Thorsten Euler* and Fabian Trennt**

More or less the same?

An exploration of the evolution of the PhD wage premium in a decade of higher education expansion.***

Abstract: The expansion in higher education over the last decade or more has led to an increase in the number of tertiary education graduates entering the labor market, both with and without doctoral degrees. On the one hand this process has been accompanied by concerns of graduate oversupply; on the other hand, proponents of higher education expansion point towards an increasing demand for highly-skilled workers in a knowledge-based economy, especially concerning PhD holders, as they are the driving forces of innovation. Against this backdrop we ask to what extent higher education expansion has affected the earnings of PhD graduates in comparison to higher education graduates without doctoral degrees. Our analysis is based on the 1997, 2001, 2005, and 2009 cohorts of the German Centre for Higher Education and Science Studies (DZHW) graduate panel studies. Within these, surveys were conducted for each respective cohort about ten years after graduation. In accordance with human capital theory, we find a constant PhD wage premium between the different cohorts for those employed in the private sector. In the public sector, we detect a stable but insignificant PhD wage premium. Descriptive and analytic results show a significant wage growth for the 2009 cohort, regardless of sector and PhD state.

Keywords: higher education expansion; labor market returns; graduates; wages; doctoral degree

Alles beim Alten?

Eine Untersuchung der Entwicklung der Lohnprämien von Promovierten in Zeiten der Bildungsexpansion

Zusammenfassung: Im Zuge der Ausweitung hochschulischer Bildung in den letzten Jahrzehnten drängt eine steigende Zahl von Hochschulabsolvent*innen – mit und ohne Doktortitel – auf den Arbeitsmarkt. Einerseits wurde dieser Prozess

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von der Sorge eines Überangebots an Hochschulabsolvent*innen begleitet, andererseits verweisen die Befürworter*innen der Expansion des Hochschulwesens auf die steigende Nachfrage nach hochqualifizierten Arbeitskräften in einer wissensbasierten Wirtschaft. Dies gilt insbesondere für promovierte Beschäftigte als treibenden Kräfte der Innovation. Vor diesem Hintergrund stellen wir die Frage, inwieweit sich die hochschulische Bildungsexpansion auf die Einkommen von Promovierten im Vergleich zu Hochschulabsolvent*innen ohne Doktortitel ausgewirkt hat. Unsere Analyse basiert auf Daten des Absolventenpanels des Deutschen Zentrums für Hochschul- und Wissenschaftsforschung (DZHW). Dort wurden Hochschulabsolvent*innen der Abschlussjahrgänge 1997, 2001, 2005 und 2009 jeweils etwa zehn Jahre nach ihrem Studienabschluss befragt. Im Einklang mit der Humankapitaltheorie finden wir einen konstanten Einkommensgewinn für Promovierte aller Kohorten in der Privatwirtschaft. Im öffentlichen Dienst hingegen lässt sich nur ein insignifikanter Lohnvorteil feststellen. Deskriptive und analytische Ergebnisse zeigen einen signifikanten Lohnzuwachs für die Abschlusskohorte 2009, unabhängig von Sektor und Promotionsstatus.

Stichworte: Bildungsexpansion; Arbeitsmarkterträge; Hochschulabsolvent*innen; Löhne; Promovierte

Introduction

Higher education is on the rise worldwide (Schofer/Meyer 2005). Although a latecomer to this trend, Germany is no exception (Alesi/Teichler 2013). Over the last two decades a growing number of people have become eligible to further their learning at an institution of tertiary education (Autorengruppe Bildungsberichterstattung 2018). Consequently, there has been an increase in the number of higher education graduates, in the proportion of tertiary degrees among those eligible to study, and also in the proportion of young people entering the labor market (Autorengruppe Bildungsberichterstattung 2018). Regarding those graduating, the rate of expansion has been fairly steady, while the development with respect specifically to doctoral degrees has been more erratic[1] (Konsortium BuWiN 2017).

Insofar as education is perceived as a means to generate earnings (Becker 1962; Mincer 1958; Spence 1973) or gain access to different social classes (Breen/Goldthorpe 1997) questions arise concerning the labor market consequences of this differential shift in labor supply. Critical observers believe that the recent educational expansion went too far, and they anticipate an excess of tertiary education graduates on the labor market (Di Paolo/Mañé 2016; Nida-Rümelin 2014; Schleglmilch 1987). Assuming a constant demand for higher education graduates, they predict poorer employment prospects for recent graduate cohorts. In Germany about 13 percent of all doctoral degree holders report that they are employed in

1 For a more detailed discussion see section 2.

jobs that do not require such a high level of education (PhD), which marks a middle position in comparison to other OECD countries (Auriol 2010: 14). Technological progress, however, changes skill demand (skill-biased technological change); the ability to cope with uncertain situations becomes more and more important while routine-based tasks will increasingly be carried out by machines and algorithms (Frey/Osborne 2017). So whereas computer technology substitutes for the latter, it complements non-routine complex tasks, thereby making incumbents of respective jobs more productive (Autor/Levy/Murnane 2003), which should in turn lead to higher rewards on the labor market. As tertiary graduates are said to possess those necessary skills (Acemoglu/Autor 2011) the negative consequences of computerization should be less severe for them (Dengler/Matthes 2015). This should particularly hold true for PhD graduates who are trained for complex and innovative tasks and processes (i.e. performing non-routine tasks) (Arbeitskreis Deutscher Qualifikationsrahmen 2011; Bogle/Dron/Eggermont/van Henten 2010; Diamond/Ball/Vorley/Hughes/Moreton/Howe/Nathwani 2014) – skills that are very important for countries such as Germany, who are poor in natural resources. As such, PhD holders are in a crucial position in shaping a knowledge-based economy (Di Paolo/Mañé 2016; Neumann/Tan 2011). Because educational decision making depends on expected returns to education (Breen/Goldthorpe 1997; Esser 1999), transparent, research-based information on returns to education are of utmost importance for a knowledge-based economy to guarantee an unbiased allocation of human capital. In the absence of this information a growing share of graduates might refrain from taking up PhD studies if the level of perceived returns is below that of actual returns. Vacancies demanding PhD skills would not be able to be staffed, which would lead to a reduction in innovation and future economic growth. In contrast to that, perceived returns exceeding actual returns would attract too many PhD candidates, resulting in a growing share of PhD holders occupying jobs where PhDs are unnecessary.

While we already have some insight into the labor market rewards that are associated with a PhD degree (Goldan/Jaksztat/Gross 2022) and the underlying mechanisms (Goldan 2021; Trennt/Euler 2019), a systematic longitudinal analysis with respect to this degree is quite rare and still lacking for the German context. Most of the existing research focusing on monetary returns of higher education graduates with and without a doctorate suggests that a PhD degree pays off (Engelage/Hadjar 2008; Falk/Küpper 2013; Heineck/Matthes 2012; Mertens/Röbken 2013; O'Leary/Sloane 2005; Trennt/Euler 2019; Wouterse/van der Wiel/van der Steeg 2017)[2]. The only longitudinal studies available that focus on changes in the returns to education due to the educational expansion in Germany do not distinguish PhD holders from other graduates. The results of relevant work are differentiated mainly

2 In contrast, Pedersen (2016) sees no wage differentials between these two groups. According to her, the differing results are due to the method used (some kind of (propensity score) matching algorithm) which eliminates unobserved heterogeneity.

by gender and analytical perspective[3]. With the exception of the late 1990s, no general decline in the monetary returns to education is reported (Gebel/Pfeiffer 2010; Göggel 2007; Lauer/Steiner 2004). More or less constant returns to higher education can also be observed with respect to access to the service class (Klein 2011; Müller/Brauns/Steinmann 2002). However, taking into consideration that the various birth cohorts might be affected differently by educational expansion, Lauer/Steiner (2004) and Boockmann/Steiner (2006) find slightly lower returns for the more recent cohorts. These results are more pronounced for women than for men. With a special focus on tertiary education graduates, Reinhold/Thomsen (2017) detect a rising wage premium from 1990 onwards for labor market entrants with higher education, in contrast to that for medium and low-skilled workers. However, the results found by Henseke (2018) suggest that this only holds true for men, while there is no wage premium for women of more recent cohorts compared to their predecessors.

To the best of our knowledge, up to this day there is only one paper that combines the analysis of wage differentials between higher education graduates and PhD holders with a longitudinal perspective. For Switzerland, Engelage/Hadjar (2008) detect no general trend in the development of the differences in earnings, risk of unemployment, or vertical job adequacy between tertiary graduates with and without a PhD. They specifically report rising advantages in earnings for academics with a doctoral degree in law while the wage differential between engineers with and without a PhD is smaller in more recent cohorts (Engelage/Hadjar 2008). While this work offers valuable insight into the development of the labor market perspectives for doctoral degree holders in Switzerland it remains unclear whether these results can be transferred to the German labor market, as expansion of higher education has been more gradual in Switzerland compared to Germany (Engelage/Hadjar 2008).

