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DISCUSSION PAPER

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Measuring Organisation Capital at the Firm Level: A Production Function Approach

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Abstract

Organisation capital is a key intangible asset, driving innovation and firm performance. Measuring this asset is notoriously difficult. This paper applies a firm-level production function approach including, in addition to labour and tangible assets, investment in all measurable intangible assets (technological and non-technological knowledge, software and databases, firm-specific human capital, brand equity), excluding the difficult to measure organisation capital. The residuum of the estimation is considered as a measure of a firm's organisation capital. We exclude profits from the output measure to avoid distortion due to the market structure in which a firm operates. Using panel data from the German innovation survey, we find higher organisation capital in young and small firms. We link this result to trust as a main element of organisation capital, which is easier to build-up in smaller and more agile organisations where interactions are more direct. Our measure negatively correlates with a firm's perception of internal organisational problems while it shows a u-shaped relation to indicators of organisational development. This result suggests that firms with low organisation capital try to overcome this shortcoming by putting more efforts into organisational development while firms with high organisation capital possess a better ability to improve their organisational capabilities.

JEL-Classification: D24, E22, L25

Key words: Organisation Capital, Production Function, CIS, Intangibles

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1 Introduction

Organisation capital has been identified as a key driver of firm performance (Lev and Radhakrishnan 2005). Building up organisation capital is hence at the centre of organisational development of firms, and a priority of a firm's management. The literature on intangible assets considers the investment in organisation capital (cost of organisational change and development) as a key component of a firm's expenditure on economic competences (Corrado et al. 2005). Measuring organisation capital is difficult, however. There are no established metrics, no category in firms' accounting and reporting systems that can be used. Some attempts have been made to measure investment in organisation capital at the firm level (see Awano et al. 2010, focussing on business process improvement).

Corrado et al. (2005) propose to use a certain share of labour cost of managers and the purchase of consulting services as a proxy. While these measures may correlate with organisation capital at an aggregate (sector, country) level, it is a less appropriate measure at the firm level. Increasing salaries of managers, employing more managers and hiring business consultants are not necessarily linked to a higher level of organisation capital. More investment in organisational development may rather indicate a deficit in organisation capital which should be overcome by these efforts, but it is uncertain if and with what time lag this investment will actually result in higher organisation capital. The same applies to expenditure related to the accounting item 'selling, general and administrative expenses' which was used by Lev and Radhakrishnan (2005) and Tronconi and Marzetti (2011) to measure investment in organisation capital at the firm level. If a firm has managed to establish organisational routines and social practices that encourage collaboration and creativity, it will have to spend little if any extra money on maintaining its high level of organisational efficiency. Effective organisational structures will rather reduce administrative expenses.

The limitations of expenditure figures for measuring the amount of organisation capital a firm has built up, led the empirical literature to focus on more qualitative measures (Mayer et al. 1995, Dietz and den Hartog 2006). While these studies provide very valuable insights into the ways firms successfully develop effective organisational routines and business processes, these measures are difficult to combine with other measures on intangible assets. They also require dedicated surveys.

This paper proposes an alternative way of measuring the extent of organisation capital in firms. The basic idea is borrowed from early works on measuring technological change as a residual in a production function (Solow 1957). If one captures all measurable tangible (capital, labour) and intangible determinants of productivity (R&D, other innovative property, software & databases, firm-specific human capital, brand equity), but excludes the difficult-to-measure organisation capital, the residual should be highly correlated with the unmeasurable.

We use firm-level panel data from the German innovation survey to empirically apply this approach and to test the plausibility of the results by comparing the estimated firm-specific residual with other qualitative measures of organisation capital. The next section discusses the role of organisation capital as part of the concept of intangible investment and summarises empirical approaches that have been used in the past to measure organisation capital at the firm level. Section 3 describes our empirical approach while section 4 presents the estimation results. Section 5 concludes.

2 Organisation Capital and Intangible Investment

Organisation capital has been defined by Evenson and Westphal (1995: 2237) as "knowledge used to combine human skills and physical capital into systems for producing and delivering want-satisfying products." This knowledge relates to various firm capabilities, including the way different activities are managed and interlinked, how the allocation of resources across activities is organised and optimised, and how change and innovation is incorporated into the organisation. Lev and Radhakrishnan (2005: 75) summarise that "organisation capital is an agglomeration of business practices, processes and designs, and incentive and compensation systems that together enable some firms to consistently and efficiently extract from a given level of physical and human resources a higher value of product than other firms find possible to attain." In this paper, we follow Corrado et al.'s (2005) classification of intangibles that considers organisation capital as one part of the category 'economic competences'. The other parts of this category, which are not considered organisation capital in this paper, include brand equity and firm-specific human capital.

