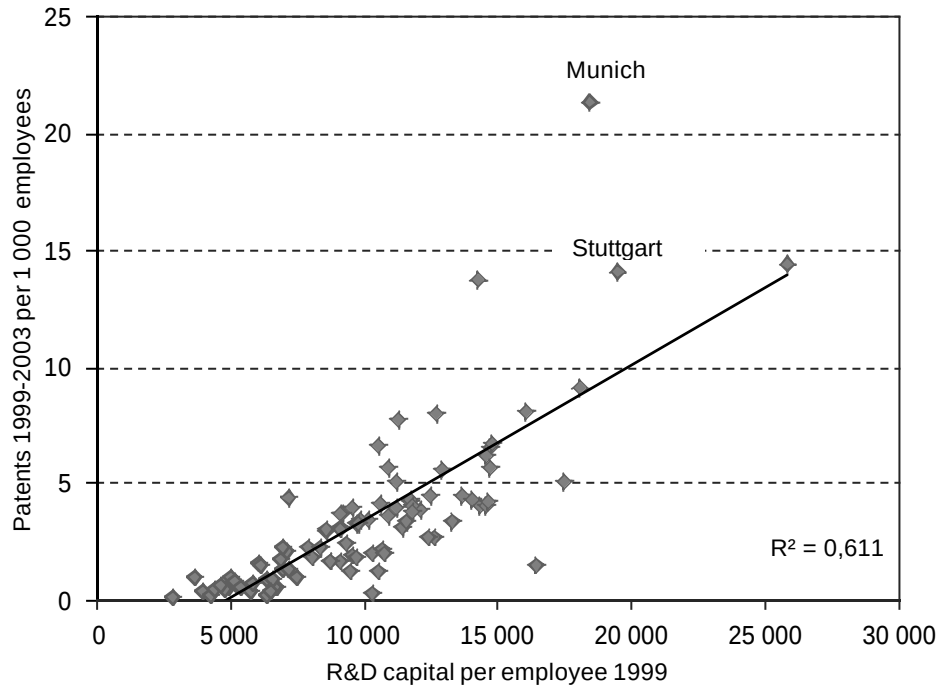
[7] R^2s from single regressions with logarithms.

[8] Spatial concentration is measured as the sum of squared shares of regions in the respective national values. If all activities were concentrated in only one region, the index would be 1; if the activities were distributed evenly across regions, the index would be close to 0 (1/92=0.01). For 2003, the index takes the values of 0.0236 for tangible capital, 0.0306 for total intangible capital, 0.0344 for ORG capital, 0.0279 for R&D capital and 0.0443 for ICT capital.

To some extent, the connections between the different categories of intangible capital at the regional level might be the result of industrial specialisation of regions, i.e., industries that are intensive in *multiple* intangibles might account for high employment shares in specific types of regions, and vice versa. This would show up then in a correlation between categories of intangibles at the regional level. But for the most part, the geographical correlations between the three kinds of intangible capital, in particular between ORG capital and ICT capital, arise from co-location of establishments and industries that are each intensive in *one* type of intangibles. At the levels of establishments and industries, we observe some positive relationship between ORG capital and R&D capital (R^2=0.12 and 0.30 respectively), but in general establishments and industries are intensive in either one *or* another type of intangibles. These results, together with the geographical correlation described above, suggest that establishments with specialisations in different intangibles tend to co-locate - and possibly cooperate.

Figure 3

R&D capital and patents



Sources: Employment statistics of the Federal Agency for Labour; Regional Accounts; EU KLEMS; own calculations.

