Yet Another Credential?
The Determinants and Effects of Doctoral Education

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List of abbreviations

BMBF	Federal Ministry of Education and Research
DFG	German Research Foundation
DZHW	German Centre for Higher Education Research and Science Studies
ECTS	European Credit Transfer and Accumulation System
EHEA	European Higher Education Area
EU	European Union
FE	Fixed effects
GDP	Gross domestic product
GDR	German Democratic Republic
GMAT	Graduate Management Admission Test
ISCED	International Standard Classification of Education
MBA	Master of Business Administration
Max.	Maximum
Min.	Minimum
NLSY	National Longitudinal Survey of Youth
OECD	Organisation for Economic Co-operation and Development
OLS	Ordinary least squared
RE	Random effects
R&D	Research and development
STEM	Sciences, technology, engineering, and mathematics
Std. dev.	Standard deviation

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1 Introduction

1.1 Motivation

Europe needs more researchers. This claim seems inevitable, given the European Union's (EU) goal to become and stay a knowledge-based society (Eurostat 2017a). In 2015, most of the EU's researchers were working in the business (49 percent) or the higher education sector (39 percent), while another 12 percent were employed in the government sector (Eurostat 2017c). And while there is an undersupply in research skills as of today, the demand for this highly skilled group of personnel will increase even further in the future (Eurostat 2017a). So the question arises as to how we can steer their numbers to meet future demand.

In general, it is supposed that researchers originate from the whole higher educational sector. And although all higher educational graduates are of the utmost importance in processing newly created knowledge and exploiting new ideas, the creators of new ideas and driving force behind its commercialisation and distribution (Eurostat 2016a) often hail from a small subgroup of tertiary graduates, i.e. doctorate holders (Pedersen 2014). As future possessors of the highest academic degree, doctoral students dedicate themselves to original research, creating new knowledge and passing it on to others (Pedersen 2016, p. 271; UNESCO, p. 39). Hence, doctoral students not only form a measure of a country's research potential (Eurostat 2017c), they are also at the centre of the EU's goal to be globally competitive as a knowledge-based society (Kehm 2006, p. 67; Pedersen 2014).

In support to Europe's call for more researchers, one of the main goals of the EU's Europe 2020 strategy is to increase the average European gross domestic product (GDP) dedicated to research and development (R&D) from currently 2.03 to 3 percent (European Commission 2017a; Eurostat 2016b, p. 9). More research and development, and eventually innovation should help Europe to create new jobs, secure existing ones and protect employment for generations to come (Eurostat 2017a). For European countries to be able to exploit these R&D expenditures, it is vital to have the highly skilled personnel capable of absorbing new knowledge and ideas as well as to create new knowledge on their own (European Commission 2017a). Under these circumstances, we would expect policy makers to be interested not only in increasing tertiary graduates (European Commission 2017a) but in increasing doctoral graduates in particular.

As mentioned before, there is already a mismatch between demand and supply of the highly qualified personnel which is threatening to increase since the EU's demand for highly qualified people is estimated to rise by about 16 million people by 2025 (European Commission 2017a), despite the increasing number of doctoral students[1] (Kehm 2006, p. 68; Pedersen 2014, p. 631).

Against this background the questions arise as to the driving forces behind the numbers of doctoral enrolment rates since we cannot simply force more people to become researchers. If we knew the drivers behind these individual enrolment decisions, we would be able to steer the number of future doctorates to some degree at least. Previous studies have already identified various important determinants of the doctoral enrolment decision such as financial aspects (Fox 1992; Millett 2003; Weiler 1991; Yang and McCall 2014), labour market conditions (Bedard and Herman 2008; Johnson 2013; Perna 2004; Zhang 2005), and educational factors, e.g. college quality (Eide et al. 1998; Zhang 2005). In Chapter 3, I bring a new educational factor to the table: the curricular structure at college level.

While increased expenditure on R&D implies more researchers in general, particularly doctorate holders in the fields of (natural) sciences, technology, engineering, and mathematics (STEM fields) are important (Pedersen 2014, p. 636) – and needed (Kehm 2006, p. 70) – in order to provide the human capital necessary to create new technologies and innovations (Pedersen 2014, p. 636), enabling the EU to move towards its goal of a knowledge-based society (Eurostat 2017a). Such differences in the demand for doctorate holders across fields are at the centre of Chapter 4, asking why doctorates in different majors are differently remunerated.

Apart from increasing R&D expenditures, the Europe 2020 strategy aims at an EU average employment rate of 75 percent among people between 20 and 64 years of age (European Commission 2017a). So far, the employment rate is at 70 percent (Eurostat 2016b, p. 9), possibly due to the still lower level of female labour market participation compared to men (Fitzenberger et al. 2004). But why are there fewer women than men in the labour market? It has been argued that to some extent this is because women more frequently choose not to participate in labour market work but to engage in family work. However, at least to some degree, the persisting gender wage gap might also cause women to choose not to work as they are still not remunerated in proportion to their skills and abilities[2]. It is an empirical fact that up to today, women all around the world still earn less than men do (England et al. 2012;

[1] Between 2000 and 2009, the number of doctoral graduates in OECD countries has risen by 38 percent (Auriol et al. 2013, p. 8).

[2] According to Blau and Kahn (2017, p. 808), numerous studies have shown that increased female wages over time play an important role in explaining rising female labour market participation.

Weichselbaumer and Winter-Ebmer 2005). And while a large part of this gender wage gap can be explained by differences in preferences and attributes of men and women, discrimination against women still exists (Blau and Kahn 2017). In Chapter 5, we will address the possibilities for women to overcome or at least reduce this discrimination by attaining doctoral degrees.

1.2 Structure

Thus, the purpose of this book is to take a closer look at the determinants and effects of doctoral education both in the national and international context. To this aim, Chapter 2 begins with a demonstration of differences in higher educational systems across countries. Based on a brief introduction to international educational classification standards, I highlight cross-country differences in higher educational systems. Focusing on differences in curricular structures between countries, one- and two-cycle structures are explained[3]. Both are vital in understanding the key changes pursued by the Bologna Process, the largest reorganisation of educational systems in Europe's history (European Commission et al. 2012, p. 15). With many European countries changing their study programs from a one-cycle to a two-cycle structure in compliance with the Bologna goals, the question arises as to how these changes will affect Europe's educational and economic future (Chapter 3). Furthermore, Chapter 4 and 5 use the national context of Germany to investigate the effect of doctoral degrees on wages. For this purpose, Chapter 2 also gives a brief description of doctoral education in Germany as well as the characteristics of the German labour market for doctorate holders.

With the relationship between the curricular structure at college level and enrolment decisions at doctoral level across European countries, Chapter 3 investigates the first research question of this book. With Europe's reorganisation of higher educational systems, the question arises as to how these changes might affect enrolment numbers in countries that now restructure their college level programs in compliance with the two-cycle structure (i.e. implementing bachelor/master systems). In line with Spence's (1973) signalling theory, I expect the more productive individuals to attain higher educational levels to differentiate themselves from the less productive graduates at lower levels. With only one degree at college level as in the one-cycle system, an individual can only distinguish herself[4] from the majority of graduates by gaining a post-college level degree, i.e. a doctorate. In contrast, her counterpart in the two-cycle

[3] The key difference is the number of degrees awarded at college level. While there is only a single degree (e.g. German Diplom) in one-cycle systems, there are up to two degrees (bachelor and master) in the two-cycle systems.

[4] I will refer to the individual as female and to the employer as male. Doing so should enhance readability and does not refer to any possible gender specific attributes.

system holds two degrees (bachelor and master). Thus, she has already differentiated herself from students who only attend first degree studies (bachelor). Her incentive to acquire a doctoral degree to distinguish herself further is therefore lower compared to her counterpart in the one-cycle system.

To the best of my knowledge the study in Chapter 3 is the first to examine the effect of a country's curricular structure at college level on doctoral enrolment rates. Based on random effects estimations on cross-country data from 23 European countries between 1995 and 2005, I confirm the hypothesis that doctoral enrolment rates are higher in the one-cycle system than in the two-cycle system after controlling for factors of educational institutions, labour market conditions, and a population's socio-economic characteristics. This result raises concerns about whether the implementation of the Bologna Process ultimately contradicts its own goals and those of the Europe 2020 strategy, both aiming at higher tertiary enrolment rates. However, the implementation of a universal two-cycle system to pursue this goal might be done at the expense of the number of doctoral graduates as results in Chapter 3 suggest. Potentially fewer doctoral students might imply fewer researchers, fewer university-industry relationships, and fewer future teaching personnel in higher education. Hence, policy, educational institutions, and firms might suffer from this development. Recognising a potential shortfall in future researchers at an early stage helps us to conquer this threat and to improve or implement alternative mechanisms to keep on attracting the most qualified college graduates for doctoral education. This will help meeting future demand for a highly educated workforce and could help Europe to achieve its economic goals.

While Chapter 3 uses an international comparison to investigate doctoral enrolment decisions, Chapters 4 and 5 use data from Germany to analyse doctoral wage premiums at an individual level. Focussing on Germany is advantageous for three main reasons: First, compared to other countries, Germany shows a larger number of doctoral graduates in general as well as a larger fraction of doctorate holders employed in the private than in the public sector. This provides us not only with a broader sample of doctoral graduates but also gives us the chance to evaluate how doctoral degrees are valued largely in the absence of compressed wage structures and collective agreements. Second, Germany ranks high on employment protection scales in international comparisons making it more difficult for employers to easily termine employees' contracts. Employment decisions, therefore, have more far-reaching consequences than in countries where a 'hire and fire' mentality can be exercised. Hence, identifying productive candidates is far more important. Third, Germany has strong parental leave laws and traditional gender roles (Leuze and Strauß 2016, p. 804), which together might contribute to a reluctance to employ women, or result in comparatively large gender wage gaps even among the highly educated (Leuze and Strauß 2016, p. 804). This is particularly important for Chapter 5, were we investigate the possibility for women to overcome discrimination by attaining doctoral degrees.

In Chapter 4, I investigate my second research question by looking at differences in doctoral wage premiums[5] across major groups. Inspired by Kalmijn and Lippe (1997) and McDowell (1982), I expect college majors to differ not only with respect to their imparted major-specific knowledge (e.g. technical/analytical versus communicative/caring skills) but also with regard to the durability of their imparted human capital (e.g. time-durable and time-erodible knowledge). While employers are interested in major-specific knowledge imparted by certain college majors, they have to accept the durability nature of the respective skills. Additionally, in contrast to education at college level, doctoral studies at post-college education focus on imparting research skills that enable their students to familiarise themselves with new topics autonomously and even create new knowledge. In line with Becker's (1962) human capital theory, I assume that an employer will only reward human capital that he can put to use productively. With time-erodible knowledge eroding over time, research skills help time-erodible major graduates to enhance their productivity with the employer as they enable them to constantly renew their knowledge on their own. Hence, an employer in need of time-erodible human capital will reward these research skills because they enable him to profit from the respective employee in the future. Employers in need of time-durable knowledge, however, can put this knowledge productively to use for a long period without the need of any refreshing. Thus, these employers are not in need of research skills and will not remunerate this kind of expertise. I therefore expect a doctoral wage premium only for those doctoral graduates who attained time-eroding majors. By developing this argument, Chapter 4 contributes to the literature that explains differences in doctoral wage premiums across majors. Focussing on the durability of imparted knowledge, it is (to my knowledge) the first to give a supply-based explanation. I am therefore able to explain differences in doctoral wage premiums that existing demand-based arguments fail to explain.

To test for doctoral wage premiums in time-durable and time-erodible major groups, I use information on German university graduates from 2005 drawn from the German Centre for Higher Education Research and Science Studies (DZHW) Graduate Panel (DZHW 2005), a

[5] Wage mark-up for holding a doctoral degree on top of the highest degree at college level, i.e. the difference between expected earnings with and without a doctoral degree.

nationwide representative longitudinal survey (Baillet et al. 2016). Running multiple OLS regressions separately for both major groups and controlling for individual, educational, and occupational characteristics, I can confirm both hypotheses: While among time-erodible major graduates, doctorate holders earn significantly higher wages than non-doctorate holders five to six years after graduation, there is no significant doctoral degree effect among the time-durable major graduates. Given that employers remunerate research skills of time-erodible major graduates because these skills are important in order to keep on exploiting this type of human capital, firms need to understand how important it is to provide the research environment necessary to perform research and create new ideas. Otherwise, we might not be able to exploit the human capital provided by society and, thus, achieve the EU's smart growth aspirations[6].

Chapter 5 pays attention to the gender wage gap among the highly educated and investigates with the third research question of this book whether doctoral degrees can help to reduce the gender wage gap among mixed major (e.g. business administration and economics) graduates. Distinguishing between two types of work attitudes (family orientation and career orientation), we understand a family-oriented person as an individual whose first priority is family work, e.g. child rearing. Such individuals either choose not to engage in the labour market in order to focus on family work; or try to find a job that helps them to support their families financially without interfering with their family duties. A career-oriented individual, in contrast, is a person whose first priority is labour market work and who will not interrupt employment relationships for a longer period. We expect employers to prefer career-oriented employees over family-oriented ones and therefore to pay higher wages to the former. Based on considerations in Chapter 4, we anticipate time-durable majors to be chosen by family-oriented individuals, and time-erodible majors by career-oriented ones. Thus, while Chapter 4 focuses on the productivity enhancing effect of education in line with human capital theory, Chapter 5 looks at the signalling function of college major choices and doctorates regarding inherent work attitudes.

There are, however, majors that impart neither predominantly time-durable nor time-erodible knowledge but a combination of both. Such heterogeneous majors are business administration, economics, and law (i.e. mixed majors). In line with the idea of career orientation, we would not expect mixed majors to be chosen by predominantly family- or career-oriented individuals, but by both. As a consequence, employers of mixed major

[6] The EU emphasises on "smart, sustainable and inclusive growth" (European Commission 2017a) to overcome Europe's structural economic weaknesses and to improve its competitiveness in the global market (Eurostat 2017a).

graduates will be in the dark regarding their true work attitudes and will use other indicators such as the applicant's gender to assess her career orientation. Based on the concept of statistical discrimination (Arrow 1973; Phelps 1972), we assume that employers believe men to be predominantly career-oriented and women family-oriented. In order to be paid according to her true level of career orientation, a career-oriented woman can use a doctorate to differentiate from the family-oriented ones. Due to this signalling effect of doctoral degrees for women in contrast to men, who are believed to be career-oriented even without a doctorate, we would expect higher doctoral wage premiums for women than for men in mixed majors. We refer to this phenomenon as the doctoral premium gap. Consequently, we believe that doctoral degrees in mixed majors enable women to reduce the gender wage gap.

Based on Oaxaca-Blinder decompositions (Blinder 1973; Oaxaca 1973) of the gender wage gap among German graduates (DZHW 2005), we can confirm our hypothesis showing that women in mixed majors can reduce the gender wage gap by 1.78 percent. Within highly educated societies such as Germany, this result might demonstrate a way for career-oriented women to gain wages that better reflect their inherent work attitudes and possibly increase future labour market participation rates of women (even of those without a doctoral degree) via their trailblazing role. This might allow European countries to increase their total employment rates in accordance with the goals set by the Europe 2020 strategy.

Chapter 6 concludes the book. After summing up the research questions, arguments, and empirical results of Chapter 3 to 5, I highlight their implications for politics, firms, and individuals as well as the need for future research within the determinants and effects of doctoral degrees.

2 Higher education in Europe with a special reference to the German doctorate

2.1 The typical route for doctoral students in Europe

Educational systems vary across countries (Eurostat 2017b). To facilitate international comparisons and to assess educational goals, the UNESCO developed the ISCED classification (International Standard Classification of Education) (UNESCO 2017). Its purpose is to allocate comparable educational programs at any stage in life to worldwide common educational levels based on internationally agreed definitions and criteria (Eurostat 2017b; UNESCO 2017, 2006, pp. 11–16). Therefore, these levels reflect "broad steps of education progression from very elementary to more complex experiences" (UNESCO 2006, p. 15).

Since they were first developed in 1976, the ISCED classifications were updated three times in 1997, 2011, and 2013 (UNESCO 2017). As ISCED classifications are not comparable across different editions, nor do they contain information about the educational systems for years previous to the introduction of each new edition, I will use the ICSED 1997 classification throughout the entire book as this classification was the incumbent one at the time of the data used in this book (1995 to 2005).

The ISCED 1997 classification has seven broad educational levels, ranging from "0" (pre-school education) to "6" (education that leads to advanced research qualifications) and encompasses primary (level 1), secondary (level 2–4[7]), and tertiary education (level 5–6) (UNESCO 2006, p. 19). Apart from this vertical differentiation, educational programs at level 2 to 5 also consist of different program orientations (horizontal differentiation), classified as "A" (theoretically oriented programs), "B" (vocationally oriented programs preparing for further vocational education), or "C" programs (vocationally oriented programs providing direct access to the labour market and sometimes – as with ISCED 3C and 4C – also access to other educational programs).

While there are different avenues through which a student can reach ISCED 6 education, the majority of doctoral students follow a succession of theoretically oriented programs ("A" programs). Having passed optional pre-school education and obligatory basic education

[7] Although defined as post-secondary (non-tertiary) education, I assign ISCED 4 programs to secondary education to explicitly distinguish these from programs at tertiary level. This is in line with UNESCO (2006, p. 31), arguing that "ISCED 4 programs can, considering their content, not be regarded as tertiary programs. They are often not significantly more advanced than programs at ISCED 3". The purpose of ISCED 4 education is to broaden the knowledge of students who have already successfully completed studies at level 3 (UNESCO 2006, p. 31).

at primary educational level (UNESCO 2006, p. 22), these students mostly joined theoretically oriented programs in secondary education at level 2 and 3. After that, they attended theoretical-based studies at first stage tertiary level (level 5), before having enrolled in doctoral studies (second stage tertiary education) which are by definition theoretically based (UNESCO 2006)[8].

The key difference between the first (ISCED 5) and second stage (ISECD 6) tertiary education is that only the latter one directly leads to an advanced research qualification (e.g. doctorate) (UNESCO 2006, pp. 34–39). Accordingly, programs at ISCED 5 and 6 levels differ in their curricula: While ISCED 5 education is mainly "built on structured and course-based programs and examinations", focusing on imparting (basic) knowledge in a certain field, the "most predominant and essential component of [ISCED 6 education] is research […] without an emphasis on structured courses" as they focus on bringing forth new researchers (European University Association 2005, p. 35). Hence, instead of consuming knowledge as at ISCED 5 level, students at ISCED 6 level devote themselves to original research and eventually become "creators of knowledge" themselves (Pedersen 2016, p. 271; UNESCO, p. 39). To emphasise the curricular difference between first and second stage tertiary educations, I refer to the former as college level and the latter as post-college level education.

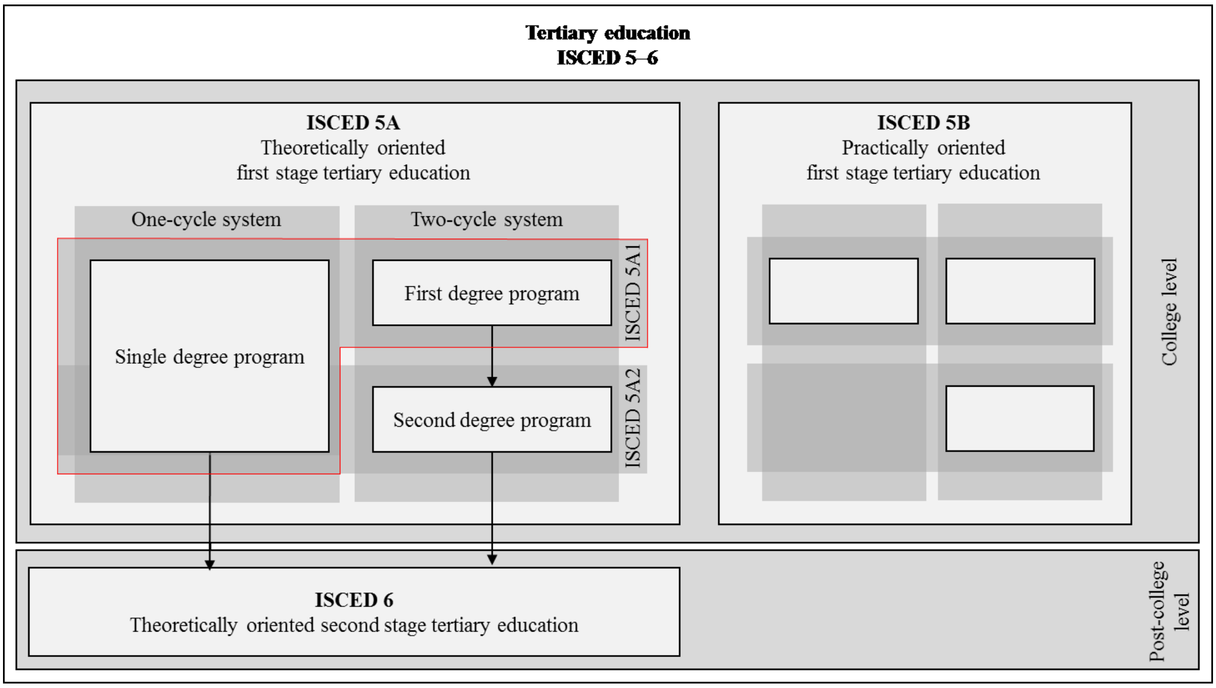
As mentioned before, curricular orientation is one dimension in which programs at college level differ. Accordingly, college level education is divided into ISCED 5A and 5B programs. Following the idea of "A" and "B" labelling, 5A programs are theoretically based and prepare students for future research work or give "access to professions with high skills requirements" (UNESCO 2006, p. 34), while 5B programs are practically based, providing "occupationally specific skills" that are aligned with the needs of the labour market. These programs are usually shorter than 5A programs (UNESCO 2006, p. 35) and do not provide direct access to level 6 education (UNESCO 2006, p. 18).

Furthermore, programs at college level differ largely in terms of study duration. On the one hand, this is because 5B programs are usually shorter than 5A programs (UNESCO 2006, p. 35). On the other hand, differences in the curricular structure cause this variability. Most programs at college level can be assigned to either the one-cycle or two-cycle system. While in the former, there is only one degree awarded (single degree programs, such as the German

[8] The careful reader might miss level 4 education. Level 4 programs are post-secondary non-tertiary programs that come after secondary education at level 3 but do not belong to tertiary education at level 5. Often, studies at level 4 are not more advanced than regular studies at level 3 but are designed to teach students who, although having completed level 3 education, did not receive the curriculum necessary to enrol in level 5 programs. Although these programs might enable students to enrol in doctoral studies later on, this is not the typical road for students to follow to reach level 6.

Diplom), there are up to two degrees in the latter system (first and second degree programs, e.g. bachelor and master). Thus, in the two-cycle system, a student can leave tertiary education after about three years of study, while it takes her counterpart in the one-cycle system about five years before she can gain her first college level degree (UNESCO 2006, p. 37). Regarding their knowledge, however, the student in the one-cycle system receives an education that is similar to that of a graduate of a second degree program in the two-cycle system (e.g. master) (UNESCO 2006, p. 37). Figure 1 depicts the dimensions in which programs at college level can differ across countries. As both single degrees (one-cycle system) and first degrees (two-cycle system) mark the first point at which students can leave tertiary education with a degree, both are assigned to first degree programs by the ISCED classification (ISCED 5A1 for theoretically oriented programs). master programs (or equivalents) are grouped with second degree programs (ISCED 5A2 for theoretically oriented studies) (UNESCO 2006, p. 38).

Figure 1: Dimensions of tertiary education in international comparison



Source: Own illustration based on information extracted from UNESCO (2006)

Typically, only the highest qualification at college level provides access to level 6 education (UNESCO 2006, p. 37). Hence, as depicted in Figure 1, a student in the one-cycle system needs to hold the single degree to proceed to post-college education, while her counterpart in the two-cycle system needs the second degree on top of her first degree (Ministerial Conference 2003, p. 4).

As mentioned before, programs at post-college level are “devoted to advanced study and original research and are not based on course-work only” and therefore differ largely from education at college level (UNESCO 2006, p. 39). While there are both theoretically and practically oriented programs at ISCED level 5, studies at ISCED level 6 are by definition solely theoretically oriented. Hence, the scope of programs is quite small and does not need further distinctions (e.g. “A” and “B” labelling). To successfully complete this educational stage, students at this level are required to submit “a thesis or dissertation of publishable quality” (UNESCO 2006, p. 39). This thesis is expected to be “the product of original research” and should bring out “a significant contribution to knowledge” (UNESCO 2006, p. 39). Given their theoretical orientation, programs at this level prepare their graduates for occupations in theoretically based college level education as well as in research departments in both private and public sector industries (UNESCO 2006, p. 39).

2.2 The Bologna Process: Reorganisation of Europe’s tertiary education

Section 2.1 showed that tertiary education especially at college level varies widely across countries with regard to curricular structure and study duration. This was especially true for European countries before 1999 (EHEA 2017b). Since then, Europe’s higher education experienced major changes and will continue to undergo alterations in the years to come.

For almost a thousand years since the world’s first university was founded in Bologna, Italy, in 1088, European universities were the centres of sciences and research, until US universities took the lead during the last 50 years (Caddick 2008, p. 18). In order to reclaim European universities’ places among the world’s top ranked universities and in answer to growing international competition and increased student cross border mobility, Europe’s higher education ministers agreed to make their universities more competitive again (European Commission et al. 2012, p. 15).

Their signature on the Bologna Declaration in 1999 set off the Bologna Process, the largest collaborative process in higher education ever to take place in European history (European Commission et al. 2012, p. 15). Its aim was not so much to standardise but to harmonise Europe’s higher education systems and to pull down educational borders between European countries (Adelman 2009, viii). With such a wide ranging project, this was not done with a single declaration but required (and still requires) constant evaluation and adjustments. Since the Bologna Declaration in 1999, Europe’s educational ministers have met every second to third year (European Commission et al. 2015, p. 25) to meet these challenges. What started as a common understanding of four European countries (France, Germany, Italy, and UK) with the Sorbonne Declaration in 1998, was confirmed by 31 European educational ministers in the Bologna Declaration in 1999 and resulted in the European Higher Education Area (EHEA) which represents an agreement of (so far) 48 European and peripheral[9] European countries to implement common tools to harmonise higher educational systems (EHEA 2017a; European Commission et al. 2012). All these members committed themselves to implement reforms and to join a process of continuously adapting their higher education systems to create a higher education area of comparable credit systems and academic degrees as well as higher education of equal quality (EHEA 2017a; European Commission et al. 2012). While jointly aiming for enhanced students', teachers' and researchers' mobility and employability in future labour markets (EHEA 2017a), all member states maintain control over how they implement the reforms within their educational system. Hence, the 48 member countries still vary with regard to student population, educational institutions, and funding, but are more equal in curricular structure, credit system and, therefore, awarded degrees (European Commission et al. 2012, p. 19).

The key strategic elements to facilitate the Bologna aspirations were (i) the introduction of a universal credit system that allows students to easily transfer their educational achievements from one country to another and (ii) the implementation of a common two-cycle (and later three-cycle) system in accordance with the curricular structure already implemented in the UK and USA (Caddick 2008, pp. 18–19; European Commission et al. 2012, p. 15).

With student credits based on course workload and learning achievements, the implemented European Credit Transfer and Accumulation System (ECTS) allows to compare students' level of knowledge across countries and universities (European Commission 2017b). This universal credit system enhances the transparency of individual learning achievements and makes it easier to recognise studies undertaken in other countries (European Commission 2017b). A student can, thus, attend courses in different universities in different countries and transfer the credits she gained from one university to another where eventually they add up to her degree program (European Commission 2017b).

As early as in the Bologna Declaration of 1999, the aspiration of a common curricular structure based on two cycles (undergraduate and graduate) was formulated (Ministerial Conference 1999, p. 3). While in this early version, doctoral studies were considered as part of graduate studies (Ministerial Conference 1999, p. 3), the ministerial conference in 2003 deliberately excluded doctoral studies from second degree programs and thus implemented a

[9] Azerbaijan, Armenia, and Georgia

third cycle (Ministerial Conference 2003, p. 4). In their 2003 declaration, “all [educational] ministers commit themselves to having started the implementation of the two-cycle system by 2005” (Ministerial Conference 2003, p. 3).

During the course of their two-cycle studies, students have to achieve between 180 and 240 credit points in first degree studies and additional 60 to 120 credit points in second degree studies if they want to complete the second college level degree (European Commission 2017b; Westerheijden et al. 2012, p. 7). Thus, the average full time student attends several courses which add up to about 60 credits per year (European Commission 2017b). The “180+120” credit point model turned out to be the prevailing program structure in Europe representing study durations of three and two years, respectively (European Commission et al. 2015, p. 52; Westerheijden et al. 2012, p. 7), although a specific Bologna model was never defined in any of the official Bologna Process documents (Westerheijden et al. 2012, p. 15). Moreover, there are some study programs that were excluded from the introduction of the two-cycle structure. In most countries, this was the case for studies in the field of medicine and health sciences, mostly for reasons connected to the respective disciplines (Westerheijden et al. 2012, pp. 17–18).

Almost two thirds of the 48 member states maintained that they had some form of two-cycle structure in place before the Bologna Declaration in 1999 (Westerheijden et al. 2012, p. 15). While many reported already having two-cycle systems that complied with the Bologna requirements[10], others showed curricular structures that were not in strict accordance with these requirements, e.g. in terms of study duration (credit points) at each stage. Countries such as Albania, France, Norway, and Slovakia – despite having pre-Bologna two-cycle structures – still had to adjust their programs to the new requirements, reporting full implementation (i.e. at least 90 percent of students enrolled in the Bologna-confirm structure) not before 2006 (Norway and Slovakia), 2008 (Albania), and 2010 (France) (European Commission et al. 2012, p. 32; Rauhvargers 2007, p. 80; Rauhvargers et al. 2009, p. 122).

For those who were traditionally organised according to the one-cycle structure and therefore had to implement the two-cycle structure (i.e. introducing shorter first cycle and new second cycle studies), this was a more time consuming process. Table 1 shows in which academic year former one-cycle countries reported for the first time that at least 90 percent of all students were enrolled in a Bologna-confirm two-cycle structure.

[10] Cyprus, Denmark, Greece, Iceland, Ireland, Latvia, Liechtenstein, Lithuania, Malta, Slovenia, Turkey, and UK.