Organisation capital is a very special type of intangible asset, quite different from the others (technological and non-technological knowledge, software and databases, firm-specific human capital, brand equity). Organisation capital is mainly built up through interaction of people and

the establishment of organisational routines and social practices which facilitate collaboration among individuals and encourage creativity (e.g. by building trust). This type of investment is only partially related to monetary expenditure. Organisation capital is mainly embodied in employees and how employees interact with each other (se Jovanovic 1979)

Measuring organisation capital is particularly difficult owing to its tacit nature. Investment in organisation capital is not captured by accounting categories, and usually firms do not track such investment in their internal reporting system (Corrado et al. 2005:76f). In the literature, various approaches have been explored to come up with estimates on organisation capital at the firm level:

(a) An input-based approach attempts to identify the costs of organisational change and development, using revenues of the management consulting industry and wages in executive levels (see Corrado et al. 2005).
(b) A task-based approach (see Squicciarini and Mouel 2012) uses the salaries of managers in certain managerial occupations as a proxy for investment in organisation capital.
(c) An accounting-based approach uses the accounting category 'selling, general and administrative expenses' from firm accounts as a starting point for estimating investment in organisation capital (Lev and Radhakrishnan 2005, Tronconi and Marzetti 2011).
(d) A survey-based approach tries to collect data on expenditure related to improving the efficiency and the effectiveness of business processes, including both internal costs and purchased services. Awano et al. (2010a,b) for the UK, and Perani and Guerrazzi (2012) for Italy run such surveys.
(e) Related to the survey-based approach are attempts to derive qualitative indicators on organisation capital investment, e.g. using measures on how well or how sophisticated an organisation operates (Bloom and van Reenen 2006, 2010, Bloom et al. 2012, Brynjolfsson et al. 2002) or whether firms implement organisational innovations (Polder et al. 2009, Schmidt and Rammer 2007).
(f) A production function approach aims to identify the contribution of measurable capital inputs (fixed capital, labour, measurable intangibles) to output and analyse the part of output not accounted for by these inputs with respect to organisation capital (Lev and Radhakrishnan 2005,Atkeson and Kehoe 2005, Sadowski and Ludewig 2009, Miyagawa and Kim 2008).

In this paper, we follow the production function approach, aiming to advance it in three ways (a) by capturing all major components of intangible assets except organisation capital, (b) by explicitly taking into account likely impacts of market structure on output (which may affect the estimated residual and hence the derived measure of organisation capital if not taken into account), and (c) by evaluating the derived organisation capital measure against other measures of organisational development.

In the existing literature, intangible inputs other than organisation capital have been captured either incomplete or with very imprecise measures. Several studies used information on selling, general and administrative expenses (SG&A) to proxy for organisation capital (Eisfeldt and Papanikolaou 2013, Li et al. 2014, Che 2009), following Lev and Radhakrishnan (2005). Lev and Radhakrishnan (2005) used SG&A as an instrument to capture organisation capital by simultaneously estimating a production function and a function of SG&A. The extra revenues generated by a firm given its level of resources is the difference between the predicted revenue with and without organisation capital. This extra revenue is viewed to arise from organisation capital. Eisfeldt and Papanikolaou (2013), Li et al. (2014) and Che (2009) capitalised and amortised SG&A to derive a direct proxy for organisation capital while Gourio and Rudanko (2014) used only selling expenses. All these studies find a positive association of SG&A and productivity or other firm performance measures. However, only a fraction of SG&A can be associated with intangible assets, e.g. expenses related to research and development, advertising and marketing, training, and information technology expenses. A large part of SG&A are expenses for administrative staff and cost of transport, distribution and facilities, which all do not contribute to building up organisation capital.

Other studies such as Miyagawa and Kim (2008) and Ramirez and Hachiya (2006a,b) used a more narrow approach for capturing other intangibles aside from organisation capital by considering R&D and branding. The elasticities of R&D and branding derived from a production function estimation are used to estimate organisation capital at the firm level, assuming that the elasticities exceeding 1 is the contribution of organisation capital to output. The obvious shortcoming of this approach is that the organisation capital measure will also include the contribution of other intangibles such as software and databases, or firm-specific human capital.

Atkeson and Kehoe (2005) used a different approach. They analysed the specific productivity of plants which is assumed to depend on the vintage of the plant's technology and its built-up

stock of knowledge on how to use that technology. The growth of a plant's specific productivity is viewed to result from a stochastic learning process and will increase over time. The rents exceeding the rental payments for physical capital and labour are interpreted as organisation rents based on the built-up organisation capital. These rents, and hence organisation capital, increases over time in Atkeson and Kehoe's (2005) model. Sadowski and Ludewig (2009) follow a similar approach based on productivity differentials of establishments. The variation in these differentials is explained by variables on organizational practices and control variables. The contribution of organizational practices to performance differentials is interpreted as an index of organisation capital.

What is common to most existing studies using the production function approach is the neglect of likely impacts from market structure, resulting in different levels of profitability which enter the output variable. If one does not account for profitability differences caused by different levels and types of competition, the estimates of organisation capital are likely to include effects of variation in market structure. In this paper, we address this issue by excluding profits from our output measure, hence simulating that all firms operate under perfect competition in the output market with zero profits.

3 Empirical Approach

Our approach starts with a production function at the firm level. Gross output (sales net of profits) is a function of intermediary input (materials, energy, services), labour, tangible capital (fixed assets) and intangible assets. We distinguish five types of measurable intangibles, following Corrado et al. (2005):

- technological knowledge (result of R&D)
- non-technological knowledge (result of other innovative activities such as design)
- software and databases (result of in-house programming and data generation and externally purchased software services and databases)
- firm-specific human capital (result of training activity)
- brand equity (result of marketing and advertising activity)

As these intangibles cover all major intangible categories of Corrado et al.'s (2005) framework except organisation capital, the part of firm-specific output that could not be explained by these

tangible and intangible inputs (= the residual in the production function) should be related to organisational capital.

