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Do literacy and numeracy pay off? On the relationship between basic skills and earnings

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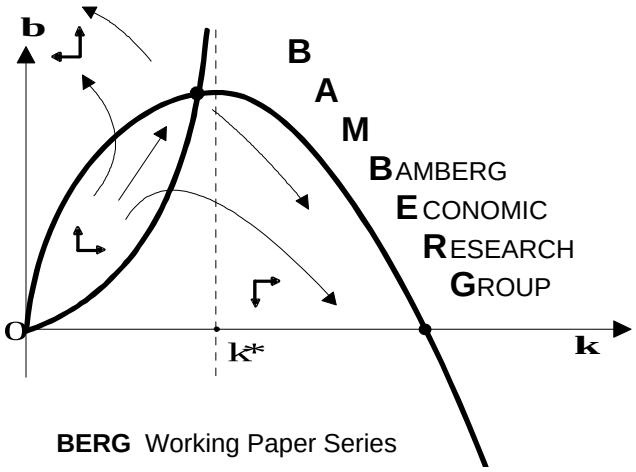

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Do literacy and numeracy pay off? On the relationship between basic skills and earnings*

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September 17, 2012

Abstract

Is there a reward for basic skills in the German labor market? To answer this question, we examine the relationship between literacy, numeracy and monthly gross earnings of full-time employed workers. We use data from the ALWA survey, augmented by test scores on basic cognitive skills as well as administrative earnings data. Our results indicate that earnings are positively related to both types of skills. There furthermore is no evidence for non-linearity in this relationship and only little heterogeneity when differentiating by sub-groups.

JEL classification: I21, J31

Keywords: Literacy, numeracy, earnings, administrative data, Germany, ALWA

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1 Introduction

Ever since its establishment in the early 1960s (Becker, 1962; Schultz, 1961), research on human capital had a focal interest on the labor market returns to individuals' schooling, which was considered to represent individuals' productivity. However, it was soon recognized that the indicator typically used, time spent in education, may not necessarily be a good proxy for individuals' capabilities, and that the resulting coefficients will be biased if ability cannot be accounted for (Griliches and Mason, 1972).

Though there is a small but established literature on the returns to cognitive ability,[1] it might be argued that adults' basic skills, i.e. literacy and numeracy, are at least as relevant for earnings. Not only may they be considered as better indicators for individuals' productivity than schooling credentials, but they are also more malleable than innate cognitive abilities. The latter are partly determined by pre-natal circumstanced, are mainly developed in childhood and early youth and cannot be altered easily later on in the life course (Cunha and Heckman, 2007). In fact, numerous policy programs that are embedded in the "lifelong-learning" debate show that the removal of deficiencies in and the enhancement of adult's basic skills are of high interest to policymakers.[2] But similar to the literature on cognitive abilities, there is only little evidence on the role of adults' literacy and numeracy. This is not surprising since data on adults' basic skills are rather scarce and have a focus on Anglo-Saxon countries, with only very limited evidence from other countries.

We add to the literature by providing first evidence on the association between adults' literacy and numeracy skills and individual earnings for Germany. In contrast to evidence on the formation of basic skills in the school student population, for which there has been a surge in research interest after the German "PISA shock" in 2000 (see Klieme et al., 2010), our analysis will shed some light upon the situation of adult workers for whom there is barely any research. To be able to do this, we base our analysis on the ALWA-ADIAB and ALWA-KOMP data, a combination of data sources that is unique in several aspects, even beyond the German context.

To be clear, the set of basic skills as given in our data will neither allow us to separate innate abilities from literacy and numeracy skills, nor can we disentangle causal mechanisms that might lead to differences between the returns to educational attainment and to basic skills. We primarily aim at providing evidence on whether literacy and numeracy adds to the explanation of variation in earnings beyond individuals' educational attainment or whether

[1] It is worth noting that the available evidence is far from conclusive: On the one hand, there is a large number of studies that reveal substantial returns to cognitive abilities (e.g., Bronars and Oettinger, 2006; Cameron and Heckman, 1993; Green and Riddell, 2003). On the other hand, there are as many studies suggesting that cognitive abilities have barely any additional effect on earnings (Bound et al., 1986; Murnane et al., 1995) and that they are a poor predictor of earnings compared to a direct measure of education, family background, and environment (Cawley et al., 2001; Zax and Rees, 2002).

[2] See, for example, Recommendation 2006/962/EC of the European Parliament and of the Council on key competencies for lifelong learning.

potential effects are fully absorbed by educational credentials. Despite its more descriptive character, our analysis is relevant for both economists and policy makers as it furthers our understanding of the returns to education and skills beyond formal schooling.

The remainder of our paper is as follows: We review prior research on the returns to basic skills in section 2, introduce the data sets in section 4 and provide results in section 5. Section 6 draws conclusions.

2 Background and Previous Research

As noted above, interest in individuals' abilities is nothing new in the empirical literature on human capital. Where available, researchers used information on individuals' cognitive abilities for technical reasons, i.e. in order to remove potential issues caused by omitted variables. Researchers are also interested in the labor market value of cognitive abilities – and along the same line of argument, of basic skills – as they may reflect individuals' productivity as good as formal schooling, if not better. If so, implications from human capital theory would predict that such a set of skills will pay off.