Table 1: First academic year of fully implemented Bologna-confirm two-cycle structure

2006/07	2008/09	2013/14
Belgium (French), Czech Republic, Finland, Italy, Netherlands	Belgium (Flemish), Estonia, Luxembourg, Portugal, Romania, Spain, Sweden	Austria, Croatia, Germany, Hungary, Macedonia, Switzerland, Poland

Source: Information extracted from European Commission et al. (2015, p. 50), Rauhvargers et al. (2009, p. 122), and Rauhvargers (2007, p. 80)

In some countries, however, this process was not so much an introduction of new study programs but a reorganisation of existing ones as they simply split former longer single degree studies into two programs (Caddick 2008, p. 20). According to European Commission et al. (2015, pp. 49–50), the two-cycle structure is now fully implemented in all member countries. The few countries that did not show a two-cycle enrolment rate of at least 90 percent by 2015 are characterised by large numbers of students enrolled in programmes that are not meant to be aligned to the Bologna structure (which does not imply that other Bologna objectives e.g. the credit system have not been implemented) (European Commission et al. 2015, p. 50).

An important aspect of the Bologna two-cycle system is the matter of access. The educational ministers clearly stated at their 2003 conference that "[f]irst cycle degrees should give access[11] […] to second cycle programmes [and s]econd cycle degrees should give access to doctoral studies" (Ministerial Conference 2003, p. 4). Not all first cycle programs, however, give access to two-cycle studies (European Commission et al. 2015, p. 59). With regard to theoretically and practically oriented programs, combinations exist where students of e.g. practically oriented first degree studies or theoretically oriented studies in a different field need to attend bridging programs or fulfil additional requirements before attending theoretically oriented second degree studies (in another field) (European Commission et al. 2015, pp. 59–60). Furthermore, there are some (particularly practically oriented) first degree programs without a natural succession of a second degree program, and often graduates of practically oriented second degree programs cannot enrol in doctoral studies (European Commission et al. 2015, p. 59).

While, at least in theory, all first degree holders are allowed to enrol in second degree studies in the same field, this is not what ministers hoped for (European Commission et al. 2015, p. 62). For some time now, the share of first degree graduates who enrol in second degree studies has been shrinking (European Commission et al. 2015, p. 62): While in 2011, 13 countries showed a continuation rate beyond 76 percent, this was the case for only 6 countries in 2014. This development indicates that first degrees are more readily accepted by

[11] In the sense of having "the right to be considered for admission" (European Commission et al. 2015, p. 59).

the labour market since more students would otherwise continue for second degree studies (European Commission et al. 2015, p. 62).

At the 2003 Bologna conference, Europe's educational ministers decided to deviate from what was written in the Bologna Declaration and to introduce doctoral studies as third-cycle studies instead of assigning them to second cycle studies (EHEA 2017b; Ministerial Conference 2003, p. 4). Being the highest educational level, this cycle is characterised by the smallest enrolment rate with less than 5 percent of students in most European countries (European Commission et al. 2015, p. 52). Based on information from the Bologna Follow-up Group, most countries have continuation rates to doctoral studies below 30 percent (European Commission et al. 2015, p. 63).

On rare occasions, 19 member countries also allow access to doctoral studies to individuals who do not hold a second degree provided that these students show exceptional qualifications (European Commission et al. 2015, p. 64). The share of doctoral students without a second degree is therefore quite small (below 5 percent) but exceptionally large in Ireland and Portugal (16–25 percent) (European Commission et al. 2015, p. 63).

Normally, it takes 3 to 4 years to attain a doctoral degree, with 3 years being the typical duration given full time studies (Westerheijden et al. 2012, p. 19). However, in some countries[12] doctoral studies can take up to 5 years (Westerheijden et al. 2012, p. 19).

There are various forms of doctoral programs (e.g. structured programs, supervised studies), but the traditional supervised approach is still the most common one (European Commission et al. 2015, p. 65). Here, doctoral students work closely together with their supervisor, typically doing their original research within the research area of their supervisor. In contrast, students in structured programs attend courses. Within the Bologna Process, it was not explicitly intended to apply the credit system to the third cycle (Westerheijden et al. 2012). Nonetheless, the use of ECTS points is growing in doctoral studies with 35 countries already using this credit system at least to some degree (European Commission et al. 2015, p. 65).

2.3 Doctoral education in Germany

Countries like Germany, which have relatively few natural resources, depend on a knowledge-based economy that produces knowledge-intensive goods and services and that is innovative in order to be internationally competitive (Konsortium Bundesbericht Wissenschaftlicher Nachwuchs 2017, p. 45). Central to the evaluation of a country's innovativeness is its

[12] Albania, Germany, Iceland, Malta, Serbia, and Switzerland

expenditure on research and development (Konsortium Bundesbericht Wissenschaftlicher Nachwuchs 2017, p. 45). With 2.88 percent of German GDP spent on R&D in 2014, Germany almost met the goal of 3 percent set by the EU (Konsortium Bundesbericht Wissenschaftlicher Nachwuchs 2017, p. 45). As in other countries, the highly qualified personnel in Germany necessary to exploit these R&D investments originate largely from universities, universities of applied sciences, and four large non-university research institutions[13] (Konsortium Bundesbericht Wissenschaftlicher Nachwuchs 2017, pp. 45–47).

While universities focus on fundamental and value-oriented research and education (ISCED type A education), universities of applied sciences focus on practically oriented type B research and teaching and have close relationships with industry (Konsortium Bundesbericht Wissenschaftlicher Nachwuchs 2017, pp. 46–47)[14]. In line with this difference in curricular orientation, only universities are allowed to award doctoral degrees (Konsortium Bundesbericht Wissenschaftlicher Nachwuchs 2017, p. 47).

In 2014, 153,888 students gained a diploma or master degree (ISCED level 5) awarded by a university[15] allowing them to enrol in doctoral studies (Konsortium Bundesbericht Wissenschaftlicher Nachwuchs 2017, p. 85). They therefore joined the group of 1,664,000 individuals under the age of 35 who were entitled to enrol in doctoral studies (Konsortium Bundesbericht Wissenschaftlicher Nachwuchs 2017, p. 85). Compared to this group size, the number of those who actually pursue a doctoral degree is small (in the winter term of 2014/15, 196,200 students were enrolled in doctoral studies, i.e. 12 percent) (Konsortium Bundesbericht Wissenschaftlicher Nachwuchs 2017, p. 88).

Nonetheless, Germany shows the highest number of doctoral students in Europe (see Figure 2). Using German data for empirical analyses in Chapter 4 and 5 of this book is advantageous, because the larger sample size regarding doctorates reduces the risk that identified effects are caused by few but large outliers.

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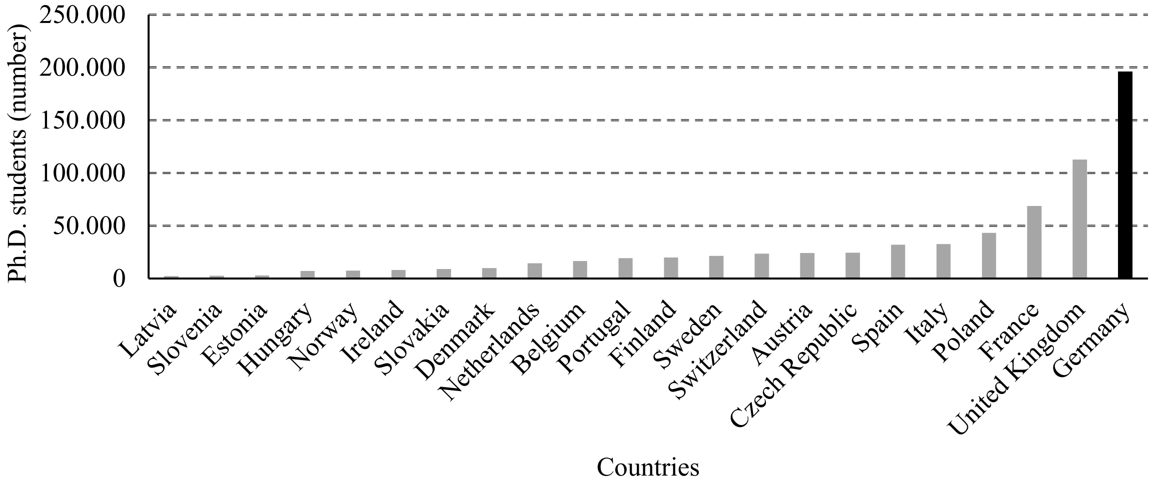
[13] Fraunhofer, Helmholtz, Max-Planck, and Leibniz

[14] There are 427 higher educational institutions in Germany consisting of 181 universities and 246 universities of applied sciences (Konsortium Bundesbericht Wissenschaftlicher Nachwuchs 2017: 46). Although there are more practically than theoretically oriented higher educational institutions in Germany, the majority of students (66 percent) are enrolled in universities (Konsortium Bundesbericht Wissenschaftlicher Nachwuchs 2017: 47).

[15] In principle, master and diploma graduates of universities of applied sciences are also entitled to enrol in doctoral studies (Konsortium Bundesbericht Wissenschaftlicher Nachwuchs 2017, p. 85). The majority of over 75 percent, however, holds a university degree (Konsortium Bundesbericht Wissenschaftlicher Nachwuchs 2017, p. 87).

Figure 2: Numbers of doctoral students in 2015

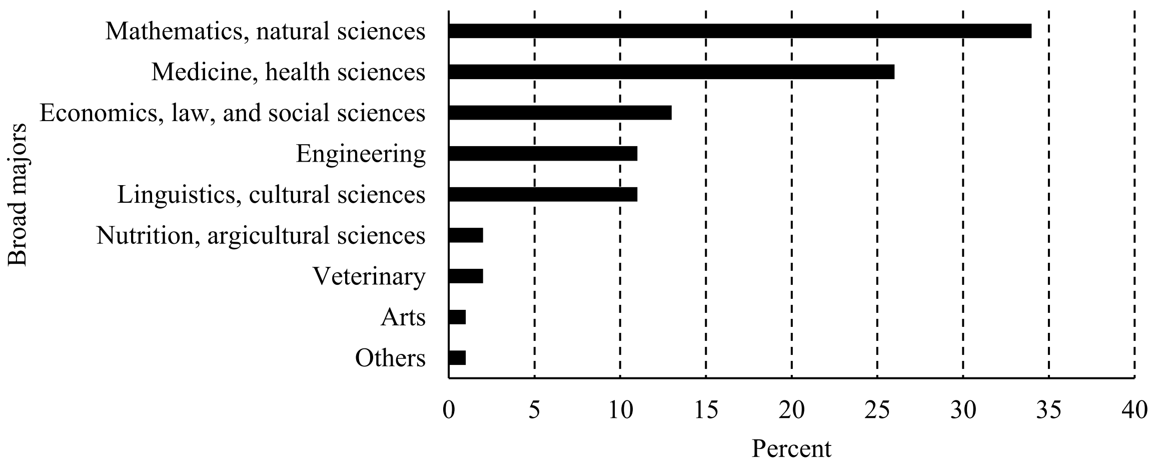


Source: Own illustration based on data extracted from Eurostat (2017d)

The true number of German doctoral students might be even higher than depicted in Figure 2 because registration of doctoral candidates is not mandatory. Only those who are enrolled as doctoral students, e.g. at a university, are officially registered and this number accounts only for 57 percent of the actual doctoral candidates (Hähnel and Schmiedel 2016, p. 35; Konsortium Bundesbericht Wissenschaftlicher Nachwuchs 2017, p. 88). Data on doctoral graduates, however, do not have this limitation because they are collected on all graduates, regardless of whether someone was enrolled (Hähnel and Schmiedel 2016, p. 7).

Among those who gained their doctoral degree in Germany in 2014, the largest single group (34 percent) graduated in the broad major group of mathematics and natural sciences, followed by medicine and health sciences (see Figure 3).

Figure 3: Doctoral graduates in 2014 (in percent)

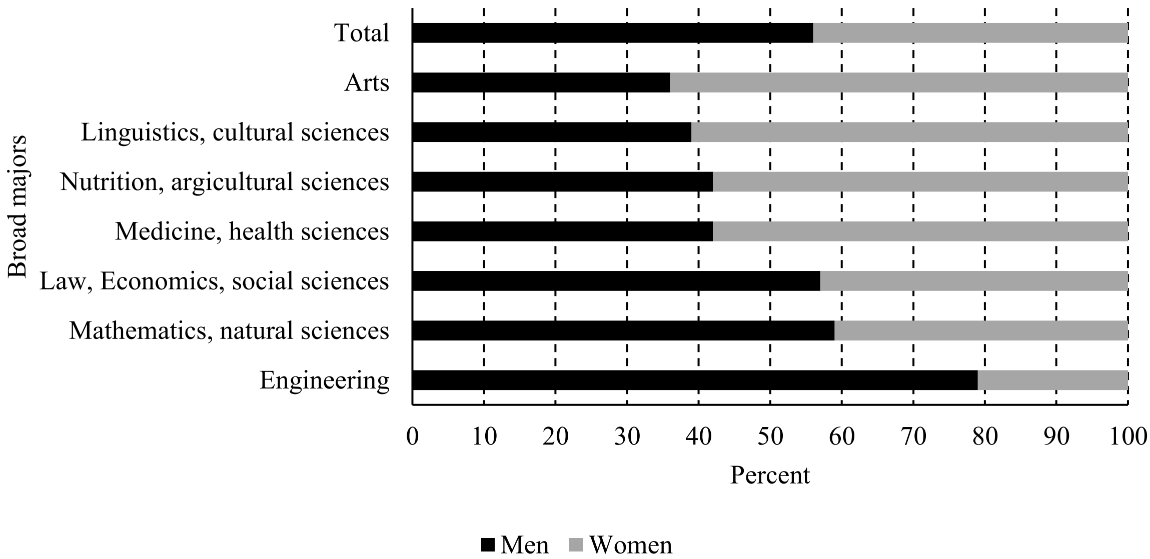


Source: Own illustration based on data extracted from Hähnel and Schmiedel (2016, p. 26)

Figure 3 might suggest that doctorates are more important in fields such as natural sciences and medicine than in linguistics and arts. In Chapter 4, I will have a closer look at this suggestion. Assuming that doctoral studies impart research skills, I argue that such skills are particularly important in fields that impart predominantly knowledge that decays over time (e.g. engineering, mathematics, and natural sciences), while research skills are less important for graduates of majors that focus on knowledge that is stable over time (e.g. art, linguistics, and cultural sciences).

Since 2000, the number of doctorates steadily increased in most majors (Konsortium Bundesbericht Wissenschaftlicher Nachwuchs 2017, p. 93). This increase might originate in the increasing share of women in doctoral studies (Konsortium Bundesbericht Wissenschaftlicher Nachwuchs 2017, p. 94; OECD 2010, p. 4). Out of the 196,200 doctoral students registered in the winter term of 2014/15, 44 percent were female (see Figure 4). However, there are major differences in male and female enrolment rates across majors. While women dominate fields characterised by time-durable knowledge or social, communicative, and caring skills (e.g. arts, linguistics ,and cultural sciences), men prefer majors of time-erodible knowledge that impart technical and analytical skills (e.g. engineering, mathematics, and natural sciences) or majors that promise larger incomes in future work life (e.g. economics).

Figure 4: Gender distribution in doctoral studies of different fields in 2014/15 (in percent)



Source: Own illustration based on data extracted from Hähnel and Schmiedel (2016, p. 27)[16]

[16] Information on veterinary and other majors was not provided.

Furthermore, 83 percent of the doctoral students were employed during their studies (Hähnel and Schmiedel 2016, p. 39). Out of these, the majority (64 percent) were employed at higher educational institutions, 5 percent worked at non-university research institutions and in the business sector, respectively, and 9 percent were otherwise employed (Hähnel and Schmiedel 2016, p. 37). In addition to, or instead of, undertaking employment during studies, some doctoral students in Germany gain scholarships (16 percent of all doctoral students in the winter term of 2014/15) (Hähnel and Schmiedel 2016, p. 37).

Closely connected to one's state of employment during the doctorate is the environment in which the doctorate is pursued. Either the doctoral candidate is employed at the university where she conducts the doctorate or she is not employed at the university where she hands in her thesis but possibly at another research facility or in the business sector. In some cases, doctoral candidates can pursue the doctorate during their college level studies, e.g. in medicine (Hähnel and Schmiedel 2016, p. 35).

Statements regarding the length of doctoral studies in Germany are difficult to give, since there was no agreement as to the starting point (point of enrolment entitlement, start of employment at chair/structural program, etc.) and end point (handing in of thesis, date of certificate, etc.) (Konsortium Bundesbericht Wissenschaftlicher Nachwuchs 2017, p. 152). In the future, there will be a common definition of start and end points: Doctoral studies begin with a written confirmation of acceptance of the doctoral student by the supervising institution and end with the date when the examiners officially decide on the grading (Konsortium Bundesbericht Wissenschaftlicher Nachwuchs 2017, p. 153). Surveys asking for a self-assessment of study duration come to an average of 3.9 years (Konsortium Bundesbericht Wissenschaftlicher Nachwuchs 2017, p. 153).

These comparably long study durations also cause the average age of graduation to be quite high: the average age of doctoral graduates in Germany is 32.6 years varying between 31.5 (mathematics and natural sciences) and 38.6 (arts) (Konsortium Bundesbericht Wissenschaftlicher Nachwuchs 2017, p. 95). In OECD comparison, however, this is not exceptionally high as the average age is 34.1, varying from 29 years in Belgium to 41 in Malta (OECD 2013).

While there is a large variety in the detailed structure of doctoral studies, a distinction is often made between two major forms of programs – the traditional supervisor program and the (new) structured program – with the rest being variations and combinations of these. The traditional program is less a program but more a "master-apprentice" (Kehm 2006, p. 69) approach, where the doctoral student normally has one supervisor who is at the same time her examiner and manager, as most of these doctoral students are employed at the supervisor's chair for the time of the doctorate (Konsortium Bundesbericht Wissenschaftlicher Nachwuchs 2017, p. 149). Over time, this approach was criticised for its long study durations (Konsortium Bundesbericht Wissenschaftlicher Nachwuchs 2017, p. 152) and the dependence on the objectivity of one's supervisor/manager who will evaluate the final thesis and might take advantage of these interdependencies (Konsortium Bundesbericht Wissenschaftlicher Nachwuchs 2017, p. 149). To address these potential drawbacks, structural programs were introduced, where the supervision, and eventually the examination, is done by a team instead of a single person (Konsortium Bundesbericht Wissenschaftlicher Nachwuchs 2017, p. 149). However, even in the traditional model, the vast majority (76 percent) reports to have more than one supervisor but the number of supervisors per student is higher in structural programs (Konsortium Bundesbericht Wissenschaftlicher Nachwuchs 2017, p. 149).

As there is no overall accepted definition of a structural program (e.g. whether a formal membership or only actual participations are counted), information on the participation rate in such programs varies (Konsortium Bundesbericht Wissenschaftlicher Nachwuchs 2017, p. 146). According to the definition of the federal statistical office, a structural doctoral program consists of a mandatory educational program which needs to be finished within a given period of time (Hähnel and Schmiedel 2016, p. 60). This program however does not need to be specified in the examination regulations of a university. According to this definition, all federal and state graduate schools and programs as well as programs and schools of the German Research Foundation (DFG) and excellence initiatives provide such structural programs. In the winter term of 2014/15, 23 percent of all doctoral students were enrolled in such programs (Hähnel and Schmiedel 2016, p. 32). Again, there are differences across majors, with natural sciences reporting the largest share of students enrolled in structural programs (33 percent) and medicine and health sciences the lowest share (14 percent) (Hähnel and Schmiedel 2016, p. 32).

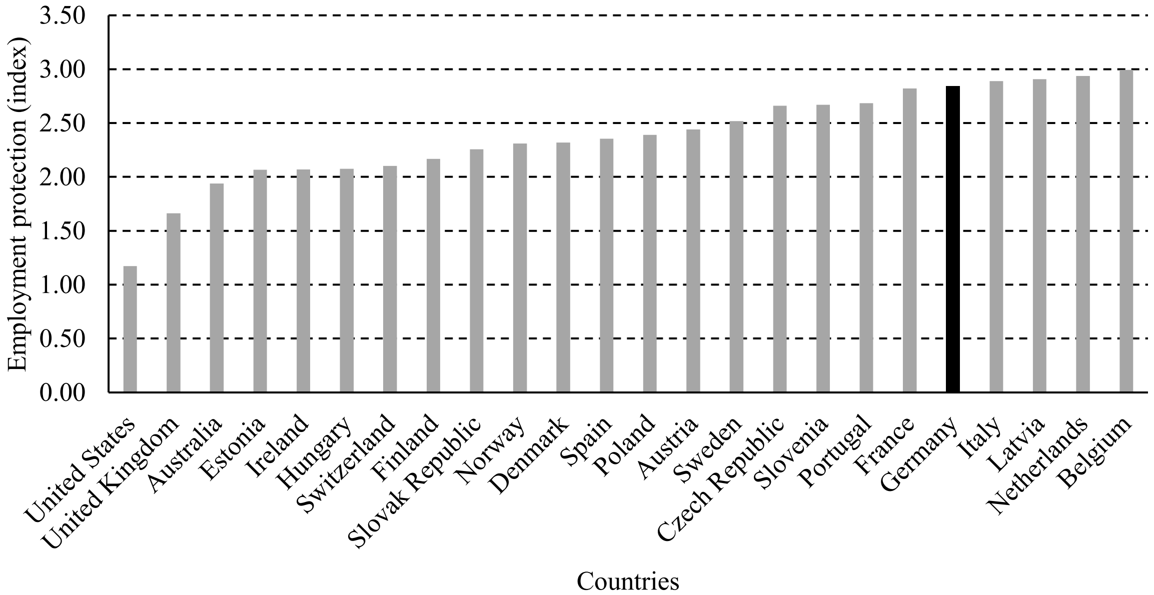
To successfully complete their doctoral studies, students have to write a thesis of original research and master an oral exam. There are two common versions of the written part: the monograph (essentially one large thesis) and the cumulative thesis (a compilation of several scientific articles) (Hähnel and Schmiedel 2016, p. 33). Currently, the monograph is the dominant form of doctoral thesis (77 percent of all doctoral theses in the winter term of 2014/15 were monographs) (Hähnel and Schmiedel 2016, p. 33).

2.4 The characteristics of the German labour market for doctoral graduates

With 772,000 people (45 percent women), the group of doctorate holders makes up almost 1 percent of the total German population (Konsortium Bundesbericht Wissenschaftlicher Nachwuchs 2017, pp. 92–94). In the following section, I will first give a short description of the framework of the German labour market, before providing information on the labour markets for doctorate holders.

In international comparison, the German labour market is characterised by large-scale employment protection legislation, as Figure 5 shows, to protect people against individual and collective dismissals. This employment protection index "measures the procedures and costs involved in dismissing individuals or groups of workers and the procedures involved in hiring workers on fixed-term […] contracts" (OECD 2017c).

Figure 5: Protection from individual and collective dismissals in OECD countries in 2013

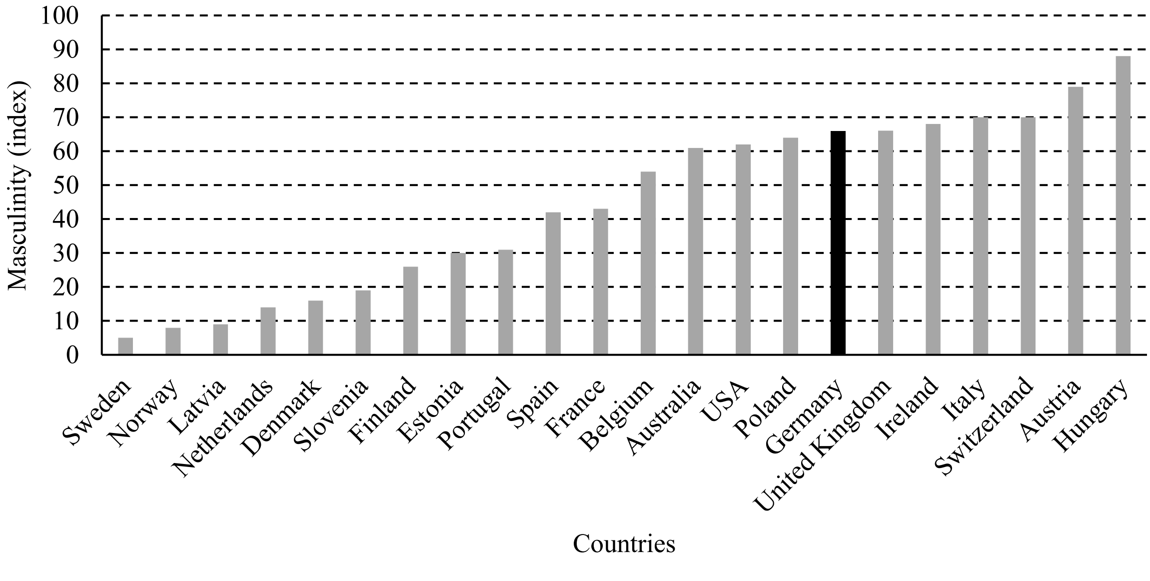


Source: Own illustration based on data extracted from OECD (2017d)

According to this index, ranging between 0 and 6 (OECD 2018), dismissing employees from regular contracts is costly and time-consuming in Germany, and thus creates additional pressure on employers to find employees who are productive (i.e. contribute to their revenue growth) as mistakes cannot be easily corrected. Against this background, Chapter 4 addresses the relationship between doctoral degrees and wages across two different groups of majors. I argue that doctoral studies equip graduates with research skills and that, furthermore, these research skills allow their possessors to constantly renew their knowledge and to allow their employers to profit from the employment relationship further on. Given the difficulties associated with laying off personnel in countries with high employment protection legislations, employers might prefer to employ individuals able to renew their knowledge on their own, in preference to hiring and firing employees again and again as soon as their knowledge becomes obsolete. Thus, using data drawn from a country with high employment protection legislation such as Germany, I am able to estimate the value research skills hold for employers which we would not detect in countries with an excessive 'hire and fire' mentality in place.

Apart from productiveness, employers are also interested in career-oriented individuals who are committed to the organisation and whose first priority is labour market instead of family work. Career orientation, however, is something employers traditionally might not expect of women, especially in societies characterised by strong traditional gender role models. Here, society and employers might prefer socially adequate roles for men and women, understanding women as in charge of family work (e.g. child rearing) while men pursue labour market careers. A proxy for the persistence of the traditional gender role model across countries is Hofstede's masculinity index, depicted in Figure 6.

Figure 6: Hofstede's masculinity index

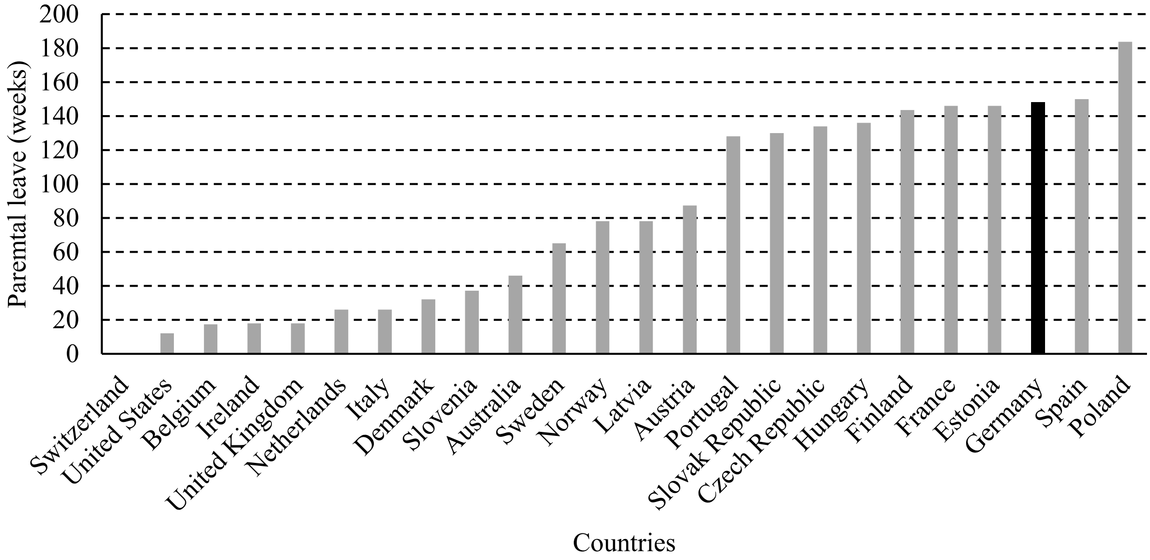


Source: Own illustration based on data extracted from Geert Hofstede (2017)

According to Figure 6, Germany ranks high on Hofstede's masculinity index, suggesting that German society is largely characterised by traditional gender roles.

Furthermore, employers' reluctance to hire women might be even greater in countries with extensive parental leave regulations that allow women to leave the labour market for a longer period of time after childbirth while the employer is expected to provide her with an occupation equivalent to that prior to her leave. Figure 7 shows an international comparison of the number of weeks mothers can spend on parental leave after maternity leave without having to fear for their jobs (OECD 2017a). As with traditional gender roles, Germany ranks high on parental protection (Leuze and Strauß 2016, p. 804). Hence, it is even more vital for German employers to identify and hire personnel who are career-oriented and will not leave the organisation for a longer period.