Model

Following the literature on the econometric estimation of production functions at the firm level (e.g. Griliches and Mairesse 1998, Mairesse and Sassenou 1991), we derive our organisation capital measure from a Cobb-Douglas production function of the following form:

$$Y_{i,t} = A_{i,t} L_{i,t}^{\beta_L} K_{i,t}^{\beta_K} M_{i,t}^{\beta_M} \quad , \tag{1}$$

where labour $L_{i,t}$, tangible capital $K_{i,t}$ and intermediate goods $M_{i,t}$ correspond to the typical production function inputs. $Y_{i,t}$ denotes firm revenues net of profits, and $A_{i,t}$ total factor productivity. We augment this standard production function by considering five intangible assets, as additional inputs of the production process, effectively assuming that $A_{i,t}$ only consists of the five intangible assets $\boldsymbol{I_{i,t}}$, organisation capital $\omega_{i,t}$, a constant and an idiosyncratic error term. Taking the logarithm on both sides, the estimation equation becomes:

$$y_{it} = \beta_0 + \beta_K k_{i,t} + \beta_L l_{i,t} + \beta_M m_{i,t} + \boldsymbol{X}_{i,t}\gamma + \boldsymbol{I}_{i,t}\delta + \omega_{i,t} + \epsilon_{i,t} \tag{2}$$

The lower case variables denote corresponding logarithmic values. We also include a group of industry dummy variables and a dummy for being located in Eastern Germany as control variables in vector $\boldsymbol{X_{i,t}}$. The error term capturing unobserved shocks and measurement errors is represented by the variable $\epsilon_{i,t}$.

To estimate equation (2) we use a two-stage structural production function estimator developed by Olly and Pakes (1996), Levinsohn and Petrin (2003), and Ackerberg et al. (2015) to avoid simultaneity issues between revenues, input choices and the unobserved organisation capital. Following Levinsohn and Petrin (2003) we use the intermediate input demand function

$$m_{i,t} = f_t(k_{i,t}, \omega_{i,t}, l_{i,t}, \boldsymbol{X}_{i,t}, \boldsymbol{I}_{i,t}) \tag{3}$$

as the proxy for organisation capital by inverting (3) for $\omega_{i,t}$ resulting in

$$\omega_{i,t} = f_t^{-1}(k_{i,t}, m_{i,t}, l_{i,t}, \boldsymbol{X}_{i,t}, \boldsymbol{I}_{i,t}) \tag{4}$$

Substituting $\omega_{i,t}$ in the production function (2) with the proxy from equation (4) we obtain

$$y_{it} = \beta_0 + \beta_K k_{i,t} + \beta_L l_{i,t} + \boldsymbol{X}_{i,t}\gamma + \boldsymbol{I}_{i,t}\delta + f_t^{-1}(k_{i,t}, m_{i,t}, l_{i,t}, \boldsymbol{X}, \boldsymbol{I}_{i,t}) + \epsilon_{i,t} \quad (5)$$

We approximate $f_t^{-1}(k_{i,t}, m_{i,t}, l_{i,t}, \boldsymbol{X}_{i,t}, \boldsymbol{I}_{i,t})$ with a second order polynomial and estimate this first stage with OLS. However, because all input variables appear both in the first part of the production function and the inverse demand function, the β parameters are not separately identified from $f_t^{-1}(k_{i,t}, m_{i,t}, l_{i,t}, \boldsymbol{X}_{i,t}, \boldsymbol{I}_{i,t})$.

In the second stage of the estimation we identify these parameters. Using the predicted values from the first stage we can calculate the composite term

$$\phi_{i,t}(.) = \beta_0 + \beta_K k_{i,t} + \beta_L l_{i,t} + \boldsymbol{X}_{i,t}\gamma + \boldsymbol{I}_{i,t}\delta + f_t^{-1}(k_{i,t}, m_{i,t}, l_{i,t}, \boldsymbol{X}_{i,t}, \boldsymbol{I}_{i,t}) \quad (6)$$

This allows us to obtain our organisation capital measure $\omega_{i,t}$ for any value of the parameters β, γ and δ as

$$\omega_{i,t} = \hat{\phi}_{i,t} - (\beta_0 + \beta_K k_{i,t} + \beta_L l_{i,t} + \boldsymbol{X}_{i,t}\gamma + \boldsymbol{I}_{i,t}\delta) \quad (7)$$

Assuming organisation capital to develop following a Markov process $\omega_{i,t} = g_t(\omega_{i,t-1}) + \zeta_{i,t}$ we can also recover the innovation to organisation capital $\zeta_{i,t}$ given the values of β, γ and δ. This combined with a set of moment conditions described in Ackerberg et al. (2015) allows us to estimate the parameters β, γ and δ using GMM while relying on bootstrapping to estimate the standard errors of the parameter point estimates.

After obtaining point estimates of all parameters we then compute our measure of organisation capital as:

$$\widehat{\omega}_{i,t} = \hat{\phi}_{i,t} - (\hat{\beta}_0 + \hat{\beta}_K k_{i,t} + \hat{\beta}_L l_{i,t} + \boldsymbol{X}_{i,t}\hat{\gamma} + \boldsymbol{I}\hat{\delta}) \quad (7)$$

Data

We use data from the German innovation survey, i.e. the German part of the EU's Community Innovation Survey (CIS) initiative. In contrast to most other national CIS, the German survey is designed as a panel survey and conducted annually (called the 'Mannheim Innovation Panel - MIP', see Peters and Rammer 2013 for more details). In addition to the standard questionnaire programme of the CIS, the MIP survey includes questions on expenditure related to intangibles.

We use annual expenditure for measuring intangible assets instead of stock variables. This choice is mainly driven by data availability. For most firms, we do not have a sufficiently long time series on investment in intangibles in order to calculate stocks. In addition, there is no information on depreciation rates for intangibles. Other survey results (Awano et al. 2010) suggest that the economic life time of intangible investment is rather short, so that annual expenditure should be a valid proxy of the actual stock variables.