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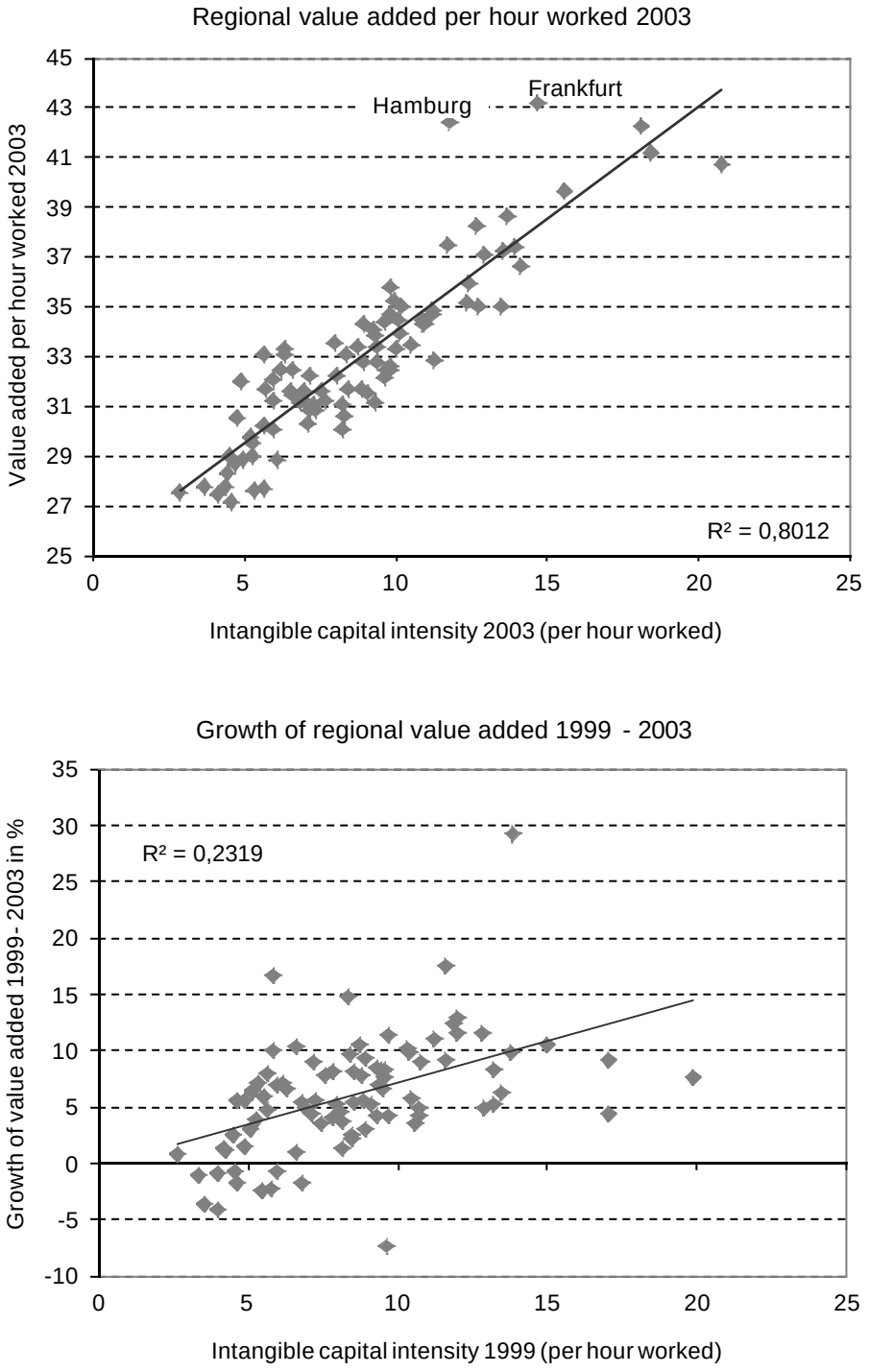
Figure 4

Intangible capital and economic performance of regions



Sources: Employment statistics of the Federal Agency for Labour; Regional Accounts; EU KLEMS; own calculations.

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For one component of intangible capital, R&D capital, we can directly explore the connection between input and output at the regional level. There is a close geographical correlation between innovation input in 1999 - measured by R&D capital - and subsequent innovation output from 1999 to 2003 – measured by patents (R^2=0.61) (Figure 3). The correlation appears to be much stronger among regions with low or medium levels of R&D capital, but this is due to a few outliers (e.g. Munich) and may, at least partly, result from problems with the correct regionalisation of patent information.