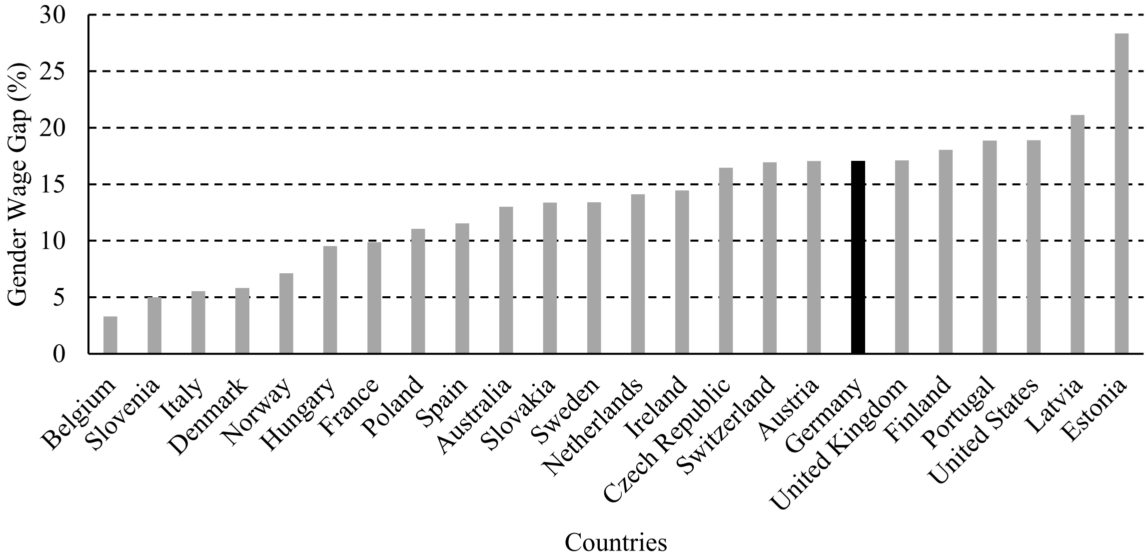
Figure 7: Length of parental leave with job protection in 2016 (in weeks)



Source: Own illustration based on data extracted from OECD (2017a)

With both productiveness and career orientation as desired characteristics, employers will pay higher wages to those who possess these characteristics. Hence, in a society characterised by traditional gender roles combined with excessive parental protection legislation as evident in Germany, it might not be surprising that women receive on average lower wages than men. Figure 8 depicts the raw gender earning gaps for various countries in 2015. The raw gender wage gap is the difference in median earnings of men and women relative to median male earnings (OECD 2017b, p. 215). As one can see from Figure 8, the gender wage gap in Germany is relatively large.

Figure 8: Gender wage gap in 2015 (in percent)



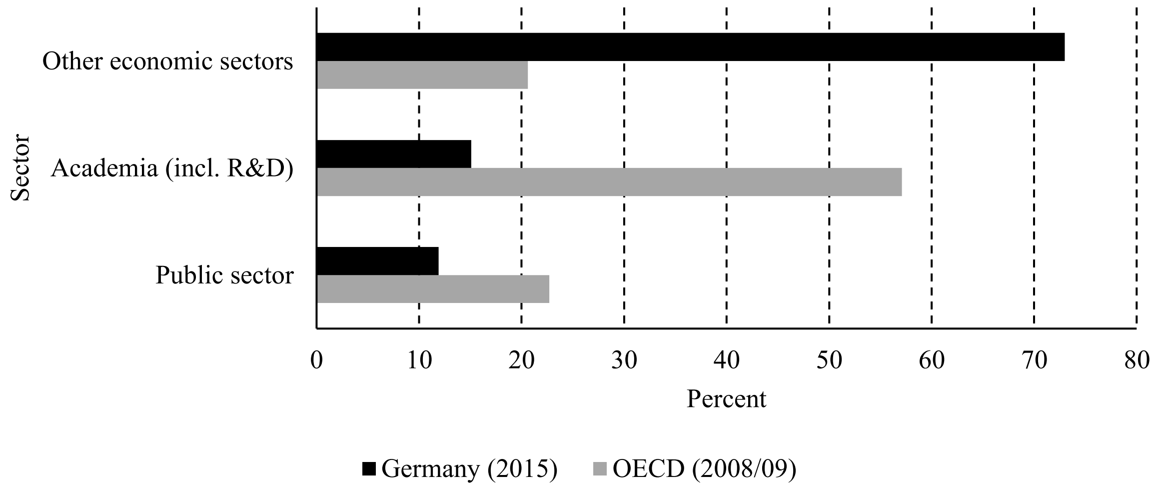
Source: Own illustration based on data extracted from OECD (2017b, p. 215)

In Chapter 5, we will investigate whether a higher academic degree such as a doctorate helps women to reduce the gender wage gap. By gaining a doctoral degree, we argue that women can at least partly overcome potentially generalised expectations of women by the labour market that are rooted in the traditional role model manifested in the society.

Due to their high level of education, employers might regard doctorate holders – both men and women – as an elite subgroup of highly productive and career-oriented individuals who are, therefore, desirable candidates. Across all countries, doctoral students benefit from high employment rates as well as higher wage premiums compared to tertiary graduates at lower levels (OECD 2010, pp. 5–7). This is in line with economic literature, arguing that employment ratios and wages rise with higher educational levels (e.g. Becker (1962), Spence (1973)). In 2014, 93 percent of German doctorate holders under the age of 65 were employed, while only 2 percent were unemployed (5 percent were not part of the labour force) (Konsortium Bundesbericht Wissenschaftlicher Nachwuchs 2017, p. 92). Hence, they show lower unemployment rates than those with only college level degrees (Konsortium Bundesbericht Wissenschaftlicher Nachwuchs 2013, p. 254).

Another reason for the low unemployment rate among doctorate holders lies in the variety of occupations which a doctorate open doors to, both within as well as outside academia and in different sectors (Konsortium Bundesbericht Wissenschaftlicher Nachwuchs 2013, p. 254). While shortly after graduation, 48 percent of German doctoral graduates are still engaged in academic occupations – either at a higher educational or research institution, or in other R&D sectors (Konsortium Bundesbericht Wissenschaftlicher Nachwuchs 2017, p. 182) – a large proportion (73 percent of the doctoral labour force) leave the university environment in the long run and pursue careers outside academia and the public sector (Konsortium Bundesbericht Wissenschaftlicher Nachwuchs 2017, 46, 185). Only 15 percent stay in academia (incl. research and development) and a further 12 percent in the public sector (Konsortium Bundesbericht Wissenschaftlicher Nachwuchs 2017, p. 185). In many other OECD countries[17], however, the majority of doctoral degree holders are employed in the higher education sector (57 percent) and in the public sector (23 percent) (OECD 2013). Figure 9 depicts these differences between Germany and other OECD countries.

Figure 9: Employment of doctorate holders by sector (in percent)



Source: Own illustration based on data extracted from Konsortium Bundesbericht Wissenschaftlicher Nachwuchs (2017, p. 185) and OECD (2013)

Wages in the public sector, however, are often more compressed, e.g. for political reasons, as governments are reluctant to pay far lower wages to the less qualified (Melly 2005, p. 506). Investigating the labour market effects of doctorates in Germany as in Chapter 4 and 5 allows to assess the value of the doctorate in an environment where wages are comparably freely negotiated. Otherwise, an insignificant degree effect might mistakenly be interpreted as a non-existent doctorate effect on wages whereas the true reason for the non-detecting of the effect lies in the compressed wage structure. Therefore, using German data in Chapter 4 and 5 to investigate the effects of doctoral degrees on wages is advantageous.

[17] Belgium, Bulgaria, Croatia, Denmark, Hungary, Iceland, Latvia, Lithuania, Malta, Netherlands, Poland, Portugal, Romania, Russia, Slovenia, Spain, Turkey, and the US.

3 Curricular structure and doctoral enrolment: A European comparison[18]

3.1 Introduction

The Bologna Declaration in 1999 marks the beginning of major changes in the structure of Europe's higher education. A main aim of the reform was to increase enrolment rates in higher education by introducing a curricular structure based on a two-cycle system, e.g. the bachelor/master system. Before, curricula in many European countries were organised in a one-cycle structure, with only one single degree at college level (e.g. the Diplom in Germany). For these countries, the reform implied (i) a shortening of first cycle studies and (ii) the introduction of a second degree at college level. Recent literature includes studies of the effect of shortening first cycle studies on the enrolment rates at college level (e.g. Di Pietro 2012). This chapter, however, aims to explain how a second degree at college level affects enrolment decisions at post-college level. I use the terminology of education at college level to subsume one-cycle studies as well as both elements of the two-cycle system (e.g. bachelor and master level studies). Doctoral studies are assigned to education at post-college level.

Based on Spence's (1973) signalling theory this chapter hypothesises that the existence of a second degree at college level causes doctoral enrolment rates to be lower, compared to an educational system with only one degree at college level. It reasons that the more productive individuals choose to attain further education in order to validly distinguish themselves from the less productive ones. In the one-cycle system the individual's only chance to distinguish herself from the majority of graduates is to attend doctoral studies. In contrast, in a two-cycle system this individual already holds two academic degrees. Thus, she has already distinguished herself from the majority of students who solely attend first degree studies. Her incentive to acquire a doctoral degree in order to distinguish herself further is therefore lower compared to her counterpart in the one-cycle system.

With former one-cycle countries restructuring their higher educational systems according to the Bologna objectives, the goal of enhancing enrolment rates in Europe's higher education might be at stake at the doctoral level. The results of this chapter are of interest for

[18] This chapter is based on Froehlich (2016) but presents some content in more detail. To this purpose, I extended the discussion of the literature in Section 3.2 by a discussion of the literature on enrolment decisions based on human capital theory (Section 3.2.1) and restructured the theoretical part (Section 3.3) to support the verbal argumentation (as in Froehlich (2016)) using a model-based approach. Furthermore, I included a more comprehensive explanation of the methodological approach (Section 3.4.5) and additional robustness checks (beyond those in Table 5, Section 3.4.7) in the empirical analysis (Section 3.4). To fit the extended content, some other subchapters were adjusted. Reuse of content by permission from Springer Nature Service Centre GmbH: Springer Nature Journal of Business Administration, Does the curricular structure affect doctoral enrolment? A European comparison, A. C. Froehlich, 2016, DOI: 10.1007/s11573-016-0812-x.

educational institutions and firms as potentially fewer doctoral students imply fewer future teaching personnel in higher education as well as fewer university-industry relationships (i.e. fewer knowledge spill-overs).

The hypothesis is put to an empirical test based on data from 23 European countries between 1995 and 2005. Random effects estimations reveal higher doctoral enrolment rates in countries where curricula are organised in a one-cycle structure, after controlling for factors of educational institutions, labour market conditions, and a population's socio-economic characteristics.

To the best of my knowledge this study is the first to examine the effect of a country's curricular structure at college level on doctoral enrolment rates. By doing so, it contributes to the literature on educational economics in two ways:

First, it adds to a large body of literature on the determinants of graduate[19] and doctoral enrolment. Viewing educational decisions as investment decisions in human capital, these studies investigate how various factors influence the trade-off between expected educational costs and expected educational wage premiums[20].

Second, this study adds to the literature on educational signalling that links changes or differences at certain educational levels to enrolment decisions at other levels (e.g. Bedard 2001, Lang and Kropp 1986). Assuming asymmetrically distributed information between the individual and future employers, more productive individuals attend further education in order to validly distinguish themselves from less productive ones. In line with this idea, this chapter argues that the decision to enrol in doctoral studies depends on whether the individual has had the opportunity to distinguish herself from less productive ones at college level by attaining a second cycle degree.

The remainder of this chapter is organised as follows. Section 3.2 provides a review of the literature on educational enrolment decisions. Section 3.3 develops the argument on how the existence of a second degree at college level (e.g. master degree) affects the decision to enrol in doctoral studies. Section 3.4 describes the dataset, presents the estimations, and discusses the empirical findings. Section 3.5 concludes the chapter.

[19] Especially in US literature, the concept of graduate education subsumes second-cycle studies as well as doctoral studies (e.g. Mullen et al. (2003), Zhang (2005)) as "doctoral education is considered part of graduate education" in the USA (Kehm 2006, p. 68).

[20] The wage premium represents the difference between expected earnings with and without further education.

3.2 Literature on graduate and doctoral enrolment decisions

In 1962, Becker stated that people pursue education because it raises productivity. Given that future wages will be paid according to productivity, attending higher education today results in higher wages in the future, all else being equal (Becker 1962).

Inspired by Akerlof's (1970) "The Market for Lemons", Spence developed the signalling theory as a further explanation for why people pursue education. He states that even if education is assumed to have no productivity enhancing effect it might lead to an increase in future wages because it reflects inherent productivity (Spence 1973). Instead of pursuing higher education in order to become more productive, the individual is inherently more productive and attains further education to signal this information to employers (i.e. to distinguish herself from the less productive). Thus, human capital theory explains rational educational decisions under symmetric information where educational choices are largely unaffected by those of others (Bedard 2001, p. 751), while signalling theory refers to rational enrolment decisions under asymmetric information where education is a means to distinguish oneself from less productive individuals (Spence 1973, p. 356).

In what follows, I will discuss the literature explaining graduate and doctoral enrolment decisions based on human capital and signalling theory.

3.2.1 Investment in human capital

When deciding whether or not to invest in further education, an individual trades off ex ante expected educational costs and wage premiums. The literature based on human capital theory focuses on explaining how various factors influence this trade-off and therefore enrolment decisions.

Expected educational costs are affected by educational institutions such as quality and funding of education. Eide et al. (1998) and Zhang (2005), for example, examine the effect of college quality on graduate or doctoral enrolment. They reason that the educational quality at previous levels determines educational choice at higher levels. Colleges of higher quality prepare their students more effectively for further education, resulting in lower information costs for the individual. If educational quality at undergraduate level is high, the odds are that more individuals choose to enrol in graduate or doctoral education. Eide et al. (1998) and Zhang (2005) operationalise college quality by using selectivity ratings of US colleges drawn from Barron's "profile of American colleges" (Eide et al. 1998, p. 372; Zhang 2005, p. 319). They create six categories of college quality, depending on whether the institution is privately or publicly controlled and whether the selectivity rating defines an institution as most or highly competitive, (very) competitive, or less or non-competitive in terms of student selection. Eide et al. (1998) run a probit regression on US college graduates from 1972, 1980, and 1982 (Eide et al. 1998, p. 372), while Zhang (2005) uses information on US college graduates who received their degree in 1992/93 (Zhang 2005, p. 317). Both studies find support for their hypothesis that graduates from high-quality private colleges are more likely to enrol in graduate studies than low-quality public graduates.

Fox (1992), Millett (2003), and Weiler (1991) study whether undergraduate indebtedness affects graduate or doctoral enrolment decisions. The authors expect indebtedness to have a negative effect on enrolment as it requires higher wage premiums to compensate for. Nonetheless, results were ambiguous in the past. Weiler (1991) uses US data from the third follow-up of the High School and Beyond Survey in 1986, restricting the sample to college or university graduates with an average grade of B or better to select individuals who are potential graduate or doctoral students (Weiler 1991, p. 215). In contrast, Fox (1992) uses data drawn from the US Department of Education survey of 1985–1986 college graduates, which provides information on far more college graduates than the dataset in Weiler (1991) (Fox 1992, p. 671). While Weiler (1991) finds no support for undergraduate debt deterring post-college enrolments, Fox (1992) can prove the hypothesis for women, only. Millett (2003), drawing US data from the Baccalaureate and Beyond Longitudinal Study of 1992–93, finds evidence that undergraduate debt impairs further enrolment decisions regardless of gender.

While these studies focus on the effect of an individual's financial situation at lower levels, Yang and McCall (2014) test whether financial support at higher levels (e.g. loans, grants or endowments to educational institutions) affects educational attainment at college level and beyond. They argue that financial support lowers the educational costs individuals have to bear. Hence, enrolling in further education becomes more attractive. The authors run a fixed effects regression to test the effect of educational finances on tertiary enrolment (including undergraduate, graduate, and doctorial education) in 86 countries between 1998 and 2009. Public spending on all educational levels (primary, secondary, and tertiary level) as percentage of GDP and public spending per student (in US dollars) at each of the three educational levels operationalise educational finance policies in a country (Yang and McCall 2014). While the first indicates a country's priorisation of education in general, the latter focuses on the government's role in sharing individual costs at each educational level (Yang and McCall 2014, p. 29). The results suggest that public spending on education as percentage of GDP has the expected positive effect, but public expenditure per primary and secondary student has no significant effect. However, public expenditure per tertiary student has a significant negative effect on tertiary enrolment. Yang and McCall (2014) explain this counterintuitive result as some evidence of relatively fixed budget levels for higher education. If budgets do not increase proportionally with enrolment levels, competition for financial support causes enrolment rates to decrease (Yang and McCall 2014, p. 12).

The determinants discussed so far refer to the educational costs an individual has to consider when deciding whether or not to enrol in graduate or doctoral studies. There are, however, also factors, such as labour market conditions, that affect the size of the wage premium. The larger the wage premium, the larger is the incentive to pursue further education, all else being equal. Bedard and Herman (2008) and Johnson (2013) argue that during times of recession, unemployment rates are relatively high, and therefore forgone earnings are low. This results in high wage premiums. Hence, enrolment in graduate or doctoral studies increases. However, the authors also reason that with higher unemployment rates, competition for school places increases or tuition fees rise due to reduced endowments from governments. Thus, enrolment rates might as well decrease during recessions (Bedard and Herman 2008, p. 199; Johnson 2013, p. 123). Bedard and Herman (2008) and Johnson (2013), therefore, posit the effect of recession – and unemployment as one of its consequences – as an empirical question (Bedard and Herman 2008, p. 200; Johnson 2013, p. 123). To address this question, Bedard and Herman (2008) use US data from 1990 to 2000 on science and engineering bachelor graduates and state level unemployment rates as a proxy for recession. Johnson (2013) extends the study of Bedard and Herman (2008), as he uses data on bachelor graduates beyond the fields of science and engineering between 1994 and 2010. Both studies run a probit regression to estimate the probability of bachelor graduates to enrol in graduate or doctoral studies right after graduation (Bedard and Herman 2008, p. 200; Johnson 2013, p. 126). The results, however, differ in some respects. Bedard and Herman (2008) observe higher unemployment rates to correlate with increased enrolment in doctoral studies for men but not for women. Johnson (2013) finds no significant effect of unemployment on doctoral enrolment, neither for men nor women. Thus, the effect of business cycle fluctuations on enrolment in graduate or doctoral studies seems to vary depending on the field of study (Johnson 2013, p. 128). For example, Holley and Gardner (2012, p. 117) suggest that there are field of studies where it is necessary to gain a doctoral degree in order to pursue one’s career aspiration. Thus, opportunity cost might be less important.

Perna (2004) and Zhang (2005), on the contrary, use undergraduates’ majors as a proxy for foregone earnings and examine whether certain undergraduate majors have an effect on graduate or doctoral enrolment decision. While Zhang (2005) differentiates between twelve different groups of majors[21], Perna (2004) assigns undergraduate major fields to four almost equally sized groups in order to reflect differences in amounts of foregone earnings[22]. Due to scarce data on doctoral enrolment, Perna (2004) cannot test the effect of different majors on doctoral enrolments (Perna 2004, p. 501). Zhang (2005), however, confirms a strong effect of undergraduate major (i.e. foregone earnings) on doctoral enrolment based on a logit regression on US bachelor degree recipients from 1993 (Zhang 2005, pp. 324–325). The results suggest that students who majored in fields like mathematics or natural sciences, social science, the humanities and psychology are more likely to enrol in doctoral studies than graduates who majored in education. Business graduates however are less likely to enrol in doctoral education (Zhang 2005, pp. 324–325).

3.2.2 Investment in differentiation through education

While human capital theory can explain many educational decisions, some previous literature has focused on educational signalling to explain educational decisions that cannot be explained by human capital theory. As shown before, the key difference between both theories is that signalling theory assumes asymmetric information between the individual and the employer regarding the individual's true productivity. The highly productive individual, therefore, pursues further or higher-quality education in order to share this private information with the employer and, thus, validly distinguish herself from other individuals (Spence 1973).

Accordingly, one can distinguish between two types of differentiation through education: vertical and horizontal differentiation. While with vertical differentiation more productive individuals distinguish themselves by graduating from higher educational levels (e.g. Lang and Kropp 1986), individuals can also horizontally distinguish from others, e.g. by graduating from better schools at the same level (e.g. Bol and Werfhorst 2011).

Referring to vertical differentiation, Bedard (2001), Chevalier et al. (2004), and Lang and Kropp (1986) investigate how exogenous shocks that affect differentiation from others at a certain educational level influence individual enrolment decisions at other levels (i.e. higher or lower levels). In Chevalier et al. (2004) and Lang and Kropp (1986) this shock is a change in minimum years of schooling. Before mandatory years of schooling were increased to a certain level, an individual might have chosen this educational level to distinguish from those at lower

[21] Undergraduate major groups in Zhang (2005, p. 320): "business, education, engineering, health, public affairs, biology science, social science, math/science, history, humanities, psychology, and other majors".

[22] Undergraduate major groups in Perna (2004): education, history and psychology; humanities, social sciences, public affairs and social services; business and management; math, sciences, health professions and engineering (Perna 2004, p. 493).

levels. When minimum years of schooling increase to a certain educational level, attaining this level no longer distinguishes an individual from those at lower levels as it is not possible to leave school at lower levels. Therefore, more individuals will enrol in higher education beyond minimum years of schooling to maintain differentiation from others. Lang and Kropp (1986) can confirm their hypothesis using US data between 1910 and 1970. To retest this hypothesis, Chevalier et al. (2004) use data from England and Wales where the minimum school leaving age was increased in 1973. In contrast to Lang and Kropp (1986), they find no support for the hypothesis.

According to Chevalier et al. (2004, p. 512), Bedard (2001) is a symmetric version of the idea of Lang and Kropp (1986) and, hence, Chevalier et al. (2004). Bedard (2001) argues that relaxing constraints, which previously prevented some individuals from attaining college, causes high school dropout rates to increase. The reason is that high school students, who never intended to go to college, now decide to drop out of high school. Bedard (2001) reasons that as soon as the constraints are relaxed, the most productive individuals among the high school students will go to college, causing the average marginal productivity of the remaining high school graduates to drop. Given that wages are paid according to the average marginal productivity of a group, the wage offered to high school students will drop accordingly. Thus, the least productive individuals among the high school students have less incentive to graduate from high school and join the group of high school dropouts instead. Using US data from the late 1960s and early 1970s, Bedard (2001) tests whether this crowding out effect among the high school students exists. The results support her hypothesis.

While these studies focus on vertical differentiation, there are some studies within the literature on educational signalling that focus on horizontal differentiation instead. Bol and Werfhorst (2011), for example, hypothesise that the more heterogeneous a country's educational system is, the larger is the effect of degrees on occupational status. They reason that in countries with many types of schools coexisting at the same educational level, it is easier for employers to discriminate graduates. In Bol and Werfhorst (2011), the heterogeneity of the educational system is reflected by the number of different tracks in secondary education. In Bergh and Fink (2009), elite institutions cause this variability. Following a similar idea, Hämäläinen and Uusitalo (2008) examine the effect of the introduction of new study programs on future incomes. They argue that as soon as there are people graduating from these better structured programs, the wages of individuals graduating from the old less structured programs decrease. Their results support their hypothesis. However, these studies do not explain differences in doctoral enrolment decisions.

Franck and Opitz (2007) argue that variability in educational institutions explains variances in the proportions of doctorate holders. The authors examine the proportions of top managers holding doctoral degrees in Germany, France, and the USA. They reason that in Germany, with its rather homogenous higher educational institutions, i.e. less horizontal differentiation, the only chance to distinguish from others is to pursue a doctoral degree. In France and the USA, where college level institutions are more heterogeneous, an individual who graduates from certain educational institutions has already distinguished herself and does not need a doctoral degree to do so. Based on descriptive analyses of 100 top managers of the largest companies in Germany, France, and the USA in 2001, Franck and Opitz (2007) can show that while in Germany over 58 percent of the top managers hold a doctoral degree, this is only true for about 4 and 5 percent of the top managers in France and the USA. They argue that French and US top managers seem to prefer elite colleges, while this is not the case in Germany.

3.2.3 Contribution to the literature

As shown above, there is a vast literature that explains graduate or doctoral enrolment decisions as a rational trade-off between ex-ante expected educational costs and returns. This literature has identified various factors that affect either educational costs[23] or the size of the wage premium[24] and therefore determine graduate or doctoral enrolment decisions. This chapter contributes to this literature by explaining how the curricular structure at college level affects the doctoral wage premium and thus determines doctoral enrolment decisions.

I further highlighted the different assumptions of human capital and signalling theory regarding the information distribution between the individual and the employer and, hence, the difference in the individual's motivation to pursue further education. Signalling theory explains the acquisition of an educational degree as a means to share information about the individual's productivity with the employer and, thus, to validly distinguish oneself from the less productive ones, while human capital theory understands educational investments as means to enhance productivity. Thus, one might understand arguments based on signalling theory to explain enrolment decisions as reactions to enrolment decisions of others[25], whereas pure human capital based arguments see enrolment decisions as individual decisions largely independent of the

[23] e.g. quality of college level education (Eide et al. 1998; Zhang 2005), undergraduate indebtedness (Fox 1992; Millett 2003; Weiler 1991), and financial support (Yang and McCall 2014)

[24] e.g. business cycle fluctuations (Bedard and Herman 2008; Johnson 2013) and forgone earnings (Perna 2004; Zhang 2005)

[25] The more productive one chooses to enrol in further education because the less productive one would not enrol.

enrolment decisions of their peers. To this end, signalling theory helps to understand enrolment decisions that human capital theory fails to explain.

Based on the signalling idea of acquiring further education to distinguish from others, previous studies have linked changes or differences at certain educational levels to enrolment decisions at other levels (e.g. Bedard 2001, Chevalier et al. 2004, Lang and Kropp 1986). This chapter contributes to this literature as it links enrolment decisions at higher levels to the curricular structure at lower levels. With regard to the argument, this study is similar to Chevalier et al. (2004) and Lang and Kropp (1986): It also expects that the opportunity to distinguish oneself from others at lower levels will influence an individual's decision to enrol in higher levels (in this study, particularly in doctoral studies). The question whether someone was already able to distinguish herself from the less productive ones at lower levels is, again, determined by the respective educational system (in this study the curricular structure at college level).

Although the arguments in Chevalier et al. (2004), Lang and Kropp (1986) and this study might be similar at least to some degree, they vary widely with regard to the educational level where the enrolment decision takes place (school vs. doctoral level). The paper potentially closest with regard to the dataset is Franck and Opitz (2007), although they do not investigate enrolment decisions at doctoral level per se, but study the proportion of doctorate holders among German, French, and US top managers. Moreover, while this study explains variations in doctoral enrolments through differences in the individual's opportunity to vertically differentiate at college level (i.e. through attaining a second college level degree), Franck and Opitz (2007) argue that doctoral enrolment decisions are affected by the individual's chance to horizontally differentiate at college level (through attending elite colleges). Hence, to the best of my knowledge this study is the first to argue and test how a country's curricular structure at college level affects its doctoral enrolment rates.

3.3 The relationship between curricular structure at college level and doctoral enrolment rates

This section develops the argument on how the existence of a second degree at college level affects educational attainment at doctoral level. The central idea is that an individual who holds two degrees at college level has already distinguished herself from the less productive students by completing this second college level degree. Compared to a person in a one-cycle system with only one degree at college level, her incentive to enrol in doctoral studies to further distinguish herself is smaller. Thus, enrolment rates in doctoral studies are lower if a second degree at college level education exists.

The argument is developed in two steps: First, I describe the basic assumptions within a signalling framework based on Spence (1973) and explain the basic signalling argument in accordance with the standard Spence model. In the second step, I transfer Spence's idea of differentiation through education to a situation with two and three educational degrees, respectively.

3.3.1 Educational signalling

I consider two players within a framework that is fully in line with Spence (1973): the individual and the future employer. The individual decides whether or not to enrol in doctoral studies, given that she has already graduated from the highest educational level at college level. Her objective is to maximize her expected lifetime income. The employer aims to maximize his expected profit. He is interested in hiring the most productive applicants.

The population considered subsumes all individuals who are qualified and sufficiently equipped to obtain at least some college education. The individuals differ only with regard to their inherent level of productivity (Spence 1973). Assume that productivity is continuously distributed over the whole population. The employer cannot (fully) observe the productivity of a certain individual. This information is private to the individual. The distribution of productivity over the whole population is common knowledge. As long as the employer cannot discriminate between more and less productive individuals, any rational risk neutral employer will offer wages according to the expected marginal productivity within the population. In order to be paid according to her marginal productivity, the individual needs to validly distinguish herself from the less productive ones.

This leads to the concept of Spence's (1973) signalling theory: The better informed party (i.e. the individual) sends a signal to the less informed party (i.e. the employer) about her productivity. Spence (2002, 1973) has already shown that education (and a degree in higher education for that matter) is a valid signal for productivity as it meets the following requirements: First, the individual can decide whether she wants to attend higher education and eventually receive a degree which is, second, observable by the employer as she can submit it with other application documents. Third, this degree informs the employer about her educational level (and field of knowledge). Fourth, the marginal costs of acquiring further education are higher for less productive students than for more productive ones (e.g. because less productive students might need to spend more time studying or pay for additional tutoring).

Trading off expected educational costs and expected returns on investment, the individual will choose the educational level that maximises the difference between expected wages and educational costs (Spence 1973). As the employer cannot observe productivity, he will base his wage offer on his beliefs about the relationship between marginal productivity and education. If he is fully convinced that only productive individuals will send a certain signal he will pay wages above the average marginal productivity of the whole population. Consequently, the costs of attaining further education must be negatively correlated with productivity so that the less productive individual will not acquire further education (Spence 1973). The wage offer, in turn, reflects the return on investment in education and hence, determines the individual's decision to enrol in further education (Spence 2002, 1973, pp. 359–361). Once this mechanism comes full cycle without any adjustments (i.e. neither the individual nor the employer deviate from their decisions) we are in a state of equilibrium (Spence 1973). Moreover, if a group of productive individuals chooses to attend doctoral studies whereas a group of less productive ones does not, this state of equilibrium is a semi-pooling one[26] (Franaszek 2012).

Within this framework, this chapter asks whether the existence of a second degree at college level causes two equally productive individuals to attend different educational levels in the two higher educational systems.

3.3.2 Doctoral enrolment in context of the curricular structure

I assume that curricula can either be structured in a one-cycle or a two-cycle structure. In the one-cycle system, only one degree is awarded at the end of college level studies (e.g. the German Diplom). In the two-cycle system, up to two degrees are awarded at college level. After finishing the first college level degree (e.g. bachelor), students decide whether they want to join the labour market (i.e. leave the educational system) or attend further more advanced studies that lead to the second college level degree (e.g. master).