It is therefore not surprising that the interest in adults' basic skills has also been around for some time, and particularly so in the political spheres. Faced with the challenges of increasing demands for a skilled workforce in knowledge based societies, it was only in the more recent past, that the OECD implemented two comparative studies, the International Adult Literacy Survey (IALS), that was conducted in three periods between 1994 and 1998 and covered 21 countries, and the 2003 Adult Literacy and Lifeskills Survey (ALL) that covered six countries.

Some of the studies that examined the returns to basic skills are based on either ALL or IALS data. Yet, before looking at findings in more details, it is useful to first address the concepts of numeracy and literacy which are, as Dougherty (2003, p. 512) puts it, "... susceptible to definitional variability". It furthermore is necessary to distinguish basic skills measures as given in the database we use from cognitive abilities as included in, for example, the National Longitudinal Survey of Youth (NLSY). Such measures are typically used as proxies for individuals' innate abilities and are mainly taken from a common cohort and when individuals are still in education.

We however use data drawn from basic skills tests conducted during a survey with adult respondents. Our measures therefore are mainly from individuals who have completed their educational and vocational training and are of different age. Beyond that, and more importantly, the tests aim at capturing skills that are needed in individuals' everyday life. Since the basic skills scores in our data are based on tests that were included in ALL, we follow its definition for prose literacy and numeracy (Statistics Canada and OECD, 2005, p. 16):

> *Prose literacy:* "the knowledge and skills needed to understand and use information from texts including editorials, news stories, brochures and instruction manuals."

Numeracy: "the knowledge and skills required to effectively manage the mathematical demands of diverse situations."

Since the data do not contain actual measures of innate ability, our basic skills measures should be interpreted as a compound measure of an individual's innate abilities, educational gains, and post-education experiences of the individual in both her working and private life.

As outlined above, there is only little evidence on the association between workers' basic skills and labor market success, measured by either employment participation or earnings. While there are a few studies from the 1970s (see Dougherty, 2003), we concentrate on more recent studies to allow some comparison to the current German setting. As most of the research on the association between adults' basic skills and labor market success focuses on Anglo-Saxon countries, we outline first a few relevant studies the North Americas and the UK before we look at other countries, including Germany.

Dougherty (2003) uses data for the US from the NLSY which provides test scores from the Armed Services Vocational Aptitude (ASVAB) test. Rather than using the composite AFQT score that can be derived from the ASVAB scores, the author employs numeracy scores, based on the individuals' arithmetic reasoning attainment, and literacy scores, a joint verbal composite based on word knowledge and paragraph comprehension. The results suggest that numeracy is strongly related to earnings, working indirectly via its effect on college attainment but also directly, controlling for educational attainment. While the effect is small in absolute terms, it appears to increase over the 1988-1996 period covered in the analysis. Compared to that of numeracy, the literacy earnings gradient is smaller and less significant.

Ishikawa and Ryan (2002) use only the prose literacy measures from the 1992 National Adult Literacy Survey (NALS) for the US and examine both the formation of basic skills and their association to earnings. They attempt to disentangle basic skills that are learned in school from those acquired in the post-school periods and conclude that it is the "substance of learning in school [...] that counts" (ibid., p. 241), which emphasizes the need to account for both schooling and basic skills. Their results further suggest that compared to their white or hispanic counterparts, black workers do not benefit from basic skills acquired in school.

McIntosh and Vignoles (2001) use data from the 1991 British National Child Development Study (NCDS) and data on the UK from the 1994 IALS.[3] The authors focus on individuals in the bottom part of the skills distribution, and their findings for numeracy imply that low skilled individuals are substantially more likely to be employed, and, if employed, earn some 16-21% more than the lowest skilled. The results for literacy are more heterogenous and there are large differences between results based on either data set, so that the authors avoid a concluding answer.

[3]This is interesting on its own, since the authors compare the methodological strengths and, above all, weaknesses of both data sources. The authors in fact conclude that both data sets "... suffer from significant, but different, measurement problems" (McIntosh and Vignoles, 2001, p. 474).

Another recent study for the UK is by Vignoles et al. (2011) who use data from the British Cohort Study (BCS) for 2004, and, for comparison over time, NCDS data for 1995. Similar to the study by McIntosh and Vignoles (2001), the authors find that both numeracy and literacy skills measured at age 16, 21, and 34 are positively related to the earnings of 34-year old workers. The earnings premia are at about 11% for a standard deviation increase in numeracy, and 14% for literacy, respectively, with no substantial differences between men and women. These results are robust to a range of different specifications. The findings further imply that despite numerous policy efforts to increase the supply of skills over the period 1995 to 2004, the value of basic skills has remained stable in the UK.

Evidence for full-time working male Canadians is provided by Green and Riddell (2003) who use the country component of the 1994 IALS. They employ the average of test scores on document, prose and quantitative skills and run quantile regressions in order to examine whether basic skills vary across the wage distribution. Their results however suggest that this is not the case, but they too find a strong association between their skills measure and the earnings of male workers.

The analysis of Shomos (2010) complements the overall picture of the positive relationship between adults' basic skills and labor market success as measured in earnings. Using data from the Australian Adult Literacy and Lifeskills Survey (ALLS)[4] for 2006, his results suggest a 14 percentage points increase in wages for an increase in skills, which are measured in categories, from the lower to the next higher skill level. Separated by gender, there are somewhat stronger effects for men than for women.

