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Keywords: Board and director interlocks, network core, network formation, market capitalization

JEL classification: D85, L20, M14, M51

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The Small Core of the German Corporate Board Network: New Evidence from 2010 *

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Abstract

Milaković, Alfarano and Lux (2010) have identified a small core of directors who are both highly central to the entire network of German corporate boards as well as closely connected among themselves. While their analysis has been based on data for the management and supervisory boards of a sample of 287 publicly traded companies with high market capitalization as of May 2008, a subsequent study by Milaković, Raddant and Birg (2010) using somewhat smaller samples from the years 1993, 1999, and 2005 has confirmed that this closely connected core is a persistent stylized fact for the German corporate sector. In this note, we provide an update of our previous results using the composition of management and supervisory boards as of December, 2010. Again, almost all qualitative properties of previous samples are confirmed despite considerable turnover within the group of persons constituting the network core.

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1 Introduction

Interlocks of corporate boards and their directors have mostly been investigated under the perspective of the effects of simultaneous membership of one

*This paper continues our research reported in Milaković, Alfarano and Lux (2010) which has benefited from the financial support by the Volkswagen Foundation through their grant on "Complex Networks as Interdisciplinary Phenomena". We are grateful to Philipp Mundt for his able research assistance

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director within multiple supervisory boards, or membership of a member of the management board of a company in supervisory boards of other corporations. Since multiple memberships are both considered problematic due to the accumulation of influence and economic power in the hands of single individuals, and because of the arguably decreasing returns of the services of a board member with multiple appointments due to time constraints, many countries impose legal restriction on the upper limit of simultaneous appointments. In Germany, for instance, §100 of the *Aktiengesetz* (German Stock Companies Act) allows for a maximum of ten simultaneous positions in different corporate boards (with the possibility of up to five additional seats in boards of companies belonging to the same trust). However, as we saw in previous studies and also confirmed in the present update, these limits are non-binding. At least among our relatively large sample of highly capitalized companies, the maximum observed number of seats always remains considerably below this limit. The literature indeed has documented a general tendency toward a decline in the number of multiple board memberships at least over the nineties. Balsmeier, Buchwald and Peters (2005) report that among the 100 largest German corporations the chairmen of their supervisory boards had additional seats in other boards in 1996 in one quarter of all cases. Until 2004 this fraction had decreased to ten percent after which it increased again somewhat up to 15 percent as of 2006. The chairmen had an average of 2.2 additional seats in 1996 decreasing to just 1.2 in 2004 and increasing again slightly to 1.4 in 2006.

A similar overall tendency towards less concentration of economic power and influence can also be inferred from the raw data of our sample. For example, with a very similar overall number of board positions (3,728 in our current sample against 3,773 in the 2008 sample), we find: 281 directors with at least 2 simultaneous appointments in 2008 against 251 in 2010, 72 with at least 3 simultaneous appointments in 2008 against 60 in 2010, 26 with at least 4 simultaneous appointments in 2008 against 19 in 2010, 9 with at least 5 simultaneous appointments in 2008 against 2 in 2010. While two directors were working for six different companies in 2008, no such accumulation of appointments is found in 2010 anymore. While these numbers seem to speak in favor of a tendency towards less concentration of economic power and influence over time, our more involved network analysis of the previous papers showed a quite different picture. In terms of statistics for the degree of the connectivity, the core of the German corporate board *network* has remained similarly dense and central over all the years for which data have been collected (1993, 1999, 2005, 2008). As we will see, the same still holds in 2010. We also confirm that the dense network core is overwhelmingly located in large (mostly DAX 30) companies.