While the MIP data span the period from the first CIS survey (1992) to the most recent one (2018 at the time this paper was produced), expenditure data on all five types of intangibles are only available from 2011, restricting our observation period to 2011 to 2018. For this period, at total of 20,116 observations from 8,962 different firms are available. The five types of expenditures on intangibles are defined as follows

- technological knowledge: current expenditure on in-house R&D and expenditure for contracted-out R&D
- non-technological knowledge: total current innovation expenditure excluding R&D expenditure and innovation expenditure on training and marketing (these remaining other innovation expenditure mainly includes design and engineering)
- software and databases: expenditure for in-house software development and databases, purchase of external software and databases
- firm-specific human capital: expenditure for training of staff
- brand equity: expenditure for advertising, market research and other marketing activities (excluding general selling expenses)

Output is measured as sales net of profits, in order to avoid likely impacts of unobserved market structure and competition on our production function estimation. While the MIP surveys the amount of annual sales, data on profits is obtained as a categorical variable for the profit margin only, using seven categories for the share of profits before taxation in total sales (<0%, 0 to <2%, 2 to <4%, 4 to <7%, 7 to <10%, 10 to <15%, 15% and more, see Czarnitzki and Kraft 2010 for more details). For obtaining metric profit data, we estimate interval regressions on the profit margin, using size, age, industry, location, credit rating, R&D activity and product/process innovation as determinants and predict profit margins for each firm and

each year.[1] Labour input is measured as the number of employees in full-time equivalents. Tangible capital is measured as the net stock of fixed assets. Data on both variables is directly collected in the MIP.

The descriptive statistics shown in Table 1 reveal that among the five intangibles, investment in technological knowledge (R&D) is by far the largest component (€14m average annual investment at 2005 prices), followed by investment in brand equity (€7.1m) and non-technological knowledge such as design (€3.36m). The average annual investment in software and databases is €2.9m while firms spend on average less than €1.0m per year on building-up firm specific human capital.

Table 1: Model variables

Model variable	Indicator	Mean	Std.D.	Min	Max
Output	Sales net of profits (m€)	392.51	2578.35	0.004	72444.45
Labour	No. employees (FTE)	1104.47	6225.66	1	184650
Tangible capital	Net stock of fixed assets (m€)	245.95	1926.97	0.001	52720.79
Intermediary input	Purchase of material, energy, services (excl. material/services related to R&D, software, databases, training, marketing) (m€)	259.14	1826.27	0	57370.55
Technological knowledge	R&D expenditure (m€)	14.00	152.56	0	5347.91
Non-technological knowledge	Current innovation expenditure excl. R&D (m€)	3.36	32.47	0	1166.94
Software & databases	In-house and extramural expenditure on software and databases (m€)	2.93	26.77	0	1070.23
Brand equity	In-house and extramural expenditure on advertising and other marketing (m€)	7.11	80.96	0	3151.63
Firm-specific human capital	In-house and extramural expenditure on firm-specific training (m€)	0.89	6.46	0	198.61

Notes: All monetary variables are deflated using a German wide GDP deflator with base year 2005.

4 Estimation Results

Production function

[1] Through this procedure, we also estimate profits for firms that did not disclose information on their profit margin, which is the case for 34% of the sample firms. Estimated profit margins were adjusted in a way that mean and standard deviation of estimated profit margins correspond to the mean and standard deviation of observed profit margins.

The estimation results of (2) are shown in Table 2. We find an elasticity for labour input of 0.544, for physical capital input of 0.041 and for material input of 0.399. With respect to investment in intangibles, all but other current innovation expenditure show a statistically highly significant positive impact on firm productivity. Highest elasticities are found for firm-specific training (0.0319) and software and databases (0.0275). The contribution of branding (0.0160) and R&D (0.00642) are substantially lower.

Table 2: Results of production function estimation

Dependent variable: log(sales)	coefficient	t value
log(employees)	0.5440***	726.75
log(fixed assets)	0.0409***	42.18
log(intermediary input)	0.3990***	572.95
log(R&D expenditure)	0.0064***	10.85
log(other current innovation expenditure)	0.0005	0.67
log(software and databases expenditure)	0.0275***	34.87
log(advertising/marketing expenditure)	0.0160***	22.76
log(training expenditure)	0.0319***	40.07
# observations	20,116	
# firms	8,962	

Sector dummies and a dummy for East Germany are included. Reference period: 2011 to 2018
*** $p < 0.001$

Organisation capital measure

We derive our measure for organisation capital from (7). This measure is an index which shows the relative role of organisation capital for a firm's productivity, based on the residual in the production function. For some firms, we arrive at either extremely low (minimum 0.0036) or extremely high values (maximum 81.18), which are likely due to measurement errors in either input or output variables. In order to avoid a bias from unrealistically high or low values, we exclude firms with organisation capital values below the lowest percentile (which is 0.38) and the highest percentile (2.64) from further analyses. When applying this data modification, the mean of the index across all firms is close to 0.8 with a standard deviation 0.3 (Table 3). The index is size neutral, i.e. it indicates that the relative importance of organisation capital is independent of the organisation's size and is hence not a measure of the stock of organisation

capital. The index allows to investigate the heterogeneity of the importance of organisation capital across industry, size, age and other firm characteristics.