One of the few studies on non-Anglo-Saxon countries is by Denny and Doyle (2010) who use the 1998 IALS components for the Czech Republic, Hungary, and Slovenia. The authors employ semi-parametric econometric techniques and find that returns to basic skills are significant in Slovenia and the Czech Repulic, but to a lesser extent in Hungary. Based on the flexible semi-parametric part of their analysis, the authors conclude that the returns vary considerably between numeracy and literacy as well as across the countries in their sample.

For Germany, there is only very limited evidence: Measures of individuals' cognitive abilities, as approximated by an ultra-short IQ test that was implemented in the 2006 wave of the German Socio-Economic Panel Study (SOEP), are used by Heineck and Anger (2010). Their results indicate that, controlling for education, speed of cognition is positively related to the earnings of males, but not relevant for females. However, since their measure is a proxy for individuals' innate abilities rather than for basic skills, the comparability to our analysis is limited.

The German 1994 IALS component has, to our knowledge, been explored only by Freeman and Schettkat (2001). They use the IALS numeracy scores, and compare Germany to the US with a focus on how much the skills distribution contributes to the differences in the wage

[4]Note that while this survey bears the same name, Australia was not one of the six countries in the comparative survey in 2003.

distributions in both countries. So, again, comparability to what we do in this analysis is limited, and even more so since the German IALS provided information only on net rather than gross income, and only the workers' position in one of 20 income brackets rather than actual income.

3 Hypotheses

Both theoretical considerations and implications from the empirical findings mentioned above allow us to derive hypotheses on the relationship between basic skills and earnings. One of the fundamental implications of the human capital theory is that one's productivity—and thereby one's wage—depends on the skills one is endowed with. This includes cognitive and non-cognitive abilities (Heckman et al., 2006; Heineck and Anger, 2010), as well as basic skills as given in our data. The assumed relationship is positive, which leads straightforwardly to *Hypothesis 1*:

> **H1:** Conditional on education and other productivity-related characteristics, basic skills are positively related to labor market earnings.

Although signalling (Spence, 1973) and screening (Stiglitz, 1975) theories are related to innate abilities rather than basic skills, some of their extensions offer implications different from those of the human capital theory. Riley (1976) and Psacharopoulos (1979) laid the ground for what Farber and Gibbons (1996) later on termed "employer learning": employers may base hiring decisions and initial wage levels on formal educational certificates as signals for productivity; over time, they will increasingly take observable productivity into account for wage setting decisions. *Hypothesis 2* summarizes the implications of employer learning for our analysis:

> **H2:** The higher the tenure at a given firm, the higher the rewards for basic skills.

Based solely on theoretical considerations we would not expect any differences in the strength of the relationship between earnings and either of the domains of basic skills we consider. After all, human capital theory does not predict that any aspect of human capital should generally yield highher monetary payoffs than others. Contrary to that, several studies mentioned in the previous section do find significant differences. Based on these results of higher earnings payoffs to numeracy than to literacy we put forward *Hypothesis 3*:

> **H3:** If there are any differences between the rewards to literacy and numeracy, there should be a stronger relationship of earnings with numeracy than with literacy.

Some of the findings mentioned above indicate differences in rewards to basic skills between socio-demographic groups, e.g. by gender or ethnicity. Theories that attempt to explain individual earnings, though, do not offer any explanation for such heterogeneity. In fact, we

argue that such findings result from omitted variable bias as they are confounded by the influence of unobserved determinants of earnings. As our linked data set allows us to comprehensively control for important characteristics such as the educational and employment history, as well as tenure and job characteristics, we do not expect to find significant heterogeneity in the rewards to basic skills. Consequently, *Hypothesis 4* reads as follows:

> **H4:** Rewards to literacy and numeracy do not vary between different sub-groups in the labor market.

4 Data

For our empirical analysis we use a combination of data sources that is innovative and unique in several aspects, even beyond the German context. We bring together longitudinal survey data on educational activities with actual measures of basic skills and top that off with accurate and reliable earnings information from administrative employment data. The origin of the data is the survey "Working and Learning in a Changing World" (ALWA), which was conducted in 2007/2008 and included 10177 retrospective interviews.[5] A broad set of cross-sectional variables includes, for instance, the migration background as well as language skills. The longitudinal survey data comprise monthly educational, employment, residential, partnership and parenthood histories. One of the main foci of the questionnaire has been on educational activities. That allows for a particularly accurate measurement of human capital investments over the life courses of the respondents.

About 4000 of the ALWA respondents also took part in basic skills tests in the domains prose literacy and numeracy. These tests had originally been designed for IALS and ALL but were adapted for ALWA by the Educational Testing Service (ETS), Princeton. Both domains were tested in a separate, fully fledged battery of tasks, with an average duration of 30 minutes per battery.[6] As defined above, the results of the tests in both domains reflect the respondents' knowledge and skills relevant in situations of everyday life as well as on the job.

The tests on these basic skills were run only once, shortly after the longitudinal interview in ALWA, so that we have a cross-sectional measure only. Although these types of skills are potentially subject to change over time, we have to assume them to be constant over our observation period to be able to do more than mere cross-sectional analysis. In particular, we only consider employment spells in the year of measurement and up to three years after that. During this relatively short time-span, we have to rely on the assumption that basic skills are not likely to change substantially.