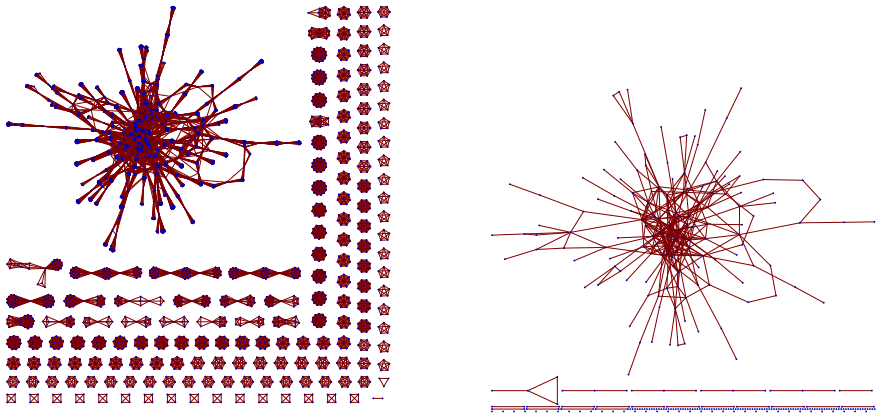
2 Data and methodology[1]

Following Milaković, Alfarano and Lux (2010) we have again collected board membership information for companies which either have a large market capitalization or are included in one of the four prime standard indices of the German Stock Exchange (i.e., the DAX, MDAX, TecDAX and SDAX indices). While we have included as in our 2008 sample all companies with market capitalization of more than one hundred million Euro, we have also expanded the previous sample somewhat by considering another about fifty relatively highly capitalized companies from the CDAX (*composite* DAX) list of stocks. This extension was mainly motivated by our intention to test the robustness of our previous results when varying the sample size of companies. As it turns out, all findings for the core remain essentially unchanged as they appear to be driven mainly by the composition of the boards of DAX 30 and some MDAX companies. Overall, the 2010 sample amounts to a total of $N = 3,728$ board positions (both management and supervisory boards) within $c = 332$ companies as of December, 2010.

We follow the methodology of Milaković, Alfarano and Lux (2010) and Milaković, Raddant and Birg (2010) by first constructing the bipartite graph of this network of board membership. To this end we consider the incidence matrix M with $m_{ij} = 1$ if director i is on the board of company j and 0 otherwise. The projection $\mathbf{D} = \mathbf{M}\mathbf{M}^{\mathbf{T}}$ gives the weighted adjacency matrix of director interlocks, and $\mathbf{B} = \mathbf{M}^{\mathbf{T}}\mathbf{M}$ those of company interlocks. In both cases, the diagonals correspond to the total number of memberships of one director (the total number of board positions), and the off-diagonals show on how many boards two directors serve together (how many directors two companies have in common). Fig. 1 shows visualizations of the network of both director and board interlocks. About 93 percent of all directors (3,145 out of a total of 3,396 individuals) in our sample serve on a single board. Similarly, a considerable part of company boards do not have any overlap in membership with other companies yielding the isolated structures of the trivially connected individuals of single boards on the bottom and to the right of Fig. 1a. As their counterpart, we see at the bottom of Fig. 1b a chain of boards without any overlap in membership with other boards as well as some simple structures due to multiple seats of single individuals without any further connections in the network.

However, both networks also clearly show a *large connected component*. This means that there exists a large subset of the overall network in which any director (company) can be *reached* from any other director (company) by travelling along the links created via multiple board positions of some individuals. As for directors, the large component contains 1,949 individuals

[1] For background on the concepts used in quantitative network research, cf. Newman, Barabási and Watts (2006). An overview on previous applications to company board data can be found in Milaković, Alfarano and Lux (2010).



(a) (b)

Fig. 1: The network of German director interlocks (left panel) is composed of 3,396 nodes (circles) and 25,719 links (lines). The large connected component contains 1,949 (57% of all) nodes and 19,264 (75% of all) links. The corresponding board network (right panel) consists of 332 nodes and 359 links, and its connected component contains 146 (44% of all) nodes and 331 (92% of all) links. Notice that the number of subgraphs that do not belong to the large connected component of the director network equals the number of nodes that are not in the connected component of the board network. The average director serves on 1.10 boards (1.14 in the large component), and the average board contains 11.23 seats (15.34 in the large component).

(about 57 percent of all directors in the sample), and 19,264 of 25,719 links (about 75 percent with the remaining ones being mainly the trivial ones of joint membership within an isolated board). For companies, their large connected component comprises 146 of a total of 332 (44 percent) firms with 331 of 359 links (92 percent).