Against this backdrop we ask whether higher education expansion has been accompanied by rising, falling, or constant monetary returns to doctoral education in Germany. As the German doctorate – in contrast to many other countries – not only qualifies its holder for research activities within academia but also for many jobs outside (Enders 2002; Franck/Opitz 2007) – especially in departments of research and development in the private sector (Konsortium BuWiN 2017; Buenstorf/Heinisch 2020) – we additionally differentiate our analysis by sector of employment. To answer this question, we use the third waves of the DZHW graduate panel studies 1997, 2001, 2005, and 2009 cohorts. The surveys took place about ten years after the respondents' respective graduation from an institution of higher education in Germany. At this point in time most of the (planned) doctoral

3 As the studies differ among other things with respect to observed periods and cohort classification, a direct comparison is very difficult and should therefore just be understood as a tendency.

studies have already been finished. Besides covering a relevant period of higher education expansion, the data includes some basic variables that explain selection into a PhD degree course, enabling us to consider possible compositional changes between the cohorts. Both aspects make the data suitable to answer the research question. This paper is structured as follows: In the subsequent section (2) we present a theoretical framework to explain why there should be a differential in wages between tertiary graduates with and without a PhD degree and why this difference could have changed during the last decade(s). Section 3 describes the data and the research method. Afterwards (4) we present the empirical results of our analysis. We finish with a discussion and further research perspectives in section 5.

Theoretical Framework

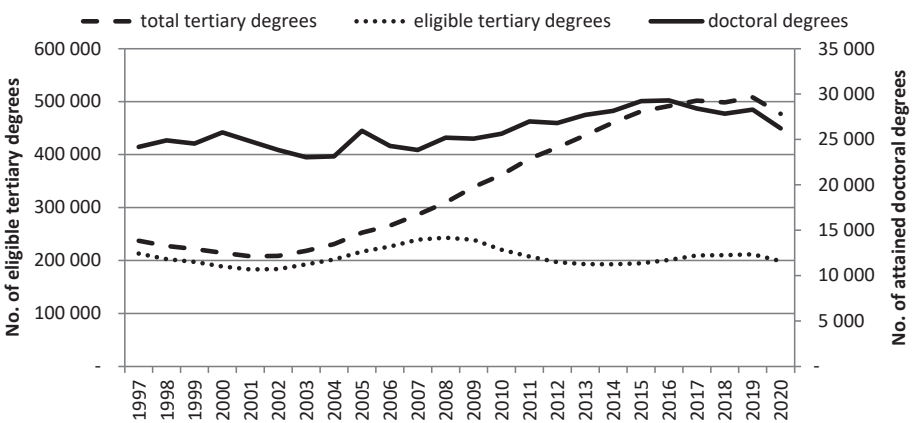
Human capital theory (HCT) postulates that (individual) differences in earnings are exclusively based on differences in marginal productivity (Becker 1962; Mincer 1958). According to this approach, productivity is a function of human capital (i.e., skills and knowledge). It is assumed that human capital itself is not invariable or determined but can be altered (increased) by either investment in education or through on-the-job training. To maximise lifetime profits, individuals voluntarily (if applicable) stay in the educational system (i.e., invest in their personal human capital stock) as long as the additional return exceeds the additional costs of education, and the foregone earnings due to lack of time while learning (opportunity costs). As doctoral degree holders spend more time in the higher educational system compared to graduates without a doctoral degree the former should accumulate more personal human capital which later is converted into higher wages. Thus, we conclude that:

> H1: Graduates with a doctoral degree receive higher wages compared to graduates without a doctoral degree.

However, the central topic of this paper is changes in earnings differential between graduates with and without doctoral degrees, due to changes in the labor market supply of graduates. Therefore, we need to look deeper into the assumption that individuals are always paid by marginal productivity. Being rooted in neoclassical labor market theory, HCT assumes that demand and supply of labor strive to be at equilibrium (Sesselmeier/Blauermel 1998). For this statement to be true, companies must be able to easily adjust their production to new labor supply (McGuinness 2006). Likewise, people are willing and able to adapt educational decision-making to expected returns to education. Hence – from a human capital point of view – it can be argued that changes in wage differentials between graduates with and without doctoral degrees should not be expected, as changes in labor supply would be balanced by either companies or individuals adjusting their decisions based on foreseeable labor market conditions.

Contrary to this, critics argue that in reality companies are not able to adjust production as swiftly as in theory. Instead, they are subject to complexity in work procedures, underlying path dependencies, and rigid institutional arrangements (McGuinness 2006). This argument is supported by the Job Competition Theory (JCT) which states that earnings depend on job characteristics and hence positions (Thurow 1979). Based on this, job positions require certain skills to be exercised. These requirements persist regardless of labor supply. As most work-relevant skills are acquired through training-on-the-job, applicants are selected by the employer according to the expected cost of training. Since these costs are not directly visible, companies utilize background characteristics (education, grades etc.) as a proxy and rank applicants accordingly – a mechanism that resembles the argumentation of signalling theory (Arrow 1973; Spence 1973). Those with the lowest anticipated training costs get the best paid jobs (Thurow 1979). From this perspective, a rising supply in PhD graduates might be accompanied by declining returns because doctoral degree holders increasingly compete for non-doctoral positions with lower wages. However, as this paper tackles wage differentials between graduates with and without doctoral degrees we must also take into account the labor market supply of non-PhD graduates. If supply of this group also exceeds demand, they will compete for less-well-ranked jobs with lower wages, too. Additionally, if PhD holders compete for non-doctoral positions they will oust non-PhD graduates from the best jobs, too.

Figure 1: Higher education expansion in Germany 1997–2020



Source: Statistisches Bundesamt 2022.
Note: Own depiction. Eligible tertiary degrees: Diploma, Magister, Master, State examination.

Therefore, in order to derive hypotheses on the evolution of the PhD-wage-benefit one has to examine the actual supply of tertiary degree holders with and without additional PhDs. As can be seen in figure 1, since its low point around the year

2001, the total number of tertiary degrees completed at German higher education institutions has been rising constantly. Only at the end, in 2020, do all graphs show a sharp drop which can most likely be attributed to the deterioration in study conditions and the delayed completion of exams due to the Covid pandemic.

However, most of the increase needs to be understood in light of the so-called Bologna Process and the transition from the traditional German one-tier system into a two-tier degree system with consecutive Bachelor's and Master's degrees (Bologna Declaration 1999). On the one hand a new group of graduates emerges, completing their studies and leaving the academic system with a Bachelor's degree. On the other hand, even those graduating with consecutive Master's degrees must first achieve a Bachelor's degree. As a result, graduates who previously would have studied a single traditional degree (Diploma, Magister, State examination) began to complete an equivalent Master's degree, building upon an additional previous degree (Bachelor). If we focus only on degrees that generally[4] qualify the holder to pursue doctoral studies (Diploma, Magister, State examination, Master) we can observe the fact that the number of degrees eligible for further doctoral studies has remained fairly constant. It climaxed in 2008 before levelling out to between 200,000 and 210,000 during the last decade. At the same time the number of PhDs attained at German higher education institutions has been rising from about 23,000 in 2003 to more than 29,000 in 2016 (figure 1). Consequently, the ratio of PhD holders compared to eligible graduates increased. Therefore, according to JCT we derive the following hypothesis:

> H2: The PhD wage premium declines for more recent cohorts due to a higher ratio of PhD degrees compared to degrees eligible to pursue a PhD.

A further theoretical strand putting a stronger focus on job characteristics to explain wage differentials is the so called task based approach (TBA) (Autor/Handel 2013). Contrary to JCT it assumes that employers are able to redesign production processes, especially in response to evolution of technology (Autor/Handel 2013). Its main perception lies in the idea of computerization leading to a shift in labor demand in favor of highly-qualified people and a rising polarisation of wages favoring higher education graduates (Autor/Handel 2013). The underlying mechanism is that (non-manual) routine tasks usually performed by less-well-educated employees have been substituted by computer programs while non-routine cognitive tasks performed by highly educated persons are complemented by computer technology making them more productive (Autor/Levy/Murnane 2003). At the same time demand for problem-solving, communication, and improving production (i.e., managing tasks) skills is enhanced (Autor/Levy/Murnane 2003). From this point of view rising wage differentials between groups with different levels of education are conceivable. But employing this argument for possible changes in wage differentials

4 Despite this general mechanism, there are other paths for pursuing a PhD such as fast-track PhD programs that require only a Bachelor's degree.

between graduates with and without PhD degrees assumes substantial differences in skill endowment between these groups. Arbeitskreis Deutscher Qualifikationsrahmen (2011) argues that the additional scientific knowledge and autonomy of attaining a PhD should strenghten the value of the PhD by pushing forward innovation compared to the previously more passive mode of studying a degree. A second argument in favor of PhD holders in this respect may be that this degree indicates managerial skills, as it requires students to carry out complex and tedious tasks while often balancing these with additional employment (Franck/Opitz 2007). Thus, we suggest that:

H3: The wage premium of PhD holders increases for recent cohorts (due to the rising importance of non-routine cognitive tasks and the productivity involved).