[5] The acronym is derived from the study's German name "Arbeiten und Lernen im Wandel". More information on the data is given by Kleinert et al. (2011). The data are provided by the Research Data Centre of the Federal Employment Agency at the Institute for Employment Research (FDZ). See http://fdz.iab.de/en.aspx for further information.

[6] See Kleinert et al. (2012) for more details on test design and scaling of the skill measures in the so-called ALWA-KOMP data.

Both data sets are linked with the Integrated Employment Biographies (IEB), which provide daily longitudinal information about dependent employment, registered unemployment, job search activities as well as on participation in measures of active labor market policy. The IEB are derived from administrative data of the German Federal Employment Agency, which are based on mandatory social security notifications by employers and data from internal processes of the local employment agencies (see Jacobebbinghaus and Seth, 2007). That is why the given information on earnings is highly accurate and reliable.[7]

These administrative data have some shortcomings, though we argue that they are not relevant for our analysis. First, the data do not include spells of self-employed, civil servants or students in higher education, as these groups do not contribute to the pension insurance schemes underlying the data of the Federal Employment Agency. However, neither of these groups is relevant when examining the valuation of basic skills in dependent employment. The majority of German civil servants are remunerated according to strict rules and mainly on the basis of their position. This does not leave much room for differentiation on the basis of individual skills, nor is career advancement of civil servants mainly determined by such skills. The income of self-employed is determined by the success of their enterprise and is therefore not comparable to income from dependent employment.

Second, information on educational levels provided by employers are not relevant for social security entitlements, which is why they are reported less accurately and less comprehensively than information on earnings. This leads to missing or inconsistent information on educational levels in about 10% of the employment spells in the IEB. As we combine the administrative employment data with ALWA, we are able to compensate for this shortcoming by using the detailed educational histories given in the survey data.

For our empirical analyses we are only able to use data on ALWA respondents who both participated in the skills tests and could be identified in the administrative data. The intersection of these cases, the removal of cases with missing values, a restriction on spells of full-time employment as well as the exclusion of spells of current vocational training relationships finally lead to data on 1818 individuals. This leaves us with a total of 5924 observations over the period 2007-2010, with a reference date of June 30.[8] Table 1 provides descriptive sample statistics and indicates the source of each variable.

Our dependent variable reflects the log monthly gross earnings computed for each of the above spells, deflated to the year 2005 by the consumer price index. Our central interest lies on the relationship of these earnings with individuals' basic skills, prose literacy and numeracy. To ease interpretation of the estimated coefficients, the scores from the tests are standardized and

[7] See Antoni and Seth (2012) for an introduction to ALWA-ADIAB, a combined version of ALWA and the IEB, and its availability at the FDZ. For more details on the linkage procedure see Antoni (forthcoming).

[8] See Table A.1 in the appendix on the loss of observations due to each of the data preparation steps. All other tables were produced using *estout.ado* (see Jann, 2005, 2007).

Table 1: Sample statistics of independent variables

	source	mean	s.d.	min	max
Literacy (ML estimate)	S	307.64	(34.10)	153	500
Numeracy (ML estimate)	S	307.98	(53.87)	0	500
No professional degree	S	0.07	(0.26)	0	1
Vocational degree	S	0.67	(0.47)	0	1
Academic degree	S	0.25	(0.43)	0	1
Employment experience in years	A	17.52	(8.33)	.033	36
Male	S	0.65	(0.48)	0	1
Age in years	S	41.28	(8.64)	19	54
Migration background	S	0.18	(0.39)	0	1
Native language German	S	0.97	(0.18)	0	1
East Germany	A	0.18	(0.38)	0	1
Tenure in years	A	6.89	(6.79)	.0028	36
Firm size (no. of employees)	A	1213.78	(4931.68)	1	52156
2007	A	0.24	(0.43)	0	1
2008	A	0.25	(0.43)	0	1
2009	A	0.26	(0.44)	0	1
2010	A	0.26	(0.44)	0	1

Notes: ALWA-ADIAB, ALWA-KOMP, own unweighted calculations based on 5924 observations. Omitted: occupation and industry dummies. Letters S or A denote survey or administrative data, respectively.

included as z-scores with a mean of zero and unit standard deviation. The second important aspect of human capital in our analysis, professional qualification, is measured by the levels "no professional degree", "vocational degree" and "academic degree". Another element of human capital is employment experience. We are able to differentiate between the total employment experience and tenure in a given job, which we both compute based on the employment history given in the administrative data, and include as a polynomial.

In addition to that we control for the respondent's age, as most elements of cognitive functioning, including both cognitive abilities and basic skills, are subject to decline over the life-course (Hertzog et al., 2008). That is why it is important to control for employment experience as well as age in the given context. To account for the fact that the gender wage gap is considerable in Germany (see Antonczyk et al., 2010), the gender of the respondent is included as a dummy variable. A first, second or third generation migration background is defined by a single dummy variable and is supplemented by whether the respondent's native language is German.

Contrary to the human capital theory, job and firm characteristics are considered as important predictors of individual earnings in theories of segmented labor markets (see Leontaridi, 1998). Along the line of these theories we include a number of variables reflecting the demand side of the job relationship. These variables are the occupational segment (10 categories), the

firm's size and its industry (18 categories) as well as the year of the employment spell (years 2007-2010). As labor market outcomes in Germany are strongly related to regional aspects, we include a dummy variable for being employed in East Germany.