When comparing results with those of our previous paper(s), one should take into account the difference in sample size for boards. For instance, the current sample comprises 48 companies more than the one of 2008. The drop in the coverage ratios of the large connected component with respect to the number of nodes and links should, therefore, mainly be due to a higher number of small and medium-sized firms with unconnected or relatively sparsely connected boards in our sample. Note, however, that despite the increase of the sample, the large connected component still contains more than 90 percent of all links between companies. The complete data set shows a clear reduction in average board size compared to 2008 (which certainly is partially due to our increase of the sample of companies): The average board in the 2010 sample has about 11 members while the average size was equal to 13 in 2008. However, this reduction is mainly confined to the more

peripherical entries. In the large connected component, the average board size had declined only very slightly from 15.8 in 2008 to 15.3 in 2010.

While the visualization suggests some kind of network core, this purely data analytical approach is not *per se* informative about whether this degree of concentration is statistically significantly different from what one would get under random assignment of director positions to the pool of individuals in our data base (which by construction would mean that with n directors assigned to N board positions, a certain number of persons had to end up with multiple positions). Comparing the empirical frequencies with those expected under random assignments, we obtain virtually the same pattern as we did for the 2008 data, cf. Fig. 2. As in the previous sample, we observe that while two simultaneous seats occur somewhat less often than expected by random assignment, from three simultaneous seats on the observed frequencies are way above (in fact, orders of magnitude higher for four to five multiple seats) the random benchmarks (the lower number of persons with two seats compared to the random benchmark is, of course, the direct consequence of a higher number of triple to quintuple positions). Again, the conclusion is that there are systemic tendencies at work favoring that a small number of individuals assembles a comparatively high number of simultaneous board positions.

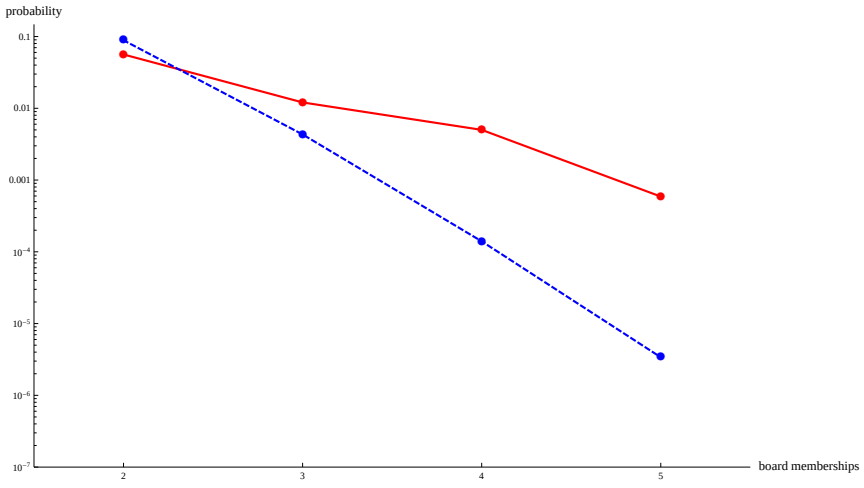


Fig. 2: The solid curve shows the relative frequency of multiple board membership, while the dashed curve illustrates the binomial probability of observing multiple board membership in an independent sequence of $k = 332$ (the number of second to fifth board positions, i.e. 332 = 3728 - 3396) Bernoulli trials with probability $p = 1/3396$ of success. The semi-log scale reveals deviations of increasing orders of magnitude for $b > 3$.

3 The core of the network

As before, we take a closer look at the apparently non-randomly formed core of the network. Figure 3 shows the network structures formed by considering only directors with an increasing threshold of board membership $B > b$ (with $b = 2, ..., 5$). Table 1 displays network statistics for these cores. We report the *density* (the ratio of existing links to the number of links in a completely connected graph), the *radius* (the minimum distance between two nodes), and the *diameter* (the maximum distance between two nodes). Also given in Table 1 are various measures of *centrality*, that quantify how pivotal the B-core members are with respect to the complete network. *Degree centrality* simply sums over the links that each node has whereas *closeness centrality* measures the distance of a node to all other nodes. *Eigenvector centrality*, finally, is obtained in a somewhat more complex way by taking into account the relative importance of other nodes to which an individual is connected. To obtain such a weighted measure, the relative importance of each node is determined by the eigenvector corresponding to the largest eigenvalue in a simultaneous system determining these scores.