Conversely, if a close connection between innovation input and innovation output of regions is taken as a given fact (Uppenberg 2009), the geographical correlation found here confirms that our measure of R&D capital is a valid indicator of innovation input (and patents are an appropriate indicator of innovation output).

For the two other components of intangible capital, ORG and ICT capital, we cannot show connections between capital stock (usage) and outcome. But we can relate the overall intangible capital of regions to their economic performance. We find a very close positive correlation between intangible capital intensity and productivity of regions (R^2=0.80) (Figure 4).

Even if a single regression does not tell us much about causality, intangible capital appears to be a firm basis of regional economic performance. And this is not only true for the *level* of productivity but also for economic *growth*. The increase of regional value added from 1999 to 2003 is positively related to the intangible capital intensity of regions in 1999 (R^2=0.23).

4 Productivity of establishments, agglomeration effects and localised spillovers

The descriptive analysis in section 3 has provided information on the distribution of intangible capital across establishments, industries and regions and has indicated the importance of intangibles for the economic performance of regions. We now turn to the analysis of the effects of intangible capital on the productivity (wages) of establishments, controlling for other establishment characteristics and the regional economic environment of each establishment. In order to keep the estimations tractable, we randomly reduce our sample to around one tenth of its original size and then drop all es-

tablishments with less than 10 employees or an output of less than one million Euros.[9] The resulting estimating sample comprises around 30 000 observations (establishments) per year.

The dependent variable in our cross-sectional regressions for the years from 1999 to 2003 is the average hourly wage of establishments as an indicator for labour productivity.[10] On the right hand side we include variables that capture the well known facts that larger establishments pay higher wages than small ones, capital intensive establishments pay higher wages than labour intensive ones, and establishments in dense urban areas pay higher wages than those in rural regions. In detail, the explanatory variables are establishment size (number of employees), intangible capital intensity, tangible capital intensity, 3-digit industry classification, and settlement type/employment density of locations. In additional regressions, the latter variable is replaced by specific variables that characterise the economic environment of establishments: number of own-industry establishments, own-industry intangible capital intensity, regional economic diversity, other-industry intangible capital intensity.[11]

The average wage level of establishments is largely determined by their industrial affiliation. Including 3-digit industry dummies in the regressions raises R^2 from around 0.20 to around 0.60. Also important is the East dummy, indicating that even twenty years after reunification there is still a considerable wage gap between West and East Germany. Taking account of this gap increases R^2 to around 0.70. The other results of the cross-sectional regressions are shown in Table 3. In the first regression (column 1) all coefficients are highly significant. Doubling the intangible capital intensity of establishments - which ranges from zero to a maximum of more than 3 000 Euros per hour worked - increases the average wage levels by one percent. The same elasticity applies to the size of establishments (measured by employment). Tangible capital intensity of establishments pushes up wages even more than intangible capital intensity. The coefficient is 0.059.[12]

The average wage level of an establishment is also connected to the industrial environment of establishments. The usual summary measure of this environment is density (regional employment per square kilometre). Theory and numerous empirical analyses suggest that productivity and wages are

[9] Most of the small establishments have no or very little own-account intangible capital (see section 3).
[10] Using wages instead of labour productivity as dependent variable allows a direct comparison of estimates for the average wage level of establishments and for the wages of employees who are not involved in the production of intangible capital. Results of regressions with labour productivity as dependent variable are similar to those with wages.
[11] We experimented with a number of other regional variables, e.g., patents per capita, existence and size of universities, but these variables are highly collinear with the agglomeration variables.
[12] Results are essentially the same when we exclude industries that create intangible assets not only for their own use but also – and primarily – for other firms and industries (see section 3).

positively related to density, and most studies find elasticities of wages with respect to density between 4 and 10 percent (Ciccone, Hall 1996; Ciccone 2002; Rice, Venables 2004; Combes et al. 2008 and 2010; Puga 2010). Our estimate on density (not shown here) is within this range (5 percent). In column 1 we report results based on a different specification of the economic environment: settlement types. Controlling for establishment and industry characteristics, we find that establishments in large metropolitan areas pay 12 percent more than those located in rural regions and about 9 percent more than establishments in small metropolitan areas or intermediate regions. This result is consistent with other estimates on the "urban wage premium" (Glaeser, Maré 2001; Yankow 2006).