I assume individuals to differ only with regard to their inherent productivity, θ, which is continuously distributed over the interval $[\underline{\theta}; \overline{\theta}]$. The cumulative distribution function of θ is $F(\theta)$. Based on their inherent productivity, θ, individuals choose the educational level, e, that

[26] In contrast to a pooling equilibrium, where any given individual chooses the same educational level and a separating equilibrium where any individual with a different productivity chooses a different educational level, a semi-pooling equilibrium exists when individuals within a certain range of productivity choose the same level of education, whereas individuals within another rage of productivity choose a different level of education (Franaszek 2012). Put differently, although individuals might differ regarding their productivity, they might choose the same level of education and are pooled in the same group. These groups differ from each other regarding their educational level and can be distinguished by employers.

maximises the difference between ex-ante expected wages, $w(e)$, and educational costs, $c(e, \theta)$ (Spence 1973),

$$e = \arg\max\{w(e) - c(e, \theta)\}. \tag{1}$$

Wages $w(e)$ reflect the average marginal productivity of all individuals who chose the respective educational level, yielding

$$w(e) = E(\theta | \theta \in \Theta_e), \tag{2}$$

with Θ_e as the expected group of individuals (and their productivities) that chose educational level e (Franaszek 2012, p. 4). The educational costs, $c(e, \theta)$, are conditional on the educational level, e, and the individual's productivity, θ. These costs increase with educational level,

$$\frac{\partial c(e,\theta)}{\partial e} > 0, \tag{3}$$

and decrease with one's productivity (Spence 1973),

$$\frac{\partial c(e,\theta)}{\partial \theta} < 0. \tag{4}$$

Moreover, an increase in education results in higher costs for the less productive individual compared to the more productive ones (Mas-Colell et al. 1995, p. 453),

$$\frac{\partial c(e,\theta)}{\partial e\, \partial \theta} < 0. \tag{5}$$

I further assume that for an individual with productivity θ, acquiring the second degree at college level in the two-cycle system (e.g. master degree) is equally costly as acquiring the one degree at college level in one-cycle systems (e.g. German Diplom). The same is true for attending doctoral studies in both systems[27]. Hence, while the educational wage premium, i.e. the difference in wages with and without an additional educational degree, is equal for more and less productive individuals[28], the educational costs are higher for the less productive ones. Thus, due to the structure of wages and educational costs, only the more productive individuals rationally choose to attain higher degrees. Consequently, the average marginal productivity of individuals with higher degrees is higher than the average marginal productivity of individuals with lower degrees.

As employers cannot observe the individuals' productivities, they assign them to productivity groups based on their highest educational degrees. Consequently, there are two groups regarding the two degrees in the one-cycle system: the single degree group with educational level e_1 and the doctoral degree group with educational level e_2, with $e_1 < e_2$. In the two-cycle system there are three groups: the first degree group with level e_0, the second

[27] For a more detailed discussion of the cost function, see appendix A.1.

[28] As wages are paid according to the expected average marginal productivity of all individuals with the respective educational degree.

degree group with level e_1, and the doctoral degree group with level e_2, with $e_0 < e_1 < e_2$. Employers offer wages according to the average marginal productivity of each group.

The important difference between the two higher educational systems is that even without acquiring a doctoral degree, an individual in the two-cycle system has already validly distinguish herself from the less productive first degree group by obtaining a second college level degree[29]. Thus, a potential employer is willing to offer her a wage which is higher than the wage offered to members of the first degree group. In contrast, an individual in the one-cycle system can only distinguish herself from the less productive students by attaining a doctoral degree. Without this degree potential employers will assign her to the single degree group and offer her a wage according to the average marginal productivity of all college level graduates.

In what follows, I will consider two equally productive individuals, one in each system. Furthermore, the individual in the two-cycle system is assumed to be indifferent between attaining the second degree and the doctoral degree. The question is whether her counterpart in the one-cycle system would be indifferent between the doctoral degree and the highest degree at college level, as well[30].

3.3.2.1 Doctoral enrolment in two-cycle systems

Assuming that each educational level in the two-cycle system, e_0, e_1, and e_2, is chosen by at least some individuals, there are two productivity thresholds, θ' and θ'', that separate the three educational groups from each other.

It can be shown that θ' and θ'' are semi-pooling equilibria that satisfy the intuitive criterion for separating equilibria as formulated by Cho and Kreps (1987). A separating equilibrium exists if different groups of individuals send different signals (i.e. all educational levels e_0, e_1, e_2); as employers know that all educational levels that are chosen with positive probability in equilibrium maximise the individuals' lifetime income, neither individuals nor employers will deviate from their decisions (i.e. attending an educational level and paying wages according to the average marginal productivity of the respective group)[31].

[29] Based on information on ISCED5A first (e.g. bachelor) and second degree graduations (e.g. master) extracted from Eurostat (2014a), transition rates from first to second degree studies were calculated for two-cycle countries. The mean transition rate between 2004 and 2005 was 35.21 percent, i.e. second degree studies were not obtained on a regular basis. I therefore assume second degrees to be a valid mean to distinguish from the less productive first degree group.

[30] See Ryan (2001) for similar considerations regarding changes in minimum years of schooling.

[31] A more formal proof of the existence of a semi-pooled equilibrium under the assumption of equally distributed productivity is given in appendix A.2.

I expect that an individual with productivity θ' is indifferent between e_0 and e_1 if the wage premium from attaining e_1 equals the marginal costs of doing so,

$$w(e_0) - c(e_0, \theta') = w(e_1) - c(e_0, \theta') - c(e_1, \theta'), \qquad (6)$$
$$w(e_1) - w(e_0) = c(e_1, \theta').$$

Each wage offer reflects the expected average marginal productivity of all individuals that chose the respective educational level, yielding

$$E(\theta|\theta' < \theta < \theta'') - E(\theta|\underline{\theta} < \theta < \theta') = c(e_1, \theta'). \qquad (7)$$

Analogously, an individual with θ'' would be indifferent between e_1 and e_2 if the wage premium from attaining e_2 equals the marginal costs of doing so,

$$w(e_1) - c(e_0, \theta'') - c(e_1, \theta'') = w(e_2) - c(e_0, \theta'') - c(e_1, \theta'') - c(e_2, \theta''), \qquad (8)$$
$$w(e_2) - w(e_1) = c(e_2, \theta'').$$

Again, the wage offers reflect the expected average marginal productivity of each group, so that

$$E(\theta|\theta'' < \theta < \overline{\theta}) - E(\theta|\theta' < \theta < \theta'') = c(e_2, \theta''). \qquad (9)$$

Note that $F(\theta)$ is the cumulative distribution function of productivity, θ. Thus, $1 - F(\theta'')$ is the fraction of the population with productivities larger than θ''[32]. With θ'' representing an individual who is indifferent between e_1 and e_2 and with costs decreasing in θ, all individuals with $\theta > \theta''$ will choose e_2. Hence, $1 - F(\theta'')$ is the fraction of the population that holds doctoral degrees in a two-cycle system.

3.3.2.2 Doctoral enrolment in one-cycle systems

For the sake of the argument, I introduce a thought experiment: For the moment I assume that the individual with θ'' in the one-cycle system was also indifferent about continuing to a doctoral degree beyond the highest degree at college level (i.e. single degree). All previous assumptions still hold. Consequently, the wage offer after attaining a doctoral degree would be equal in both systems[33],

$$w(e_2) = E(\theta|\theta'' < \theta < \overline{\theta}). \qquad (10)$$

The additional costs of attaining doctoral studies, $c(e_2, \theta'')$, would be equal, too.

Without a doctoral degree, the employer would assign her to the single degree group. He will offer a wage that reflects the average marginal productivity of all graduates at college level,

[32] See Ryan (2001, pp. 195–196) for similar considerations.

[33] Given that any more productive individual (i.e. more productive than the individual who is indifferent between attaining and not-attaining a doctoral degree, $\theta > \theta''$) rationally chooses to attend doctoral studies, e_2, and given that wages are paid according to the average marginal productivity of all individuals with a doctoral degree. A proof is given in appendix A.2.

$$w'(e_1) = E(\theta|\underline{\theta} < \theta < \theta''). \quad (11)$$

Assuming equal populations in both systems, the wage offer to the individual in the one-cycle system in this scenario, $E(\theta|\underline{\theta} < \theta < \theta'')$, would be lower than the wage offer to her counterpart in the two-cycle system, $E(\theta|\theta' < \theta < \theta'')$, since the latter is paid according to the average marginal productivity of a more productive subgroup of college graduates,

$$E(\theta|\underline{\theta} < \theta < \theta'') < E(\theta|\theta' < \theta < \theta''), \text{because } \underline{\theta} < \theta'. \quad (12)$$

In both systems the individuals trade off doctoral wage premiums[34] and educational costs. Note that within the thought experiment, the wage offer to the individual in the one-cycle system without doctoral education is smaller than to her counterpart in the two-cycle system (12), while the wages after attaining a doctoral degree are assumed to be equal (10). Hence, the wage premium from attaining doctoral education is smaller in the two-cycle system than in the one-cycle system as,

$$E(\theta|\theta'' < \theta < \overline{\theta}) - E(\theta|\underline{\theta} < \theta < \theta'') < E(\theta|\theta'' < \theta < \overline{\theta}) - E(\theta|\theta' < \theta < \theta''), \quad (13)$$
$$w(e_2) - w'(e_1) < w(e_2) - w(e_1).$$

Additionally, I assume doctoral education to be equally costly in both systems (e.g. in terms of study duration)[35]. Since both individuals are equally productive, the educational costs of attaining doctoral studies are equal in both systems, $c(e_2, \theta'')$.

Thus, facing the same educational costs as her counterpart in the two-cycle system but with a higher doctoral wage premium, (13), the individual in the one-cycle system cannot be indifferent between attaining and not-attaining a doctoral degree as assumed at the beginning of this thought experiment. In fact, in contrast to her counterpart in the two-cycle system, she will pursue a doctoral degree because the return from doing so exceeds the costs,

$$E(\theta|\theta'' < \theta < \overline{\theta}) - E(\theta|\underline{\theta} < \theta < \theta'') > c(e_2, \theta''), \quad (14)$$
$$w(e_2) - w'(e_1) > c(e_2, \theta'').$$

In turn, this implies that there is no state of equilibrium at θ'' in the one-cycle system.

Hence, due to the higher doctoral wage premium, the individual with θ^* who is in fact indifferent between the single and the doctoral degree in the one-cycle system is actually less productive than the individual with θ'' who is indifferent between the second and the doctoral degree in the two-cycle system. As each individual, who is more productive than the

[34] Difference between the wage that is offered to a person who holds a doctoral degree and the wage offered to a person with the highest degree at college level.

[35] There seems to be no reason to believe that durations of doctoral studies differed significantly across the two higher educational systems (European University Association 2005, p. 17; Westerheijden et al. 2012, p. 19).

"indifferent" individual, will enrol in doctoral studies, enrolment rates in one-cycle countries will be higher than in two-cycle countries.

In fact, all individuals with productivity $\theta, \theta^* < \theta < \theta''$, will choose e_2 in the one-cycle system. An individual with θ^* is indifferent between e_1 and e_2[36] if the wage premium from attaining e_2 equals the marginal costs of doing so, yielding

$$w(e_1) - c(e_1, \theta^*) = w(e_2) - c(e_1, \theta^*) - c(e_2, \theta^*), \quad (15)$$
$$w(e_1) = w(e_2) - c(e_2, \theta^*),$$
$$w(e_2) - w(e_1) = c(e_2, \theta^*).$$

Again, the wage offers reflect the expected average marginal productivity of each group, so that

$$E(\theta | \theta^* < \theta < \overline{\theta}) - E(\theta | \underline{\theta} < \theta < \theta^*) = c(e_2, \theta^*). \quad (16)$$

Note that educational costs decrease in θ. With an individual θ^* being indifferent between e_1 and e_2, all individuals with $\theta > \theta^*$ choose e_2 as their highest educational level. Thus, in the one-cycle system the group of individuals with a doctoral degree is $1 - F(\theta^*)$. This group is larger than the corresponding group in the two-cycle system, $1 - F(\theta'')$, as $\theta^* < \theta''$. Hence, there are more doctoral enrolments in the one-cycle than in the two-cycle system.

So far, I have assumed the populations in both systems to be equal. This implies that all individuals who attend college in the two-cycle system would do so in the one-cycle system. One might argue, however, that due to shorter study durations for the first college level degree more students enrol in the two-cycle system than in the one-cycle system[37]. Thus, in extreme cases no individual who solely attends first degree studies in the two-cycle system (e.g. bachelor studies) would enrol in college in the one-cycle system. Consequently, only those who would attend second degree studies on top of first degree studies in the two-cycle system would attend single degree studies in the one-cycle system. Hence, the least productive individual acquiring a second degree in the two-cycle system equals the least productive individual who attends any college education in the one-cycle system,

$$\theta' = \underline{\theta}. \quad (17)$$

With (11) it can be shown that the wage offer to the individuals without doctoral education would be equal in both systems. Thus, doctoral wage premiums would be equal, too (given (17) and (13)). Therefore, the individual who is indifferent between the highest college level degree and the doctoral degree would be equal in both systems,

[36] Appendix A.2 shows that an individual with θ^* exists who is indifferent between attaining e_1 and e_2.

[37] Di Pietro (2012), for example, argues that reducing study durations from five to three years might make college level education more attractive to individuals who would like to continue their education beyond high school education but lack e.g. the ability or willingness to do so for another five years of study.

$$\theta'' = \theta^*. \quad (18)$$

Hence, we would expect no differences in doctoral enrolment rates across the two systems.

Consequently, the question of whether enrolment rates in doctoral studies vary across both systems depends on the assumption regarding the population. As soon as we allow for some students who would attend college in the one-cycle system to attend solely first degree college education in the two-cycle system, doctoral enrolment rates are expected to be larger in the one-cycle system.

H 1: Enrolment rates in doctoral studies are higher in one-cycle than in two-cycle systems.

3.4 Empirical evidence on the relationship between curricular structure at college level and doctoral enrolments

The central question of this study is whether enrolment rates in doctoral studies are higher in one-cycle systems than in two-cycle systems, after controlling for factors of educational institutions, labour market conditions, and a population's socio-economic characteristics.

3.4.1 Sample

The data is drawn from 23 European countries[38] between 1995 and 2005. Focusing on European countries ensures that there is a fixed order in which students attend educational levels. In the one-cycle system, attaining doctoral studies requires the college level degree obtained after one-cycle studies. In the two-cycle system, first cycle degrees give access to second cycle studies and second cycle degrees give access to doctoral studies (Ministerial Conference 2003)[39]. Thus, in the two-cycle system there are up to two college level degrees followed by a doctoral degree at post-college level. Moreover, due to the changes in accordance with the Bologna Process, organisations such as the Bologna Follow-up Group provide comprehensive information on the way curricula are structured in different countries. Their reports allow conclusions on the organisation of higher education before the Bologna Process.

[38] Austria, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Iceland, Ireland, Italy, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland, and United Kingdom.

[39] This is different from most Anglo-American countries where entrance into most doctoral programs only requires a bachelor degree (Kehm 2007, p. 309).

Due to the availability of data on doctoral enrolments, the time interval of the dataset has a lower bound at year 1995 and an upper bound at year 2005 as until then many European countries still organised their studies according to the one-cycle system[40].

3.4.2 Central variables

The dependent variable in this study is a country's *Ph.D. rate.* The ISCED classification assigns doctoral studies to level 6 education as it "typically requires the submission of a thesis or dissertation of publishable quality" (UNESCO 2006, p. 39). The Ph.D. rate in year t is defined as the ratio of ISCED 6 graduations in all fields of study in year $(\mathrm{t}+3)$ to the population of the corresponding age cohort (25 to 34 years of age) in thousands:

$$\mathrm{Ph.D.\,rate_t} = \frac{\text{graduations at ISCED6}_{\mathrm{t+3}}}{\frac{1}{1000}\text{total population aged 25−34}_{\mathrm{t+3}}}. \tag{19}$$

In contrast to data on enrolments in doctoral studies, data on graduations are available from 1998 onwards. Furthermore, as mentioned in Section 2.3, information on doctoral enrolment rates might be distorted as registration of doctoral students is not mandatory in every country (e.g. Germany). Assuming that the average duration of doctoral studies is three years[41], a person who graduates from ISCED 6 level in year $(\mathrm{t}+3)$ enrolled in year t. Data on graduations and populations are drawn from the Eurostat "Education and Training" database (Eurostat 2014a). In order to ensure cross-country comparability, I use a relative measure rather than absolute numbers[42].

The independent variable of interest *one-cycle system* is a dummy variable that is 1 if curricula at college level are organised in a one-cycle structure and 0 if curricula are organised in a two-cycle structure. The term "organised in a one-cycle structure" in this context means that at least 50 percent of all students of the respective country are enrolled in study programs where only a single degree is awarded at the end of studies at college level. According to the structure in which curricula were predominantly organised between 1995 and 2005, I assign each country either to those countries where curricula are structured according to the one-cycle

[40] In three one-cycle countries, the two-cycle system was already the predominant curricular structure before 2006. Predominant in this case means that more than 50 percent of students were enrolled in two-cycle studies. Thus, in the dataset the Netherlands are only represented until 2003, and the Czech Republic and Italy until 2004 (Bologna Follow-up Group 2005; Eurydice 2003; Italian Ministry for Education, University and Research 2003).

[41] The standard timeframe for completion of full-time studies in doctoral education is three to four years (European University Association 2005) with three years being the most frequent answer (Westerheijden et al. 2012). However, a robustness check using a four year duration of studies was run, as well (Table 5, Model 1).

[42] In an alternative operationalisation, ISCED 6 graduations in $(\mathrm{t}+3)$ were put in relation to graduations from first college level studies (i.e. ISCED 5A first degree) of the corresponding cohort. A robustness check using this operationalisation of the Ph.D. rate is shown in Table 5, Model 2.

structure (one-cycle countries) or the two-cycle structure (two-cycle countries). The assignment is based on Westerheijden et al. (2012) and complemented with information from European Commission (1998) and Eurydice (2003), where possible. Table 2 provides information on the assignment of countries to the different higher educational systems.

Table 2: Assignment of countries according to curricular structure

One-cycle countries	Two-cycle countries
Austria, Croatia, Czech Republic[1], Estonia, Finland, Germany, Hungary, Italy, Netherlands, Poland[2], Portugal[3], Spain[4], Sweden, Switzerland	Denmark, France, Iceland, Ireland, Malta, Norway, Slovakia, Slovenia, United Kingdom

Notes:
[1] Next to the one-cycle system, a two-cycle system existed. Before the Bologna Process, however, students were mainly enrolled in the one-cycle system (Westerheijden et al. 2012).
[2] Westerheijden et al. (2012) assign Poland to the two-cycle countries as the two-cycle structure has existed since the 1990s (Eurydice 2003). Nonetheless, Bologna Follow-up Group (2005) and Boltruszko (2006) indicate that Poland's curricula at college level were predominantly organised according to the one-cycle structure before 2006 as most students were enrolled in one-cycle studies.
[3] Prior to the Bologna Process a two-cycle system only existed in polytechnics (Westerheijden et al. 2012).
[4] A two-cycle system existed before the Bologna Process, yet more than 50 percent of students were enrolled in the one-cycle system (Westerheijden et al. 2012).

3.4.3 Control variables

The control variables considered in this study are grouped in factors of educational institutions, labour market conditions, and a population's socio-economic characteristics.

3.4.3.1 Characteristics of educational institutions

Public spending on (tertiary) education as a percentage of a country's GDP indicates how important (tertiary) education is to the government, compared to other social sectors, e.g. health (Hwang and Jung 2006; Mimoun 2008; Yang and McCall 2014). It refers to a government's stake in directly bearing the expenses of educational institutions or supporting students and their families via public loans and scholarships (Eurostat 2014b). The corresponding data on *total public spending on tertiary education as a percentage of GDP* are drawn from the Eurostat "Education and Training" database (Eurostat 2014a).

Besides public spending on higher education, I control for the heterogeneity of a country's higher education at college level. Franck and Opitz (2007) suggest that there are more doctoral graduates in countries with less heterogeneous educational institutions. They reason that there is less incentive to pursue a doctoral degree if someone can distinguish herself from the majority of graduates by graduating from e.g. prestigious schools. Following the idea of Bergh and Fink (2009), I operationalise this heterogeneity with the ratio of students enrolled in theoretically oriented college level studies in private institutions[43] to those enrolled in ISCED 5A studies in any form of college level institution. ISCED 5A studies refers to programs at the first stage of tertiary education that are theoretically based and can provide access to doctoral education (UNESCO 2006). To successfully operate in the educational market, private providers may target the educational needs of certain individuals or labour markets. That is, they try to exactly meet the needs of (small) distinct groups of individuals or markets rather than providing broad but less tailored education to the whole population. If a large share of education at college level is provided by private institutions, then the educational landscape is quite heterogeneous as each private provider may target a different group of individuals. Thus, future employers can discriminate between graduates as they can observe the educational institution they graduated from. As a consequence, an individual might not need to further distinguish herself though attaining a doctoral degree. The corresponding data to operationalise the ratio of *students enrolled in private college level education* are also drawn from the Eurostat "Education and Training" database (Eurostat 2014a).

An additional control variable is the *ratio of graduations from practically to theoretically based college studies*. Specifically, it is the ratio of people graduating from practically oriented studies to those graduating from theoretically based first degree college level programs (i.e. first degree ISCED 5B and ISCED 5A studies). Only those who graduate from the latter can enrol in doctoral studies later on. ISCED 5B studies, on the contrary, focus on occupationally oriented skills preparing for labour market entrance (UNESCO 2006). Thus, enrolments in doctoral studies might be lower the more people choose a practically oriented educational path. The corresponding data on graduations from first degree ISCED 5A and ISCED 5B studies are taken from the Eurostat "Education and Training" database (Eurostat 2014a).

Osipian (2012) states that the signalling function of a doctoral degree is distorted if degrees are available for purchase. The author understands the existence of a market for ghost writing as corruption in education (Osipian 2012). There might be two ways in which corruption (i.e. ghost writing) influence doctoral enrolment: On the one hand, the easier it is to receive a post-college degree (e.g. by simply "buying" it) the more people might be tempted to do so. On the other hand, the more people receive a post-college degree without having the inherent ability necessary, the lower is the signalling value of such a degree and Ph.D. rates might drop (Osipian

[43] According to Eurostat (2014b), an educational institution is called private if the ultimate control over the institution rests on non-governmental organisations, such as business enterprises or churches.

2012). The *Corruption Perceptions Index* (CPI) is used to operationalise a country's corruption. The corresponding data is drawn from Transparency International (2014b) as it provides sufficient data for all years between 1995 and 2005[44]. The CPI ranks countries based on the perceived corruption of the public sector on a scale of 0 to 10, with 0 meaning that a country is "highly corrupt" whereas 10 refers to a "very clean" country (Transparency International 2014b). A downside is that CPI is highly correlated with GDP per capita, so coefficients may be biased.

3.4.3.2 Characteristics of the labour market

A further group of control variables are factors of labour market conditions, which refer to the opportunity costs of students enrolled in doctoral studies. Following Bedard and Herman (2008) and Johnson (2013), high unemployment rates among people with college education serve as a proxy for low opportunity costs. The lower the opportunity costs, the larger is the incentive to enrol in doctoral studies, all else being equal. The respective data to calculate the *unemployment rate among people with college level education* (both ISCED 5A and 5B education) as their highest educational level attained were provided by Eurostat through an ad-hoc request from the European Union Labour Force Survey.

Inspired by Perna (2004), the ratio of *students graduating in "high income" majors* to those graduating in any field of study in theoretically based first degree college level programs serve as a further proxy for forgone earnings. College majors with high returns on education are in fields that prepare for occupations where a large share of specific or innovative human capital is needed (García-Aracil 2008; Ochsenfeld 2014), such as engineering, manufacturing, construction, and sciences (incl. mathematics and computer sciences) (Machin and Puhani 2003, p. 396). As this form of human capital is less portable or erodes more quickly, employers need to compensate respective graduates for their higher risk by offering higher wages (Ochsenfeld 2014, p. 4). In turn, this means that opportunity costs of post-college education are higher for graduates from high income college majors. Thus, one might expect enrolment rates in post-college education to be small if many students in a country are enrolled in high income college majors. The data on graduations in high income majors as well as in any field of study in theoretically based first degree college level studies are drawn from Eurostat's "Education and Training" database (Eurostat 2014a).

[44] Other indices, such as the Global Corruption Barometer and the Bribe Payers Index were considered, too (Transparency International 2014c, 2014a). However, data on the Global Corruption Barometer is not available before 2003. The Bribe Payers Index started collecting data in 1999. From there on, data are collected every second to fourth year. Thus, both indices only provide data for two to three years between 1995 and 2005.

3.4.3.3 Characteristics of a country's population

In addition, socio-economic characteristics of a country's population are considered. Following Yang and McCall (2014), the proportion of elderly people (65 years or more) in a country might influence enrolment rates. Having reached the age of retirement, people will have less return on investment in education and are therefore less eager to attain further education. The corresponding data are taken from the Eurostat "Demography and Migration" database (Eurostat 2014a).

Another variable considered is the *ratio of female to male first degree college level graduates*. Perna (2004) shows that even though women are acquiring more bachelor degrees compared to men, they acquire less doctoral degrees. It seems that women – for various reasons – are not interested in extending their educational attainment beyond college level education[45]. Given that attaining post-college education requires a college degree, and assuming that women are less interested in attaining post-college education, greater ratios of women to men at college level will correlate with less enrolments at post-college level, all else being equal. To compute the ratio of female to male graduates, I use data on first degree ISCED 5A graduations of men and women drawn from Eurostat's "Education and Training" database (Eurostat 2014a).

As Stolzenberg (1994) suggests, college graduates might be less dependent on their parents than individuals at lower educational levels. Thus, the influence of the individual's family background, and therefore financial support, might be less important. Nonetheless, as education is costly, it is reasonable to assume that people with higher incomes will attain more education (Hwang and Jung 2006). One reason might be that the direct costs of study are perceived to be rather small, and therefore return on education is assessed to be relatively large. A country's *GDP per capita* (measured in purchasing power standards) operationalises income at country level. Following Hwang and Jung (2006) and Yang and McCall (2014) and for reasons of interpretation a log-transformed version of GDP per capita is used. The corresponding data is taken from Eurostat's "Economy and Finance" database (Eurostat 2014a).

3.4.4 Descriptive statistics and illustrative evidence

Table 3 summarizes the variables described above. The mean Ph.D. rate over all observations is 1.60 per 1,000 people of the corresponding age cohort. With 62 percent of the observations, the group of one-cycle countries is larger than the group of two-cycle countries. Regarding the ratio of women to men in college education, one can see that women dominate. In fact, there

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[45] One reason might be that women believe that they will not participate in the labour market as long as men, e.g. due to child rearing.

are over 50 percent more women in college education than men. This is in line with the empirical findings of Perna (2004).

Table 3: Descriptive statistics of variables at country level

	Mean	Std. dev.	Min.	Max.
Ph.D. rate	1.60	0.87	0.19	3.78
One-cycle system	0.62	0.49	0.00	1.00
Public spending on tertiary education (% of GDP)	1.33	0.49	0.70	2.71
Students enrolled in private college level education (%)	25.78	33.32	0.00	100.00
Ratio of graduations from practically to theoretically based college studies	0.36	0.37	0.00	1.30
Corruption Perceptions Index	7.02	2.05	3.40	9.90
Unemployment among people with college level education (%)	3.95	1.97	1.24	8.79
Students graduating in "high income" college majors (%)	22.04	6.32	9.90	31.79
People aged 65 years or older (%)	15.03	1.89	11.10	19.00
Ratio of female to male college graduates	1.51	0.35	0.79	2.29
GDP per capita (log)	9.91	0.37	9.13	10.59
Observations	93			

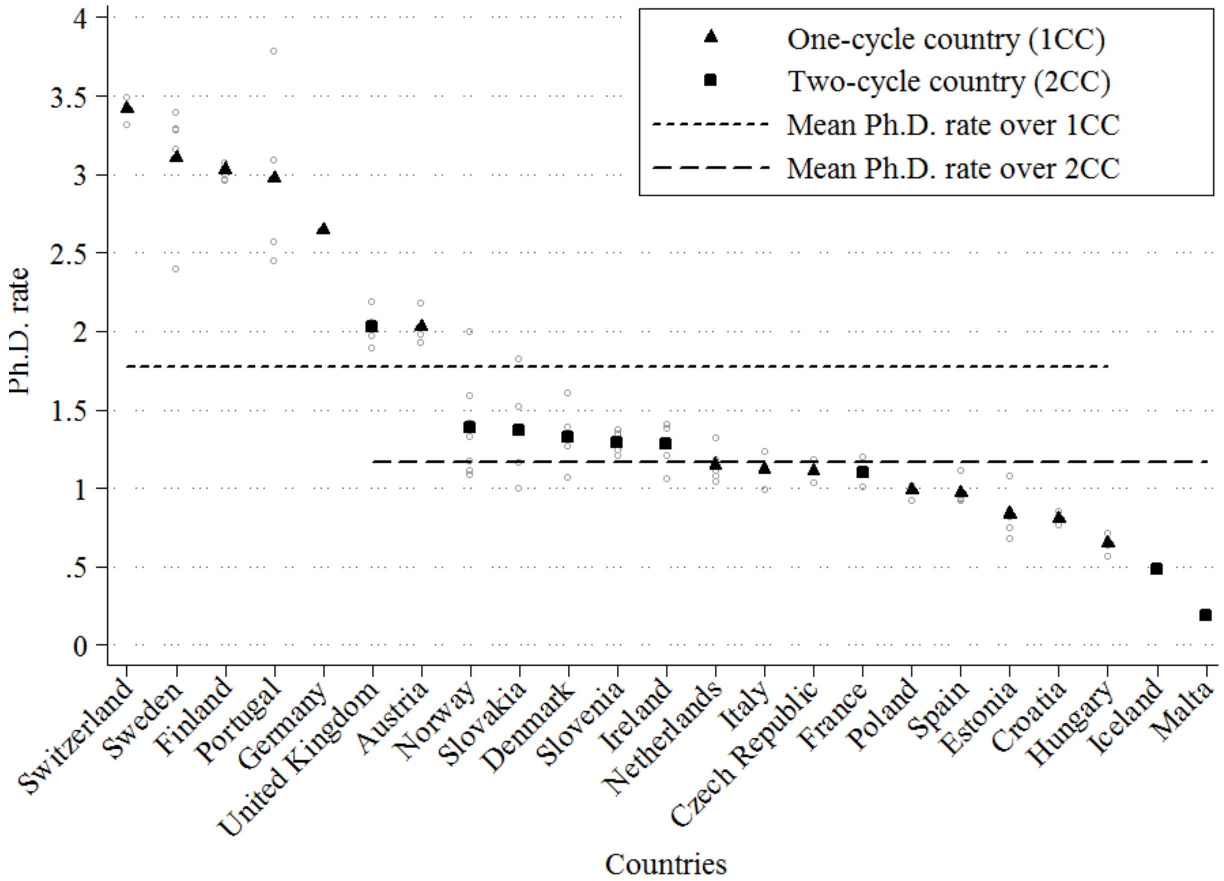
Source: Own calculations based on Eurostat (2014a).