While decreasing numbers for the diameter and the radius speak in favor of a more closely connected network, higher density comes along with increases in the density and centrality measures. As we see from Table 1, all network measures indicate a more closely intertwined network when moving from $b = 1$ to $b = 4$. All these measures, in fact, change monotonically with b in the direction of closer ties between the remaining directors over this range. For the two remaining directors with five seats, the B-core statistics are trivial and reflect the mere fact that there is no overlap in the boards in which they are serving. However, the two of them still have on average a higher degree and closeness centrality than the average member of the $b = 4$ core, and the market capitalization that their appointment represent is again on average higher. Interestingly, the more than over proportional increase in capitalization per capita is observed *despite* one of the two being rather a specialized board member of medium-sized companies. Again it is worthwhile to emphasize that there is no intrinsic bias in such an analysis toward more closely connected and more central cores for higher b. Under random assignment of multiple seats, it would rather be the opposite we would expect: the few remaining directors for high levels of b should rather be isolated from each other than so closely knit together. Similarly as for the 2008 data, these findings strongly support the conclusion that there seems to be some intrinsic tendency towards an accumulation of board seats in a certain subset of the most closely connected directors.

Similary as for 2008, Table 1 also shows that this well-connected core is formed preferentially in the companies with high market capitalization. Note also, that in comparison with the B-cores of 2008 the various network statistics show no tendency of decline. Taking into account the smaller

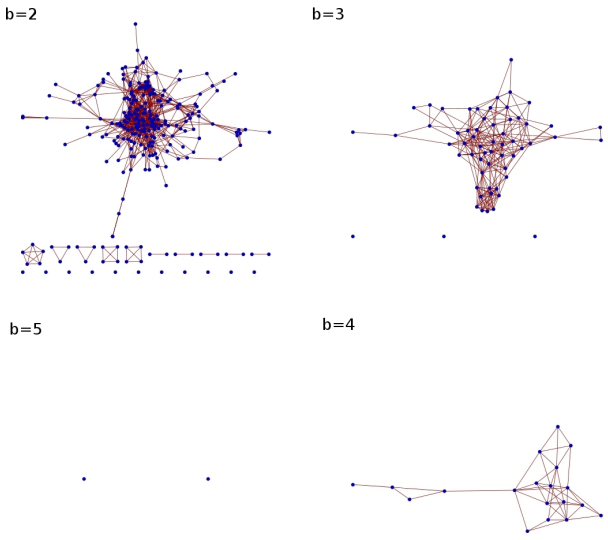


Fig. 3: Network structures formed by considering directors with an increasing threshold of board memberships $B \geq b$. The respective numbers of directors are 251, 60, 15, and 2 for $B \geq 2$ through 5. Note that while the B-4 core is completely connected, the two remaining individuals with as many as five board positions have no overlap in their appointments. This is mainly due to the fact that one of them (Robert J. Koehler) is a very rare example of a specialist for medium sized companies with a specific business profile while the other (Manfred Schneider) belongs to the much more typical group of directors with multiple board memberships that supervise the most highly capitalized companies without any obvious sector-specific specialization. Table 2 indicates that almost all the directors with $B \geq 3$ appointments belong to the latter category.

number of individuals in the B-cores of 2010, this rather speaks for a higher degree of concentration of influence in 2010. We have also computed the conditional probability of adding an additional board membership to an already existing one, cf. Fig. 3. The interesting finding is once more that except for the highest number ($b = 5$, i.e. the conditional probability $P(5|4)$) it is *positive*. Having two or three seats makes it statistically more likely for the director to be offered still another seat in a corporate board. So, at least over most of the observed numbers of simultaneous occurrences decreasing returns from multiple membership would not explain the empirical patterns.