5 Empirical Analysis

Method

We estimate a Mincer-type earnings equation (Mincer, 1958) augmented by the scores of prose literacy and numeracy as well as the set of control variables as outlined in the previous section. This is summarized by

$$\ln y_{it} = x'_{it}\beta + c'_i\gamma + u_{it}, i = 1, ..., N, t = 1, ..., T. \tag{1}$$

The dependent variable $\ln y_{it}$ are the log monthly gross earnings, x_{it} is the vector of controls, and c_i represents the proficiency scores in numeracy and prose literacy, standardized as z-scores. The idiosyncratic error term is denoted by u_{it}, and the parameters of interest are β and γ. The data provide us with an unbalanced panel structure with up to four observations per person.

We estimate the earnings equation using feasible GLS random effects regression (Balestra and Nerlove, 1966). As we have to assume that there is correlation between different observations of a given respondent, we introduce α_i as an individual-specific component of the error term:

$$u_{it} = \alpha_i + \epsilon_{it}. \tag{2}$$

To test whether this improves our specification compared to a regression with a single error term we use a modified version of the Breusch-Pagan Lagrange multiplier test (Breusch and Pagan, 1980) for random effects that is suitable for unbalanced panels (Baltagi and Li, 1990). The null hypothesis is that the individual-specific component of the error term is not different from zero ($H_0 : \sigma^2_\alpha = 0$). This would imply that the error correlation between different observations of a given individual is negligible and pooled ordinary least squares regression is adequate for our analysis. This null hypothesis is clearly rejected (χ^2: 4615.06, p: 0.000).

By computing standard errors that correct for clustering on the individual level (see Huber, 1967; White, 1980) we specifically consider the intra-individual correlation between different observations. If we did not, the standard errors would be biased downwards despite the fact that we already consider the panel structure by using the random effects model.

Results

The first panel of Table 2 shows our estimates including the basic skills measures, which we compare to a more standard earnings regression given in the second panel in order to examine whether and to what extent the returns to education are affected by omitting individuals'

capabilities. As basic skills are included as standardized terms, we learn that an increase of literacy or numeracy by one standard deviation is related to an increase in monthly earnings by 3% or 6%, respectively, which is line with Hypothesis 1. Compared to prior research for other countries, the skills premia are lower. This is, however, not problematic as it may be caused by, for example, differences in wage settings schemes, or differences in the sample structures. The differential in the coefficients furthermore hints at a stronger relationship between earnings with numeracy than with literacy, but a Wald test shows that the difference between the two coefficients is not statistically significant (χ^2: 2.37, p: 0.124). Our results therefore show that basic skills do matter but, in line with Hypothesis 3, that there are no different rewards by skill type.

Table 2: Augmented Mincer-type earnings equation, random effects GLS estimates with and without basic skills scores, respectively (2007-2010)

	with scores (1)		without scores (2)	
Literacy (z-score)	0.031***	(0.012)		
Numeracy (z-score)	0.058***	(0.011)		
Vocational degree	0.109	(0.109)	0.128	(0.108)
Academic degree	0.407***	(0.098)	0.479***	(0.094)
Employment experience in years	0.041***	(0.005)	0.040***	(0.005)
Employment experience squared/100	−0.039***	(0.012)	−0.038***	(0.012)
Male	0.265***	(0.028)	0.282***	(0.028)
Age in years	0.012	(0.010)	0.016	(0.010)
Age squared/100	−0.028**	(0.013)	−0.034***	(0.013)
Migration background	0.036	(0.029)	0.018	(0.029)
Native language German	−0.042	(0.057)	−0.010	(0.059)
East Germany	−0.092***	(0.027)	−0.106***	(0.027)
Tenure in years	0.009***	(0.003)	0.009***	(0.003)
Tenure squared/100	−0.031**	(0.013)	−0.031**	(0.013)
Firm size (no. of employees)	0.000***	(0.000)	0.000***	(0.000)
Firm size squared/100	−0.000***	(0.000)	−0.000***	(0.000)
Constant	6.614***	(0.224)	6.480***	(0.222)
R^2 overall	0.488		0.475	
R^2 between	0.511		0.498	
R^2 within	0.086		0.084	
Observations	5924		5924	

Notes: ALWA-ADIAB, ALWA-KOMP, own calculations, log monthly earnings as dependent variable, cluster-robust standard errors in parentheses. ***/ **/ * indicates significance at the 1/ 5/ 10% level. Reference: no professional degree. Variables not shown: occupation, industry and year dummies.

As for the standard human capital covariates, we find that in neither of the two specifications do respondents with a vocational degree earn significantly more than those without any professional degree. This may seem puzzling but is likely due to the sample's restriction on spells of full-time employment. Those individuals without any professional degree that manage to become full-time employed are most likely a positive selection in terms of their productivity.