Figure 10 describes the dependent variable Ph.D. rate and relates it to the independent variable of interest, one-cycle system. The vertical axis displays the Ph.D. rate measured in enrolments in doctoral studies per 1,000 people of the relevant age cohort. The grey circles indicate the Ph.D. rate in a certain country and in a certain year. A vertical stack of the grey cycles indicates within-variation over time for a certain country. Especially the presence of within-variance suggests using panel regression models rather than simple cross-section models.

The black triangles (squares) in Figure 10 represent the mean Ph.D. rates of one-cycle countries (two-cycle countries) averaged over the respective observations in the dataset. Taken together they indicate between-variation in Ph.D. rates across countries.

Furthermore, the triangles and squares in Figure 10 allow the comparison of mean Ph.D. rates across the two systems. On average, the mean Ph.D. rates in one-cycle countries seem to be higher than in two-cycle countries. For clarification, the short- and long-dashed lines indicate the means of the country averages in the two systems. While in two-cycle countries there are on average 1.16 enrolments in doctoral studies per 1,000 people of the corresponding age cohort, there are on average 1.77 enrolments in one-cycle countries. The difference is statistically significant[46]. This is a first illustrative support for the hypothesis of this study. Section 3.4.6 presents a more sophisticated multiple analysis with control variables to test the effect of curricular structure on doctoral enrolment.

Figure 10: Ph.D. rates in one- and two-cycle countries between 1995 and 2005



Source: Own illustration based on data extracted from Eurostat (2014a); own calculations

[46] Regressing mean Ph.D. rates on the curricular structure using a simple OLS-Regression with robust standard errors indicates a significant difference of mean Ph.D. rates between one- and two-cycle countries (coef. = 0.609, robust std. err. = 0.330).

3.4.5 Methodological approach

Figure 10 displays variation in the dependent variable Ph.D. rate over time as well as across countries. The two most frequently used models with regard to panel structure are fixed and random effect models[47] of the form

$$\text{Ph.D. rate}_{it} = \sum_{k=1}^{K} \beta_k x_{k,it} + u_i + \varepsilon_{it}, \tag{20}$$

where the K observed variables $x_{k,it}$ could (i) change over time and country, (ii) be invariant over time, but vary between countries, or (iii) be constant for all countries, but change over time (Wooldridge 2002, p. 251). Given the data in the dataset, the curricular structure of a country's college level education refers to the second form (i.e. time-invariant but different across countries), while the other regressors are of the first form (i.e. varying across time and country). Additionally, u_i and ε_{it} represent the unobservable variables. The idiosyncratic error, ε_{it}, is supposed to vary over time and countries and is assumed to be independent and identically distributed (Cameron and Trivedi 2010, p. 261). The country effect, u_i, indicates unobservable characteristics of a country that do not change over time, such as cultural preferences (Verbeek 2012, p. 381).

Fixed effect models use within-transformation which is, simply put, to control for the mean value of each variable. Therefore, all coefficients of time-invariant variables – such as the central independent variable one-cycle system – are omitted (Cameron and Trivedi 2010, p. 257)[48]. Thus, one might be tempted to use random effects instead of fixed effects estimators, which are able to estimate coefficients of time-invariant regressors. However, random effects estimators are only efficient if the unobservable country effect, u_i (which is controlled for in fixed effects models) is uncorrelated with the regressors in the model (Wooldridge, 2002: 252). Using a random effect model despite correlation between u_i and the regressors would result in omitted variable bias and, hence, inconsistent and biased estimators. Thus, it is important to test for this critical assumption.

One option that is frequently applied is the Hausman test (Hausman 1978): It relies on the idea that, if both fixed and random effects models are consistent, their estimates should not differ significantly (Andreß et al. 2013, p. 168; Wooldridge 2002, p. 288). Thus, the test compares the estimates of the fixed and random effects model and tests whether they are

[47] Pooled OLS models only rarely produce correct standard errors. They are often used as starting points for analyses but are seldom the final estimators used (Andreß et al. 2013, p. 163).

[48] Nonetheless there is the possibility to estimate the effect of time-invariant regressors in two-step approach as in Table 7 and Table 8.

systematically different. Since the fixed effects estimator is consistent even if the country effect, u_i, and the regressors are correlated but the random effects estimator is not, a statistically significant difference between the fixed and random effects estimates is interpreted as evidence against the random effects assumption (of no correlation between the country effect and the regressors) (Wooldridge 2002, p. 288). Failing to reject the null hypothesis of no systematic differences in the coefficients between fixed and random effects estimations thus lends support for using a random effects specification.

The model estimated in this study is:

$$\text{Ph.D. rate}_{it} = \beta_0 + \beta_1 * (\text{one-cycle system})_i + \sum_{k=2}^{10} \beta_k z_{k,it} + u_i + \varepsilon_{it}, \tag{21}$$

with the variable "one-cycle system" being a time-invariant dummy variable indicating whether studies at college level in country i are primarily organised according to the one-cycle system in lieu of the two-cycle system. $z_{k,it}$ indicates the nine control variables described before. u_i denotes the unobserved country effect and ε_{it} the idiosyncratic error (with country and year dimension).

Within the analysis of this study a sample of European countries is used. As these countries are assumed to be randomly drawn from a larger population, the country effect is assumed to be uncorrelated with the regressors in the model. Furthermore, I estimate the same model using fixed and random effect specification and run a Hausman test[49]. Failing to reject the null hypothesis of no systematic differences in the coefficients between the fixed and random effects estimations lends support for using a random effects specification.

3.4.6 Empirical analysis

Table 4 presents the regression results of the random effects estimations using cluster-robust standard errors. The basic model is shown in Model 1. It tests the effect of the one-cycle system on Ph.D. rate, controlling for factors of educational institutions, labour market conditions, and a population's socio-economic characteristics. Models 2 to 5 present modifications to Model 1.

[49] For regression results of fixed and random effects estimations as well as the Hausman test, see Table 6.

Table 4: Random effects estimation regressing doctoral enrolment rates on one-cycle system

	(1)	(2)	(3)	(4)	(5)
One-cycle system	0.862***	0.844***	0.840***	0.873**	1.021**
	(0.326)	(0.317)	(0.324)	(0.368)	(0.451)
Public spending on tertiary education (% of GDP)	0.074 (0.224)	0.017 (0.219)	-0.018 (0.204)		
Students enrolled in private college level education (%)	0.001 (0.001)	0.001 (0.001)	0.0005 (0.001)	0.001 (0.001)	0.001** (0.001)
Ratio of graduations from practice to theoretically based college studies	0.360 (0.285)	0.313 (0.296)	0.298 (0.296)	0.390 (0.357)	0.208 (0.264)
Corruption Perceptions Index	0.078 (0.069)	0.098* (0.058)	0.108* (0.057)	0.001 (0.086)	0.030 (0.098)
Unemployment among people with college level education (%)	0.060** (0.024)	0.061*** (0.023)	0.057** (0.023)	0.033 (0.045)	-0.070 (0.071)
Students graduating in "high income" college majors (%)	0.019 (0.012)	0.020* (0.012)	0.019* (0.011)	0.023** (0.010)	0.035** (0.016)
People aged 65 years or older (%)	-0.052 (0.061)	-0.050 (0.058)	-0.053 (0.061)	-0.037 (0.075)	-0.079 (0.098)
Ratio of female to male college graduates	-0.113 (0.412)	-0.119 (0.401)	-0.113 (0.373)	0.067 (0.413)	0.402 (0.510)
GDP per capita (log)	1.164*** (0.277)			1.303*** (0.379)	0.868* (0.509)
1st lag of GDP per capita (log)		1.124*** (0.216)			
2nd lag of GDP per capita (log)			1.023*** (0.235)		
1st lag of public spending on tertiary education (% of GDP)				0.526*** (0.116)	
2nd lag of public spending on tertiary education (% of GDP)					0.440** (0.175)
Constant	-11.037***	-10.666***	-9.551***	-12.945***	-8.432**
	(2.384)	(1.937)	(2.099)	(3.057)	(4.159)
Number of countries	23	23	23	23	23
Number of observations	93	93	93	77	60
Significance of u_i	0.000[a]	0.000[a]	0.000[a]	0.000[a]	0.000[a]

*p<0.10, **p<0.05, ***p<0.01; cluster-robust standard errors in parentheses
[a] Breusch and Pangan test for random effects
Source: Own calculations based on Eurostat (2014a).

The central independent variable is the way curricula at college level are predominantly structured. According to Model 1 in Table 4, the Ph.D. rate in one-cycle countries is significantly larger than in two-cycle countries after controlling for factors of educational institutions, labour market conditions, and a population's socio-economic characteristics. That is, in countries where college level education is predominantly structured in a one-cycle structure, Ph.D. rates are 0.086 percent-points higher than in two-cycle countries. The result confirms the theoretically derived hypothesis.

The theoretical section of this chapter linked differences in the curricular structure at college level to the educational decision at doctoral level, reasoning that a person in a situation with only one degree at college level, as an individual in a one-cycle country, has a larger incentive to enrol in doctoral studies than an individual who already holds two degrees at college level. For the individual in the one-cycle system the only chance to validly distinguish from others is to pursue a doctoral degree. The individual in the two-cycle system, however, could already distinguish herself from the less productive students by completing her second college level degree. Therefore, the wish to distinguish from less productive people is stronger in a one-cycle system than in a two-cycle system.

According to Model 1 in Table 4 only two control variables show the expected effect: The coefficients of GDP per capita and unemployment rate among people with college level education are both significant and positive. However, GDP per capita and the corruption perception index (CPI) are highly correlated[50]. Due to this high correlation, income and corruption effects cannot be disentangled.

Moreover, Model 1 may suffer from endogeneity. Both economic growth and expenditure on education should be handled with caution. Bergh and Fink (2008) point out that there might be two-way causation, as expenditure on education might not only enhance educational enrolment, but more enrolment might exert some pressure on policy-makers to assign more resources to the educational sector. To address this problem, Models 2 to 5 use lagged versions of the variables (first and second lag). As can be seen from these models, the central independent variable one-cycle system remains significant and positive.

When controlling for the first and second lag of GDP per capita (Models 2 and 3), their coefficients as well as those of CPI, unemployment rate among people with college level education, and students graduating in "high income" majors are significant and positive.
With regard to GDP, CPI, and unemployment rate, this is as expected. The coefficient of "high income" major on the other hand, does not show the expected effect. According to Perna (2004) we would expect lower enrolment rates in doctoral studies with more students graduating from majors with high income prospects. However, the opposite is the case. A possible explanation is that – in practice – there are some college majors where a doctoral degree is the default degree (Holley and Gardner 2012). In Germany, for example, almost 91 percent of college graduates in chemistry, physics and biology enrol in doctoral studies (Bundesagentur für Arbeit 2012).

[50] The correlation coefficient is 0.855. Due to the high correlation between GDP and CPI, model specifications controlling separately for these two variables were estimated as well (Table 9).

As I include natural sciences in the concept of “high income” majors the positive coefficient might be reasonable. Moreover, I will show in Chapter 4 that students in these majors receive a wage premium from doctoral education which might also explain higher doctoral enrolment.

In the case of the lagged versions of public spending on tertiary education (Model 4 and 5) their coefficients as well as the coefficients of GDP per capita and students graduating in “high income” majors are again significant and positive. Moreover, when controlling for the second lag of public spending on tertiary education in Model 5 the coefficient of ratio of students enrolled in private college level institution to any form of college level institution is significant and positive. This is not as expected. In line with Franck and Opitz (2007), I argued that heterogeneity in education might deter enrolments at post-college level, as graduating from more prestigious institutions serves as a signal itself. However, the most prestigious schools are not necessarily private. In France, for example, some of the most prestigious schools are public (Franck and Opitz 2007), suggesting that the proportion of students enrolled in private institutions might not be the best proxy for heterogeneity in higher education.

3.4.7 Robustness of results

In this section, I investigate the robustness of my findings in the previous section. Regarding the time to doctoral degree, I so far used a study duration of three years as, according to European University Association (2005), the standard timeframe for doctoral studies is three to four years with three years as the most frequent answer (Westerheijden et al. 2012). Using a dependent variable that assumes a four year study duration does not qualitatively alter the effect of interest. According to the second column in Table 5, Ph.D. rates are still significantly higher in one-cycle systems than in two-cycle systems.

Apart, from doctoral study durations, one might argue that variations in apprenticeship enrolment rates of potential college students (i.e. high school graduates with the potential to enrol in college) across countries might cause differences in doctoral enrolment rates. In this case, we would expect lower Ph.D. rates in countries with high levels of apprenticeship enrolment, as academic students could already distinguish themselves from vocationally trained individuals by obtaining a college level degree (i.e. horizontal differentiation). Thus, the need to distinguish further would be smaller, resulting in lower doctoral enrolment rates. Figure 10, however, shows a different picture, as Austria, Germany, and Switzerland (known for their strong apprenticeships) are among the counties with the highest (mean) Ph.D. rates.

I further implicitly control for this variability in apprenticeship enrolments by relating Ph.D. enrolments to first college level graduations of the corresponding cohort (third column in Table 5). If more potential college students prefer to enrol in apprenticeships, the number of college graduates would decrease. Note that one- and two-cycle systems differ in whether first cycle students can directly continue with doctoral studies: While this is possible in one-cycle systems, it is not in two-cycle systems. Here, students need to attend second cycle studies for another two years, first (see Figure 1 in Section 2.1). Hence, while in one-cycle systems, the college graduates of interest are those who graduate from first cycle studies in the respective year, the graduates of interest in two-cycle systems are those who graduates from first cycle studies two years ago. Thus,

$$\mathrm{Ph.D.\ rate_t} = \begin{cases} \dfrac{\mathrm{graduations\ at\ ISCED6_{t+3}}}{\mathrm{First\ cycle\ graduations_t}}, \text{if one-cycle system} \\ \dfrac{\mathrm{graduations\ at\ ISCED6_{t+3}}}{\mathrm{First\ cycle\ graduations_{t-2}}}, \text{if two-cycle system.} \end{cases} \tag{22}$$

According to Table 5, the results regarding the effect of interest do not change qualitatively.

Table 5: Alternative operationalisations of dependent variable in preferred model (M1)

	Proportion of age cohort (25–34) enrolled in four year doctoral studies[51]	Proportion of college graduates enrolled in three year doctoral studies
One-cycle system	0.925***	0.035**
	(0.307)	(0.014)
Public spending on tertiary education (% of GDP)	0.244	0.023
	(0.195)	(0.017)
Students enrolled in private college level education (%)	0.0004	0.0001
	(0.001)	(0.0001)
Ratio of graduations from practice to theoretically based college studies	0.038	0.057***
	(0.219)	(0.019)
Corruption Perception Index	0.105	-0.002
	(0.076)	(0.003)
Unemployment among people with college level education (%)	0.035*	-0.001
	(0.021)	(0.002)
Students graduating in 'high income' college majors (%)	0.026**	-0.001
	(0.011)	(0.001)
People aged 65 years or older (%)	-0.099	0.001
	(0.062)	(0.003)
Ratio of female to male college graduates	0.183	-0.035**
	(0.300)	(0.014)
GDP per capita (log)	1.117***	0.032**
	(0.273)	(0.015)
Constant	-10.602***	-0.261**
	(2.370)	(0.112)
Number of countries	23	23
Number of observations	92	91

*p<0.10, **p<0.05, ***p<0.01; cluster-robust standard errors in parentheses
Source: Own calculations based on Eurostat (2014a).

In the Section 3.4.5, I argued that we can only use random effects estimations if we expect the country effect, u_i, not to be correlated with the regressors as otherwise results would be biased. To test for this assumption, a Hausman test is performed in the fourth column of Table 6 after estimating the random and fixed effects models (column 2 and 3 in Table 6). The Hausman test indicates that there is no difference between the coefficients of the regressors in the fixed and random effects model specification. Hence, I conclude that using the random effects model is appropriate.

[51] Coefficients vary from Froehlich (2016, p. 1087) as regression was run on the same subsample as in Table 4 instead on all available observations as in Froehlich (2016, p. 1087).

Table 6: Fixed and random effects estimations of preferred model specification (M1)

	Fixed effects estimation (FE)	Random effects estimation (RE)	(FE-RE) difference
One-cycle system	omitted	0.862**	–
		(0.381)	
Public spending on tertiary education (% of GDP)	-0.114	0.074	-0.188
	(0.258)	(0.212)	(0.148)
Students enrolled in private college level education (%)	0.001	0.001	-0.0002
	(0.002)	(0.002)	(0.001)
Ratio of graduations from practice to theoretically based college studies	0.380	0.360	0.020
	(0.399)	(0.298)	(0.266)
Corruption Perception Index	0.077	0.078	-0.001
	(0.119)	(0.075)	(0.092)
Unemployment among people with college level education (%)	0.067*	0.060*	0.007
	(0.037)	(0.033)	(0.016)
Students graduating in 'high income' college majors (%)	0.008	0.019	-0.011
	(0.018)	(0.016)	(0.010)
People aged 65 years or older (%)	-0.138	-0.052	-0.086
	(0.117)	(0.075)	(0.090)
Ratio of female to male college graduates	-0.293	-0.113	-0.180
	(0.415)	(0.289)	(0.297)
GDP per capita (log)	1.488***	1.164***	0.324
	(0.409)	(0.325)	(0.249)
Constant	-11.624***	-11.037***	
	(3.717)	(2.788)	
Number of countries	23	23	23
Number of observations	93	93	93
Hausman test			$\text{Chi}^2(9) = 5.67$ $\text{Prob} > \text{Chi}^2 = 0.773$

*p<0.10, **p<0.05, ***p<0.01; standard errors in parentheses
Source: Own calculations based on Eurostat (2014a).

Given that the coefficient of the variable of interest is omitted in the fixed effects estimation in Table 6, the Hausman test does not include these coefficients when testing for differences in coefficients across fixed and random effects models. Thus, one might be interested in a t-statistic version of the Hausman test regarding the variable one-cycle system (Wooldridge 2002, p. 290). As this is not possible due to the nature of this variable, I use a estimation approach based on a two-stage fixed effects model to test for robustness (Bryan and Jenkins 2016): In a first step, the model specification is estimated based on a fixed effects estimation (Table 7). Due to its time-invariance the variable of interest (one-cycle system) is omitted from the regression results and the effect is included in the country-specific effect, u_i.

Table 7: two-step fixed effects approach (first step)

	PhD rate. Enrolments in ISCED 6 level as % of 1,000 people of cohort, 25-34 year
One-cycle system	omitted
Public spending on tertiary education (% of GDP)	-0.114
	(0.321)
Students enrolled in private college level education (%)	0.001
	(0.001)
Ratio of graduations from practice to theoretically based college studies	0.380
	(0.505)
Corruption Perception Index	0.077
	(0.100)
Unemployment among people with college level education (%)	0.067***
	(0.022)
Students graduating in 'high income' college majors (%)	0.008
	(0.014)
People aged 65 years or older (%)	-0.138
	(0.089)
Ratio of female to male college graduates	-0.293
	(0.392)
GDP per capita (log)	1.488***
	(0.322)
Constant	-11.624***
	(3.078)
Number of countries	23
Number of observations	93

*p<0.10, **p<0.05, ***p<0.01; cluster-robust standard errors in parentheses
Source: Own calculations based on Eurostat (2014a).

By predicting the country effect in a second step and regressing it on the variable one-cycle system using a between estimator, its effect on the dependent variable Ph.D. rate can be estimated. The result regarding the variable of interest is qualitatively robust (Table 8).

Table 8: Two-step fixed effects approach (second step)

	Country-specific effect
One-cycle system	1.079***
	(0.335)
Constant	-0.731**
	(0.261)
Number of countries	23
Number of observations	93

*p<0.10, **p<0.05, ***p<0.01; standard errors in parentheses
Source: Own calculations based on Eurostat (2014a).

Before, I argued that the CPI and GDP per capita are highly correlated and that, hence, income and corruption effects cannot be disentangled. As a robustness check, Table 9 provides two alternative model specifications, one excluding the CPI as regressor (column 3 in Table 9) and the other excluding GDP as regressor (column 4 in Table 9). Doing so does not qualitatively alter the effect of interest compared to the preferred model specification (column 2 in Table 9).

Table 9: Robustness multicollinearity of GDP and CPI

	Full model specification (FM)	FM without CPI	FM without GDP
One-cycle system	0.862***	0.825***	0.582*
	(0.326)	(0.319)	(0.299)
Public spending on tertiary education (% of GDP)	0.074 (0.224)	0.125 (0.198)	0.219 (0.288)
Students enrolled in private college level education (%)	0.001 (0.001)	0.001 (0.001)	0.00003 (0.001)
Ratio of graduations from practice to theoretically based college studies	0.360 (0.285)	0.360 (0.283)	0.197 (0.345)
Corruption Perception Index	0.078		0.176***
	(0.069)		(0.060)
Students graduating in 'high income' college majors (%)	0.019 (0.012)	0.018 (0.012)	0.031* (0.016)
Unemployment among people with college level education (%)	0.060** (0.024)	0.055** (0.024)	0.061** (0.028)
People aged 65 years or older (%)	-0.052 (0.061)	-0.042 (0.055)	0.022 (0.056)
Ratio of female to male college graduates	-0.113 (0.412)	-0.096 (0.402)	0.159 (0.429)
GDP per capita (log)	1.164***	1.280***	
	(0.277)	(0.250)	
Constant	-11.037***	-11.817***	-1.897**
	(2.384)	(2.148)	(0.958)
Number of countries	23	23	23
Number of observations	93	93	93

*p<0.10, **p<0.05, ***p<0.01; cluster-robust standard errors in parentheses
Source: Own calculations based on Eurostat (2014a).

3.5 Conclusion

Prior to the Bologna Process, most European study programs could be assigned either to a one-cycle system or a two-cycle system. While in the first, only a single degree is awarded at the end of college level studies, there are up to two degrees awarded in the two-cycle system. In both systems, a doctoral degree is awarded after graduating from studies at post-college level.

Based on Spence's signalling theory (Spence 1973), this study argues that doctoral enrolment rates in one-cycle countries are higher than in two-cycle countries. While attaining a doctoral degree is the individual's only chance to distinguish from other college graduates in the one-cycle system, an individual in the two-cycle system can already distinguish herself at college level by attaining a second cycle degree. Thus, her incentive to enrol in doctoral studies is comparably low.

Using data from 23 European countries between 1995 and 2005, random effects estimations reveal that one-cycle countries observe higher enrolment rates in doctoral studies than two-cycle countries and, thus, lend support to the hypothesis.

In 2003, when Europe's ministers of education encouraged the member states of the Bologna Process to organise studies at college level in a two-cycle structure, they aimed to enhance Europe's numbers in graduation (Di Pietro 2012; Ministerial Conference 2003). However, while some recent studies testify a positive effect of the two-cycle curricular structure on enrolments in first cycle programs (e.g. Di Pietro 2012), this chapter reveals a negative effect of the two-cycle structure on enrolments at post-college level (e.g. doctoral studies). The introduction of the two-cycle curricular structure might, therefore, put the Bologna objective of enhancing graduations rates – at least at post-college level – at stake. This, in turn, might have several major implications.

First, fewer doctoral students imply less (potential) teaching personnel in higher education. In many European countries, a substantial part of academic teaching is supported by doctoral students[52]. With decreasing doctoral enrolment rates, policy-makers and educational institutions might feel the need to promote academic careers more actively or to start to recruit potential academic personnel even earlier than they do today[53]. Thus, they would need to design

[52] According to Hakala (2009), about half of the academic staff in Finnish universities in 2004 were doctoral students. Although the author suggests that the Finnish higher education system might not represent the average European teaching situation, it might still give an impression of the relevance of doctoral students in academic teaching. For the UK, Park and Ramos (2002, p. 48) state that graduate students become increasingly important for undergraduate teaching and for Germany, Gerhardt et al. (2005, p. 88) note that teaching is an important part of the duties of doctoral students.

[53] See Brosi and Welpe (2015) for a discussion of employer branding attributes that attract post-doctoral talents for academic positions.

sustainable doctoral studies and funding to keep on attracting potential future doctorates and therefore potential teachers and future researchers. Europe's higher education ministers are aware of the importance of doctoral education for Europe's future. While focusing on the restructuring of college level studies at first, they deliberately included doctoral education as the third cycle in the Bologna Process in 2003 (Ministerial Conference 2003). Since then, Europe's ministers of higher education have increasingly focused on promoting quality and transparency in doctoral education (EHEA Ministerial Conference 2012).

Second, there might also be consequences for a country's economy. Knowledge generating institutions, such as universities, transfer their knowledge to firms through university-industry relationships and thereby enhance innovation, performance and eventually economic growth (Audretsch et al. 2005; Mueller 2006) which targets the EU's 2020 strategy objectives (Eurostat 2017a). With fewer doctoral students, however, this knowledge spill-over and therefore growth might suffer.

Third, fewer doctoral students might have consequences on a political level as well. In its presidential conclusions, the European Council set the strategic goal for the European Union "to become the most competitive and dynamic knowledge-based economy in the world" (European Parliament 2000). Doctoral students as potential future researchers are an important means to achieve this goal. A potential decrease in the numbers of highly educated people therefore clearly contradicts the idea of a knowledge-based society.

There are some limitations to this study. Unfortunately, we are not yet able to test whether Ph.D. rates will actually drop (or increase to a lesser degree) in countries that have changed their curricular structure from a one-cycle structure to a two-cycle structure. Thus, any predictions regarding the development of doctoral enrolment rates in former one-cycle countries based on the results of this study should be made with caution. Furthermore, limited availability of data is a major drawback when examining the determinants of doctoral enrolment at country level as in this study. Thus, potential determinants that might affect doctoral enrolment decisions cannot be controlled for (due to the availability or observability of data). One might reason, for example, that variations in the popularity of apprenticeships for potential college students might affect doctoral enrolments. In the robustness section, this is implicitly addressed by using an alternative version of the dependent variable Ph.D. rate (Model 2 in Table 5). Relating Ph.D. enrolments to first college level graduations of the corresponding cohort implicitly controls for differences in apprenticeship enrolment across countries.

In Models 2–5 in Table 4, I used lagged versions of GDP and expenditure on education to address the potential endogeneity due to these variables. Nonetheless, as both change only slowly over time, using lagged versions of these variables cannot rule out the possibility of multi-correlation or two-way causation. Robustness checks in Table 9 showed, however, that omitting either one of these to variables from the regression does not alter the effect of interest qualitatively.

Furthermore, there are other possible mechanisms that might explain the observed outcome. One explanation lies in potential job profiles for doctoral graduates. While in some countries doctoral graduates mostly stay in academia (e.g. in Poland and Italy (Kehm 2006, p. 70)), the doctoral degree might be highly appreciated by the private sector in other countries. In those countries, individuals in certain occupations or positions in the private sector might even be expected to have a doctoral degree. Hence, future job profiles rather than the possibility of distinguishing oneself from others might explain variations in doctoral enrolment decisions.

Nonetheless, this study is of interest as it (i) points to possible challenges former one-cycle countries should be aware of, and (ii) provides a starting point for future research on the development of doctoral enrolment rates after the curricular restructuring of Europe's college level education according to the Bologna objectives is completed (i.e. when students in former one-cycle countries who studied according to the two-cycle structure decide whether to continue to a doctoral degree). However, it will take time before the corresponding data is available.

4 The doctoral wage premium across major groups

4.1 Introduction

While studies seem to agree that – at lower educational levels – more years of schooling lead to higher wages, researchers do not see eye to eye when it comes to the doctoral level (Mertens and Röbken 2013, p. 218). The few results regarding the doctoral wage premium are mixed and indicate that the level of return depends on one's major.

Existing arguments fail to explain the observed differences in doctoral wage premiums across majors and while some authors present explanations for the observed doctoral wage premiums in some selected majors, they do not incorporate other majors in their ideas. Hence, a comprehensive explanation that allows us to understand the wage premium differences across majors is still missing.

This study contributes to the literature by developing such an explanation. Based on Becker's (1962) human capital theory, I argue that whether the labour market rewards a doctoral degree depends on the durability of knowledge and the knowledge and skills the respective major imparts. Inspired by McDowell (1982), I distinguish between majors of time-durable and time-erodible human capital (i.e. time-durable and time-erodible majors). Time-durable human capital is imparted, e.g. by humanities and arts, where fundamental progress is made on a larger time scale. In time-erodible majors, like, e.g. in natural sciences and engineering, progression is faster and today's technologies might be outdated tomorrow. I hypothesise that, while an employer will reward an individual's doctoral degree if she graduated in a time-erodible major, he will not remunerate the doctoral degree of a time-durable major graduate. I reason that an employer in need of knowledge imparted in time-erodible majors also requires the employee to be able to renew this knowledge constantly. Expecting doctoral graduates to be capable of renewing and expanding their knowledge on their own, the employer is willing to pay a doctoral wage premium for these research skills. With time-durable majors, however, knowledge does not erode over time (or as quickly). Hence, an employer who requires this type of knowledge does not need his employee to renew her knowledge and, therefore, will not reward research skills imparted by doctoral studies.

To test the hypotheses of this chapter, I use information on German students who graduated from university in 2005 and were surveyed again in 2011. These most recent data on German graduates are drawn from the German Centre for Higher Education Research and Science Studies (DZHW), a nationwide representative longitudinal survey (Baillet et al. 2016). I run several multiple OLS regressions separately for both time-durable and time-erodible majors controlling for individual, educational, and occupational characteristics. The results support my hypotheses: While there is a positive and significant effect of doctoral degrees on wages five to six years after first degree graduation within the time-erodible major group, I find no significant effect for the time-durable major group.

The remainder of this chapter is organised as follows. Section 4.2 provides a review of the literature on the effects of education on wages. Section 4.3 develops the argument on how field differences with regard to the imparted knowledge cause differences in the employers' demand for research skills, and consequently, result in field differences in doctoral wage premiums. Section 4.4 describes the dataset, presents the estimations, and discusses the empirical findings. Section 4.5 concludes the chapter.

4.2 Literature on the educational wage premium

Since Mincer (1974), a large number of studies has investigated the effect of education on wages. While earlier research focused on labour market surveys measuring education through years of schooling (e.g. Mincer (1974)), a large stream of today's literature uses surveys of college graduates to investigate the schooling effect among the highly educated. Using surveys on college graduates enables researchers to control for academic characteristics, such as majors or different post-college degrees, in more detail, while labour force surveys typically aggregate post-college and college level degrees into a single group (e.g. Livanos and Nunez 2012; Kilbourne et al. 1994).