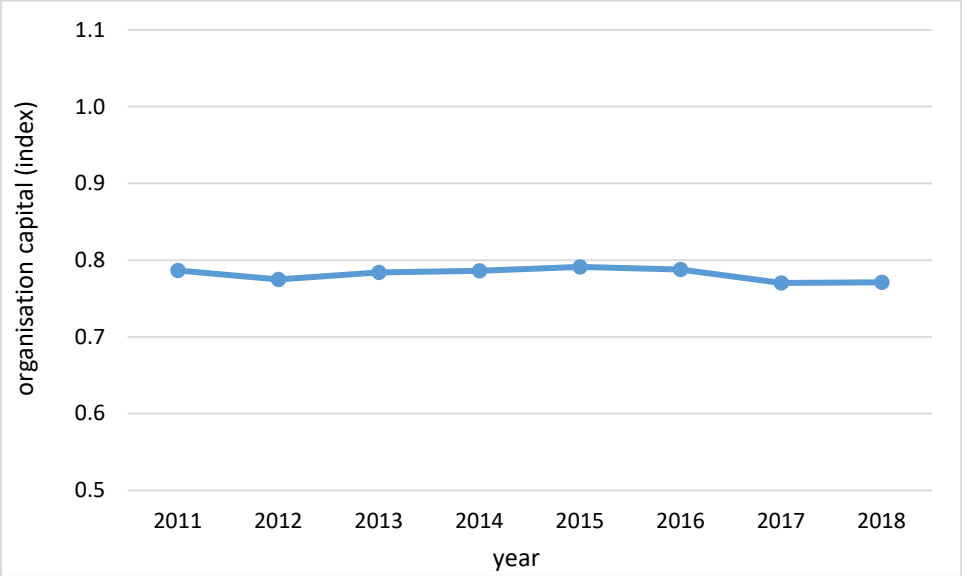
Table 3: Summary statistics of the organisation capital index

	Mean	Standard deviation.	Median	Skewness	Minimum	Maximum
organization capital	0.808	0.296	0.736	2.270	0.379	2.642

We exclude the lowest 1% and highest 1% of estimated organization capital

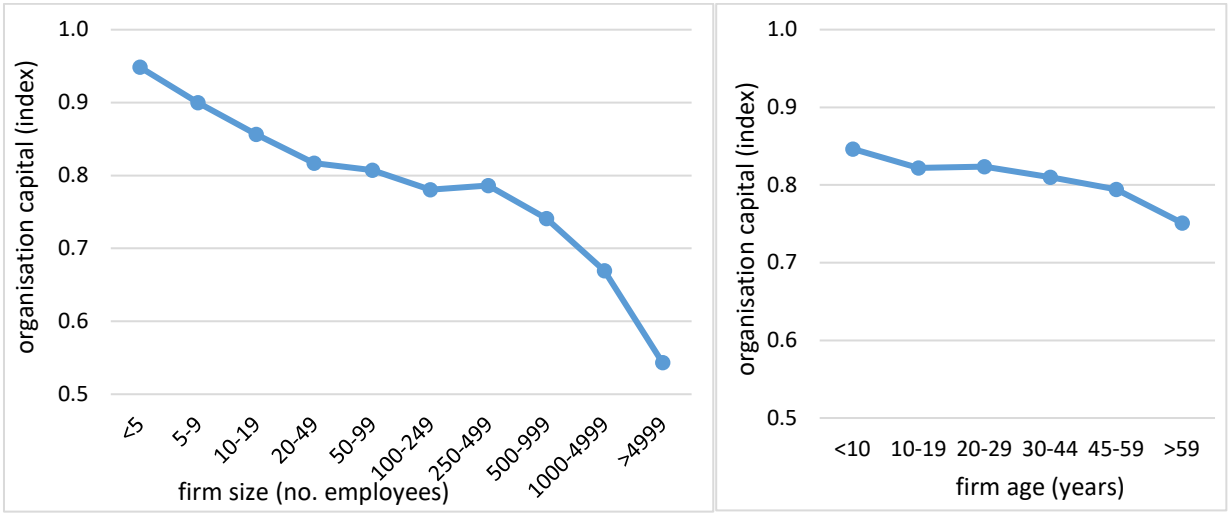
First, we see little variation in the index over time (Figure 1). For our 8-year observation period, the lowest average value is found for 2017 and the highest for 2015.

Figure 1: Organisation capital by observation year



However, we do find substantial differences by firm size and firm age (Figure 2). Smaller and younger firms show relatively higher organisation capital than large and old firms. Firms up to nine years of age show the highest index. This cohort represents about 11% of our sample. There are rather small differences among firms between 10 and 59 years which represent 72% of all firms in the sample. Firms which have been founded 60 or more years ago show a significantly smaller index for organisation capital.

Figure 2: Organisation capital by firm size and age



For firm size, we find the highest index of organisation capital for the smallest firms in our sample (less than 5 employees). The index monotonously decreases until size class 20 to 49 employees. From this size class up to medium-sized firms with 200 to 499 employees, differences in the index of organisation capital are minor. Larger firms with 500 to 4,999 employees, and particularly very large firms with 5,000 or more employees (representing about 5% or our sample) report substantially lower index values for organisation capital.