However, the ability or need to adapt to changes in labor market supply might differ between private- and public-sector employers, since in the private sector market forces (i.e., competition between companies for market share or customers) probably induce a stronger urge to change compared to public sector companies (Robertson/Seneviratne 1995). Following this reasoning we would expect mechanisms according to JCT be more pronounced in the public sector, while an explanation based on TBA should be more suitable for the private sector. Additionally, according to Doeringer (1967) the private and public sectors each employ different labor market mechanisms. While the public sector is more focused on credentials and objective requirements for job allocation, the private sector is more flexible and oriented at individual performance. Finally, workplaces in the public sector are often subject to tedious decision-making processes while the goal-setting in private companies can be adjusted swiftly.

Summing up, the discussion suggests following hypotheses concerning the evolution of wage differentials between higher education graduates – with and without PhD degrees – alongside higher education expansion in the public and private sectors. JCT assumes compensation according to job characteristics and a more rigid relation of labor demand and supply, allowing changes in wage differentials depending on actual relation on labor market (im)balances between the groups. Contrary to this, TBA suggests a rising demand for non-routine skills and productivity-enhancing technology for those skills and assumes that organisations adapt to technological change. The ability to adapt to changes in labor supply should depend on sector of employment (i.e., private vs. public). So TBA should be more appropriate for the private sector while JCT may paint a more accurate picture for the public sector. This leads to the following hypotheses:

H4: The wage premium of PhD holders between different labor market entry cohorts declines over time in the public sector (according to JCT and slow adaption).

H5: The PhD wage premium between different labor-market entry cohorts in the private sector increases over time (according to TBA and stronger adaption).

Data & Methods

Data

To answer our research question, we use data from the 1997, 2001, 2005, and 2009 cohorts of the DZHW Graduate Panel Study, a survey conducted by the German Centre for Higher Education Research and Science Studies (DZHW).[5] Since 1989, every four years a representative sample of graduates who attained an academic (tertiary) degree from a state-approved institution[6] of higher education in Germany in the respective academic year of the cohort (i.e., winter term 2008/2009 and summer term 2009 for the 2009 cohort) is drawn. Graduates are invited to participate in three surveys ("waves") about one, five, and ten years after graduation respectively. Originally, respondents were only comprised of graduates with the traditional degrees Diploma, Magister, and State examination. For the 2005 cohort an additional non-representative sample of graduates with a Bachelor's degree was deliberately drawn. Due to its deviating sampling procedure and limited representativeness this sample was excluded from our analysis. This ensures greater homogeneity between cohorts and improved comparability of respondents. The 2009 cohort consists of graduates with traditional degrees or Bachelor's degrees, with the latter predominantly having obtained a Master's degree by the time of the third survey (Autorengruppe Bildungsberichterstattung 2020: 196f.; Briedis/Klüver/Trommer 2016).

For our analysis we use data collected in the first (about one year after graduation) and third (about ten years after graduation) wave of each cohort. Data from the first wave includes non-time-dependent information such as the gender of the respondent, educational background of parents, and the final grade of the higher education entrance certificate. Time-dependent information such as the attainment of a PhD, current hourly wages, and professional experience were utilized from the third wave. The third survey was chosen as most graduates pursuing a PhD have finished studying at this point of time and graduates (with and without PhD) have generally had time to establish themselves on the labor market (Euler/Trennt/Trommer/Schaeper 2018).

Like most other (panel) data the DZHW-graduate panel studies suffer from item- and unit-nonresponse that might bias the results if it occurs non-randomly (Schnell/Hill/Esser 2013). In order to mitigate this problem we calculated panel attrition weights (Enders 2010) for the respective cohorts by following the procedure described in Baillet/Franken/Weber (2019). Additionally, we handled missing data by including them as separate categories except for our main independent variable (PhD state) and the dependent variable. We decided against multiple

5 The Stata do-file used for our analyses is available via the DZHW Research Data Centre: https://doi.org/10.21249/DZHW:euler2023:1.0.0

6 Some specialized institutions (Berufsakademien, Fern-, Bundeswehr- und Verwaltungsfachhochschulen) were not part of the population and hence not included in the sample.

imputation for dealing with missing data (Enders 2010; Schafer/Graham 2002) as the proportion of missing data[7] is quite low (table A1) and therefore should not be problematic concerning possible biased results (Bennett 2001; Schafer 1999). Apart from those two exceptions we performed complete case analysis. All in all, our pooled data comprises 33,469 observations (1997=9,583; 2001=8,122; 2005=10,160; 2009=5,604). Almost half of them (n=16,032) participated in the third wave (1997=5,471; 2001=4,734; 2005=3,760; 2009=2,067). Due to different wage-generating mechanisms (no employer for signalling etc.) we excluded graduates in self-employment from our analysis. We also dropped graduates with a degree in human or dental medicine. Within these subjects most graduates pursue a doctoral degree and this would therefore account for a substantial share of all PhDs in the sample. As a doctorate in these subjects usually differs significantly from those in other subjects (requirements, scope of work etc.), the PhDs would become not comparable[8]. Additionally, we excluded graduates from universities of applied sciences (UAS) as these institutions predominantly (especially for the older cohorts) do not have the right to award doctorates. Graduates with a degree from a university of applied sciences are usually unable to pursue a doctorate at their alma mater and face stricter requirements when applying for doctoral studies at another university. This substantial heterogeneity concerning the possible selection into a doctorate could potentially produce bias in the analysis. Therefore our models will only be based on graduates from universities (and equivalent), and will omit graduates in human or dental medicine. Finally, as we perform separate analyses for respondents employed in the private sector from those in the public sector, we also excluded observations with no information on work sector.

Excluding observations with missing values on our dependent (gross hourly wages) and main independent (PhD status) variable(s) leaves us with 8,312 observations (1997=3,042; 2001=2,447; 2005=1,584; 2009=1,239). They are distributed into 4,353 (1997=1,736; 2001=1,227; 2005=823; 2009=567) observations in the private sector and 3,959 (1997=1,306; 2001=1,220; 2005=761; 2009=672) in the public sector.

Dependent Variable

Our dependent variable is the natural logarithm of gross hourly earnings. To compensate for inflation between cohorts they were standardized against prices from 2010[9]. Gross hourly wages were calculated based on self-reported gross monthly earnings and actual working hours per week of the main employment. Using the

7 Note that table A1 (in the appendix) shows the proportion of missing data for the respective variables only for observations with information on the dependent variable. As the dependent variable shouldn't be imputed (Hippel 2016) we consider the amount of missing values conditional on non-missing values on the dependent variable as the decisive size.

8 In other countries a differentiation exists between medical doctorates (M.D.s in the U.S. system) and scientific doctorates (PhD).

9 Foreign currencies were converted into Euro according to their purchasing power.

natural logarithm approximates the skewed distribution to a normal distribution and thus helps to fulfill the assumption of ordinary least squares (OLS) regression (Sauer/Valet/Liebig 2016).

Independent Variable

Our main independent variable is the attainment of a PhD. It distinguishes between graduates having successfully finished their PhD studies (PhD holders) at the time of the third survey (within the cohort) and graduates without a PhD degree at that point in time (including ongoing, suspended, or discontinued PhD studies).

Control Variables[10]

Besides our central independent variable, several controls are included in our models. They serve two main purposes. First, they are included with respect to variables relevant for selection into a PhD degree course (Jaksztat 2014; Jaksztat/Lörz 2018) or its completion (Jaksztat/Neugebauer/Brandt 2021). Secondly, they represent factors relevant for wage determination (e.g., job experience). These variables can partially be found of importance for both. We included the following variables in our models: We control for gender (male, female), parental education according to the CASMIN-scheme (Brauns/Scherer/Steinmann 2003) aggregated into three categories (high[3a,3b], medium[1c,2b,2a,2c_gen,2c_voc], low[1a,1b]), parenthood (no, yes), final grade of the higher education entrance certificate standardized at the federal state level and aggregated by quartiles (higher values/quartiles indicate poorer performance and field of study (see table A1 for categories). Besides this we also consider labor market experience and labor market experience squared in years as proxy for human capital acquired on the job. This also accounts for slight differences in field time of the third waves, diverging times of respondents' graduation within the respective academic year, and phases within the ten-year timespan that weren't suitable for acquiring human capital (e.g., unemployment or parental leave). In the appendix, table A1 shows the unweighted distribution of our control variables as well as our dependent and independent variable by cohort and sector of employment. It can be seen, that while the ratio of graduates with and without a PhD is fairly stable between sectors and cohorts, other variables are subject to bigger differences. This applies especially for the gender ratio and the proportion of fields of study. While women are more likely to be found in the public sector, the private sector is more attractive for engineers, and graduates of linguistic and cultural studies comprise the largest group within the public sector.

10 Gender, parental education, field of study, and final grade in the higher education entrance certificate also entered the panel attrition model calculation for the attrition weight. The attrition model also includes the age (aggregated by quartiles) of the respondent.