Tab. 1: Various characteristics of B-cores and their respective directors. The notation $b = 1$ refers to all directors in the large component $\mathbf{C}$

	$b=1$	$b=2$	$b=3$	$b=4$	$b=5$
B-core statistics:					
Diameter	10	8	5	5	∞
Radius	5	4	3	3	∞
Density	0.01	0.03	0.14	0.26	0
Centrality averages:					
Degree centrality	19.77	38.77	66.87	87.26	90.5
Closeness centrality	0.67	0.77	0.86	0.92	0.94
Eigenvector centrality	0.08	0.22	0.43	0.59	0.44
MarketCap per capita:					
Entire B-core	511.09	4063.5	15243.87	43124.74	80849.1
B-core isolates	N/A	596	2959	N/A	N/A

Note: For one company, Bertelsmann AG, we do not have publicly available data on market capitalization as its shares are not publicly traded. In this case, the ballpark figure of 70 *Billion Euro* has been used as guesstimate of its market capitalization. This has been a typical number in the financial press at the time of our previous 2008 survey, and there seemed not much reason to change this number. Over a large range, changes to this number would, anyway, not affect the results reported in this table.

4 The persons in the core of the German corporate sector

Table 2 provides the list of directors in $B > 3$ cores together with various measures of their network centrality. As compared to our 2008 sample, the overall number of individuals with four or more board positions has declined from 26 to 19. There is an overlap of nine persons who appear both in the list of directors with highest numbers of appointments in 2008 and 2010. Interestingly, these have often changed part of their affiliations which again provides support to the conjecture that it is the multiplicity of appointments *per se* rather than some specific expertise that appears valuable to the companies involved. Under random assignments, giving up one board position of four and adding another one would again be very unlikely.

Among the overall board positions represented by these 19 directors, 55 out of 78 are in DAX30 companies. There is only one person, Robert J. Koehler, who works for a sample of five medium sized firms (in fact, all MDAX members) with a relatively homogeneous focus on mechanically complex manufacturing goods. No such sector specific specialization can be

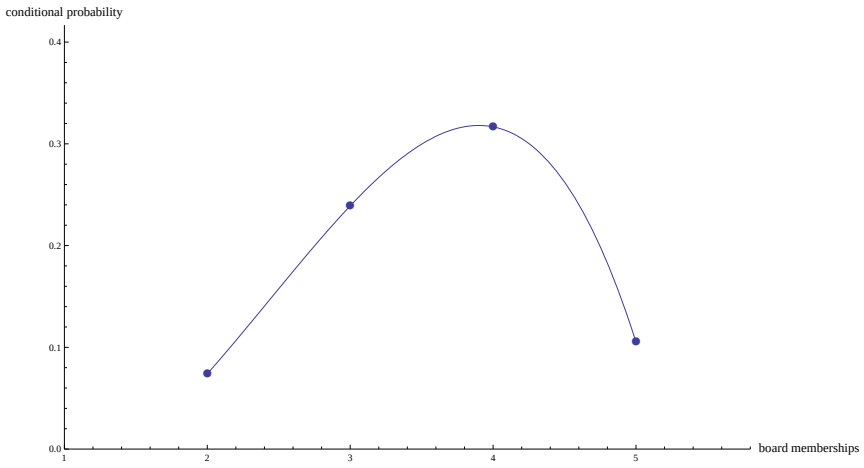


Fig. 4: The conditional probability $P(b|b-1)$ of board membership is calculated from the ratio of successive B-core sizes; for instance, 60 of the 251 directors in the B-2 core form the B-3 core, and the conditional probability $P(3|2)$ of observing $b = 3$ memberships is $60/251 = 23.9\%$. While the conditional probability of board membership increases at first, the fitted parabolic shape indicates that the number of board appointments per director is obviously limited.

found among the remaining 18 top directors, but they rather seem to have more of an all-rounder's profile serving in companies from various sectors. All these are multiple members of boards of mostly the firms with highest market capitalization typically from the DAX30, the leading German stock index.

Tab. 2: List of directors in $b > 3$-cores.