4.2.1 Vertical differentiation by educational level

Both, human capital and signalling theory, expect wages to rise with educational level. This is either because schooling enhances productivity (as argued in human capital theory) or because higher educational levels reflect higher inherent productivity levels (as argued in signalling theory). Hence, doctoral graduates, having the highest educational levels, differentiate themselves from the less productive individuals at lower levels (see Chapter 3).

In the past, various studies have investigated the effect of post-college degrees on wages, focussing on master degrees (e.g. Espenberg et al. (2012), Montgomery and Powell (2003)) or grouping master and doctoral graduates into a common group of postgraduates in their analyses (e.g. Eide (1994), Morikawa (2015), Walker and Zhu (2011)). While these studies provide us with a general understanding of the valuation of graduate degrees, they do not facilitate to explicitly investigate the effect of doctoral degrees on wages. As master and doctoral studies differ widely regarding their curricular orientation (with the former focussing on imparting basic knowledge within a specific field while the latter focus on research skills), we might expect different wage effects from gaining these degrees. Compared to other educational degrees, however, the number of studies that explicitly investigates the effect of doctoral degrees on wages is rather small (Wouterse et al. 2017, p. 440). Furthermore, their results often differ (Mertens and Röbken 2013, p. 218; Wouterse et al. 2017, p. 441). While Dolton and Makepeace (1990), for example, find no effect of doctoral degrees on wages compared to a person with a bachelor degree six years after graduation when using UK graduate data for the class of 1980, Waite (2017) using Canadian labour force data in 2011 finds a significant and positive effect of doctoral over bachelor degrees. Similarly, Falk and Küpper (2013) find a positive effect of doctoral degrees on wages for German graduates of 2003/04. However, while also using data on German graduates but running separate regressions for men and women, Braakmann (2013) confirms a doctoral wage premium only for men. And Craft and Baker (2003), using US graduate data in 1993 to investigate the effect of different undergraduate majors on wages of lawyers, show that graduates who hold a doctorate receive higher wages at least in the self-employed sector. For the for-profit and government sectors, the effect was insignificant.

What all these studies have in common is that they pool graduates from all fields of studies within their empirical analyses. They therefore implicitly assume that doctoral wage premiums do not differ with regard to field of study. Given the empirical evidence on wage differences across fields of study for any fixed educational level (i.e. horizontal differentiation), however, this assumption is highly questionable.

4.2.2 Horizontal differentiation by field of study

There is a vast body of literature indicating that – at any educational level – certain majors are better remunerated than others (e.g. Finnie and Frenette (2003), García-Aracil (2008), Ochsenfeld (2014)). There are various explanations for this observation. In the following section, I will group them into gender-based, supply-based, and demand-based arguments.

The gender-based argument is rooted in the devaluation theory. It argues that traditional male majors – that is, majors with a male majority[54] – are better remunerated precisely because they lack women (England et al. 2007, p. 26; Leuze and Strauß 2016, p. 805; Ochsenfeld 2014, p. 1). According to England et al. (2007, p. 25), the cultural devaluation of women led to a

[54] Traditional male majors are mathematics, physics, natural and computer sciences, and engineering, while typical female majors are education, languages, humanities, fine arts, and social sciences (Machin and Puhani 2003, pp. 395–396; Morgan and Carney 1985, p. 28).

devaluation of everything that is associated with women. This includes jobs and field of study, and, therefore, gives gender a causal effect on wage differences across majors (Leuze and Strauß 2016, p. 805; Ochsenfeld 2014, p. 1). Thus, wages for typical male major graduates are higher than for traditional female major graduates[55].

Rather than arguing that certain majors are devaluated because of their gender composition, economic theories provide a supply-based argument: Majors differ with regard to the nature of their imparted human capital, which, in turn, leads to different remuneration across majors (Blakemore and Low 1984, p. 157; Ochsenfeld 2014, p. 4). According to Paglin and Rufolo (1990), for example, some majors are better paid because they provide skills that are rather scarce, and for which demand grew over time (Klein 2016, p. 46). So far, literature failed to solve whether women are paid less because of their gender or because they predominantly perform tasks that are valued less (Leuze and Strauß 2016, p. 805).

Rather than due to scarcity of skills, majors might be differently remunerated because they impart different types of human capital. Based on Becker‘s (1962) human capital theory, Leuze and Strauß (2009, p. 265) argues that some majors impart more general human capital while others impart more specific human capital, with the latter being better paid if specialisation is desired by the labour market. Alternatively, Tam (1997, pp. 1657–1658) argues that specific human capital is better paid because investment in this form of human capital inflicts higher opportunity costs on the individual which future employers will compensate for.

In a "variant of human capital theory" (Estevez-Abe 2005, p. 184), Polachek (1981) argues that skills differ in their "atrophy rates" (Polachek 1981, p. 62)[56]. Based on this idea, Ochsenfeld (2014, p. 4) expects majors of specific human capital to be better remunerated because this kind of knowledge is less durable, and, hence, forces their possessors to constantly refresh their knowledge to stay productive (McDowell 1982). Ochsenfeld (2014, p. 4) expects employers to have to compensate employees for taking this risk of decaying knowledge[57] by paying higher wages (Tam 1997, pp. 1657–1658). Otherwise, no rational individual would invest in such education, all else being equal, but opt for knowledge that is more durable and, therefore, less risky.

[55] Queuing theory further explains why women keep on studying these less appreciated majors (England et al. 2007, p. 27): Assuming that employers prefer men, they will employ men instead of women, if possible. Thus, even if women study better paid male majors, employers will not hire them as long as there are men willing to take the job. Thus, women stay with the less lucrative jobs, which promise employment.

[56] In line Blakemore and Low (1984), McDowell (1982), and Polachek (1981), I also argue that some majors provide knowledge which "rapidly becomes obsolete" (McDowell 1982, p. 753).

[57] See Grip and Loo (2002) for an overview of different reasons for knowledge and skill obsolescence.

While these explanations emphasise the characteristics of the knowledge that certain majors impart, an alternative explanation is more demand-based as it focuses on how the curricula of these majors are aligned to the needs of the labour market.

Klein (2016, pp. 44–45), Monaghan and Jang (2017), and Noelke et al. (2012, p. 705), for example, argue that some majors are better aligned to the needs of the labour market. These majors provide a high "degree of occupational specificity" already at bachelor level (Noelke et al. 2012, p. 706), while other majors often do not offer routes into occupations before the graduate level (Monaghan and Jang 2017, p. 3). Hence, Monaghan and Jang (2017) expect higher wages for bachelor graduates of occupation-specific degrees (Monaghan and Jang 2017, p. 3). Based on their descriptive statistics on US bachelor graduates, the results confirm their hypothesis.

4.2.3 Doctoral wage premium across college majors

While these theories explain why wages might differ across majors at a certain educational level (including doctoral level), they do not explain why wage premiums for gaining an additional level differ across majors.

Arguments that – at least in part – explain differences in wage premiums across majors are referred to by Falk and Küpper (2013) and Monaghan and Jang (2017).

Monaghan and Jang (2017) argue that the extent to which a graduate degree is additionally remunerated depends on the design of the undergraduate curriculum. While practical majors prepare their graduates for specific occupations as early as at bachelor level, academic majors such as arts and sciences are not designed for specific occupational employment at bachelor level and, thus, generally do not provide routes to specific occupations until the graduate level. Here, the graduate might engage in an occupation such as research assistant or professor (Monaghan and Jang 2017, p. 3). While the authors expect lower wages at bachelor level for graduates from academic majors, they expect the graduate wage premium in these majors to be larger than for more practical majors, such as teaching[58].

Falk and Küpper (2013) on the contrary argue that differences between doctoral wage premiums across majors are caused by differences in the design of the doctoral/graduate curricula. While the authors generally assume a positive effect of doctoral degrees on wages for all majors, they expect the doctoral wage premium to be particularly high in natural sciences and engineering. They argue that in these majors, doctoral students often work in third-party

[58] Mertens and Röbken (2013, p. 230) explain the lower doctoral wage premiums in the field of education as a result of common job opportunities for college and doctoral graduates in this field (as both work as teachers).

funded projects, which are more practice-oriented and provide better preparation for future occupations such as heads of research and development departments (Falk and Küpper 2013, p. 63).

As both explanations argue that the curricular design of either the undergraduate or the graduate/doctoral education (and thus differences in the orientation of studies towards employment) causes differences in the doctoral wage premium, I assign both to the group of demand-based arguments. In contrast, the study at hand argues that differences in the doctoral wage premium across major groups result from differences in the imparted human capital and, therefore, takes a supply-based view, as I will show in Section 4.3.

Although explanations for differences in doctoral wage premiums across majors as well as studies on the doctoral wage premium in general are rather scarce, a few previous empirical studies investigated the differences in the doctoral wage premiums across majors using different kinds of datasets and various methodological approaches. Their results are mixed.

As mentioned before, while some studies use labour force or other broader population surveys (e.g. Mertens and Röbken (2013)), most studies use information on college graduates (e.g. Heineck and Matthes (2012), Pedersen (2016)). While graduate surveys allow to control for academic characteristics in more detail than labour force surveys, they are also more homogeneous as all individuals surveyed are of roughly the same age, with similar labour market experience and prior college characteristics. This enables studies based on graduate data to control for at least some of the unobserved heterogeneity that one might face when using broader population surveys.

Furthermore, it matters at which point in time doctoral wages are observed. While studies based on broader population survey usually analyse wages at any point in work life (e.g. Mertens and Röbken (2013), Waite (2017)), studies based on graduate data typically focus on wages at the time of labour market entry. Note that doctoral degrees might open avenues into top management positions later in work life which one would not gain without a doctorate. Hence, the reward on a doctoral degree in the long-run might not be based solely on the imparted knowledge or differences in the curricular design, but also on the doctorate's function as a door opener into top positions[59]. Hence, results from studies based on broader population and graduate surveys should be compared with caution.

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[59] There are several reasons why Ph.D.s might open doors to top management positions regardless of their imparted knowledge: e.g. recruiters prefer to hire persons that fit their own background. Alternatively, Falk and Küpper (2013, p. 62) expect doctorate holders to occupy management positions because of their expertise in certain fields.

Moreover, previous studies differ with regard to their methodological approach. Some studies base their analysis on single equation wage regressions with interaction terms for doctorate and major (Monaghan and Jang 2017) or doctorate and sector (Pedersen (2016)). Using a matched sample of Danish master and doctoral graduates, Pedersen (2016) investigates the wage effect of holding a doctoral degree three and five years after graduation across different sectors. Based on her results, she concludes that while there even is a doctoral penalty in the business services and chemicals sectors three years after doctoral graduation, wages of doctoral and master graduates do not differ within all sectors five years after doctoral graduation.

Monaghan and Jang (2017, p. 12) operationalise academic majors as majors with high graduate-school-attendance rates. Using US college graduate data, they find a significantly higher return to graduate degrees for individuals who attended an undergraduate field where many students continue to graduate school (Monaghan and Jang 2017, p. 12). However, ranking majors by their graduate-school-attendance rate to operationalise labour market demand for certain bachelor level graduates is debatable. It is not surprising that majors with large graduate-school-attendance rates have larger returns for graduate degrees; otherwise, rational students would not attend graduate schools in the first place. Therefore, it is less clear whether higher graduate-school-attendance rates (as a proxy for labour market demand) lead to higher returns for graduate degrees or whether the higher returns lead to higher graduate-school-attendance rates.

A drawback arising from single equation regressions with interaction is that they do not fully appreciate the differences in labour markets across majors, as they allow wages across sector/majors to differ only with respect to the interacted factor (i.e. doctoral degree) but not with other characteristics.

In line with Klein (2016) and Leuze and Strauß (2009), however, I expect separate labour markets for different (groups of) majors. Based on labour market segmentation theories, Klein (2016, p. 46) argues that the labour market consists of several partial labour markets, which cannot likewise be entered by all job applicants. Rather, each occupation hires individuals who possess a more or less restricted set of educational attributes like educational field and level (Couppié et al. 2014, p. 371). Correspondingly, individuals occupy jobs that match their occupation-specific qualifications (Klein 2016, p. 46). Further, Leuze and Strauß (2009, p. 265) and Klein (2016, p. 46) claim that market segregation is especially true for the German labour market which I will investigate in this chapter.

Technically, one way of reflecting differences in the composition of wages is to run separate regressions for each sector/major[60]. While Pedersen (2016) states that she ran separate regressions for each major field as a robustness check, the respective results are not reported. She declares that the result of insignificant doctoral wage premiums does not change when running separate regressions (Pedersen 2016, p. 285). The insignificance of the doctoral wage effect, however, might be due to small samples when splitting 1,122 observations three years (and 706 observations five years) after doctoral graduation into five subsamples and is worth re-investigating (Pedersen 2016, p. 273).

Based on a simple t-test comparing wages of doctorates and non-doctorates separately for four major groups, Falk and Küpper (2013, p. 66) confirm a doctoral wage premium of 1,392 € per month in the major of engineering but premiums lower than 500 € per month for linguistics/cultural sciences, economics, and mathematics/sciences, respectively. Separate multiple regressions for these majors, however, controlling for individual, occupational, and other educational characteristics, are not performed.

Studies that investigate the doctoral wage premium across different majors based on separate multiple regressions are Engelage and Hadjar (2008), Heineck and Matthes (2012), Mertens and Röbken (2013), and Wouterse et al. (2017). While Engelage and Hadjar (2008) investigate the effect of doctoral degrees on wages across different majors[61] for Switzerland, Heineck and Matthes (2012), and Mertens and Röbken (2013) test the effects for Germany[62] and Wouterse et al. (2017) for the Netherlands[63]. Engelage and Hadjar (2008) find a significant doctoral wage premium for all majors at least for men (for women, the effect is unclear). The authors, however, do not control for individual, educational, or occupational characteristics beyond age and doctoral degree. For Germany, while Mertens and Röbken (2013) also testify to significant doctoral wage premiums across all majors (although with differing magnitudes[64]), Heineck and Matthes (2012) show that there is even a doctoral wage penalty in linguistics and cultural sciences. Wouterse et al. (2017), however, report wage penalties for exact and natural

[60] Another possibility would be to interact sector/major with all other n regressors. This approach, however, leads to n more coefficients that need to be estimated which will use up n more degrees of freedom. Possibly for this reason, the separate regressions approach is often preferred.

[61] Business and economics; humanities and social sciences; exact and natural sciences; engineering; and law.

[62] Mertens and Röbken (2013) distinguish between humanities and arts; education; social sciences; economics and law; mathematics, natural and computer sciences; and engineering, whereas Heineck and Matthes (2012) distinguish between linguistics and cultural sciences; psychology; law; natural sciences; medicine; business and economics; engineering; mathematics and computer sciences; agricultural sciences; and other majors.

[63] Agriculture; exact and natural sciences; engineering; health sciences; economics; law; behaviour and society; and linguistics and cultural sciences.

[64] Although Mertens and Röbken (2013, p. 229) state that the doctoral wage premiums differ significantly over the various majors, they do not test whether these differences are actually statistically significant.

sciences, economics, and engineering. As discussed above, these different results might originate in the different datasets used in these studies. For example, Mertens and Röbken (2013) and Wouterse et al. (2017) use broad population or labour force datasets (investigating the effect of doctoral degrees on wages during the whole work life), while Heineck and Matthes (2012) and Engelage and Hadjar (2008) use surveys of university graduates, thus, investigating wages at the time of labour market entry. Hence, results should be compared with caution.

Although running separate regressions for a large number of majors might be insightful in theory, we might face possibly biased results from small samples, in practice. With five (Pedersen 2016), six (Mertens and Röbken 2013), eight (Wouterse et al. 2017), or ten (Heineck and Matthes 2012) separate regressions, the subsamples are rather small. Heineck and Matthes (2012, p. 95), for example, argue that in addition to the small sample of linguistics and cultural sciences graduates, only two percent attained a doctoral degree. Hence, they reason that observed doctoral wage penalties might be due to selectivity within the subsample.

In the study at hand, I will address this issue by pooling majors of similar forms of human capital into common major groups. Studies that are closest – at least regarding the idea of major grouping – are possibly Espenberg et al. (2012) and Walker and Zhu (2011). Both group certain fields of study to common major groups (two and four distinct groups, respectively) and run separate regressions. The major groups in Espenberg et al. (2012, p. 49) are "natural and exact sciences" and "social sciences (incl. economics and law)". Those in Walker and Zhu (2011, p. 1178) are science, technology, engineering, mathematics, and medicine; social sciences, arts, humanities, and linguistics; law, management administration, and economics; and combined majors. The authors, however, do neither provide a (comprehensive) theoretical motivation for their major categorisation nor do they test for the specific effect of doctoral degrees on wages. Instead, they investigate the wage effects of master (Espenberg et al. 2012) or graduate degrees in general, including master degrees (Walker and Zhu 2011).

An approach that is based on separate multiple regressions is the Oaxaca-Blinder decomposition. Adopted from gender wage gap literature, Grave and Goerlitz (2012) use this technique to investigate wage differentials between pairs of different college majors for German graduates[65]. In particular, they investigate the wage gap between humanities and arts graduates and graduates of another major group (social sciences, natural sciences, or engineering). Using

[65] Another study that uses Oaxaca-Blinder decomposition to investigate major wage gaps is Espenberg et al. (2012). The authors, however, focus on bachelor and master graduates but not on doctoral graduates.

Oaxaca-Blinder decomposition to investigate such major wage gaps means to investigate how wages of humanities and arts graduates would change if their endowments and coefficients (i.e. how the labour market values these endowments) were adjusted to those of, e.g. engineering graduates. Hence, this set-up implicitly assumes, first, that humanities and arts graduates were discriminated by the labour market while the latter major group (engineering in this example) was not. Second, it implies that there is a common labour market for graduates of both major groups[66]. With regard to the second assumption and in line with our theoretical considerations and the literature on wage differences between majors, however, this is not what we would expect. Again, we would expect distinct labour markets for certain major groups (Couppié et al. 2014, p. 371). Hence, using Oaxaca-Blinder decomposition, essentially asking how mean wages of humanities and arts graduates would change if they attained on average as often doctoral degrees as, e.g. engineering graduates, or if their doctoral degrees were valued as engineering doctoral degrees[67], would not be appropriate as it would assume a common labour market although one expects distinct labour markets for different major groups. Hence, I argue that it is necessary to estimate distinct wage regressions for each major group and to interpret the results independently of each other.

O'Leary and Sloane (2005) use UK labour force data between 1994 and 2002 and Oaxaca-Blinder decompositions to investigate the mark-up of a doctoral degree over a bachelor degree in ten broad majors. Arguing that the unexplained part of the degree wage gap represents this mark-up, the authors implicitly assume differences in the valuation of individual and occupational characteristics of bachelor and doctoral graduates by the labour market to cause this wage premium. While this is a valuable contribution, it does not allow us to investigate how research skills imparted by doctoral studies are remunerated and whether differences across majors exist.

4.2.4 Contribution to the literature

The contribution of this study is twofold: First, it contributes to the empirical evidence on the doctoral wage premium across majors. In line with Mertens and Röbken (2013, p. 218), I showed that former studies came to contradicting results. Moreover, I demonstrated why these results might differ by pointing at different methodological approaches the various studies used

[66] Grave and Goerlitz (2012) also report the results from declaring the other major group (i.e. social sciences, natural sciences, or engineering) as the discriminated group. In this case, they implicitly ask how wages of the respective graduates would change if their endowment were adjusted to those of humanities and arts graduates.

[67] With humanities and arts as the non-discriminated group, one would ask how mean wages of engineering graduates would change if they attained on average as often doctoral degrees as, e.g. humanities and arts graduates or if their doctoral degrees were valued as humanities and arts doctoral degrees.

to investigate differences in doctoral wage premiums across majors. I argued that both single regression with interaction term (as in Monaghan and Jang (2017) and Pedersen (2016)) as well as Oaxaca-Blinder decomposition (as in Grave and Goerlitz (2012)) fail to address the issue of distinct labour markets for graduates of different major groups. Hence, I concluded that it is necessary to estimate distinct wage functions regarding each major group.

Furthermore, I argued that in order to test whether research skills are differently remunerated by the labour market depending on one's major, we should use graduate surveys instead of broad labour market surveys. This is because later in life the effect of doctoral degrees on wages might not only result from their imparted research skills but also from their function as a door opener into top management[68].

Regarding their methodological approach and data used, I group this study to those of Heineck and Matthes (2012) and Pedersen (2016) who test for the doctoral effect on wages by running separate multiple regressions for various majors controlling for individual, educational, and occupational factors based on graduate data. A limitation in these studies is, however, the (possibly) small sample size as they run separate regressions for five (Pedersen 2016) or ten (Heineck and Matthes 2012) different majors. One can argue that selectivity within these small samples leads to biased results. By running separate regressions for only a few distinct major groups as for example in Espenberg et al. (2012) or Walker and Zhu (2011), this study addresses this issue by trying to maintain sufficiently large subsamples while taking into account the idea of distinct labour markets. In contrast to Espenberg et al. (2012) or Walker and Zhu (2011), however, I explicitly investigate wage effects of doctoral degrees. With doctoral studies differing fundamentally from studies at master level, results from Espenberg et al. (2012) and Walker and Zhu (2011) cannot be transferred to doctoral graduates.

Second, this study contributes to the theoretical literature that helps to explain why doctoral wage premiums differ across majors. While Falk and Küpper (2013) and Monaghan and Jang (2017) give demand-based explanations, this study contributes a supply-based explanation arguing that the knowledge imparted by doctoral studies is rewarded only in fields where knowledge decays more rapidly. Demand-based arguments as in Monaghan and Jang (2017) argue that graduates of academic majors (e.g. natural and cultural sciences) should receive higher doctoral wage premiums than practical major graduates, e.g. engineers (Monaghan and Jang 2017, p. 6). Empirical findings as in Heineck and Matthes (2012),

[68] According to Seadle (2016, p. 29), a doctorate opens doors into management positions, both in the private and public sector. It therefore has the role that the MBA has in North America (Seadle 2016, p. 29).

however, indicate that doctorial wage premiums are high for engineering but low (and even negative) for linguistics and cultural sciences graduates. The supply-based perspective, developed in this chapter allows us to understand these differences in doctoral wage premiums which demand-based arguments fail to explain. Instead of grouping majors according to their curricular design, I assign them by their form of human capital, i.e. time-erodible and time-durable knowledge. To do so, I use theoretical considerations and empirical findings of prior studies (e.g. McDowell (1982)) and, therefore, depart from common practice that groups majors by degree awarding faculties (Dolton and Makepeace 1990, p. 37).

4.3 The relationship between knowledge durability and doctoral wage premiums

In what follows, I will argue that the knowledge imparted by doctoral studies is rewarded only in fields where knowledge decays more rapidly. I, therefore, need to distinguish (i) between majors with rapidly decaying knowledge and majors with slowly decaying knowledge and (ii) between knowledge imparted at college level and at doctoral level. Then, I will show how demand for knowledge imparted at doctoral level differs across major groups.

4.3.1 Knowledge and skill differences across majors and higher educational levels

Some previous studies demonstrated that college majors differ with regard to their imparted knowledge and skills. For example, while some majors predominantly impart communicative and caring skills (e.g. humanities and arts), others focus on technical and analytic skills (e.g. engineering and natural sciences) (e.g. Kalmijn and Lippe (1997) and Mertens and Röbken (2013)). Employers will hire those graduates who provide the knowledge and skills needed to perform a certain job to maximise productivity (Werfhorst 2002, p. 290). An employer who requires a person with technical skills will hire a person that graduated in a technical or analytical field instead of a communicative or caring major graduate. I argue, therefore, that there are distinct labour markets with regard to these groups of majors, as graduates of the former group will not work in or be hired for an occupation predominantly in need of skills provided by the latter group and vice versa.

Apart from the difference in the nature of these skills and knowledge, there are differences in the importance to constantly renew them to keep up to date. With this in mind, McDowell (1982) ordered seven research fields according to their knowledge decay rate. Based on this ranking and on studies that categorise majors by their imparted skills (e.g. Kalmijn and Lippe (1997) and Mertens and Röbken (2013)), I conclude that knowledge imparted by communicative and caring majors decays less rapidly than knowledge imparted by technical and analytical majors. This conclusion is in large parts supported by Ochsenfeld (2014), who introduced measures of math-intensity[69] (i.e. analytical skills) and need for on-the-job-training (i.e. knowledge decay) and ranked college majors accordingly. In the following, I will, therefore, distinguish between time-erodible and time-durable majors with regard to the durability of their imparted human capital and group technical and analytical majors into the time-erodible category, where knowledge has to be renewed constantly, and communicative and caring majors into the time-durable major category, where knowledge and skills can still be productively put to use after some time.

I further distinguish between college level education and doctoral education, defining college level education as first and second cycle college level education that usually leads to bachelor and master degrees, respectively. A doctorate, in turn, is one of the highest educational degrees universities can award (Engelage and Schubert 2009, p. 214; Pedersen 2016, p. 271)[70]. This third cycle education deliberately differs from college level education with regard to its curricular orientation: While college level education focuses on imparting knowledge in a certain field, doctoral education focuses on bringing forth new researchers, with research being "the most predominant and essential component" of doctoral studies (European University Association 2005, p. 35). Hence, instead of consuming knowledge as in first and second cycle studies, doctoral students become the "creators of knowledge" (Pedersen 2016, p. 271) who know how to acquire new knowledge on their own. Thus, while first and second cycle studies focus on imparting basic knowledge and skills within the field of a certain major, third cycle studies focus on imparting research skills that (at least to some extent) are similar across majors[71] and enable their students to renew and create knowledge on their own.

4.3.2 Differences in the demand for doctoral skills across majors

Based on Becker's (1962) human capital theory, I will argue that these research skills are only remunerated for graduates of time-erodible majors but not for time-durable major graduates. Becker's (1962) central idea is that education raises productivity; more precisely, that education

[69] To develop this measure, Ochsenfeld (2014) used information on how often students in the respective fields stated that mathematics was one of their favourite subjects in school (Ochsenfeld 2014, p. 6). It therefore does not explicitly indicate whether the college major focuses on analytical skills. Ochsenfeld (2014, p. 8) finds the proxy to better distinguish between broad groups of math-intensive and math-shallow majors than between majors within these groups.

[70] In Austria, Germany, and Switzerland, the highest educational level is the "Habilitation", which enables its holders to take up a post as chair at a university within a certain field (Engelage and Schubert 2009, p. 214).

[71] I agree with Falk and Küpper (2013, p. 63), arguing that doctoral graduates might possess a wider and deeper knowledge within their field of expertise than graduates without a doctorate. Nonetheless, I argue that the focus of doctoral education is on developing research skills rather than creating experts in a certain narrow field.

equips students with knowledge and skills that can be productively put to use with the employer. Assuming that wages correspond to the individual's marginal productivity, attending higher education today results in higher wages in the future, all else being equal.

Most studies examining the relationship between doctoral degrees and wages argue that doctoral education raises marginal productivity regardless of major. They thus implicitly argue doctoral education to be just another (higher) educational level that raises marginal productivity similarly to college level education. In contrast, I have shown that doctoral education differs from college level education in its curricular orientation and as such focuses on imparting research skills rather than major-specific (basic) knowledge.

Before, I argued that knowledge imparted by time-durable majors does not erode for a long time. Hence, an employer in need of the respective type of knowledge (e.g. communicative skills) does not need the employee to refresh her knowledge constantly to stay productive. Therefore, the employer has no need for research skills imparted by doctoral studies that enable the employee to renew her knowledge on her own. Thus, an employer in need of a time-durable major graduate will not remunerate a doctoral degree. In contrast, time-erodible majors impart less stable knowledge (e.g. technical skills). An employer who is interested in this type of knowledge could only put these skills into use productively for a short period of time unless he makes sure that this kind of human capital is constantly renewed.

To this aim, the employer's first option is to hire a new college level graduate as soon as the knowledge and skills of the current employee become obsolete. Assuming that teaching material in college is constantly renewed, the new graduate will be equipped with more current knowledge than the current employee. However, as turnover is costly, the employer might refrain from regularly laying off employees to replace them with newer ones.

A second option is to keep the employee and improve her knowledge by providing training. In this case, her knowledge corresponds the state of the art, just as if a new college graduate was hired. However, sponsoring training to keep employees up to date results in costs for the employer. Furthermore, a hold-up problem might occur if the employee threatens to leave the firm after training – taking the knowledge with her, and leaving the firm without a return on preceding educational investments. Hence, Becker (1962, p. 13) argues that the employee should fully sponsor the training so that both, costs and revenues fall on the same party. With her knowledge becoming obsolete over time, the employee would – without training – not find employment with any employer and therefore might be willing to fully bear the training costs herself. The employer would prefer this option to the first one (i.e. constantly laying off employees), as there would be no additional costs.

Another solution, which also enables the employer to keep training costs low and avoid turnover, is to hire individuals who are able to keep their knowledge up-to-date on their own. As elaborated above, doctoral graduates should be able to act accordingly as they learned to renew and develop knowledge during their doctoral studies. Moreover, employers might prefer their employees to be proactive and, hence, develop new knowledge themselves in order to exploit first-mover-advantages and create new products and services instead of simply using knowledge that was developed by others. Again, with doing research as a major part of doctoral studies, doctoral graduates are trained in developing new ideas. Hence, not only are research skills important for a business to stay up to date, they are also important in creating new business opportunities. Both aspects are vital for the employer who is aiming to maximise profit.

While they might not choose to lay off employees regularly in practise, employers interested in time-eroding human capital might prefer one of the latter two options: Either they employ college graduates and except them to bear the costs of future training themselves, or they hire doctoral graduates who are able to renew their knowledge on their own and further allow them to exploit first-mover-advantages and create new business opportunities[72]. Therefore, I argue that – at least to some employers – research skills are of particular interest.

Assuming that research skills obtained through doctoral studies increase the marginal productivity of time-erodible major graduates and further assuming that wages are paid according to one's marginal productivity, I expect individuals who attained doctoral studies on top of college level studies in time-erodible majors to receive higher wages than those without a doctoral degree.

H 2a: If a person holds a doctoral degree in a time-erodible major, she receives a higher wage.

Employers who are mainly interested in majors that impart time-durable human capital are interested in knowledge that is comparatively stable over time. Hence, there is less pressure for continuous research and less need for research skills. Consequently, while these employers might need people who possess this kind of knowledge, they may not be in need of research skills as these skills do not raise the graduate's marginal productivity with the employer. Therefore, I expect that research skills will not be additionally remunerated for these graduates.