Methods

Our main goal is to determine whether a PhD wage premium (i.e., wage differences between graduates with and without a doctoral degree) exists, and whether it differs depending on sector and/or cohort. For this aim we must ensure that the cohorts we are comparing are as equal as possible concerning characteristics that influence selection into a PhD degree and also determine the wages. In order to take these into account we rely on OLS regressions with log gross hourly wages as the dependent variable. We are aware that selection on unobservables might confound the relationship between a PhD degree and wages as well as possible differences in PhD wage premiums across cohorts. Accordingly, our results are at best interpreted as robust correlations rather than true causal effects. However, by including covariates like field of study or final grade in the higher education entrance certificate we are confident of capturing some of the most relevant unobservables such as aptitude, motivation, and interests.

We calculate individual cohort-specific models, an integrated model with pooled data and an interaction term between cohort and PhD state, and finally a three-way interaction model with an interaction term between cohort, PhD state, and sector. We estimate all models twice: without (a) and with (b) control variables. All models employ panel attrition weights and cluster[11] robust standard errors. Due to the logarithmic dependent variable, model coefficients are exponentiated to facilitate interpretation. As such, coefficients can be interpreted as changes of the gross hourly wage in percent if the respective variable changes (for example: PhD holders of the 1997 cohort earn 8.4 % more than graduates without a PhD; table 1, model b). Regression coefficients are reported for both the cohort-specific and the integrated model (tables 1 and 2 in the following section; tables A2-A5 in the appendix). For the three-way interaction model predictive margins and average marginal effects (AME) are presented (figures 3 and 4 in the following section).

Results

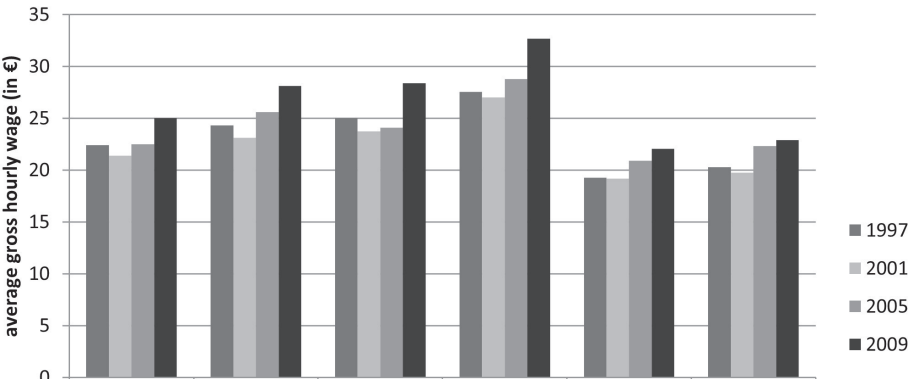
Beginning with a few descriptive findings on wage differences between higher education graduates with and without PhD degrees, figure 2 shows weighted gross hourly wages by cohort and sector of employment as well as across sectors (total). It can be seen that PhD holders – in accordance with hypothesis H1 – generally achieve higher gross hourly wages compared to graduates without PhD degrees. This wage premium persists across sector of employment and cohorts. For the public sector of the 1997 cohort, the difference in gross hourly wages is rather small

11 Clusters are determined by higher education institution and field of study and reflect the sampling design which in the first place drew a random sample of subjects at specific institutions (primary sampling units (PSU)) and then sampled all graduates within each PSU (secondary sampling units (SSU)). With the clusters we take unobserved heterogeneity between universities and between subjects within universities respectively into account.

at about €0.56. Employees in the private sector achieve higher wages than graduates working in the public domain. The average pay is generally higher in the private sector. As a result, despite having a wage premium within their respective sector, PhD holders in the public sector still earn less than graduates without a PhD in the private sector.

On the evolution of wage differentials between graduates with and without PhD degrees the overall trend shows several developments, especially considering that these numbers already account for inflation. First, gross hourly wages slightly decrease from the 1997 to the 2001 cohort in both sectors and also in total. This applies for graduates both with and without PhDs. Second, the average pay increases for the 2005 and 2009 cohorts. Again, this applies for graduates both with and without a PhD, in both sectors, and in total. Third, the increase in hourly wages is most profound for the 2009 cohort, rising about €2.51-€2.54. Comparing graduates with and without a PhD, PhD holders earn on average €1.75-€1.88 more than persons without a doctorate for the 1997 and 2001 cohort and on average €3.09 (€3.07-€3.10) per hour for the two more recent cohorts. Following our hypotheses, this trend opposes H2 but is in accordance with H3.

Figure 2: Average gross hourly wages of respondents by PhD status, sector, and year (in Euro)



	total		private sector		public sector	
	without PhD	with PhD	without PhD	with PhD	without PhD	with PhD
1997	22.41	24.29	25.01	27.55	19.27	20.30
2001	21.37	23.12	23.74	27.00	19.18	19.74
2005	22.49	25.59	24.11	28.76	20.88	22.31
2009	25.03	28.10	28.38	32.68	22.04	22.90

Source: DZHW graduate panel studies 1997, 2001, 2005, 2009.
Note: Own calculations. Weighted data. Wages standardized against prices from 2010.

Looking at sectors separately, we can examine these general trends (higher earnings for PhD holders, decrease for all in the 2001 cohort, increase for all in the more recent cohorts) in both sectors, too. Nevertheless, there are differences. First, there is a wage premium for the private sector. Private-sector graduates both with and without PhDs earn more than their respective counterparts in the public sector (€6.45-€9.78 with a PhD; €3.23-€6.34 without a PhD). This difference is high enough to even result in public-sector PhD holders still having a lower wage than private employees without a doctorate. Second, the overall increase in hourly wage is more profound in the private sector. In the 2009 cohort in the private sector, PhD holders earn €5.13 and graduates without a doctorate earn €3.37 more than their counterparts in the earlier 1997 cohort. For the public sector, this wage increase lies at only around €2.60 for PhD holders and €2.77 for graduates without a doctorate respectively. Third, within the sectors, the PhD wage premium varies. In the 2009 cohort, private PhD holders earn €4.30 more than graduates without a doctorate while the public PhD wage premium is only €0.86. As a result, hypothesis H4 should rejected and H5 supported.

Table 1: OLS regression of log hourly wages (across sectors; private sector; public sector) on PhD status (extracted from tables A2, A3, and A4).

	1997		2001		2005		2009	
	a	b	a	b	a	b	a	b
				Model across sectors				
PhD	1.094	1.084	1.080	1.058	1.132	1.088	1.126	1.098
	(0.024) ***	(0.019) ***	(0.026) **	(0.021) **	(0.029) ***	(0.027) ***	(0.039) ***	(0.046) *
N	3,042	3,042	2,447	2,447	1,584	1,584	1,239	1,239
				Model private sector only				
PhD	1.125	1.089	1.148	1.119	1.188	1.141	1.174	1.124
	(0.032) ***	(0.027) ***	(0.043) ***	(0.035) ***	(0.049) ***	(0.044) ***	(0.064) **	(0.061) *
N	1,736	1,736	1,227	1,227	823	823	567	567
				Model public sector only				
PhD	1.040	1.058	1.030	1.025	1.072	1.053	1.043	1.057
	(0.026)	(0.026) *	(0.023)	(0.025)	(0.028) **	(0.029)	(0.037)	(0.044)
N	1,306	1,306	1,220	1,220	761	761	672	672

Source: DZHW graduate panel studies 1997, 2001, 2005, 2009.

Note: Own calculations. Weighted data. Exponentiated coefficients. Standard errors in parentheses. Control variables not shown. a = without control variables; b = with control variables. * p<0.05, ** p<0.01, *** p<0.001.

This first descriptive view could be an indication against the oversupply argument of the JCT that predicts competition for jobs with lower earnings in the face of higher education expansion. Nevertheless, the overall economic situation and unobserved influences should also be considered. While the 2001 cohort was surveyed shortly after the global financial crisis, the 2009 cohort entered the labor market in a continuous phase of a positive economic climate and a growing lack of professionals. Additionally, the composition of respondents within cohorts, PhD status, and sectors could vary in attributes that are correlated with income.

To answer our hypotheses more specifically, we therefore focus on the results of the OLS regression models (table 1 depicting only the main independent variable, tables A2, A3, and A4 in the appendix depicting all variables). These are presented in two model specifications respectively: model specifications a) show the regression of log gross hourly wages on the attainment of a PhD degree without any control variables, and therefore reflect a basic model. Model specifications b) include the complete set of control variables. In the following, testing of the hypotheses will predominantly focus on the latter coefficients, as these present a more comprehensive picture.

Across sectors all cohorts show a highly significant wage effect of the attainment of a PhD. Depending on the cohort, PhD holders report between around eight and 13 percent higher wages than graduates without a PhD in model a). Including the control variables reduces the wage premium of PhD holders to between around six and ten percent respectively. All coefficients remain significant. By this account, our first hypothesis (H1) can be confirmed. PhD holders do indeed receive higher wages on average than graduates across both sectors without a PhD. Concerning hypotheses H2 and H3 a first glance indicates a rather inconclusive picture as the PhD wage premium across sectors remains between eight and ten percent for most cohorts.