In order to describe in more detail the agglomeration effects and to explore the potential role of intangible capital in these processes, we replace in our regressions the summary measures of agglomeration (density and settlement type) by specific underlying features of the spatial concentration of economic activities. Economies of agglomeration can arise from spatial clustering of specific industries, leading to localisation economies, and/or from co-location of diverse industries, leading to urbanisation economies. In addition to this sectoral dimension we have to consider a functional dimension, i.e., the spatial sorting of specific economic activities, irrespective of their industrial classification. Wight collar jobs and highly qualified employees tend to concentrate in space, constituting a hierarchy of knowledge - and thus intangible capital - with large cities and metropolitan areas at the top and rural regions at the bottom (Duranton, Puga 2005; Markusen, Schrock 2006). The spatial concentration of intangible capital in Germany described in section 3 is consistent with such a hierarchical pattern. With the more detailed cross-sectional regressions we try to find indications for potential effects of localisation, urbanisation and regional intangible capital on the wage level of individual establishments.

The localisation variable is specified as the number of other own-industry establishments in the region. This choice (see also Henderson 2003) is based on the assumption that each unit, irrespective of its size, is a potential source of industry-specific externalities, e.g., the intentional or unintentional exchange of ideas or the sharing of inputs. Urbanisation is measured with an index of diversity

$$D_j = 1 \Big/ \sum_i \left(\frac{E_{ij}}{E_j} - \frac{E_i}{E} \right)^2$$

where the summation is over the squared differences between the employment shares of industry *i* in region *j* and in the national economy.[13] Regional intangible capital in the own industry and in the rest of the regional economy is measured in terms of intensities (per hour worked).

The results suggest that on average establishments do not benefit much from industry-specific externalities at their location. The coefficient on the number of other own-industry establishments is highly significant but rather low at 0.0064 and 0.0033, respectively (columns 2 and 3).[14] The effect of own-industry intangible capital intensity in the region is even weaker (0.0013). In contrast, we find strong indications for urbanisation economies. There is a clear positive relation between the industrial diversity of a region and the average wage level of establishments located there. By far the most important factor is regional intangible capital. Doubling the intangible capital intensity of a regional economy (outside the own industry) increases the average wage of an establishment there by around 8 percent. In this context, regional R&D and ICT capital appear to be more important than ORG capital. Part of the high elasticity of establishment wages with respect to intangible capital in the region is probably due to unobserved differences in the internal structure of establishments. Workers with high observed and unobserved skills tend to gravitate to metropolitan areas, raising the wage levels there (Borjas et al. 1992). For an in-depth study of the effects of spatial sorting on regional wages see Combes et al. 2008.

A much discussed issue in the estimation of localised spillovers is the geographical extent of those externalities. If establishments in one region also benefit from activities in neighbouring regions, our estimates on the economic environment of the own region are biased upwards. The potential relevance of such a bias depends on the definition of regions. With our concept of functional planning regions we can be confident that the bulk of spillovers are internal. On average, these regions have a population of 900 000 and extent over an area of almost 4000 square kilometres (section 2). A stylised fact of empirical research in this field is that externalities are subject to a rapid decay with distance. Most studies identify ranges of well below 100 kilometres (e.g. Rosenthal, Strange 2003 and 2008; Henderson 2003; Duranton, Overman 2005; Graham 2008) and only a few find evidence for somewhat more extensive externalities (Rodriguez-Pose, Crescenzi 2008).

[13] In both cases, localisation and urbanisation, the estimates are not very sensitive to the specification of variables. Using own-industry employment instead of the number of establishments and an inverse Herfindahl index instead of our inverse specialisation index does not substantially change the results.