Investing in an academic degree is related to substantially higher earnings compared to people without a formal professional qualification. The earnings premium is larger than 60% in the standard Mincer earnings regression (column 2), which decreases to some 50% when controlling for basic skills (column 1). Thus, some part of the earnings differences between people with different levels of qualification does indeed stem from differences in skill endowments. Not all of the earnings gap can be attributed to mere differences in educational credentials, as the signaling theory would imply. However, the coefficients for vocational and academic degrees significantly differ in the specifications both with and without the basic skills measures (χ^2: 68.37, p: 0.000 and χ^2: 78.95, p: 0.000, respectively), showing that university graduates earn more than vocationally trained workers, even when controlling for basic skills.

There is evidence for a considerable gender earnings gap. Although a coefficient of 27% may appear particularly high, it is in line with the findings of Antonczyk et al. (2010). It might also be explained by the fact that we include spells in our analysis on the basis of an administrative variable that differentiates between full-time and part-time jobs. Among those classified as full-time employed, the regular weekly working hours may still vary considerably. As we do not observe such deviations, and because our dependent variable measures the gross monthly earnings instead of the hourly wage, the gender earnings-gap may be due to different working time patterns between women and men. Moreover, we cannot control for overtime or shiftwork payments, which might also vary strongly between women and men.

Furthermore, there is a earnings gap of 9% for people working in the eastern part of Germany, compared to their West German counterparts. Moreover, although not statistically significant, the coefficient on individuals with migration background would imply a remarkable result inasmuch as it indicates higher earnings compared to native Germans. Since well educated people are over-represented in our data (Kleinert et al., forthcoming), we assume that to be a result of sample selectivity in terms of willingness to take part in the skills tests.

We also examine whether there is non-linearity in the relationship between basic skills and earnings. In the specification shown in Table 3 we additionally include squared terms of literacy and numeracy. Both literacy and numeracy remain to be positively related to earnings, as indicated by the individual significance of both linear terms, but neither of the squared terms is statistically significant. Furthermore, Wald tests clearly reject the hypothesis that the linear and the quadratic terms for literacy and numeracy are jointly equal to zero (χ^2: 6.80, p: 0.033 and χ^2: 25.72, p: 0.000, respectively). As the positive relationship between basic skills and earnings seems to be linear, we conclude that there would be a monetary payoff to efforts of increasing a person's basic skill endowments, regardless of where she might initially be located in the skill distribution.

To examine potential heterogeneity in the skills-earnings relationship between different groups in the labor market, Table 4 provides the results of a specification that includes regressors interacting the skills measures with other important control variables. The single coefficient of

Table 3: Augmented Mincer-type earnings equation, random effects GLS estimates including squared basic skills scores (2007-2010)

Literacy (z-score)	0.030**	(0.014)
Literacy (z-score, squared)	−0.000	(0.003)
Numeracy (z-score)	0.059***	(0.013)
Numeracy (z-score, squared)	−0.002	(0.004)
Vocational degree	0.107	(0.110)
Academic degree	0.406***	(0.099)
Employment experience in years	0.041***	(0.005)
Employment experience squared/100	−0.039***	(0.012)
Male	0.265***	(0.028)
Age in years	0.012	(0.010)
Age squared/100	−0.028**	(0.013)
Migration background	0.037	(0.029)
Native language German	−0.044	(0.056)
East Germany	−0.092***	(0.027)
Tenure in years	0.009***	(0.003)
Tenure squared/100	−0.031**	(0.013)
Constant	6.658***	(0.225)
R^2 overall	0.488	
R^2 between	0.510	
R^2 within	0.126	
Observations	5924	

Notes: ALWA-ADIAB, ALWA-KOMP, own calculations, log monthly earnings as dependent variable, cluster-robust standard errors in parentheses. ***/ **/ * indicates significance at the 1/ 5/ 10% level. Reference: no professional degree. Variables not shown: occupation, industry, firm size and year dummies.

numeracy strongly increases to 18%, whereas that of literacy is almost reduced to zero. Only the non-interacted coefficient of numeracy remains significantly larger than zero, though with a strongly reduced level of statistical significance. The results on the main effects of the level of qualification, sex, migration background, East Germany and tenure remain fairly stable compared to the results given in Table 2, column 1.

Table 4: Augmented Mincer-type earnings equation, random effects GLS estimates including interaction terms (2007-2010)

Literacy (z-score)	0.006	(0.075)
Numeracy (z-score)	0.178*	(0.107)
Vocational degree	0.074	(0.077)
Academic degree	0.386***	(0.077)
IA vocational degree x literacy	0.055	(0.085)
IA academic degree x literacy	0.021	(0.076)
IA vocational degree x numeracy	−0.137	(0.130)
IA academic degree x numeracy	−0.091	(0.107)
Male	0.266***	(0.028)
IA male x literacy	−0.021	(0.024)
IA male x numeracy	−0.004	(0.024)
Migration background	0.029	(0.029)
IA migration background x literacy	−0.050*	(0.029)
IA migration background x numeracy	−0.004	(0.035)
East Germany	−0.090***	(0.028)
IA East Germany x literacy	0.026	(0.031)
IA East Germany x numeracy	−0.056**	(0.027)
Tenure in years	0.009***	(0.004)
IA tenure x literacy	0.002	(0.001)
IA tenure x numeracy	−0.001	(0.003)
Constant	6.662***	(0.209)
R^2 overall	0.487	
R^2 between	0.507	
R^2 within	0.095	
Observations	5924	

Notes: ALWA-ADIAB, ALWA-KOMP, own calculations, log monthly earnings as dependent variable, cluster-robust standard errors in parentheses. ***/ **/ * indicates significance at the 1/ 5/ 10% level. Reference: no professional degree. Variables not shown: age (squared), employment exp. (squared), native language, tenure squared, occupation, industry, firm size and year dummies.