Table 1 additionally shows the individual cohort-specific models by different sectors. As can be seen, the PhD wage premium in the private sector is higher than across sectors. In model a) it lies between twelve and 19 percent. When including control variables, it is slightly reduced to between nine and 14 percent. Overall, the PhD wage premiums in the private sector are significant for all cohorts and present higher coefficients compared to the results across sectors. In contrast to this, the public sector shows a different picture. Table 1 shows that there is only a significant PhD wage premium for model a) in the 2005 cohort and for model b) in the 1997 cohort. In all other cohorts PhD holders do not receive significantly higher wages compared to their peers without a doctoral degree. The coefficients are also much lower compared to the private sector. This seems to indicate that the relevance of a PhD for hourly wages in the public sphere is rather low. Beyond that, neither the private nor public sector present a conclusive trend of PhD wage premiums over time for hypotheses H4 and H5.

Briefly looking at the control variables we can examine some expected results (tables A2, A3, and A4 in the appendix). Respondents who studied fields like engineering, law, and mathematics/sciences receive significantly higher wages compared to former students of linguistic and cultural studies in the overall model (table A2). Graduates in the lower quartiles of the final school grade face a wage penalty; the same applies to women. Parenthood shows a positive coefficient concerning earnings. Additional years of job experience increases wages but only significantly for the first and last cohort (table A2). For the individual sectors (table A3 and A4) we mostly find similar results. Nevertheless, there are some differences. While grad-

Table 2: OLS regression of log hourly wages (pooled cohorts) with interaction term cohort and PhD status (extracted from table A5).

	cross sector		private sector		public sector	
	a	b	a	b	a	b
cohort (ref: 1997)						
2001	0.958	0.990	0.940	0.977	1.002	1.011
	(0.024)	(0.013)	(0.032)	(0.020)	(0.015)	(0.014)
2005	1.009	1.022	0.964	0.989	1.079	1.066
	(0.024)	(0.015)	(0.032)	(0.021)	(0.019) ***	(0.017) ***
2009	1.112	1.190	1.120	1.245	1.140	1.157
	(0.033) ***	(0.022) ***	(0.046) **	(0.034) ***	(0.023) ***	(0.022) ***
PhD	1.094	1.076	1.125	1.085	1.040	1.046
	(0.024) ***	(0.019) ***	(0.032) ***	(0.027) ***	(0.026)	(0.024)
cohort & PhD (ref: 1997 & PhD)						
	0.987	0.982	1.020	1.038	0.990	0.979
2001 & PhD	(0.032)	(0.024)	(0.048)	(0.037)	(0.034)	(0.030)
	1.035	1.004	1.056	1.045	1.032	1.006
2005 & PhD	(0.035)	(0.028)	(0.053)	(0.043)	(0.037)	(0.035)
	1.029	1.045	1.044	1.066	1.003	1.026
2009 & PhD	(0.042)	(0.037)	(0.064)	(0.048)	(0.044)	(0.043)
N	8,312	8,312	4,353	4,353	3,959	3,959
adj. R^2	0.035	0.254	0.046	0.336	0.040	0.122

Source: DZHW graduate panel studies 1997, 2001, 2005, 2009.

Note: Own calculations. Weighted data. Exponentiated coefficients. Standard errors in parentheses. Control variables not shown. a = without control variables; b = with control variables. * p<0.05, ** p<0.01, *** p<0.001.

uates of mathematics/sciences receive higher wages in the private sector compared to former students of linguistic and cultural studies, this does not hold true for the public sector. Additionally, engineers show a significant wage premium in the private sector while this premium is lower in the public sector and insignificant for the last two cohorts. Women have a significant disadvantage on income in the private sector, but not in the public sector; respondents profit continuously from parenthood in the public sector, while only for the 1997 cohort in the private sector. Finally, neither the final school grade nor job experience seems to be of relevance within the public sector. This supports the idea of a strong credentialism and unimportance of individual performance indicators within the labor-market mechanism of the public sector.

Following the individual cohort-specific models, analysis of the integrated model with pooled data and a modelled interaction of PhD state and cohort (1997 as base category) allows a longitudinal perspective on the potential PhD wage premium (table 2 depicting only the main independent variable, table A5 in the appendix depicting all variables). It also enables us to evaluate our hypotheses concerning trends over time. In the complete model, a constant PhD wage premium across sectors of around 7.6 percent can be found supporting hypothesis H1 (table 2). There is also a significant wage increase for the 2009 cohort compared to the 1997 cohort. For the integrated model more fields of study show relevant results on wage with social sciences, mathematics/sciences, health sciences, engineering, and law being associated with higher incomes and veterinary medicine and arts associated with lower earnings compared to linguistic and cultural studies (table A5). Final school grades, gender and parenthood generally show significant effects on income. Contrary to the individual cohort-specific models, job experience is a significant contributor to hourly wage overall and for both sectors (table A5).

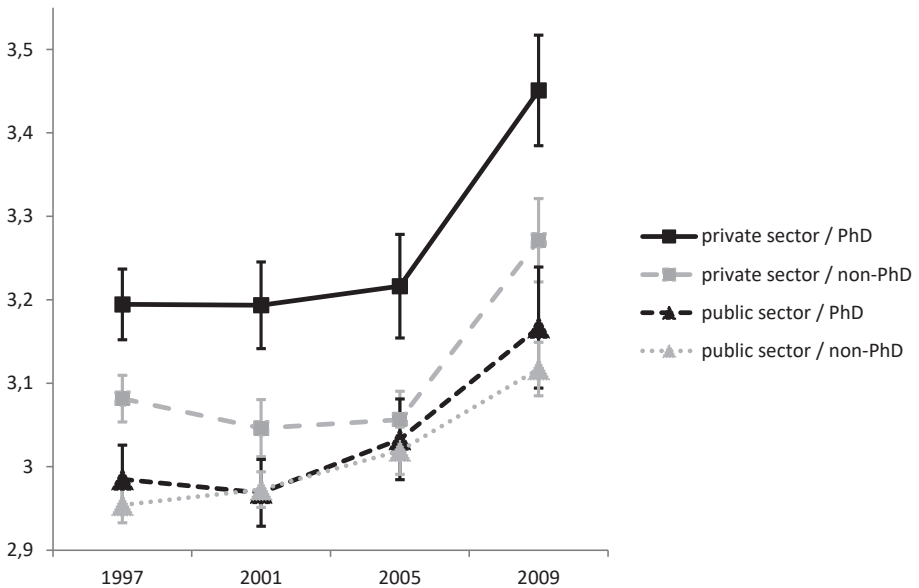
Concerning our hypotheses on the evolution of the PhD wage premium irrespective of sector of employment (H2, H3) we detect a slight increase over time that is most pronounced in the last cohort (2001=-1.8 %; 2005=+0.4 %; 2009=+4.5 %). However, as all effects are not significant, we must reject both H2 (decrease of the PhD wage premium) and H3 (increase of the PhD wage premium). Thus, across sectors, a rising supply of PhD holders seems to be counterbalanced by an equally rising demand in the course of technological change, resulting in stable returns to PhD holders compared to graduates without PhD degrees. Because this stability might be due to contrasting developments in the private and public sector, we additionally run the analysis for each sector.

Comparing sectors, the PhD wage premium is higher and only significant for the private sector (8.5 %) while it is insignificant for the public sphere. Concerning cohorts, the 2009 cohort shows a significant increase in wages compared to the 1997 cohort (private=+24.5 %; public=+15.7 %). Additionally, this holds true for public employees of the 2001 cohort (+6.6 %). While PhD holders in the private

sector experience a continuous increase in wage premiums (2001=+3.8 %; 2005=+4.5 %; 2009=+6.6 %) the evolution of the PhD wage effect in the public sector is inconclusive (2001=-2.1 %; 2005=+0.6 %; 2009=+2.6 %). As none of these results are significant, this can only be interpreted as a trend. Consequently, both hypotheses H4 and H5 must also be rejected. To sum it up, while the public sector experienced a general increase in wages, PhD holders do not profit additionally from their degree. In contrast to this, in the private sector no significant wage hike appears until recently, although private-sector PhD holders enjoy a significant advantage in remuneration when compared to private-sector workers without PhDs.

Finally, a three-way interaction model was conducted (table not reported). Based on the model, predictive margins were estimated for cohort, PhD status, and sector (figure 3). As can be seen, PhD holders in the private sector and non-PhD holders in the public sector experience a constant positive trend on average wages. In contrast, PhD holders in the public sector and non-PhD holders in the private sector show a slight decrease of wages between the 1997 and 2001 cohorts and a later positive development.