Name	Boards	Degree (Rank)	Closeness (Rank)	Eigenvector (Rank)
Ulrich Lehner	Deutsche Telekom AG *(48, 43037.45)* E.ON AG *(49, 45822.85)* ThyssenKrupp AG *(33, 15998.02)* Porsche Automobil Holding SE *(37, 5687.5)*	0.8762 (4)	0.9178 (4)	1 (1)
Berthold Huber	Siemens AG *(36, 83128.44)* Volkswagen AG *(37, 21962.02)* Porsche Automobil Holding SE *(37, 5687.5)* AUDI AG *(37, 1115.81)*	0.7238 (18)	0.8795 (36)	0.9709 (2)
Martin Winterkorn	Volkswagen *(37, 21962.02)* SALZGITTER AG *(33, 3352.81)* Porsche Automobil Holding SE	0.7429 (14)	0.8413 (111)	0.9284 (3)

Tab. 2: continued.

	(37, 5687.5) AUDI AG *(37, 11115.81)*			
Ferdinand K. Piëch	MAN SE *(37, 12569.24)* Volkswagen AG *(37, 21962.02)* Porsche Automobil Holding SE *(37, 5687.5)* AUDI AG *(37, 11115.81)*	0.6571 (25)	0.8700 (55)	0.9046 (4)
Ekkehard D. Schulz	Bayer AG *(28, 47127.71)* MAN SE *(37, 12569.24)* RWE AG *(49, 26125.45)* ThyssenKrupp AG *(33, 15998.02)*	0.8857 (3)	0.9501 (8)	0.8786 (5)
Paul Achleitner	Allianz SE *(63, 41186.79)* Bayer AG *(28, 47127.71)* Daimler AG *(37, 57711.25)* RWE AG *(49, 26125.75)*	0.8476 (8)	0.9543 (6)	0.7430 (11)
Manfred Schneider	Bayer AG *(28, 47127.71)* Daimler AG *(37, 57711.25)* Linde AG *(35, 18812.16)* RWE AG *(49, 26125.75)* TUI AG *(47, 2286.96)*	1 (1)	0.9564 (5)	0.7370 (12)
Clemens Börsig	Bayer AG *(28, 47127.71)* Daimler AG *(37, 57711.25)* Deutsche Bank AG *(60, 37221.8)* Linde AG *(35, 18812)*	0.8286 (9)	0.9470 (9)	0.7207 (14)
Theo Siegert	Deutsche Bank AG *(60, 37221.8)* E.ON AG *(49, 45822.85)* Henkel AG & Co. KGaA *(28, 8136.69)* Merck KGaA *(28, 3909.58)*	0.8667 (5)	0.8885 (29)	0.6156 (21)
Henning Kagermann	Bayerische Motoren Werke AG *(37, 39289.19)* Deutsche Bank AG *(60, 37221.8)* Deutsche Post AG *(42, 15445.18)* Münchener Rückvers AG	0.8952 (2)	0.9155 (18)	0.5859 (23)

Tab. 2: continued.

	(63, 21447.69)			
Michael Diekmann	Allianz SE *(63, 41195.88)* BASF SE *(28, 55852.64)* Linde AG *(35, 18812.16)* Siemens AG *(36, 83128.44)*	0.7905 (11)	1 (1)	0.5609 (28)
Bernhard Walter	Daimler AG *(37, 57711.25)* Deutsche Telekom AG *(48, 43037.45)* Henkel AG & Co. KGaA *(28, 8136.69)* Bilfinger Berger SE *(16, 2810.63)*	0.8667 (6)	0.9272 (15)	0.5430 (31)
Wulf H. Bernotat	Allianz SE *(63, 41186.79)* Deutsche Telekom AG *(48, 43037.45)* METRO AG *(51, 17822.8)* Bertelsmann AG *(27, 00)*	0.8476 (7)	0.9604 (3)	0.5333 (32)
Renate Köcher	Allianz SE *(63, 41186.79)* Bayerische Motoren Werke AG *(37, 39289.19)* Infineon Technologies AG *(36, 7784.33)* MAN SE *(37, 12569.24)*	0,7714 (12)	0.9887 (2)	0.5297 (33)
Klaus-Peter Müller	Commerzbank AG *(60, 6975.89)* Fresenius SE *(28, 8318.56)* Linde AG *(35, 18812.16)* Fraport AG *(45, 4400.45)*	0.8095 (10)	0.8899 (28)	0.3708 (82)
Werner Brandt	Deutsche Lufthansa AG *(45, 7897.13)* SAP AG *(73, 45633.13)* Heidelberger Druckmaschinen AG *(35, 893.65)* QIAGEN N.V. *(38, 3366.89)*	0.7429 (13)	0.9564 (4)	0.2386 (199)
Robert J. Koehler	Demag Cranes AG *(35, 766.46)* Heidelberger Druckmaschinen AG *(35, 893.65)* Klöckner & Co. SE *(28, 1409.13)* LANXESS AG *(28, 4625.23)* SGL Carbon *(36, 1754.83)*	0.6571 (24)	0.9314 (13)	0.1418 (403)

Tab. 2: continued.