[14] In regression 3 (and 4) intangible capital is split up into its three components.

Table 3

Regression results

Dependent variable: log average hourly wage of establishments

	OLS				Fixed effects	Random effects
	All employees			Non-intangible employees	All employees	
	(1)	(2)	(3)	(4)	(5)	(6)
Establishment variables						
Employment	0.0108***	0.0116***	-0.0061***	-0.0030***	-0.0046***	0.0053***
Intangible capital intensity	0.0103***	0.0103***			0.0015**	0.0087***
ORG capital intensity			0.0051***	0.0049***		
R&D capital intensity			0.0063***	0.0061***		
ICT capital intensity			0.0048***	0.0045***		
Tangible capital intensity	0.0594***	0.0566***	0.0516***	0.0533***	0.0149***	0.0187***
Economic environment						
Own-industry:						
Establishments		0.0064***	0.0033***	0.0034***	0.0003	0.0021***
Intangible capital intensity		0.0013***			0.0000	0.0004*
ORG capital intensity			-0.0006**	-0.0007**		
R&D capital intensity			0.0002	0.0002		
ICT capital intensity			0.0001	0.0001		
Rest of regional economy:						
Industrial diversity		0.0267***	0.0085***	0.0090***	-0.0021	0.0067***
Intangible capital intensity		0.0833***			-0.0180***	0.0197***
ORG capital intensity			0.0000	-0.0009		
R&D capital intensity			0.0183***	0.0195***		
ICT capital intensity			0.0166***	0.0163***		
Settlement type:						
Large Metro	0.1190***					
Small Metro	0.0335***					
Intermediate region	0.0234***					
East dummy	-0.226***	-0.180***	-0.192***	-0.193***		-0.201***
Constant	2.394***	2.127***	1.948***	1.927***	3.023***	2.498***
N	150471	150471	150471	149779	150471	150471
R-squared	0.684	0.683	0.697	0.673	0.459	0.662
Number of establishments					41156	41156

*** p<0.01, ** p<0.05, * p<0.1 (robust standard errors); variables in logarithms.

Of course, with cross-sectional regressions we cannot directly identify localised spillovers and the channels of their transmission. But our results strongly support the notion that net advantages of agglomeration have more to do with knowledge and diversity than with clustering and specialisation. This does not necessarily apply to all sectors of the economy in the same way. Some empirical studies find evidence for localisation economies in manufacturing (Moomaw 1998; Henderson 2003). In many service industries and in experimental manufacturing activities, however, advantages of agglomeration are not only stronger than in standard manufacturing, they are also clear-

ly dominated by urbanisation effects (Duranton, Puga 2001; Dekle 2002, van Soest et al. 2006; Graham 2008). And obviously, knowledge – intangible capital – is at the centre of these processes.

One of the caveats that can be raised against our findings is that they might, at least to some extent, be tautological. Since we measure intangible capital on the basis of expenditures for high-skilled workers, it appears natural that intangible capital intensive establishments show high average wages. But such a tautology is not driving our results. Column 4 shows the coefficients of a regression with the average hourly wage of *non-intangible* workers as the dependent variable. The picture is very much the same as for all workers. Non-intangible wages are positively related to the tangible and intangible capital intensity of establishments.

The similarity of estimates for all employees and for non-intangible workers might in part be the result of differences in the skill composition of non-intangible workers across types of establishments. Apart from this kind of selectivity there are several mechanisms that can relate wages and productivity of low-skilled workers to the presence of high-skilled workers in an establishment. One is the spillover of knowledge through cooperation of the two groups. Another, and perhaps more important, channel is the complementarity or interdependence between the two groups. If the innovative activities of high-skilled workers enable low-skilled workers to use more efficient processes or produce better products, the latter become more productive, even without improving their skills (Acemoglu 1996). They share the rents of innovation. Thus, intangible capital generates positive externalities not only at the regional level, but also at the level of establishments.