Figure 3: Predictive margins of log hourly wages of graduates separated by cohort, sector and PhD status (only model b)

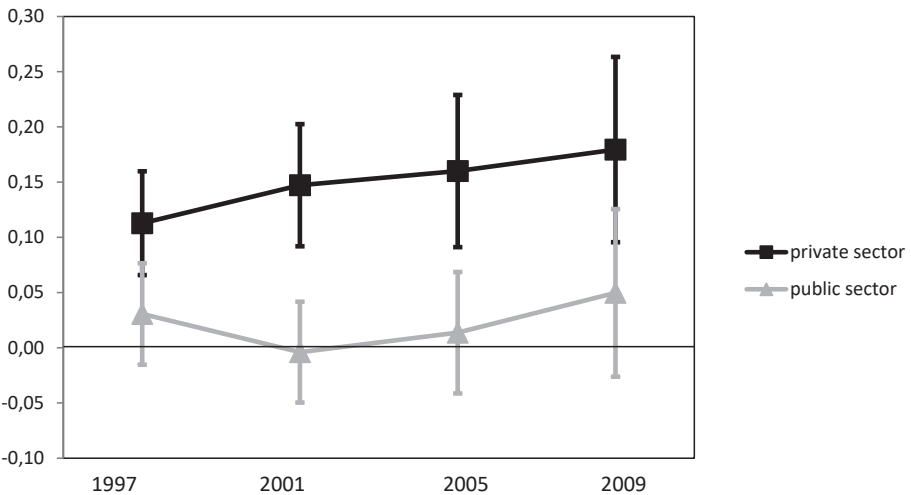


Source: DZHW graduate panel studies 1997, 2001, 2005, 2009
Note: Own calculations. 95 % confidence interval band.

Generally, employees in the private sector tend to receive higher hourly wages than their colleagues in the public sphere. For non-PhD holders this applies for the 1997, 2001, and 2009 cohorts where the average wage of private employees is significantly higher compared to public-sector workers. Meanwhile private PhD holders constantly earn significantly more than public PhD holders. For the 1997 and 2001 cohorts the latter even earn significantly less than graduates without a PhD in the private sector.

Focusing solely on the development of the PhD wage premium the average marginal effects in figure 4 show a continuous increase of the PhD wage premium for employees in the private sector from 11 percent for the 1997 cohort to 18 percent for the 2009 cohort. The wage premium is significant for all cohorts. In contrast the PhD wage premium for the public sector decreases heading into the 2001 cohort even resulting in a 0.4 percent lower hourly wage than publicly employed graduates without a PhD degree. For later cohorts the public PhD holder wage premium rises again but remains insignificant for all cohorts.

Figure 4: Difference in log hourly wages of PhD holders compared to non-PhD graduates by cohort and sector (only model b)



Source: DZHW graduate panel studies 1997, 2001, 2005, 2009.
Note: Own calculation. Baseline 0 = graduates without PhD. 95 % confidence interval band.

Additionally, we can see that PhD holders in the private sector earn significantly more in absolute terms than their counterparts in the public sector (figure 3). Considering relative terms within the sectors, private PhD holders also show a significantly higher PhD wage premium (relative to graduates without a doctoral degree in the private sector) than PhD holders in the public sector for the 2001 and

2005 cohorts (figure 4). This difference is insignificant for the oldest and youngest cohort.

Concerning our fourth and fifth hypotheses, figure 4 presents a slow widening of the wage gap (i.e., an increase of the wage premium) between graduates with and without a PhD in the private sector. PhD holders in the public sector between the 2001 and 2009 cohorts experience a slightly steeper wage increase compared to those without a PhD degree. While these changes over time present a trend for the trajectory of PhD wage premiums, these developments are all not significant between cohorts. As such our fourth and fifth hypotheses, which state that the wage premium of PhD holders should decrease in the public sector (H4) and increase in the private one (H5), must both be rejected for the more recent cohorts. Here again, the wage premiums remain rather stable over time. However, the overall positive wage development (figure 4) and at least the positive direction of the development in the private sector suggests that skill-biased technological change might be slightly more beneficial for PhD holders compared to graduates without PhD degrees.

Discussion & Outlook

The discourse on the expansion of higher education revolves around a growing demand for highly-skilled labor in a knowledge-based economy and concerns that the pace of expansion has gone too far resulting in an oversupply of graduates of higher education. As Germany lacks natural resources, innovation and a knowledge-based economy are crucial for future economic growth. Due to their prominent role in putting forward innovations, PhD holders receive particular attention in the public and scientific debate on the development of the quaternary sector. To encourage capable higher education graduates into pursuing a PhD degree, at least constant returns to a PhD degree are a prerequisite. Our analyses show that despite a growing number of PhD holders entering the labor market over the last decade relative returns in terms of wages have not declined. While we detect insignificant returns for those employed in the public sector, we see a constant PhD wage premium for doctoral degree holders in the private sector. Findings suggest that neither graduates of higher education with a PhD degree, nor those without, experience increasingly lower wages as supported by the oversupply argument. This indicates that growing supply has been accompanied by a growing demand for skills associated with a tertiary education that includes a PhD degree as well as one that does not. Possibly this has also been influenced by the overall positive economic situation during the last decade. Findings concerning the public sector are more vague. While wages for graduates with and without PhDs slowly increase, returns to a PhD degree mostly remain insignificant in the public sector.

Besides this we must take some limitations into account. Basically, our analytical strategy is based on a causal approach. In order to identify a causal effect of a

PhD degree on wages as well as a causal effect of cohort (i.e., higher education expansion) on PhD wage premium change we must first rule out that (changing) returns are due to personal characteristics that influence both the selection into a PhD degree and also earnings. We are confident that our set of control variables captures the most relevant confounders. However, as selection on unobservables is always difficult to rule out with observational data we consider our results at best to be robust correlations rather than true causal effects. As an alternative to the attrition weight that we are using, the models have also been calculated employing entropy balancing[12] to account for possible selection effects. No fundamental divergence of results could be found. Besides this, our interaction model relies on the assumption that the effects of all covariates except for PhD state do not differ across cohorts. Allowing all covariates to interact with cohort would result once again in separate models. Another limitation concerns the sectoral aggregation; as a doctoral degree is mandatory for a scientific career at universities or publicly-funded research institutes it might be beneficial to divide the public sector into academic and non-academic employment. Unfortunately, our data does not permit the identification of people engaged in research activities at universities or research institutes. Further research with alternative data could address this issue. Although we covered quite a broad period of time (12 years) with substantial expansion of higher education in Germany (in terms of PhD holders and also graduates without a doctoral degree) an extension to cohorts before 1997 would be beneficial. Additionally, the necessity to incorporate a broad period of time following graduation – to account for the time to finish a PhD and enter the labor market – prevented us from using more recent cohorts of graduates. These are nevertheless of special interest as this paper had to focus on the PhD wage premium between PhD holders and graduates with traditional degrees. These results could have differed for graduates fully incorporated into the Bologna process and the transformation of the German higher education system.

Nevertheless, our analyses provide a sustainable insight into the development of wages for German higher education graduates in the early 21st century. It furthermore presents robust results supporting a wage premium for PhD holders compared to non PhDholders. This advantage on incomes can be found in the private sector and to a lesser extent in the public sector. For the former, an increase over time can be observed. Whether these effects are generally true for the sectors overall or only apply in particular circumstances (e.g., certain branches, region, etc.) must be evaluated in future research.

12 This is a matching approach that balances treatment and control group by reweighting the control group so that the mean, variance and skewness of covariates is the same in both groups (Hainmüller 2012).

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Appendix

Table A1: Distribution and means of variables by cohort and sector of employment (in %)

	1997		2001		2005		2009	
	private	public	private	public	private	public	private	public
hourly wage[a] (€)	25.5	19.3	23.8	19.0	24.7	21.1	21.8	21.8
log hourly wage[a]	3.2	2.9	3.1	2.9	3.1	3.0	3.2	3.0
				PhD status				
no PhD	81.5	82.1	78.6	77.0	77.2	76.2	77.2	82.0
PhD	18.5	17.9	21.4	23.0	22.8	23.8	22.8	18.0
				field of study				
linguistic/ cultural studies	10.6	40.3	14.6	44.7	14.5	44.5	20.3	46.7
sport	0.3	2.6	0.6	1.3	0.5	1.3	0.2	1.3
social sciences	2.9	4.4	5.4	6.9	7.2	9.7	7.9	10.7
math./sciences	27.8	21.7	30.8	21.5	25.2	19.2	28.6	19.8
health sciences	0.0	0.0	0.0	0.0	0.0	0.5	0.4	0.9
vet. med.	2.0	2.0	1.4	1.7	3.6	2.5	3.0	1.5
agri-, forest-, nutrion studies	1.8	1.5	4.0	2.3	4.4	1.4	3.4	1.8
engineering	21.6	6.0	22.2	8.0	20.9	6.8	12.3	2.5
arts	1.0	5.5	1.2	3.9	1.8	3.3	1.9	3.1
law	6.4	8.0	4.3	5.2	4.0	5.9	4.8	6.0
economics	25.5	8.1	15.5	4.4	18.0	4.7	17.3	5.7
				final school grade				
1st quartile	29.7	26.7	33.3	30.2	34.6	31.8	32.1	30.7
2nd qartile	24.9	24.1	26.1	26.1	26.1	26.8	26.5	23.5
3rd quartile	22.9	22.5	22.2	22.8	20.7	21.2	23.1	23.2
4th quartile	17.2	21.9	17.0	19.0	17.7	18.9	17.6	21.7
missing	5.3	4.7	1.4	1.9	0.9	1.3	0.7	0.9
				gender				
male	64.6	39.1	46.9	30.5	49.2	32.5	42.0	28.9
female	35.0	60.9	53.1	69.5	50.8	67.5	58.0	71.1
missing	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				parenthood				
no	42.0	38.0	43.0	37.8	35.5	37.1	40.7	35.7
yes	57.8	61.9	57.0	62.1	64.0	62.7	58.4	63.4
missing	0.2	0.2	0.0	0.1	0.5	0.3	0.9	0.9
				parental education				
low	0.8	0.8	0.9	0.7	1.2	1.2	2.1	1.9
medium	29.6	30.8	27.5	25.9	38.3	37.1	35.6	38.2
high	68.4	67.2	70.9	73.0	60.1	61.0	61.2	57.7
missing	1.2	1.2	0.7	0.4	0.4	0.8	1.1	2.1
experience[a] (years)	9.6	9.1	9.3	9.0	9.8	9.6	8.5	8.5
experience squared[a]	93.6	85.9	88.9	82.9	97.4	94.6	75.2	74.9
N	1,736	1,306	1,227	1,220	823	761	567	672

Source: DZHW graduate panel studies 1997, 2001, 2005, 2009.