H 2b: If a person holds a doctoral degree in a time-durable major she does not receive a higher wage.

[72] It is not clear, which one of these two options employers will prefer. This will depend on the wages of college and doctoral graduates and the additional value of business opportunities created by doctoral graduates.

4.4 Empirical evidence on the relationship between knowledge durability and doctoral wage premium

4.4.1 Sample

In order to investigate the effect of doctoral degrees on wages at entry level across major groups, I use data from the DZHW Graduate Panel of the examination cohort 2005 (Baillet et al. 2016) which was funded by the Federal Ministry of Education and Research (BMBF). This nationwide representative longitudinal survey sampled data on 11,789 students of state approved German universities and universities of applied sciences who graduated in 2005 for the first time.

I deliberately chose graduate data rather than labour surveys for two reasons: First, I want to isolate the knowledge function of the doctorate (the potential productivity enhancing effect of doctoral studies as argued in Section 4.3), which I believe to be already present at entry level. Later in professional life, I expect the door-opening function to top management positions to be another important reason for doctoral wage premiums. Thus, this door-opening effect might burr the knowledge effect if we measure the wage impact of doctoral degrees later in life.

Second, graduate datasets provide us with more homogeneous information as all individuals had been enrolled in academic education and then chose to enter the labour market or attend doctoral education at the same point in time. I am therefore able to better control for unobservable characteristics that might have led to the doctoral enrolment decision in the first place. More importantly, because graduate datasets enable me to control for educational characteristics in far more detail than labour surveys, they allow me to assign individuals to time-durable and time-erodible major groups.

4.4.1.1 Survey design and sample weights

The population investigated refers to all graduates who graduated from state approved German universities and universities of applied sciences between September 2004 and September 2005[73]. Among these, the implementing institution had to decide which graduates to survey (or more precisely, which educational institutions to contact so that these passed on the survey to their graduates). The aim was to arrive at a sample that reflects the population in the best way possible (Baillet et al. 2016, pp. 15–16). To this end, they applied a quoted stratified cluster sample design (Baillet et al. 2016, p. 15). As part of this sample design, the German academic landscape was divided into clusters, with a combination of the educational institution, major,

[73] Graduates of armed forces' universities, technical college for administration, vocational academies, and distance learning universities were not sampled (Baillet et al. 2016, p. 15). The academic year at universities started in October 2004 and ended in September 2005. At universities of applied sciences the academic year was from September 2004 until August 2005 (Baillet et al. 2016, p. 15).

and the type of degree defining the primary sampling units and the actual graduates within these clusters as secondary sample units (Baillet et al. 2016, p. 15).

The sampling procedure was conducted in two steps: First, in order to receive larger sample sizes from East-Germany, clusters from East-Germany were oversampled such that 30 percent of a total of 500 clusters from East-Germany and 18 percent of a total of 2,222 West-German clusters were identified (Baillet et al. 2016, p. 15). Afterwards, clusters from both regional strata (East- and West-Germany) were sampled in proportion to the population using state (Bundesland) as well as size and type of institution (i.e. university or university of applied sciences) as strata characteristics (Baillet et al. 2016, p. 15).

In a second step, 87 additional clusters were sampled using again a combination of the educational institution, major, and the type of degree as cluster characteristics (Baillet et al. 2016, p. 15). These clusters either replaced or complemented clusters drawn in the previous step in order to better align the sample distribution to the population distribution. If a cluster dropped out, e.g. due to non-participation of the faculty, an adequate replacement was identified (Baillet et al. 2016, pp. 15–16).

After educational institutions were classified, the DZHW contacted these institutions and asked them to invite the graduates of interest to take part in the survey (these gradates of interest were identified based on characteristics such as major, type of degree, and first degree obtained in 2005) (Baillet et al. 2016, p. 18). Due to data protection regulations, the educational institutions were not allowed to provide the DZHW with the student contacts but informed the organisation about the number of potential survey candidates (Baillet et al. 2016, p. 17). The DZHW then sent the respective number of pen and paper questionnaires to the educational institutions which, in turn, distributed these to the graduates (Baillet et al. 2016, p. 17). To contact the graduates in the second survey wave directly, individual addresses were collected within the first survey (Baillet et al. 2016, p. 17).

The graduates were surveyed twice: First, within one year after their graduation (between 1st January 2006 and 18th May 2007), and for a second time five to six years later (between 6th December 2010 and 20th September 2011)[74] (Baillet et al. 2016, p. 2). To enhance responses, the DZHW sent two remainder mails to the graduates (within four and eight weeks after the questionnaire started) (Baillet et al. 2016, p. 17). While during the first wave, these remainder were sent to all graduates, only outstanding responses were contacted in the second

[74] The cohort was surveyed for a third time in 2016. At the time of this analysis, the respective data was not yet available (Baillet et al. 2016, p. 2).

wave (as by then, the DZHW could directly address students and did not need the educational institutions as intermediaries) (Baillet et al. 2016, p. 18). Furthermore, all participants in the survey took part in a raffle which aim was to further enhance responses (Baillet et al. 2016, p. 18).

In total, the educational institutions identified 47,800 graduates as potential candidates who were all contacted (Baillet et al. 2016, p. 19). Out of these, 12,114 took part in the questionnaire but with 325 responses being either not part of the population of interest or not analysable, the final dataset arrives at 11,789 observation with over 90 percent (10,706 individuals) agreeing to be contacted again for further questioning in the second wave (Baillet et al. 2016, p. 19). Hence, the response rate in the first wave was 24.7 percent (Baillet et al. 2016, p. 2).

In the second wave, 6,459 out of the 10,706 who agreed to be contacted again (60.3 percent) took part in the follow-up survey (DZHW 2, 19–20). The response rate in the second wave is higher, because only those how agreed to be contacted again were surveyed (Baillet et al. 2016, p. 20). In the end, 13.5 percent of the originally contacted graduates answered in both surveys (Baillet et al. 2016, p. 21).

In order to control for potential biases due to sample design and non-response, I use sample probability weights provided in the dataset (Baillet et al. 2016, pp. 30–31). Using these weights is important because otherwise, results could be biased (Bell et al. 2012, p. 1399). On the one hand, the graduates in the sample are not sampled randomly. Instead, the organisation deliberately sampled certain groups of individuals disproportionally to increase observations of these subgroups that would otherwise have too few observations to allow for estimation of coefficients with reasonable preciseness (Baillet et al. 2016, p. 30; Bell et al. 2012, p. 1399; Cameron and Trivedi 2010, p. 111). On the other hand, the multistage sampling described above can lead to clustered observations where the variance among individuals within each cluster is smaller than the variance between individuals in the population, resulting in small standard errors that potentially increase type I errors (rejecting the null hypothesis although it is true) (Bell et al. 2012, pp. 1399–1400; Cameron and Trivedi 2010, p. 246). Additionally, nonresponse adjustments are important to adjust the sample to the population and thus to allow for unbiased estimates of population factors (Bell et al. 2012, p. 1399).

In the dataset at hand, two forms of weighting were combined to create probability weights for traditional students[75]: cross-section and longitudinal weighting. The former adjusts the sample distribution to the population distribution and adjusts for non-responses in the first wave. The latter adjusts for additional non-responses in the second wave (Baillet et al. 2016, pp. 31–32). Due to the sample design and conduction of the first wave, it was not possible to get exact cross-section design and non-response weights (Baillet et al. 2016, p. 30). Instead, they used information about the distribution of characteristics in the population obtained from the German federal statistical office to estimate non-response behaviour and perform non-response adjustments (Baillet et al. 2016, pp. 30–32). For the second wave, respective information was available so that weights could be determined (Baillet et al. 2016, p. 31).

To estimate the design weights, the number of clusters in a strata of the sample, n_{cs}, and the number of clusters in the respective strata of the population, N_{cs}, were used (Baillet et al. 2016, p. 31). If a cluster was sampled, than all individuals within the cluster were sampled. Hence, the estimated selection probability of an individual equals the estimated selection probability of its cluster, $\frac{n_{cs}}{N_{cs}}$ (Baillet et al. 2016, p. 31). The design weight for individual i, $\widehat{dw_i}$, is the reciprocal of the estimated selection probability,

$$\widehat{dw_i} = \left(\frac{n_{cs}}{N_{cs}}\right)^{-1}, \tag{23}$$

and tells us how many individuals in the population individual i represents (Baillet et al. 2016, p. 31; Cameron and Trivedi 2010, p. 111). The design weight was additionally calibrated to the characteristics of the population obtained from the statistical office (Baillet et al. 2016, pp. 31–32). This post-stratification process is important because even after adjusting the sample with selection probabilities, the sample might still not represent the population in important characteristics (Winship and Radbill 1994, p. 240). Using information from population survey such as census data is common practise in order to force the survey sample to fit the population in certain key characteristics (Winship and Radbill 1994, p. 240).

The design weights were further adjusted with non-response weights to take account for non-responses in the second wave (Baillet et al. 2016, p. 32). Various factors obtained during the first wave were used as regressors, $x_{t1,i}$, in a probit regression to estimate the probability of

[75] Traditional students are Diplom and Magister students, for example, and hence the group of graduates this chapter is interested in. New study programs are e.g. bachelor programs. Due to a different sampling approach for bachelor students, the dataset does not provide weights for this group of graduates (Baillet et al. 2016, p. 30).

participating in the second wave, $P(p_{t2,i}|x_{t1,i})$ (Baillet et al. 2016, p. 32). The non-response weight for the second wave, $nrw_{t2,i}$, equals its reciprocal (Baillet et al. 2016, p. 32),

$$nrw_{t2,i} = [P(p_{t2,i}|x_{t1,i})]^{-1}. \tag{24}$$

The probability weight, $w_{t1t2,i}$, used to adjust information of the first and second wave to the population is the product of the design weight in the first wave and the non-response weight of the second wave (Baillet et al. 2016, p. 32):

$$w_{t1t2,i} = \widehat{dw_1} * nrw_{t2,i}. \tag{25}$$

As with the design weight in the first wave, the probability weights were calibrated to fit the same characteristics of the population as before (Baillet et al. 2016, p. 33). Furthermore, the weights were standardised to the number of observations in the sample (Baillet et al. 2016, p. 33). In this relative weighting procedure, the sum of all weights equals the sample size, n (Bell et al. 2012, p. 1399),

$$\sum_{i=1}^{n} w_{t1t2,i} = n. \tag{26}$$

Given the probability weights, $w_{t1t2,i}$, one can now determine the weighted means and regression coefficients. The weighted mean of variable x is (Cameron and Trivedi 2010, p. 112):

$$\overline{x_w} = \frac{1}{\sum_{i=1}^{n} w_{t1t2,i}} \sum_{i=1}^{n} (w_{t1t2,i} * x_i) = \frac{1}{n} \sum_{i=1}^{n} (w_{t1t2,i} * x_i). \tag{27}$$

As under-sampled observations get larger weights than over-sampled ones, their values will be up-weighted in the weighted mean. If we would use naïve means (means without weights) instead, results would be biased (Cameron and Trivedi 2010, p. 112). Hence, using sample weights is important as otherwise findings can only be generalized to the sample but not the population (Bell et al. 2012, p. 1399).

The weighted estimator, $\widehat{\boldsymbol{\beta}_{\mathbf{W}}}$, for a weighted OLS regression of the dependent variable on the K independent variables is (Cameron and Trivedi 2010, 83, 113)

$$\widehat{\boldsymbol{\beta}_{\mathbf{W}}} = \left(\sum_{i=1}^{n} w_{t1t2,i}\mathbf{x}_i\mathbf{x}_i'\right)^{-1} \sum_{i=1}^{n} w_{t1t2,i}\mathbf{x}_i y_i = \tag{28}$$

$$\begin{bmatrix} \sum_{i=1}^{n} w_{t1t2,i}x_{1i}x_{1i} & \cdots & \sum_{i=1}^{n} w_{t1t2,i}x_{1i}x_{Ki} \\ \vdots & \ddots & \vdots \\ \sum_{i=1}^{n} w_{t1t2,i}x_{Ki}x_{1i} & \cdots & \sum_{i=1}^{n} w_{t1t2,i}x_{Ki}x_{Ki} \end{bmatrix}^{-1} \begin{bmatrix} \sum_{i=1}^{n} w_{t1t2,i}x_{1i}y_i \\ \vdots \\ \sum_{i=1}^{n} w_{t1t2,i}x_{Ki}y_i \end{bmatrix}.$$

Before, I argued that probability weights inform about how many other individuals the respective observation represents. However, instead of assuming that there are $w_{t1t2,i}$ equal individuals in the sample with equal error variances, one would multiplicate the error ε_i with the weight, such that the weighted error is $w_{t1t2,i}\varepsilon_i$ and the weighted error variance is ${w_{t1t2,i}}^2\varepsilon^2$ (Winship and Radbill 1994, p. 241). Furthermore, assuming that the unweighted error variance is homoscedastic with variance ε^2, the weighted error variance is heteroscedastic if $w_{t1t2,i} \neq w_{t1t2,j}$ (Winship and Radbill 1994, p. 241). Therefore, it is important to correctly calculate the weighted standard errors (Bell et al. 2012, p. 1399), e.g. by applying Taylor series linearization (Bell et al. 2012, p. 1400).

In what follows, all estimates are corrected for sample design and non-responses through probability weights provided by the DZHW (Baillet et al. 2016, p. 31). The respective standard errors are provided as Taylor linearized standard errors (Bell et al. 2012, p. 1400).

4.4.1.2 Sample restriction and introduction of major-related subsamples

From all the individuals sampled, I excluded Diplom graduates from universities of applied sciences (3,554 individuals) and bachelor graduates (1,622 individuals) as these are not immediately entitled to attain doctoral degrees. I also excluded graduates of studies with church, artistic, and other degrees (57 individuals) as out of these studies only a very small number attain doctoral degrees[76]. Further, following Grave and Goerlitz (2012, p. 286), I exclude graduates with “Staatsexamen” (state examination degrees[77]) from the sample

[76] Among graduates with artistic or other degrees, no doctoral degrees were attained. Out of gradates with church degrees 8.11 percent attain doctoral degrees. However, theses degrees are designed for a specific part of the labour market (jobs in churches). Furthermore, these 8.11 percent equal three individuals in the dataset hence I decided to drop these.

[77] In Germany, majors that typically award such degrees are “medicine, density, veterinary medicine, law, pharmacy, food chemistry, some teacher training programs” (Higher Education Compass 2016).

(2,204 individuals). I expect majors that award these degrees such as medicine and teaching (Higher Education Compass 2016) to be designed for certain specific occupations. For these graduates, a doctoral degree is either not relevant (e.g. in teaching) or standard (e.g. in medicine) for pursuing these occupations. The reason, however, is not due to the fact that respective employers need or do not need research skill but because it is the standard degree to pursue such professions. Furthermore, in contrast to Diplom and Magister graduates, state examination graduates have to attain traineeships after their first state examination which are still part of their studies[78]. Hence, I do not expect Staatsexamen and Diplom/Magister graduates to be comparable with regard to their point of labour market entrance.

Following Braakmann (2013, p. 133), I further drop individuals who report very low monthly wages (below 1,000 €) as well as those with wages above 15,000 €. By doing so, I exclude individuals that may be engaged in mere casual work (often used to bridge the time gap between two successive jobs) and remove eleven very large outliers. As I am interested in wages five to six years after Diplom/Magister graduation, I survey university graduates who responded regarding their wages in the second wave.

In line with the argument developed above and based on McDowell (1982) concept of varying knowledge durability across research fields, I form two groups of majors: majors of time-durable human capital (time-durable majors) and majors of time-erodible human capital (time-erodible majors). I assign majors in arts, humanities, theology, linguistics, as well as cultural, educational, and social sciences to the group of time-durable majors, while I group mathematics, engineering, natural sciences, sports and health sciences, as well as agriculture and nutritional sciences among time-erodible sciences[79]. Furthermore, I categorise majors in business administration, economics, and economic law and administrative sciences as mixed majors with regard to the durability of their imparted human capital. This categorisation is similar to the broad major groups in Walker and Zhu (2011) who in contrast to this study did not give any reason for their grouping except "for reasons of sample size" (Walker and Zhu 2011, p. 4). To test the hypotheses of this article, I exclude mixed major graduates from the sample. Due to missing values, the final sample arrives at 1,540 observations (697 graduates in time-durable and 843 graduates in time-erodible majors). Table 10 provides information on the assignment of majors to major groups.

[78] "[B]efore finishing the traineeship they will not obtain the final degree" (Grave and Goerlitz 2012, p. 286).
[79] Alternative major groups are discussed in the robustness section (Section 4.4.6).

Table 10: Assignment of majors to major groups

Time-durable majors	Time-erodible majors
Arts, educational sciences, humanities, linguistics and cultural sciences, social sciences, theology	Agriculture and nutritional sciences, engineering, mathematics, natural sciences, sports and health sciences

In the following, I will describe the major categorisation approach in detail. As stated before, I base my categorisation on McDowell (1982) who showed that research fields vary in their knowledge decay rate. I depart from McDowell's (1982) terminology of knowledge decay or knowledge durability as the author does not introduce distinct major groups but arranges seven research fields according to their decay rate on a continuous index. One might argue that separating a continuum into discrete categories in ambiguous or driven by subjective preferences. Moreover, as McDowell (1982) investigated only seven majors but I aim to categorise eleven broad majors, I use similarities in argumentations with alternative major categorisations to assign further majors to the groups of time-durable and time-erodible majors[80] beyond the seven fields introduced in McDowell (1982).

A major categorisation that is commonly used within as well as outside academia is to distinguish between traditional male and female majors (e.g. England et al. (2007), Morgan and Carney (1985)). Here, majors are grouped according to their majority gender: traditional male majors are STEM-majors and business whereas traditional female majors are languages, humanities, arts, and social sciences (Morgan and Carney 1985, p. 28).

According to economic literature, women choose these majors due to their knowledge durability and the accompanying lower risk of knowledge decay during future career breaks (e.g. due to child rearing) (Ochsenfeld 2014, p. 4; Polachek 1978, p. 500). This is in line with McDowell (1982, p. 755) arguing that individuals who expect career interruptions should invest in time-durable knowledge. Hence, I expect traditional female majors to impart time-durable knowledge.

Men, however, do not anticipate career breaks and thus are willing to invest in decay-risky majors that are better paid (Ochsenfeld 2014, p. 4). Hence, I expect traditional male

[80] In Chapter 5, we will also assign majors to the group of mixed majors.

majors to impart time-erodible human capital were ongoing research is necessary to keep knowledge up to date (McDowell 1982)[81].

Furthermore, the two-dimensional gender-based categorisation assigns business administration, economics, and law to traditional male majors (Morgan and Carney 1985, p. 28). In Chapter 5, these majors form a separate major category (mixed majors), similar to the category of economic skills[82] as in Kalmijn and Lippe (1997), Mertens and Röbken (2013)[83], and Werfhorst (2002). Gender roles theory explains this assignment to traditional male fields: men choose majors that open routes into well-paid leadership positions (economic skills) to support their families as the main breadwinner. In this study, however, I will not include business, economics, and law in the group of time-erodible majors, as this assignment to male majors is not based on the idea of knowledge durability[84].

4.4.2 Central variables: Employee wage and doctoral degree

I operationalise the dependent variable *(ln) wage* with the natural logarithm of one's gross monthly total income reported five to six years after graduation (i.e. the second wave of the survey). It includes additional compensation components such as variable payments or a 13th or 14th month of pay. I use information on income at the second survey wave as those who started acquiring a doctoral degree after graduation should have completed it and started working outside university by then[85]. Those who decided against acquiring a doctoral degree have already five years of work experience. I use the ln-transform of the income to control for the right-skewed distribution of the data. Doing so reduces potential heteroscedasticity in the residuals and is common practice in wage estimation since Mincer (1974).

The independent variable of interest is the dummy variable *doctoral degree*. The variable indicates whether an individual has completed her doctoral studies prior to the second

[81] There is also a sociological explanation for why certain majors are dominated by women while others by men: According to this stream of literature, women choose majors that fit their preferences for caring for and communicating with others (Daymont and Anderisani 1984, p. 415) which is largely independent of potential returns on investment. Men, however, prefer, are more interested in, or are socially directed towards, fields that emphasise mathematical skills (Ochsenfeld 2014b, p. 5). With regard to economic skills, it is argued that they prefer majors that promise high incomes (Ochsenfeld 2014b, p. 5).

[82] Defined as programs where "people learn about the functioning and management of business, organizations, and trade" (Kalmijn and Lippe 1997, p. 5).

[83] According to Mertens and Röbken (2013, p. 222), also social sciences provide economic skills to at least some degree.

[84] Moreover, although economics and law traditionally might have been male majors (with regard to gender majority), they are more gender-neutral majors today (and have been for quite some time), while STEM majors are still predominantly chosen by men (Blau and Kahn 2017, p. 813).

[85] As mentioned in Section 2.3, objective data regarding durations of doctoral studies are hard to come by in Germany, but surveys point to an average study duration of 3.9 years (Konsortium Bundesbericht Wissenschaftlicher Nachwuchs 2017: 153).

survey wave (which is five to six years after graduation)[86]. Across all majors 17.82 percent of the individuals in the sample hold a doctoral degree within five to six years after (first) graduation from university.

4.4.3 Control variables

As suggested by the literature, there are several factors that affect wages. I group these into individual, educational, and occupational characteristics.

4.4.3.1 Individual characteristics

Given the vast literature on gender wage differences, I expect higher wages for men compared to women, even after controlling for educational and occupational characteristics as well as other individual factors. There are several reasons for this phenomenon: for example, based on taste-based discrimination, we would expect some employers to prefer to work with men, only. Women would then be forced into a labour market that hires women as well as men, resulting in lower wages due to larger labour supply in these markets. To test for gender differences in wages, I introduce the variable *female*, which is 1 if the individual is a woman and 0 otherwise. Within the dataset, 49.56 percent are women.

Following Braakmann (2013), Grave and Goerlitz (2012), and Heineck and Matthes (2012), I control for *marital status*. Like Braakmann (2013), I distinguish between individuals without partners, ones with permanent partners, and those who are married. Within the sample, 19.74 percent were without a partner at the time of the second wave, 40.77 percent were in a steady partnership, and 39.49 percent were married. Steady partnerships and especially marriages allow couples to specialise in the labour market or household work (Becker 1985) or at least to share household responsibilities. Doing so results in higher wages for a married person compared to those who are single as household work is more energy consuming than leisure and therefore more energy is left to productively engage in the labour market (Becker 1985). Hence, I assume that married individuals or individuals in steady relationships will gain higher wages compared to those who are single.

Child rearing is one form of household activity. If a person takes responsibility for child rearing he or she will have less energy left for engagement in the labour market (Becker 1985). Hence, I expect having children to have a negative effect on wages, all else being equal. I use a dummy variable, which is 1 if the individual has *at least one child* at the time of the second wave and 0 otherwise. By doing so I follow Braakmann (2013), Grave and Goerlitz (2012), and

[86] Individuals who are still in the process of gaining their doctoral degree at the time of the second wave are included in the group of those who do not hold a doctoral degree.

Reimer and Schröder (2006). Within the sample, 29.40 percent have at least one child five to six years after graduation.

Particularly in jobs for academics, wages might be more open for negotiation, because specific occupations are less comparable to other occupations and therefore fit less easily into a certain job category. Furthermore, academics' wages are usually less often restricted by collective agreements. Hence, I argue that individuals who are better able to negotiate will gain higher wages. Unfortunately, there is no item in the survey that allows to assess someone's negotiation skills. I therefore use one's self-assessment on whether the person is *adequately employed regarding her academic qualifications.* I reason that those who negotiate more effectively will more likely be in jobs that suit their academic qualifications and are better remunerated, eventually. I create an indicator variable that is 1 if someone believes to be adequately employed and 0 otherwise[87]. Within the sample, 84.76 percent believe to be adequately employed.

4.4.3.2 Educational characteristics

In line with Braakmann (2013), Grave and Goerlitz (2012), and Reimer and Schröder (2006), I control for the person's *grade of university degree*. Doing so enables me to control for an individual's ability. This is important as it as it makes it possible to further isolate the effect of doctoral degrees on wages. Otherwise, the doctoral degree coefficient might contain both the valuation of research skills by the labour market and the ability of doctoral studies to attract the more productive individuals. Assuming that only the best students attend doctoral studies, controlling for ability allows us to control for self-selection into doctoral programmes which Montgomery and Powell (2003, p. 401) draws attention to.

In Germany, grades range from 1.0 (best grade) to 4.0 (worst but still passing grade). Following Braakmann (2013, p. 133), I use three categories regarding the university grade[88]: "very good" if the individual has a final grade of 1.5 or better, "good" if the final grade is worse than 1.5 but better than or equal to 2.5, and "satisfying or sufficient" if the final grade is worse than 2.5 but equal or better than 4.0. Within the sample, 44.24 percent finished their university degree with "very good" grades, 49.15 percent achieved "good" final marks and 6.62 percent obtained "satisfying of sufficient" results.

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[87] In the survey, employment adequacy is measured on a 5-point-scale (1: "very much", 5: "not at all") (DZHW 2005). I grouped 1, 2 and 3 as qualification adequately employed and 4 and 5 as not adequately employed.

[88] While Grave and Goerlitz (2012, p. 286) and Reimer and Schröder (2006, p. 240) measure one's final university grade by continuous variables, I prefer a categorical measure as Braakmann (2013) did before. Using categorical variables reflects the ordinal scale of the data better than does a continuous variable.

I also control for the individual's *university major*. I assign the different majors registered in the dataset to one of eleven majors (proportions of students in the sample in parentheses, categorisation follows in large parts Destatis (2016b, pp. 454–456)): arts (7.78 percent), humanities (3.94 percent), theology (1.30 percent), linguistics and cultural sciences (11.22 percent), educational sciences (6.88 percent) and social sciences (17.08 percent), agricultural and nutritional sciences (2.92 percent), mathematics (2.70 percent), natural sciences (15.68 percent), engineering (27.48 percent), sports and health sciences (3.00 percent).

4.4.3.3 Occupational characteristics

Within the group of occupational characteristics, I control for several aspects of job related factors that may influence one's wage.

Following Becker (1962), I assume higher levels of on-the-job training to result in higher wages. In line with Braakmann (2013) and Grave and Goerlitz (2012), I use one's *work experience* (in months) as a proxy for accumulated on-the-job training. Beside employment and self-employment, I believe service contracts, casual work, and internships to reflect employment relationships where work experience is accumulated. Within the sample, individuals have on average 60.17 months (roughly five years) of work experience five to six years after the first questionnaire.

As I measure wages on a monthly basis, I also need to control for *working hours*. I therefore use the individual's average weekly working hours spent in her main occupation and possible secondary employments. The sampled individuals work on average 43.06 hours per week in their main and potential secondary occupation.

Different types of employment relationships might also account for differences in wages. On the one hand, individuals who are employed on a fixed-term contract possess on average less specific knowledge and often hold occupations with lower levels of responsibility. Hence, I expect lower wages with fixed-term contracts compared to unrestricted contracts. On the other hand, based on compensating wage theory, one might expect higher wages for fixed-term contracts because employees are risk-averse and need to be compensated for bearing the risk of unemployment after the end of the contract (Pfeifer 2012, p. 172). Following Grave and Goerlitz (2012), Heineck and Matthes (2012), and Reimer and Schröder (2006), I control for the individual's *form of employment*, i.e. whether someone is self-employed or whether she is employed on an unrestricted contract or fixed-term contract (including apprenticeship and service contract). Since the survey does not ask directly about the person's current or last form of employment, I use the information given about one's occupations since 2006. If the individual only has one current (or possibly last) job, I use this as the person's form of employment. Individuals may however have multiple jobs at the same time. Hence, if she has more than one current (or last) job, I use the form of employment of the main job, which I define as the position with the most working hours. Furthermore, if there are more potential main jobs (with an equal number of working hours but different forms of employment), I use the form of employment of the occupation with the longest tenure. However, if there are more potential main jobs with equal tenures but different forms of employment, I set the form of employment to missing, as one cannot tell which one the main job is[89]. Doing so resulted in two changes to missing values. Within the sample, the majority are employed in a permanent employment relationship (58.78 percent). 33.04 percent are employed on fixed-term contracts and 8.18 percent are self-employed.

I further control whether someone is employed in the *public sector* or whether her wage is adjusted to the remuneration in the public sector. In line with Melly (2005, p. 506), I assume that wages in the public sector are more compressed compared to the private sector: while at the lower wage level, the public sector should serve as a role model with regard to paying fair wages[90] (resulting in comparatively higher wages), the general public tends to disapprove of high management salaries which are comparable to the private sector (resulting in comparatively lower wages for the public sector). As I investigate wages of the highly-qualified who predominately occupy jobs in management positions, I expect lower wages for employees in the public sector compared to their counterparts in the private sector. I, therefore, use a dummy variable that is 1 if someone is working in the public sector or paid accordingly, and 0 otherwise. 37.52 percent of the wages in the sample are paid by or according to public sector terms.

Moreover, I expect larger firms to pay higher wages (Idson and Oi 1999, p. 104) as they can pay efficiency wages (i.e. wages above the market clearing wage (Akerlof 1984, p. 79)) in order to attract the most talented people (Anker 1997, pp. 334–335). I therefore use a dummy variable that indicates whether someone works in a subsidiary that is part of a corporate structure. The variable is 1 if the individual is employed in such a *large-scale company* and 0 otherwise[91]. To operationalise this information, I use a survey question that asks whether

[89] Consequently, I would not be able to match their form of employment properly to their other answers regarding their occupational characteristics. See Grave and Goerlitz (2012, p. 286) for similar considerations.

[90] On a similar note, Arulampalam et al. (2007, p. 167) argue that it is easier for the government to enforce equal opportunity regulations in the public than in the private sector.

[91] Individuals who are employed in the public sector are not working in a large-scale company (DZHW 2005).

someone is working for a department that is part of a larger company (DZHW 2005, p. 8)[92]. Among the sampled individuals, 30.22 percent are employed in large-scale companies.

I also control for the *industry* someone is working in. Following Grave and Goerlitz (2012, p. 287), I distinguish between (i) predominantly primary[93] and manufacturing[94] sector industries, (ii) public sector industries[95], and (iii) services. Due to its predominantly socio-cultural responsibilities, I expect public sector industries to be less profit-oriented and, therefore, paying lower wages compared to services and the primary and manufacturing sector. Furthermore, I expect occupations in manufacturing to be better remunerated than jobs in the service sector, as the former is known to require larger shares of specific human capital than the latter. According to Ochsenfeld (2014, p. 4), specific human capital is better remunerated than general human capital. Within the sample, 15.58 percent of the individuals are engaged in the primary or manufacturing sector, 39.75 percent work in public sector industries, and 44.67 percent work in the service sector.