Our cross-sectional regressions provide valuable information about the determinants of the average wage levels of establishments. However, OLS estimates can be more or less biased due to unobserved characteristics and selectivity. Furthermore, endogeneity and the direction of causality are serious questions that cannot be answered satisfyingly in OLS estimation. Hence, we would have liked to tackle these issues by using other estimation techniques, but with our panel over just 5 consecutive years the scope for alternative approaches is extremely limited. Instrumental variable estimation is not possible because we have no valid external (historical) instruments available, and experiments with GMM estimation with internal instruments (lagged variables) did not produce meaningful results. Given our short period of annual data, lagging variables may not be an appropriate strategy to avoid endogeneity anyway.

A practical way to cope with unobserved characteristics is fixed-effects estimation. This can, in principle, also reduce the problem of endogeneity in the sense that unobserved time-invariant locational advantages of regions are captured by the firm*location fixed effects (Henderson 2003). But the precondition for the efficient use of these methods is enough time variation in the variables. In our case, the variables capturing the industrial environment of establishments, e.g., density, diversity or regional intangible capital intensity, do not change much from year to year. And many establishments show little time variation in their own characteristics like employment or average wage. Therefore, the fixed-effects results reported in column 5 can at best serve as complementary information on the determinants of the average wages of establishments. Establishments' intensities in tangible capital and – to a minor extent – in intangible capital show positive and significant coefficients, corroborating OLS estimates. But the coefficient on the intangible capital intensity of the regional economies is negative.

Another approach to deal with unobserved characteristics is random-effects estimation. The results are similar to the OLS estimates, even though the magnitude of coefficients is considerably smaller (column 6). These estimates, however, have also to be taken with caution. The random-effects model is not supported by the Hausman test. The total variance is almost entirely due to the individual effects and these might be correlated with X-variables. In that case coefficients would be biased.

5 Conclusions

We use a large micro-dataset to assess the importance of intangible capital - organisation, R&D and ICT capital – for the economic performance of establishments and regions in Germany. In 2003 self-produced intangible capital accounted for more than 20 percent of the total capital stock of German establishments. More than half of the intangible capital is R&D capital. This high proportion is mainly due to a relatively strong and research-intensive manufacturing sector in Germany, but even in the service industries the share of R&D capital averages more than 40 percent.

Intangibles are considerably more concentrated geographically than the economic activities as a whole. More than one quarter of the capital stock has been accumulated by establishments in just four metropolitan areas in the South and West of the country. We find descriptive evidence for a close relationship between intangible capital and the economic performance of regions. This is true both for the level of economic activities and – to a lesser extent – for growth.

Based on cross-sectional regressions with pooled data for the years from 1999 to 2003 we try to assess the effects of intangible capital on the productivity (the average wage level) of establishments, controlling for other establishment characteristics and the regional economic environment. Doubling the intangible capital intensity of establishments - which ranges from zero to a maximum of more than 3 000 Euros per hour worked - increases the average wage levels by one percent. Tangible capital intensity pushes up wages even more than intangible capital intensity. Establishments in large metropolitan areas pay 12 percent more than those located in rural regions and about 9 percent more than establishments in small metropolitan areas or intermediate regions. This result is consistent with the empirical literature on the "urban wage premium". Looking at the effects of the economic environment in more detail, we find that net advantages of agglomeration for establishments have more to do with broad knowledge and diversity than with regional clustering and specialisation. Separate regressions for the wage levels of *non-intangible* workers show very similar results. These workers can share the rents of the activities of *intangible* workers. Thus, intangible capital generates positive externalities not only at the regional level, but also at the level of establishments.

One cautionary remark has to be made: all our estimates must be interpreted with the usual reservations towards OLS cross-sectional regressions. With our short period of observation – from 1999 to 2003 - and little time variation in many variables, we cannot really tackle estimation issues connected with unobserved characteristics and endogeneity. This is a task for future research based on more extended periods. In such a context it could also be possible to widen the perspective from contemporaneous to lagged effects and from static to dynamic effects.

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