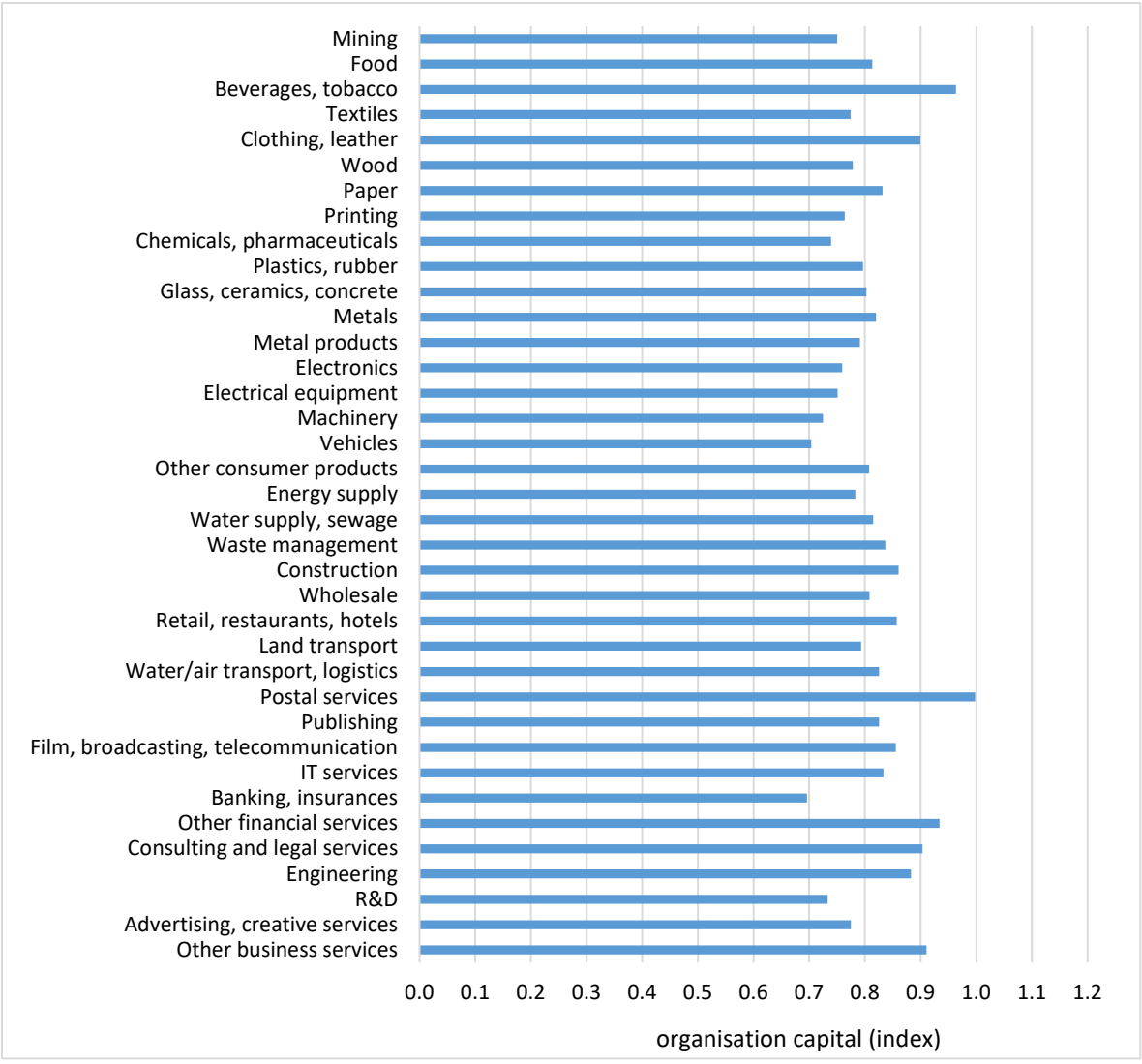
This finding is in contrast to Atkeson and Kehoe (2005) whose model assumes that organisation capital increases with the aging of a plant through the accumulation of knowledge on how to efficiently run a plant. Our results suggest that this process may be driven by other investment in intangible assets, e.g. R&D, branding or human capital. For the pure organisational part of intangible assets, young firms seem to possess more such capital in relation to other assets than large firms.

We believe that this result is meaningful. It can be linked to an important concept within the management literature, namely that of organisational trust (Mayer et al. 1995). Building up organisation capital should be cheaper for small firms than any of the other intangibles, as it is about employing the right routines and establish organisational trust among employees and towards superiors. Such trust strengthens the competiveness of a firm by fostering higher organisational commitment, achieving higher flexibility of work organisation and resolving collective action problems more easily (Leana and van Buren 1999). When an organisation grows, more and more routines have to be formalised, urging the management to build up other

types of capital, e.g. brand name, codified technological knowledge, fixed assets, training of staff etc.

The index of organisation capital also varies by industries, partly - but not only - reflecting differences in age and size composition of firms in each industry. Industries with firms showing a rather high index of organisation capital include other financial services, postal services, baverages and tobacco, clothing and leather, and consulting. Industries that are characterised by rather high expenditure on technological knowledge and branding, e.g. manufacturing of vehicles, machinery, electronics, electrical equipment, chemicals and pharmaceuticals show rather low index values. The lowest values are found for banking and insurances and vehicle manufacturing, sectors which are dominated by large firms.