Erhard Schipporeit	Deutsche Börse AG *(62, 629931.35)* SAP AG *(73, 45633.13)* FUCHS PETROLUB AG *(28, 1271.84)* Hannover Rückversicherung AG *(63, 4848.6)*	0.6571 (26)	0.8563 (67)	0.0977 (477)
Klaus Wucherer	Infineon Technologies AG *(36, 7784.33)* SAP AG *(73, 45633.13)* LEONI AG *(50, 1021.98)* Dürr AG *(35, 415.21)*	0.5905 (32)	0.8676 (57)	0.0637 (547)

Note: Brackets below company names show two-digit SCI codes of their primary business activity and market capitalization in millions of Euro as of 31 December 2010. All centrality measures have been normalized to yield a maximum of 1.

Table 2 also shows the various centrality measures for the 19 directors with four or more appointments. First, one observes that in many cases (with notable exceptions), the different centrality measures yield relatively homogeneous ranks of directors within the network. One of the major exceptions is Robert J. Koehler whom the degree and closeness centrality measures rank 24th and 13th, respectively, but who drops to rank 403 under the eigenvector centrality concept. Note that the former measures are based on the 'raw' number of connections of a person, whereas the later weights these links by the importance of the counterpart. Under this perspective, the drop of the centrality rank when using an importance-weighted measure appears completely intuitive for this person. While five simultaneous appointments in medium-sized companies might lead to a large number of links and connections to many other directors, they should not amount to a central position in the complete network when accounting for the relative importance of these connections. Under this perspective, the eigenvector centrality appears the most relevant concept for extracting information on a person's status in the system so that we have ordered the entries in Table 2 according to this measure. Note also that in terms of eigenvector centrality, the five most prominent (in terms of connectivity in the network) directors are also holders of four simultaneous board appointments.

However, those directors appearing on ranks 6 through 10 in terms of eigenvector centrality do not belong to the $B > 3$- core, i.e. they only hold at most 3 simultaneous appointments. Hence, neither is an accumulation of seats a sufficient condition for a very central position, nor does a high eigenvector centrality necessarily come along with a very high number of appointments.

An interesting result in Table 2 is that the second ranked board member in terms of eigenvector centrality is Berthold Huber, chairman of the tradi-

tionally influential *IG Metall* (the German metal workers' union). Again, it is not necessarily the sheer number of his four appointments but their strategic positioning in those firms that form the industrial base of the German economy that leads to this rank (in his case, one could also argue that the accumulation of three seats in the automobile industry reveals sector-specific specialization, and, of course, due to German co-determination laws he represents the workers' interests in important companies of the metal-working industry). He is not the only union representative who appears relatively high in our ranking. Another case in question is Frank Bsirske, chairman of *ver.di*, the largest union in the service sector who with two appointments reaches rank 84 in eigenvector centrality.

5 Conclusion

As we have already mentioned, our results for the 2010 corporate board network are in very close agreement with those obtained for previous years despite quite a large amount of turnover in directors in charge and their particular board positions. Apparently, there is some kind of 'self-organization' of the German corporate sector that despite the change of personal and companies forming the actual core leads in a very persistent way to a densely connected center of gravitation of directors with a high degree of centrality in a small selection of companies with the highest market capitalization (mostly DAX30 companies).

Since our analysis is of an entirely non-causal nature, we cannot shed light on the origin of this core formation. However, the phenomenon itself appears remarkable in particular as it stands in contrast to the observed tendency of less concentration of power in the overall German board network as a whole. This documented stylized fact of the persistent core certainly warrants a closer study of its potential socio-economic determinants.

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