Note: Own calculations. Unweighted data. a = continous variable; mean.

Table A2: OLS regression of log hourly wages (across sectors)

	1997		2001		2005		2009	
	a	b	a	b	a	b	a	b
PhD	1.094 (0.024) ***	1.084 (0.019) ***	1.080 (0.026) **	1.058 (0.021) **	1.132 (0.029) ***	1.088 (0.027) ***	1.126 (0.039) ***	1.098 (0.046) *
field of study (ref.: linguistic/cultural studies)								
sport	—	0.998 (0.036)	—	0.999 (0.074)	—	1.004 (0.104)	—	1.085 (0.088)
social sciences	—	1.066 (0.035)	—	1.090 ** (0.036)	—	1.000 (0.031)	—	1.086 (0.046)
math./ sciences	—	1.121 (0.024) ***	—	1.120 (0.027) ***	—	1.081 (0.031) **	—	1.194 (0.059) ***
vet. med.	—	0.900 (0.020) ***	—	0.890 (0.019) ***	—	0.875 (0.054) *	—	0.946 (0.033)
health sciences	—	—	—	—	—	1.098 (0.041) *	—	1.224 (0.039) ***
agri-, forest-, nutrion studies	—	0.990 (0.038)	—	1.060 (0.052)	—	0.975 (0.077)	—	1.137 (0.070) *
engineering	—	1.211 (0.048) ***	—	1.189 (0.043) ***	—	1.156 (0.044) ***	—	1.321 (0.066) ***
arts	—	0.962 (0.045)	—	0.967 (0.053)	—	0.894 (0.047) *	—	0.946 (0.058)
law	—	1.161 (0.042) ***	—	1.116 (0.036) ***	—	1.172 (0.043) ***	—	1.271 (0.051) ***
economics	—	0.998 (0.036)	—	0.999 (0.074)	—	1.004 (0.104)	—	1.085 (0.088)
final school grade (ref.: 1st quartile)								
2nd quartile	—	0.969 (0.016)	—	0.963 (0.019)	—	0.947 (0.022) *	—	0.963 (0.031)
3rd quartile	—	0.944 (0.016) ***	—	0.933 (0.018) ***	—	0.925 (0.024) **	—	0.936 (0.031) *
4th quartile	—	0.926 (0.016) ***	—	0.929 (0.019) ***	—	0.922 (0.026) **	—	0.949 (0.030)

	1997		2001		2005		2009	
	a	b	a	b	a	b	a	b
missing	—	0.805 (0.032) ***	—	0.946 (0.059)	—	0.955 (0.044)	—	0.896 (0.117)
gender (ref.: male)								
female	—	0.920 (0.013) ***	—	0.908 (0.016) ***	—	0.932 (0.020) ***	—	0.886 (0.023) ***
missing	—	1.018 (0.151)	—	—	—	—	—	—
parenthood (ref.: no)								
yes	—	1.068 (0.014) ***	—	1.051 (0.016) **	—	1.063 (0.021) **	—	1.052 (0.026) *
missing	—	0.926 (0.070)	—	2.297 (0.055) ***	—	1.422 (0.240) *	—	1.183 (0.190)
parental education (ref.: low)								
medium	—	1.046 (0.125)	—	1.065 (0.083)	—	0.846 (0.064) *	—	1.068 (0.077)
high	—	1.039 (0.123)	—	1.110 (0.088)	—	0.843 (0.064) *	—	1.099 (0.081)
missing	—	1.085 (0.143)	—	1.208 (0.131)	—	0.883 (0.119)	—	1.026 (0.093)
experience (years)	—	1.140 (0.053) **	—	1.080 (0.048)	—	1.066 (0.045)	—	1.126 (0.050) **
experience squared	—	0.996 (0.003)	—	0.999 (0.003)	—	1.000 (0.003)	—	0.996 (0.003)
N	3,042	3,042	2,447	2,447	1,584	1,584	1,239	1,239
adj. R^2	0.008	0.268	0.007	0.231	0.020	0.219	0.014	0.233

Source: DZHW graduate panel studies 1997, 2001, 2005, 2009.

Note: Own calculations. Weighted data. Exponentiated coefficients. Standard errors in parentheses. * p<0.05, ** p<0.01, *** p<0.001.

Table A3: OLS regression of log hourly wages (private sector)

	1997		2001		2005		2009	
	a	b	a	b	a	b	a	b
PhD	1.125 (0.032) ***	1.089 (0.027) ***	1.148 (0.043) ***	1.119 (0.035) ***	1.188 (0.049) ***	1.141 (0.044) ***	1.174 (0.064) **	1.124 (0.061) *
field of study (ref.: linguistic/cultural studies)								
sport	—	0.966 (0.097)	—	0.906 (0.072)	—	0.756 (0.070) **	—	0.947 (0.071)
social sciences	—	1.162 (0.067) *	—	1.194 (0.094) *	—	0.948 (0.059)	—	1.120 (0.091)
math./ sciences	—	1.223 (0.047) ***	—	1.202 (0.057) ***	—	1.125 (0.054) *	—	1.284 (0.107) **
vet. med.	—	0.910 (0.060)	—	0.816 (0.039) ***	—	0.743 (0.068) **	—	0.847 (0.057) *
health sciences	—	—	—	—	—	—	—	1.537 (0.098) ***
agri-, forest-, nutrion studies	—	1.052 (0.070)	—	1.064 (0.077)	—	0.991 (0.104)	—	1.091 (0.079)
engineering	—	1.226 (0.062) ***	—	1.204 (0.067) ***	—	1.175 (0.067) **	—	1.290 (0.098) ***
arts	—	0.942 (0.075)	—	0.785 (0.097) *	—	0.931 (0.095)	—	0.820 (0.059) **
law	—	1.213 (0.074) **	—	1.193 (0.087) *	—	1.278 (0.090) ***	—	1.441 (0.113) ***
economics	—	0.966 (0.097)	—	0.906 (0.072)	—	0.756 (0.070) **	—	0.947 (0.071)
final school grade (ref.: 1st quartile)								
2nd quartile	—	0.972 (0.024)	—	0.948 (0.024) *	—	0.937 (0.029) *	—	0.981 (0.045)
3rd quartile	—	0.922 (0.022) ***	—	0.900 (0.028) ***	—	0.892 (0.031) **	—	0.936 (0.042)
4th quartile	—	0.906 (0.023) ***	—	0.861 (0.031) ***	—	0.871 (0.040) **	—	0.921 (0.039)

	1997		2001		2005		2009	
	a	b	a	b	a	b	a	b
missing	—	0.763 (0.041) ***	—	1.067 (0.105)	—	0.945 (0.058)	—	0.920 (0.126)
gender (ref.: male)								
female	—	0.911 (0.019) ***	—	0.870 (0.025) ***	—	0.913 (0.027) **	—	0.843 (0.034) ***
missing	—	0.942 (0.154)	—	—	—	—	—	—
parenthood (ref.: no)								
yes	—	1.049 (0.018) **	—	1.041 (0.023)	—	1.048 (0.031)	—	1.056 (0.034)
missing	—	0.943 (0.071)	—	—	—	1.148 (0.105)	—	1.050 (0.192)
parental education (ref.: low)								
medium	—	1.161 (0.212)	—	1.059 (0.058)	—	0.801 (0.093)	—	1.275 (0.126) *
high	—	1.159 (0.211)	—	1.102 (0.061)	—	0.809 (0.092)	—	1.315 (0.130) **
missing	—	1.289 (0.258)	—	1.228 (0.179)	—	0.726 (0.140)	—	1.258 (0.161)
eperience (years)	—	1.213 (0.081) **	—	1.128 (0.078)	—	1.101 (0.087)	—	1.153 (0.083) *
experience squared	—	0.993 (0.004)	—	0.997 (0.004)	—	0.999 (0.005)	—	0.996 (0.005)
N	1,736	1,736	1,227	1,227	823	823	567	567
adj. R^2	0.013	0.296	0.016	0.318	0.032	0.338	0.023	0.347

Source: DZHW graduate panel studies 1997, 2001, 2005, 2009.