Figure 3: Organisation capital by industry



Link of organisation capital to other measures of organisational development

We test the link between our index of organisation capital and other measures of organisational development in firms through simple regression analyses. The MIP survey includes several variables related to organisational development. These measures are similar to the qualitative indicators on organisation capital used in survey-based studies (e.g. Bloom and van Reenen 2006, 2010, Bloom et al. 2012, Brynjolfsson et al. 2002):

- Organisational innovation: Firms are asked whether they have introduced new organisational methods in any of the following three areas: (a) business practices (including knowledge management), (b) workplace organisation (including decision making), (c) external relations that have not been previously used by the firm.
- Cooperation on innovation: Firms reported whether they actively collaborated with other firms or organisations on innovation activities.
- Organisational problems as an obstacle to innovation: Firms were asked whether innovation activities have been (a) abandoned, (b) delayed or (c) did not start because of internal organisational problems. This information was used to construct an ordered variable taking the values 3 (if all three events occurred) to 0 (if innovation were not hampered by internal organisational problems). In addition, we derived a measure of the relative importance of organisational problems by dividing the ordered value by the sum of the respective values for a total of 14 different innovation obstacles.

We regress our index of organisation capital on the measures of these variables. In order to investigate likely non-linear relationships, we run one model variant that includes the squared term of organisation capital. In addition to organisation capital, the models include several control variables (age, size, industry, share of graduates, continuous R&D activity). The results are shown in Table 4.

The first main finding is that firms with higher organisation capital are less likely to report organisational problems. This result holds both for the relative importance of organisational problems as a hampering factor for innovation, and the occurrence of organisational problems. We do not find a non-linear relationship as the model variant including a squared term for organisation capital reveals insignificant coefficients. This result suggests that firms with a relatively higher organisation capital find it easier to avoid organisational problems when pursuing innovation activities.

For organisational innovation, we find a negative relationship with organisational capital for all three types of organisational innovation, with the strongest effect for business practices and the weakest one for external relations. But when including a squared term, we find that there is a lower turning point of organisation capital for organisational innovation in business practices and in workplace organisation and decision making. This result suggests that firms with low organisation capital try to overcome this limitation by introducing new organisational methods whereas firms with medium to high organisation capital see less need for reorganisation. The slop starting beyond an index value greater than 1.5 is very flat, however (see Figure 4). For cooperation on innovation, we also find a u-shaped relationship, but with a turning point at the very end of the distribution of our organisation capital index.

Figure 4: Effect of organisational capital on the probability to introduce organisational innovation and to engage in cooperation on innovation

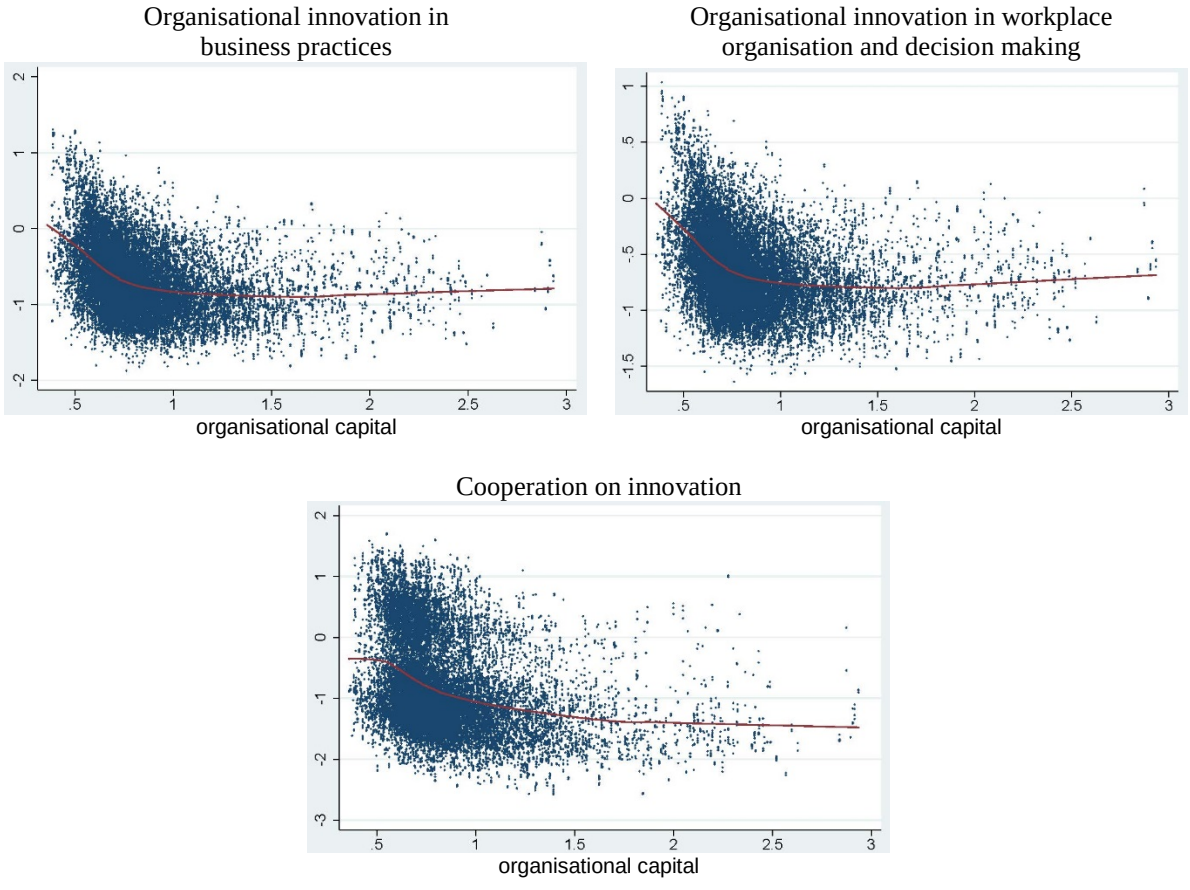


Table 4: Estimation results on regression analyses on the link between organisation capital and indicators related to organisational development