Although the joint significance of the four interaction terms of the basic skills measures with the dummies on levels of qualification is rejected by a Wald test ($\chi^2(4)$: 3.06, p: 0.547), we should pay attention to the economic significance of the results. People in the reference category, i.e. those without any formal professional degree, do show payoffs to basic skills, as indicated by the jointly significant main effects of the basic skills, and their payoffs are not significantly different from those of the better qualified. In a sense this result conveys a positive message, as low-qualified workers experience the same payoffs to basic skills as do better qualified workers.

Judging by the significantly negative coefficient of the regressor interacting a person's migration background with literacy, migrants seem to gain less from literacy than German natives. Furthermore, a Wald test shows that both migration-related interaction terms are jointly significant ($\chi^2(2)$: 4.76, p: 0.092). These are unexpected findings, especially as we also control for whether the native language of a given person is German, so a lack of language skills should not be the reason behind our findings. The result is also not confounded with any potential selection of migrants into certain jobs, as we also control for the occupational segment and the industry of the firm. We attribute the finding to unobserved individual or job characteristics, such as discrimination against migrants by their employers, and to the selection of respondents into the test sample.

The interaction between the dummy variable indicating a job in East Germany with numeracy yields a significantly negative coefficient, indicating a smaller reward for this basic skill than in jobs in West Germany. This finding can not be due to differences in the occupational or industry structures between East and West Germany, as we do control for these characteristics. One possible explanation would be persistent differences in collective bargaining coverage between East and West Germany (Addison et al., 2011). Unfortunately, our data do not include information on the wage setting regime of a given firm. Neither to they include information on overtime or shiftwork payments. Differences in payed working hours at a given earnings level between East and West Germany may thus partially explain this finding. Apart from the results regarding the migration background and East Germany, the lack of heterogeneity in rewards for different socio-economic groups corroborates Hypothesis 4.

We also included an interaction of the continuous variable tenure with both basic skill domains to infer whether actual skills are rewarded more strongly the longer someone is employed at a given firm. However, we do not find any evidence in support of employer learning (Hypothesis 2) in our data. The related interaction terms are not significant, neither taken by themselves nor tested jointly ($\chi^2(2)$: 1.62, p: 0.445).

Although there are only few significant individual coefficients, both literacy with its related interaction terms and numeracy with its interaction terms are jointly significant ($\chi^2(7)$: 18.94, p: 0.008 and $\chi^2(7)$: 32.21, p: 0.000, respectively). This is also true if testing both basic skills coefficients with all their interaction terms combined in one Wald test ($\chi^2(14)$: 66.00, p: 0.000). This tells us that there is a robust positive relationship between basic skills and earnings, even in a specification as highly differentiated as in Table 4.

Sensitivity Analyses

To infer whether our findings are a result of our specific estimation sample, of the model specification we have chosen or of general assumptions we have made, we ran a number of sensitivity analyses. The most important results are discussed in this section. Estimation results not shown here are available from the authors upon request.

We argue that it is plausible to assume that basic skills are constant at least over the short run. To test whether our four-year observation period is short enough to fulfill that assumption, we ran additional regressions based on a sample restricted to the years 2007 and 2008. If the results should differ from those of the main model, we might have to call our assumption into question. The results, which are shown in Table A.2 do not differ substantially from those shown in Table 2, column 1.

A further test examines whether the loss of individuals from the whole survey population to the intersection of the tested and successfully linked respondents shown in Table A.1 reduced the generalizability of our results. To do so, we re-estimated the standard Mincer earnings equation without basic skills scores based on all respondents with linked administrative data, regardless of whether they have been tested. The results (see Table A.3) do not differ substantially from results based on the smaller sample shown in Table 2, column 2.

Despite the highly reliable income information given in the administrative data, there is one remaining shortcoming: earnings are only measured accurately between the lower and the upper earnings limits for social security contributions, which vary over subsequent years. A few spells show values of gross monthly earnings that are outside that range for their given year. We therefore estimated our main model without those 47 cases (0.8 percent of the original sample). Again, our previous results remain robust.

Finally, we tested whether our results are robust to different specifications of a worker's formal educational level, as it is one of the central characteristics of a Mincer earnings equation. We therefore ran analyses including "years of education" instead of levels of professional education. We chose the latter for our main specification as they are more appropriate in the German context with its distinctive dual apprenticeship training system. The results of the alternative specification corroborate our main findings.

6 Conclusions

We add to the literature by analyzing whether basic skills are rewarded on the German labor market in terms of gross earnings differentials by adults' literacy and numeracy skills. Evidence on this is relevant from both the economist's and the policy maker's perspective. For economists, knowing whether there are rewards for basic skills beyond formal schooling enhances our understanding of returns to education. For policy makers, learning about the relationship between labor market outcomes and different types of basic skills may help to improve the design of, for example, "lifelong learning" programmes.