Note: Own calculations. Weighted data. Exponentiated coefficients. Standard errors in parentheses. * p<0.05, ** p<0.01, *** p<0.001.

Table A4: OLS regression of log hourly wages (public sector)

	1997		2001		2005		2009	
	a	b	a	b	a	b	a	b
PhD	1.040	1.058	1.030	1.025	1.072	1.053	1.043	1.057
	(0.026)	(0.026) *	(0.023)	(0.025)	(0.028) **	(0.029)	(0.037)	(0.044)
field of study (ref.: linguistic/cultural studies)								
sport	—	1.016	—	1.046	—	1.087	—	1.146
		(0.049)		(0.096)		(0.108)		(0.112)
social sciences	—	1.001	—	1.048	—	1.066	—	1.059
		(0.043)		(0.030)		(0.039)		(0.056)
math./ sciences	—	0.988	—	1.024	—	1.000	—	1.027
		(0.020)		(0.027)		(0.035)		(0.042)
vet. med.	—	0.926	—	0.962	—	1.111	—	1.102
		(0.055)		(0.021)		(0.080)		(0.138)
health sciences	—	—	—	—	—	1.187	—	1.166
						(0.052) ***		(0.132)
agri-, forest-, nutrion studies	—	0.913	—	1.080	—	0.923	—	1.138
		(0.039) *		(0.085)		(0.090)		(0.101)
engineering	—	1.105	—	1.117	—	1.058	—	1.177
		(0.043) *		(0.036) ***		(0.044)		(0.125)
arts	—	0.978	—	1.088	—	0.880	—	1.015
		(0.043)		(0.052)		(0.066)		(0.078)
law	—	1.119	—	1.085	—	1.121	—	1.142
		(0.030) ***		(0.036) *		(0.033) ***		(0.057) **
economics	—	1.016	—	1.046	—	1.087	—	1.146
		(0.049)		(0.096)		(0.108)		(0.112)
final school grade (ref.: 1st quartile)								
2nd quartile	—	0.968	—	0.985	—	0.983	—	0.929*
		(0.022)		(0.025)		(0.030)		(0.033)
3rd quartile	—	0.967	—	0.959	—	0.984	—	0.935
		(0.024)		(0.023)		(0.033)		(0.034)
4th quartile	—	0.959	—	1.011	—	0.997	—	0.971
		(0.023)		(0.025)		(0.030)		(0.037)

	1997		2001		2005		2009	
	a	b	a	b	a	b	a	b
missing	—	0.864	—	0.843	—	1.080	—	0.878
		(0.042) **		(0.048) **		(0.060)		(0.124)
gender (ref.: male)								
female	—	0.970	—	0.967	—	0.985	—	0.961
		(0.017)		(0.018)		(0.022)		(0.030)
parenthood (ref.: no)								
yes	—	1.096	—	1.056	—	1.076	—	1.067
		(0.019) ***		(0.019) **		(0.025) **		(0.030) *
missing	—	0.808	—	2.290	—	2.271	—	1.229
		(0.024) ***		(0.061) ***		(1.229)		(0.164)
parental education (ref.: low)								
medium	—	0.929	—	1.093	—	1.027	—	0.889
		(0.081)		(0.159)		(0.041)		(0.062)
high	—	0.907	—	1.135	—	1.004	—	0.896
		(0.079)		(0.167)		(0.036)		(0.063)
missing	—	0.898	—	1.146	—	1.160	—	0.836
		(0.096)		(0.213)		(0.152)		(0.079)
experience (years)	—	1.074	—	1.060	—	1.048	—	1.078
		(0.049)		(0.055)		(0.043)		(0.067)
experience squared	—	0.999	—	0.999	—	0.999	—	0.997
		(0.003)		(0.003)		(0.002)		(0.004)
N	1,306	1,306	1,220	1,220	761	761	672	672
adj. R^2	0.002	0.130	0.001	0.089	0.008	0.075	0.001	0.071

Source: DZHW graduate panel studies 1997, 2001, 2005, 2009.

Note: Own calculations. Weighted data. Exponentiated coefficients. Standard errors in parentheses. * p<0.05, ** p<0.01, *** p<0.001.

Table A5: OLS regression of log hourly wages (pooled cohorts) with interaction term cohort and PhD status

	cross sector		private sector		public sector	
	a	b	a	b	a	b
cohort (ref: 1997)						
2001	0.958	0.990	0.940	0.977	1.002	1.011
	(0.024)	(0.013)	(0.032)	(0.020)	(0.015)	(0.014)
2005	1.009	1.022	0.964	0.989	1.079	1.066
	(0.024)	(0.015)	(0.032)	(0.021)	(0.019) ***	(0.017) ***
2009	1.112	1.190	1.120	1.245	1.140	1.157
	(0.033) ***	(0.022) ***	(0.046) **	(0.034) ***	(0.023) ***	(0.022) ***
PhD	1.094	1.076	1.125	1.085	1.040	1.046
	(0.024) ***	(0.019) ***	(0.032) ***	(0.027) ***	(0.026)	(0.024)
cohort & PhD (ref: 1997 & PhD)						
2001 & PhD	0.987	0.982	1.020	1.038	0.990	0.979
	(0.032)	(0.024)	(0.048)	(0.037)	(0.034)	(0.030)
2005 & PhD	1.035	1.004	1.056	1.045	1.032	1.006
	(0.035)	(0.028)	(0.053)	(0.043)	(0.037)	(0.035)
2009 & PhD	1.029	1.045	1.044	1.066	1.003	1.026
	(0.042)	(0.037)	(0.064)	(0.048)	(0.044)	(0.043)
field of study (ref.: linguistic/cultural studies)						
sport	—	1.023	—	0.892	—	1.068
		(0.037)		(0.047) *		(0.044)
social sciences	—	1.057	—	1.092	—	1.046
		(0.020) **		(0.040) *		(0.023) *
math./sciences	—	1.132	—	1.214	—	1.010
		(0.019) ***		(0.035) ***		(0.016)
health sciences	—	1.182	—	1.514	—	1.162
		(0.034) ***		(0.050) ***		(0.061) **
vet. med.	—	0.903	—	0.832	—	1.012
		(0.020) ***		(0.040) ***		(0.044)
agri-, forest-, nutrion studies	—	1.040	—	1.052	—	1.013
		(0.031)		(0.044)		(0.041)
engineering	—	1.213	—	1.220	—	1.105
		(0.026) ***		(0.036) ***		(0.028) ***
arts	—	0.944	—	0.873	—	0.988
		(0.025) *		(0.048) *		(0.031)
law	—	1.178	—	1.275	—	1.116
		(0.024) ***		(0.047) ***		(0.021) ***

	cross sector		private sector		public sector	
	a	b	a	b	a	b
economics	—	1.023	—	0.892	—	1.068
		(0.037)		(0.047)		(0.044)
				*		
final school grade (ref.: 1st quartile)						
2nd quartile	—	0.960	—	0.961	—	0.965
		(0.011)		(0.016)		(0.014)
		***		*		*
3rd quartile	—	0.936	—	0.915	—	0.960
		(0.011)		(0.016)		(0.014)
		***		***		**
4th quartile	—	0.932	—	0.891	—	0.984
		(0.011)		(0.016)		(0.015)
		***		***		
missing	—	0.855	—	0.828	—	0.895
		(0.026)		(0.036)		(0.031)
		***		***		**
gender (ref.: male)						
female	—	0.909	—	0.882	—	0.967
		(0.009)		(0.014)		(0.011)
		***		***		**
missing	—	1.045	—	0.958	—	—
		(0.150)		(0.147)		
parenthood (ref.: no)						
yes	—	1.057	—	1.049	—	1.074
		(0.010)		(0.013)		(0.012)
		***		***		***
missing	—	1.213	—	1.057	—	1.370
		(0.129)		(0.094)		(0.232)
parental education (ref.: low)						
medium	—	1.005	—	1.095	—	0.948
		(0.047)		(0.081)		(0.042)
high	—	1.018	—	1.116	—	0.948
		(0.048)		(0.083)		(0.042)
missing	—	1.021	—	1.173	—	0.935
		(0.060)		(0.110)		(0.062)
experience (years)	—	1.102	—	1.149	—	1.058
		(0.025)		(0.042)		(0.028)
		***		***		*
experience squared	—	0.998	—	0.996	—	0.999
		(0.001)		(0.002)		(0.002)
N	8,312	8,312	4,353	4,353	3,959	3,959
adj. R^2	0.035	0.254	0.046	0.336	0.040	0.122

Source: DZHW graduate panel studies 1997, 2001, 2005, 2009.

Note: Own calculations. Weighted data. Exponentiated coefficients. Standard errors in parentheses. * p<0.05, ** p<0.01, *** p<0.001.