	Innovation obstacle: organisational problems (relative importance)				Innovation obstacle: organisational problems (occurrence)				Cooperation on innovation			
	(1)		(2)		(1)		(2)		(1)		(2)	
Model type:	OLS				Ordered probit				Probit			
Organisation capital	-0.013	**	-0.007		-0.261	**	-0.208		-0.417	**	-0.998	**
	(-3.32)		(-0.45)		(-4.18)		(-0.85)		(-6.63)		(-4.32)	
Organisation capital^2			-0.003				-0.023				0.267	**
			(-0.43)				(-0.22)				(2.64)	
Age (log)	0.002		0.002		0.015		0.015		-0.078	**	-0.077	**
	(1.62)		(1.61)		(0.83)		(0.82)		(-4.55)		(-4.48)	
Size (log)	0.003	**	0.003	**	0.043	**	0.043	**	0.103	**	0.099	**
	(3.83)		(3.85)		(3.76)		(3.74)		(10.04)		(9.41)	
Share of graduates	-0.003		-0.003		-0.112		-0.112		0.865	**	0.865	**
	(-0.61)		(-0.60)		(-1.38)		(-1.38)		(12.21)		(12.20)	
Continuous R&D activity	0.003		0.003		0.142	**	0.142	**	0.959	**	0.958	**
	(1.16)		(1.18)		(3.31)		(3.32)		(28.99)		(28.93)	
No. of observations	7,009		7,009		8,142		8,142		9,898		9,898	

	Organisational innovation in business practices				Organisational innovation in workplace organisation and decision making				Organisational innovation in external relations			
	(1)		(2)		(1)		(2)		(1)		(2)	
Model type:	Probit				Probit				Probit			
Organisation capital	-0.169	**	-0.654	**	-0.126	**	-0.542	**	-0.114	*	-0.404	*
	(-4.15)		(-4.25)		(-3.19)		(-3.62)		(-2.25)		(-2.14)	
Organisation capital^2			0.207	**			0.176	**			0.123	
			(3.29)				(2.89)				(1.61)	
Age (log)	-0.081	**	-0.080	**	-0.069	**	-0.068	**	-0.082	**	-0.081	**
	(-6.48)		(-6.40)		(-5.63)		(-5.57)		(-5.33)		(-5.31)	
Size (log)	0.185	**	0.180	**	0.153	**	0.149	**	0.092	**	0.089	**
	(23.03)		(22.18)		(19.59)		(18.85)		(9.52)		(9.11)	
Share of graduates	0.195	**	0.194	**	0.173		0.172	**	0.331	**	0.329	**
	(3.55)		(3.53)		(3.22)		(3.20)		(4.98)		(4.95)	
Continuous R&D activity	0.436	**	0.432	**	0.318	**	0.315	**	0.459	**	0.457	**
	(14.95)		(14.81)		(10.95)		(10.81)		(12.89)		(12.83)	
No. of observations	16,502		16,502		16,524		16,524		13,122		13,122	

Parameter estimates, t-values in brackets. ** (*): p<0.01 (0.05). All models include 32 industry dummies.

5 Conclusions

This paper made an attempt to measuring organisation capital at the firm level following a production function approach. By capturing all measurable tangible (capital, labour) and intangible determinants of productivity (R&D, other innovative property, software & databases, firm-specific human capital, brand equity), but excluding the difficult-to-measure organisation capital, the residual should be highly correlated with the unmeasurable. In contrast to similar approaches employed by other researchers before (Atkeson and Kehoe 2005, Lev and Radhakrishnan 2005, Miyagawa and Kim 2008), we are able to exploit detailed firm-level panel data on expenditure on all the above-listed types of intangibles.

A key result of our study is that organisation capital tends to be higher in young and small firms. This finding differs from Atkeson and Kehoe (2005) who assume that organisation capital increases by age as firms learn how to efficiently run a business. We relate our finding to the fact that young and small firms should find it easier to build-up organisational trust – which is a key component of organisation capital and which should be easier to develop in smaller organisations where individuals can build strong and stable relationships without the need of formalizing routines and specified roles (see Leana and van Buren 1999). We also find that firms in industries which tend to rely less on R&D show, on average, a higher level of organisation capital. Aside from indirect size effects, the result may indicate a substitutive relation between technological know-how and organisation capital.

Our measure of organisation capital negatively correlates with a firm's perception of internal organisational problems, supporting that our measure is an indicator of a firm's organisational capabilities. When examining the link between with indicators on organisational development, we find a u-shaped relation to qualitative indicators such as the introduction of organisational innovation and entering into cooperation with other organisations. It seems that firms with low organisation capital put more efforts into organisational development to overcome this shortcoming while firms with high organisation capital possess a better ability to further improve their organisational capabilities. This result challenges previous findings which pointed to a positive linear relationship between organisation capital and organisational innovation (see Sanchez-Famoso et al. 2014). Our finding would hence imply that measures on organisational development activities and organisational innovation are not adequate variables for indicating the progress a firm has achieved in building-up organisation capital.

Our study has a number of shortcomings that should be addressed by future research. First, our measure of organisation capital is a dimensionless indicator that does not indicate the size of this capital in each firm. Second, there might be unobserved drivers of productivity other than organisation capital that affect our measure. Finally, the production function estimation rests on expenditure variables for intangibles assets rather than asset stocks.

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