Our analysis is based on a unique data set, a combination of the ALWA-ADIAB and ALWA-KOMP data, which enables us to measure both domains of basic skills and to combine them with comprehensive information on educational histories and reliable and accurate register earnings data for Germany. We therefore provide the first evidence for Germany regarding this

question. Conditional on formal education, socio-economic controls as well as job and firm characteristics, our results show significant payoffs to both skills. In particular, a one standard deviation increase in numeracy is, on average, associated with a 6 percent increase in gross earnings of full-time employed workers, whereas there is an earnings differential of 3 percent for a standard deviation increase in literacy. Compared to prior research for other countries, these premia are lower. This may, however, be caused by differences in wage settings schemes between Germany and these countries, or differences in the sample structures. Moreover, to put this into perspective, the payoff to numeracy is larger than the return to the first year of a worker's job experience, which, according to our main specification, amounts to about 4 percent.

Findings from extensions of our main specification show a linear relationship between earnings and both numeracy and literacy. Beyond that, there is only little evidence on heterogeneity for different groups. There is, in particular, no significant differential in the returns to basic skills by gender, and only small gradients by migration background or by region (East-West). Given that our theoretical considerations have not given us any reason to expect such heterogeneity, this result is not surprising. The contrast to other studies, which do find heterogeneity in payoffs to basic skills between different groups in the labor market, may be because of differences in the sample composition or because of the fact that our linked data set allows us to control for otherwise unobservable individual and job characteristics. We may thus have been able to avoid omitted variable bias more comprehensively than some of the previous studies.

There may be no significant differences between literacy and numeracy, no non-linearity and no measurable heterogeneity across different groups of workers regarding the relationship between earnings and basic skills. But there may well be differences in the cost of—or necessary effort for—an increase in skill endowments between the skill domains. These costs may also depend on the initial place in the skill distribution of a person, or on any other characteristic considered in this analysis for that matter. To infer whether efforts to increase basic skills of a given person are a worthwhile investment in her human capital, one would have to compare the potential payoffs of these efforts with their costs. However, there is no empirical evidence on how much effort it takes to raise a person's literacy or numeracy level by, say, one standard deviation. We would thus argue that empirical evidence on the cost of skill improvements, differentiated by characteristics of a potential learner, is necessary for conclusions regarding the cost-effectiveness of investments in basic skills. Policy advice regarding a targeting or tailoring of learning programs for specific groups in the labor market can not be given on the basis of these results.

Although a generalization of our results is not possible in a straightforward manner, and policy implications have thus to be handled carefully, our analysis is a useful starting point for further discussion on the rewards of adults' basic skills in the labor market.

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Appendix

Table A.1: Numbers of cases by step of data preparation

	Persons	Spells
ALWA respondents (German interviews)	10177	
Tests participants	3980	
Respondents with linked administrative data	8022	
Respondent with administrative and skills data	3263	
After selection of cases	1818	5924
2007	1412	1412
2008	1478	1478
2009	1515	1515
2010	1526	1526

Source: ALWA-ADIAB, ALWA-KOMP, own calculations.

Table A.2: Augmented Mincer-type earnings equation, random effects GLS estimates, restricted to years 2007/2008

Literacy (z-score)	0.028**	(0.014)
Numeracy (z-score)	0.053***	(0.014)
Vocational degree	0.293	(0.180)
Academic degree	0.547***	(0.166)
Employment experience in years	0.046***	(0.006)
Employment experience squared/100	−0.062***	(0.015)
Male	0.282***	(0.035)
Age in years	0.008	(0.012)
Age squared/100	−0.018	(0.015)
Migration background	0.049	(0.033)
Native language German	−0.082	(0.068)
East Germany	−0.104***	(0.030)
Tenure in years	0.006	(0.004)
Tenure squared/100	−0.026*	(0.015)
Firm size (no. of employees)	0.000***	(0.000)
Firm size squared/100	−0.000***	(0.000)
Constant	6.632***	(0.306)
R^2 overall	0.473	
R^2 between	0.479	
R^2 within	0.229	
Observations	2887	

Notes: ALWA-ADIAB, ALWA-KOMP, own calculations, log monthly earnings as dependent variable, cluster-robust standard errors in parentheses. ***/ **/ * indicates significance at the 1/ 5/ 10% level. Reference: no professional degree. Variables not shown: occupation, industry and year dummies.

Table A.3: Mincer-type earnings equation, random effects GLS estimate based on all linked cases, regardless of test-participation (2007-2010)

Vocational degree	0.059	(0.037)
Academic degree	0.445***	(0.035)
Employment experience in years	0.033***	(0.003)
Employment experience squared/100	−0.027***	(0.008)
Male	0.285***	(0.017)
Age in years	0.021***	(0.006)
Age squared/100	−0.036***	(0.008)
Migration background	0.014	(0.016)
Native language German	0.023	(0.030)
East Germany	−0.136***	(0.017)
Tenure in years	0.009***	(0.002)
Tenure squared/100	−0.031***	(0.007)
Firm size (no. of employees)	0.000***	(0.000)
Firm size squared/100	−0.000***	(0.000)
Constant	6.375***	(0.142)
R^2 overall	0.476	
R^2 between	0.491	
R^2 within	0.039	
Observations	15297	

Notes: ALWA-ADIAB, own calculations, log monthly earnings as dependent variable, cluster-robust standard errors in parentheses. ***/ **/ * indicates significance at the 1/ 5/ 10% level. Reference: no professional degree. Variables not shown: occupation, industry and year dummies.

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