I also control for the person's *job location*. Most individuals were working in Germany when surveyed in the second wave. Hence, I distinguish only between East-Germany, West-Germany, and abroad (European and non-European countries) but do not distinguish between foreign countries any further. As with the individual's form of employment, I am interested in the location of her current (or possibly last) job. Again, if an individual only has one current (or last) job, I will use the location of this job. If there are more current (or last) jobs in different regions, I will use the location of the main job, which, again, is the job with the longest tenure. If there are, however, more potential main jobs with equal tenure but in different regions, I set job location to missing as I cannot identify the location of the person's main job. However, doing so does not resulted in changes to missing values. Within the sample 20.20 percent work in East-Germany, 73.18 percent in West-Germany, and 6.62 percent work outside of Germany.

4.4.4 **Descriptive statistics**

Table 11 presents the descriptive statistics of the variables discussed above separately for time-durable and time-erodible majors. Differences between both groups are reported.

[92] The original question is: „Arbeit Sie in einem Betrieb, der Teil eines größeren Unternehmens ist?“ (DZHW 2005, p. 8).

[93] Agriculture, fishing, mining, energy, and water management

[94] Manufacturing, industry, and construction

[95] Public administrations and non-for-profit organisations as well as industries in the field of education, research, and culture.

Table 11: Descriptive statistics and t-test for differences between major groups

	Time-durable majors[a]		Time-erodible majors[a]		Differences[b]	
	Mean	Std. dev.	Mean	Std. dev.		
Wage	2948.196	(1327.322)	3953.251	(1515.042)	-1005.055***	(85.742)
(ln) wage	7.901	(0.421)	8.208	(0.399)	-0.307***	(0.025)
Doctoral degree	0.075	(0.264)	0.274	(0.446)	-0.199***	(0.023)
Female	0.682	(0.466)	0.322	(0.467)	0.361***	(0.028)
Marital status						
Without partner	0.204	(0.403)	0.191	(0.393)	0.013	(0.024)
With partner	0.402	(0.491)	0.413	(0.493)	-0.012	(0.030)
Married	0.394	(0.489)	0.396	(0.489)	-0.001	(0.030)
At least one child	0.304	(0.460)	0.284	(0.451)	0.020	(0.027)
Qualification adequate employment	0.786	(0.410)	0.905	(0.293)	-0.119***	(0.024)
Final college grade						
Very good	0.462	(0.499)	0.424	(0.494)	0.038	(0.030)
Good	0.476	(0.500)	0.506	(0.500)	-0.030	(0.031)
Satisfying or sufficient	0.062	(0.242)	0.070	(0.255)	-0.008	(0.015)
College major						
Arts	0.161	(0.368)				
Humanities	0.082	(0.274)				
Theology	0.027	(0.162)				
Linguistics and cultural sciences	0.233	(0.423)				
Education sciences	0.143	(0.350)				
Social sciences	0.354	(0.479)				
Sports and health sciences			0.058	(0.234)		
Agriculture and nutrition			0.056	(0.231)		
Mathematics			0.052	(0.223)		
Natural sciences			0.303	(0.460)		
Engineering			0.531	(0.499)		
Total work experience in months	57.583	(13.391)	62.586	(11.065)	-5.003***	(0.759)
Total working hours per week	41.555	(10.378)	44.460	(8.145)	-2.905***	(0.587)

(continued)

Table 11 *(continued)*

	Time-durable majors[a]		Time-erodible majors[a]		Differences[b]	
	Mean	Std. dev.	Mean	Std. dev.		
Form of employment						
Unrestricted contract	0.553	(0.498)	0.620	(0.486)	-0.067**	(0.030)
Fixed-term contract	0.329	(0.470)	0.331	(0.471)	-0.002	(0.029)
Self-employed	0.118	(0.322)	0.049	(0.215)	0.069***	(0.019)
Public sector	0.424	(0.495)	0.330	(0.470)	0.094***	(0.029)
Working in large-scale enterprise	0.243	(0.429)	0.358	(0.480)	-0.115***	(0.028)
Industry						
Primary or manufacturing sector	0.043	(0.203)	0.261	(0.439)	-0.217***	(0.018)
Public sector industry	0.463	(0.499)	0.337	(0.473)	0.126***	(0.030)
Services	0.494	(0.500)	0.403	(0.491)	0.091***	(0.031)
Job location						
East-Germany	0.225	(0.418)	0.181	(0.385)	0.044*	(0.023)
West-Germany	0.735	(0.442)	0.729	(0.445)	0.007	(0.026)
Abroad	0.040	(0.197)	0.091	(0.287)	-0.050***	(0.014)
Observations	697		843		1540	

[a] Means with standard deviations in parentheses

[b] * p<0.10, ** p<0.05, *** p<0.01; linearized standard errors in parentheses

Source: Own calculations based on DZHW Graduate Panel (2005).

According to Table 11, the average wage of graduates from the time-erodible majors group is significantly higher than the average wage of graduates from time-durable majors. A simple t-test confirms a significant wage gap of 1005.06 € between the average wages of both groups. This is in line with the literature arguing that time-erodible majors are better remunerated in general (irrespective of doctoral degrees) (e.g. Ochsenfeld (2014)). Section 4.4.5.1 additionally provides a descriptive analysis of the wage differences between doctorate holders and non-holder in both major groups.

The two major groups also differ with regard to individual, educational, and occupational factors. Frist, the female share is significantly higher in time-durable majors than in time-erodible majors. This is in line with the idea of traditional male and female majors.

Second, the doctoral degree rate is significantly higher in time-erodible majors, with 27.42 percent of the graduates attaining a doctoral degree within five to six years after graduation, whereas in time-durable majors it is just 7.50 percent. This gives a first hint to my expectation that doctoral degrees are more important in time-erodible majors. Although time-erodible graduates pursue more doctoral degrees, their college level grades do not differ (on average): there is no evidence indicating that time-erodible graduates gain more "good" or "very good" grades. This contradicts the probable suspicion that the "better" students self-select into time-erodible studies and hence are better remunerated than time-durable graduates.

Third, there are various differences in occupational characteristics across majors. Surprisingly, time-erodible major graduates gained more work experience than time-durable major graduates. Given that, on average, they attain more doctoral degrees, and as this time is not registered as work experience, one might expect their total sum of work experience to be lower than those of time-durable major graduates. It seems that the perceived difficulty of time-durable major graduates to find jobs is true[96]. However, although the difference is significant, it is rather small (five months). The smaller market demand for (or higher supply of) time-durable major graduates might also explain their lower rate of unrestricted and qualification adequate employments: without labour supply shortage among time-durable major graduates, employers would not feel the need to attract and retain employees as employers of time-erodible major graduates might. Due to fewer job offers, time-durable major graduates might be willing to accept less satisfactory occupations. Furthermore, the possibly lower market demand for time-durable major graduates might also explain their higher rate of self-employment: If they

[96] An analysis of German job advertisements in 2017 showed that only a small fraction explicitly looked for liberal arts graduates while the largest part looked for engineering graduates (Adecco 2017).

do not find adequate employment, these graduates might prefer self-employment as an occupational alternative. Additionally, time-durable graduates work fewer hours than time-erodible graduates. In line with the gender-major literature one might reason that – as (i) more women attain these majors and (ii) women often shoulder the responsibility for family work – these graduates on average might more often choose to work part-time. Again, the difference is not excessively large (roughly 3 hours per week). As expected given their major-specific knowledge, time-durable graduates more often work in service and public sector industries than time-erodible graduates who are more likely to work in the primary and manufacturing sector as well as in larger firms. Also, the proportion of time-durable graduates who work in East-Germany is larger than the respective proportion among time-erodible majors, whereas the proportion of those working abroad is larger for the latter group.

4.4.5 Empirical analysis

Based on these descriptive findings, one can conclude that time-durable and time-erodible major graduates differ in their characteristics. In particular, they differ with regard to labour market characteristics. As shown in Table 11, almost none of the occupational factors are equal between the two major groups, supporting Klein's (2016) and Leuze and Strauß' (2009) idea of separated labour markets. In what follows, I therefore refrain from pooling both major groups into a common sample and running a single equation regression (with interaction of doctoral degree and major group). Instead, I run linear regressions separately for time-erodible and time-durable majors, after giving some illustrative evidence.

4.4.5.1 Descriptive analysis

Table 12 depicts the doctoral wage premiums in both time-erodible and time-durable major groups. Among time-durable major graduates, those without a doctoral degree earn 2,947.80 € per month, while those who gained a doctorate do not earn significantly more (2,953.04 €). Among the time-erodible major graduates, however, those who did not gain a doctoral degree get 3,889.41 € per month, while those who acquired a doctorate significantly increases their wages by 232.83 € per month to 4,122.24 €.

Thus, while the doctoral wage premium (i.e. the difference between wages with and without doctoral degrees) is insignificant for time-durable major graduates, it is significant and positive for time-erodible major graduates. This serves as a first support for the hypotheses developed in Section 4.3. In what follows, I will investigate the effect of doctoral degrees in more detail.

Table 12: Differences in doctoral wage premiums between major groups

	Time-durable majors	Time-erodible majors
Wage without doctoral degree[a]	2947.80 (1306.48)	3889.41 (1682.91)
Wage with doctoral degree[a]	2953.04 (1269.21)	4122.24 (1290.51)
Doctoral wage premium[b]	5.24 (215.41)	232.83* (130.49)

[a] Means with standard deviations in parentheses
[b] * p<0.10, ** p<0.05, *** p<0.01; results based on t-test on wages between people with and without doctoral degree. Linearized standard errors in parentheses.
Source: Own calculations based on DZHW Graduate Panel (2005).

4.4.5.2 Multiple regression analysis

In this section, I present empirical evidence on the hypotheses theoretically derived in Section 4.3. I argue that doctoral degrees enhance entry-level wages for graduates of time-erodible majors (H 2a) but do not increase wages of time-durable major graduates (H 2b). I will use OLS regressions to test for the effect of doctoral degree on the logarithmic monthly wage for both major groups controlling for different individual, educational, and occupational factors.

By using the logarithmic version of dependent variable wage, w,

$$\ln \mathrm{w} = \beta_0 + \beta \mathrm{x}, \tag{29}$$

I assume that the true relationship between wage and an independent variable, x, is exponential:

$$\mathrm{w} = \mathrm{e}^{\beta_0 + \beta \mathrm{x}}. \tag{30}$$

With regard to effect sizes in such log-linear models, we are interested in the percentage change in w if factor x is increased by one unit, $\mathrm{x}' = \mathrm{x} + 1$, all else being equal. Thus, with

$$\mathrm{w}' = \mathrm{e}^{\beta_0 + \beta(\mathrm{x}+1)}, \tag{31}$$

the effect size in percent is

$$\frac{\mathrm{w}' - \mathrm{w}}{\mathrm{w}} * 100 = \left(\frac{\mathrm{w}'}{\mathrm{w}} - 1\right) * 100 = \left(\frac{\mathrm{e}^{\beta_0 + \beta(\mathrm{x}+1)}}{\mathrm{e}^{\beta_0 + \beta \mathrm{x}}} - 1\right) * 100 = \left(\mathrm{e}^{\beta_0 + \beta(\mathrm{x}+1) - \beta_0 - \beta \mathrm{x}} - 1\right) * 100 = \left(\mathrm{e}^{\beta} - 1\right) * 100. \tag{32}$$

The regression model in this section is

$$\ln \mathrm{w_i} = \beta_0 + \beta_{\mathrm{Ph.D.}} * \mathrm{Ph.D._i} + \sum_{\mathrm{k}=2}^{\mathrm{K}} \mathrm{X_{k_i}} \beta_{\mathrm{k}} + \varepsilon_{\mathrm{i}}, \tag{33}$$

with w as the monthly wage, the dummy variable Ph.D. indicating whether someone holds a doctoral degree, the $(\mathrm{K} - 1)$ control variables specified before, and $\beta_{\mathrm{Ph.D.}}$, β_{k} as the weighted coefficients. The variable ε indicated the error term. Thus, the percentage change in wages due to attaining a doctoral degree is

$$\left(\frac{e^{\left(\beta_0+\beta_{Ph.D.}+\Sigma_{k=1}^{K} x_{k_i}\beta_k+\varepsilon_i\right)}}{e^{\left(\beta_0+\Sigma_{k=1}^{K} x_{k_i}\beta_k+\varepsilon_i\right)}}-1\right)*100=\left(e^{\beta_{Ph.D.}}-1\right)*100. \quad (34)$$

Table 13 shows the regression results. All coefficients are interpret in percentage changes in the text.

Table 13: Separate wage regressions for major groups

	Time-durable majors		Time-erodible majors	
Doctoral degree	-0.019	(0.049)	0.121***	(0.029)
Female	-0.042	(0.034)	-0.101***	(0.026)
Marital status				
Without partner	Ref. cat.		Ref. cat.	
With partner	0.025	(0.041)	0.058*	(0.031)
Married	0.033	(0.052)	0.096***	(0.034)
At least one child	-0.035	(0.038)	-0.033	(0.028)
Qualification adequate employment	0.269***	(0.031)	0.106**	(0.052)
Final college grade				
Satisfying or sufficient	Ref. cat.		Ref. cat.	
Very good	0.108**	(0.045)	0.176***	(0.060)
Good	0.111**	(0.045)	0.090	(0.056)
College major				
Arts	Ref. cat.			
Humanities	0.080	(0.060)		
Theology	0.209**	(0.093)		
Linguistics & cultural sciences	0.148***	(0.050)		
Education sciences	0.077	(0.048)		
Social sciences	0.188***	(0.048)		
Mathematics			Ref. cat.	
Sports & Health sciences			-0.285***	(0.088)
Agriculture & nutrition			-0.212***	(0.064)
Natural sciences			-0.238***	(0.050)
Engineering			-0.102**	(0.045)
Total work experience in months	0.003***	(0.001)	0.005***	(0.001)
Total working hours per week	0.015***	(0.001)	0.009***	(0.002)
Form of employment				
Fixed-term contract	Ref. cat.		Ref. cat.	
Unrestricted contract	0.129***	(0.030)	0.233***	(0.037)
Self-employed	-0.064	(0.074)	0.099	(0.080)
Public sector	0.045	(0.038)	-0.015	(0.042)
Working in large-scale enterprise	0.047	(0.039)	0.122***	(0.031)
Industry				
Services	Ref. cat.		Ref. cat.	
Primary or manufacturing sector	0.118*	(0.064)	0.100***	(0.028)
Public sector industry	-0.112***	(0.033)	-0.014	(0.047)
Job location				
East-Germany	Ref. cat.		Ref. cat.	
West-Germany	0.147***	(0.036)	0.138***	(0.029)
Abroad	0.197**	(0.084)	0.165***	(0.047)
Constant	6.511***	(0.109)	7.052***	(0.135)
R^2	0.420		0.454	
Observations	697		843	

* p<0.10, ** p<0.05, *** p<0.01; linearized standard errors in parentheses.
Own calculations based on DZHW Graduate Panel (2005).

Both major groups show the expected effect. Gaining a doctoral degree does not significantly increase wages for time-durable major graduates five to six years after college graduation. For time-erodible major graduates, however, wages are significantly higher for those who gained a doctorate. In fact, holding a doctoral degree results a wage premium of 12.86 percent for time-erodible major graduates. The results support my hypotheses derived above as well as the underlying argumentation that – while time-erodible doctoral graduates can put their research skills productivity to use with employers – this is not the case for their time-durable counterparts. With time-durable human capital not decaying over time, employers do not need their employees to constantly renew their knowledge. Thus, they feel no need to remunerate research skill, which I argue to enable graduates to renew and create new knowledge on their own. Given the results in other studies that used separated subsamples to estimate the effect of doctoral degrees on wages (e.g. Heineck and Matthes (2012), Mertens and Röbken (2013)), the effect size found in this article seems plausible.

With regard to the control variables in both subsamples, all significant effects show the expected sign. However, some coefficients are not significant. As one can see from the time-durable subsample, none of the individual characteristics except for one's negotiation affinity is significant (although the signs of coefficients are as expected). A possible explanation is that, as these majors are predominantly chosen by women (see Table 11), their employers might not be negative towards or sceptical of women because women form the majority of their workforce. Hence, they might not discriminate against them (i.e. pay lower wages compared to men). Further, as they employ many women, there is the chance that these employers enable favourable work-life-balance, either by offering childcare or flexible work arrangements so that having children does not force parents to reduce their professional commitment and makes division of household responsibilities less important. Within the subsample of time-erodible major graduates, all individual characteristics except for having children show the expected significant effects.

Among the occupational characteristics, working in the public sector does not show the expected effect either (in both subsamples). One might argue that – as I observe wages temporally close to the time of labour market entry – the sampled individuals are still in positions that are not regarded as (top) management positions and, thus, not negatively affected by wage compression.

Furthermore, the subsamples differ with regard to the expected effects of working in a large-scale enterprise or in the public sector industry. While working in a large-scale enterprise has a positive and significant effect on wages in the time-erodible subsample, the effect is not significant in the time-durable subsample. A possible explanation is that labour demand for time-durable graduates is lower than for time-erodible graduates (Klein 2016, p. 46). Thus, in the time-durable subsample, employers do not need to compete with other employers for talents and, hence, do not need to pay efficiency wages to attract and retain the more productive ones. Hence, wages paid by large-scale firms, which are argued to pay efficiency wages more likely than small firms (Schmidt and Zimmermann 1991, p. 706), are not higher than those paid by smaller firms in the subsample of time-durable majors. With regard to time-erodible graduates however, demand increases (Klein 2016, p. 46), forcing employers to compete for talents which results in large firms paying efficiency wages.

Working in the public sector industry does not affect wages in the subsample of time-erodible major graduates, while it reduces wages of individuals in the time-durable major group. Although I expect such firms to be less profit driven and, hence, to offer lower wages, those who employ time-erodible major graduates might still feel the need to offer wages as high as in the service industry to attract employees. Otherwise, time-erodible major graduates will work for other employers who pay higher wages because there is a shortage of these graduates. Without labour market shortage as in the subsample of time-durable graduates, however, employers in public sector industries might not feel the need to compete with other sectors for employees and thus pay lower wages.

Among the educational characteristics, only the subsample of time-erodible majors does not show the expected effect with regard to good college grades. This is rather surprising. It seems that only very good marks are rewarded by the labour market, while for the time-durable major graduates good grades are rewarded, too. I argue that – in line with the argument of this chapter – employers are confident that graduates with very good grades are able to do at least some knowledge-renewing on their own and will therefore reward these skills.

4.4.6 Robustness of results

In this robustness section, I will provide various setups to support the analyses and findings given above. To this aim, I will first successively complement a descriptive model with individual, educational, and occupational factors[97]. The results are shown in Table 14. Model TDM 1–TDM 4 show the results regarding the subgroup of time-durable major graduates, while TEM 1–TEM 4 depict the results for the subgroup of time-erodible major

[97] Using different model specifications allows the reader to evaluate whether certain control variables might steer the effect of interest and, hence, influence the conclusion drawn from the results (Toutkoushian and Conley 2005, p. 4). Schulze (2015), too, gradually added educational and occupational controls.

graduates. I start with a more descriptive version in models TDM 1 and TEM 1 by simply testing whether holding a doctoral degree five to six years after graduation has a significant effect on a person's ln-wage (therefore, this model is the ln-wage version of Table 12). From Models 2 to 4 (in both major groups), I add further control variables: In Model 2, I additionally control for individual characteristics (gender, marital and family status, and negotiation affinity). In Model 3, I further control for educational characteristics (final college grade and college major), while Model 4 depicts the full model by additionally controlling for occupational characteristics (job location, form of employment, working hours, work experience, industry, and firm size).

Regardless of the model specification, Models TDM 1 to TDM 4 confirm that there is no significant effect of doctoral degrees on wages in time-durable majors five to six years after graduation. For the subsample of time-erodible majors, however, the effects are significant and positive in all models, as expected (TCM 1-TCM 4).

Table 14: Separate wage regressions for major group (step-by-step approach)

	TDM 1	TDM 2	TDM 3	TDM 4	TEM 1	TEM 2	TEM 3	TEM 4
Doctoral degree	0.010	-0.033	-0.038	-0.019	0.066**	0.059*	0.117***	0.121***
	(0.078)	(0.069)	(0.075)	(0.049)	(0.033)	(0.032)	(0.036)	(0.029)
Female		-0.095**	-0.112***	-0.042		-0.231***	-0.169***	-0.101***
		(0.043)	(0.042)	(0.034)		(0.029)	(0.029)	(0.026)
Marital status								
Without partner		Ref. cat.	Ref. cat.	Ref. cat.		Ref. cat.	Ref. cat.	Ref. cat.
With partner		0.042	0.037	0.025		0.095**	0.106***	0.058*
		(0.051)	(0.048)	(0.041)		(0.040)	(0.037)	(0.031)
Married		0.039	0.024	0.033		0.175***	0.176***	0.096***
		(0.062)	(0.059)	(0.052)		(0.041)	(0.039)	(0.034)
At least one child		-0.139***	-0.147***	-0.035		-0.091***	-0.084***	-0.033
		(0.043)	(0.044)	(0.038)		(0.034)	(0.032)	(0.028)
Qualification adequate employment		0.287***	0.281***	0.269***		0.208***	0.149**	0.106**
		(0.040)	(0.039)	(0.031)		(0.066)	(0.062)	(0.052)
Final college grade								
Satisfying or sufficient			Ref. cat.	Ref. cat.			Ref. cat.	Ref. cat.
Very good			0.106*	0.108**			0.193***	0.176***
			(0.064)	(0.045)			(0.068)	(0.060)
Good			0.150**	0.111**			0.115*	0.090
			(0.063)	(0.045)			(0.065)	(0.056)
College major								
Arts			Ref. cat.	Ref. cat.				
Humanities			0.126	0.080				
			(0.080)	(0.060)				
Theology			0.155	0.209**				
			(0.132)	(0.093)				
Linguistics and cultural sciences			0.221***	0.148***				
			(0.068)	(0.050)				
Education sciences			0.128**	0.077				
			(0.064)	(0.048)				
Social sciences			0.290***	0.188***				
			(0.062)	(0.048)				

(continued)

Table 14 *(continued)*

	TDM 1	TDM 2	TDM 3	TDM 4	TEM 1	TEM 2	TEM 3	TEM 4
Mathematics							Ref. cat.	Ref. cat.
Sports and health sciences							-0.272***	-0.285***
							(0.097)	(0.088)
Agriculture and nutrition							-0.235**	-0.212***
							(0.093)	(0.064)
Natural sciences							-0.300***	-0.238***
							(0.074)	(0.050)
Engineering							-0.055	-0.102**
							(0.072)	(0.045)
Total work experience in months				0.003***				0.005***
				(0.001)				(0.001)
Total working hours per week				0.015***				0.009***
				(0.001)				(0.002)
Form of employment								
Fixed-term contract				Ref. cat.				Ref. cat.
Unrestricted contract				0.129***				0.233***
				(0.030)				(0.037)
Self-employed				-0.064				0.099
				(0.074)				(0.080)
Public sector				0.045				-0.015
				(0.038)				(0.042)
Working in large-scale enterprise				0.047				0.122***
				(0.039)				(0.031)
Industry								
Services				Ref. cat.				Ref. cat.
Primary or manufacturing sector				0.118*				0.100***
				(0.064)				(0.028)
Public sector industry				-0.112***				-0.014
				(0.033)				(0.047)

(continued)

Table 14 *(continued)*

	TDM 1	TDM 2	TDM 3	TDM 4	TEM 1	TEM 2	TEM 3	TEM 4
Job location								
East-Germany				Ref. cat.				Ref. cat.
West-Germany				0.147***				0.138***
				(0.036)				(0.029)
Abroad				0.197**				0.165***
				(0.084)				(0.047)
Constant	7.888***	7.745***	7.462***	6.511***	8.183***	7.994***	8.016***	7.052***
	(0.018)	(0.066)	(0.099)	(0.109)	(0.018)	(0.072)	(0.109)	(0.135)
R^2	0.000	0.108	0.178	0.420	0.005	0.126	0.209	0.454
Observations	795	786	769	697	969	961	941	843

* p<0.10, ** p<0.05, *** p<0.01; linearized standard errors in parentheses
Own calculations based on DZHW Graduate Panel (2005).

Before, I argued that it is imperative to use sample weights when estimating the effect of doctoral degrees on wages. Nonetheless, I also present the coefficients based on unweighted data in Table 15. The results regarding the effect of interest are qualitatively equal to those in Table 13.

Table 15: Separate wage regressions for major groups (unweighted data)

	Time-durable majors		Time-erodible majors	
Doctoral degree	-0.020	(0.052)	0.117***	(0.029)
Female	-0.083***	(0.030)	-0.127***	(0.024)
Marital status				
Without partner	Ref. cat.		Ref. cat.	
With partner	0.015	(0.035)	0.039	(0.029)
Married	0.031	(0.041)	0.082**	(0.035)
At least one child	-0.027	(0.031)	-0.062**	(0.028)
Qualification adequate employment	0.258***	(0.030)	0.070	(0.056)
Finale college grade				
Satisfying or sufficient	Ref. cat.		Ref. cat.	
Very good	0.094**	(0.045)	0.190***	(0.048)
Good	0.117***	(0.045)	0.101**	(0.046)
College major				
Arts	Ref. cat.			
Humanities	0.078	(0.057)		
Theology	0.155*	(0.085)		
Linguistics & cultural sciences	0.131***	(0.050)		
Education sciences	0.057	(0.046)		
Social sciences	0.164***	(0.046)		
Mathematics			Ref. cat.	
Sports and health sciences			-0.185**	(0.094)
Agriculture and nutrition			-0.193**	(0.075)
Natural sciences			-0.220***	(0.059)
Engineering			-0.093*	(0.056)
Total work experience in months	0.003**	(0.001)	0.005***	(0.001)
Total working hours per week	0.015***	(0.001)	0.007***	(0.002)
Form of employment				
Fixed-term contract	Ref. cat.		Ref. cat.	
Unrestricted contract	0.140***	(0.028)	0.197***	(0.034)
Self-employed	0.029	(0.066)	0.030	(0.080)
Public sector	0.061*	(0.036)	0.037	(0.036)
Working in large-scale enterprise	0.077**	(0.036)	0.168***	(0.029)
Industry				
Services	Ref. cat.		Ref. cat.	
Primary or manufacturing sector	0.148***	(0.054)	0.096***	(0.029)
Public sector industry	-0.067**	(0.030)	-0.044	(0.039)
Job Location				
East-Germany	Ref. cat.		Ref. cat.	
West-Germany	0.144***	(0.031)	0.131***	(0.027)
Abroad	0.211***	(0.074)	0.177***	(0.046)
Constant	6.553***	(0.110)	7.207***	(0.152)
R^2	0.409		0.431	
Observations	697		843	

* p<0.10, ** p<0.05, *** p<0.01; robust standard errors in parentheses
Own calculations based on DZHW Graduate Panel (2005).

In Table 13, I grouped sports, health sciences, and agriculture and nutrition with time-erodible majors. Although I used empirical and theoretical support from the literature to back-up my decisions, this assignment might still be debatable. In Table 16, I therefore assign these majors to the time-durable majors. The findings regarding doctoral degree do not change qualitatively.

Table 16: Separate wage regressions for major groups (alternative major categorisation)

	Time-durable majors		Time-erodible majors	
Doctoral degree	0.049	(0.048)	0.103***	(0.030)
Female	-0.033	(0.032)	-0.125***	(0.027)
Marital status				
Without partner	Ref.cat.		Ref.cat.	
With partner	0.009	(0.039)	0.085***	(0.032)
Married	0.024	(0.048)	0.118***	(0.035)
At least one child	-0.022	(0.036)	-0.052*	(0.029)
Qualification adequate employment	0.230***	(0.031)	0.156***	(0.058)
Final college grade				
Satisfying or sufficient	Ref.cat.		Ref.cat.	
Very good	0.122***	(0.046)	0.161***	(0.059)
Good	0.123***	(0.044)	0.069	(0.058)
College major				
Arts	Ref.cat.			
Humanities	0.078	(0.060)		
Theology	0.184*	(0.096)		
Linguistics and cultural sciences	0.148***	(0.050)		
Education sciences	0.078	(0.048)		
Social sciences	0.196***	(0.048)		
Sports and health sciences	0.160**	(0.079)		
Agriculture and nutrition	0.178***	(0.066)		
Mathematics			Ref.cat.	
Natural sciences			-0.234***	(0.049)
Engineering			-0.111**	(0.045)
Total work experience in months	0.003***	(0.001)	0.005***	(0.001)
Total working hours per week	0.015***	(0.001)	0.009***	(0.002)
Form of employment				
Fixed-term contract	Ref.cat.		Ref.cat.	
Unrestricted contract	0.134***	(0.028)	0.198***	(0.044)
Self-employed	-0.029	(0.070)	0.012	(0.094)
Public sector	0.058	(0.035)	-0.033	(0.049)
Working in large-scale enterprise	0.062*	(0.037)	0.123***	(0.031)
Industry				
Services	Ref.cat.		Ref.cat.	
Primary or manufacturing sector	0.130**	(0.054)	0.084***	(0.029)
Public sector industry	-0.104***	(0.031)	-0.053	(0.058)
Job location				
East-Germany	Ref.cat.		Ref.cat.	
West-Germany	0.157***	(0.034)	0.112***	(0.030)
Abroad	0.232***	(0.073)	0.129**	(0.051)
Constant	6.517***	(0.109)	7.079***	(0.159)
R^2	0.403		0.456	
Observations	804		736	

* p<0.10, ** p<0.05, *** p<0.01; linearized standard errors in parentheses
Own calculations based on DZHW Graduate Panel (2005).

Moreover, it would be interesting to investigate the effect separately for different majors within the broad groups of time-durable and time-erodible majors. I run separate regressions for eight out of the eleven majors as a robustness check in Table 17. For the remaining majors (educational sciences, theology, and mathematics), running separate regressions was inappropriate due to too small sample sizes. With the exception of the arts and sports and health sciences, all subsamples verify the expected effects of interest. The information on arts graduates with doctoral degrees, however, is based on only two observations in the dataset which could be two large outliers and should be re-investigated with a larger sample.

With only 30 observations in the subsample of sports and health sciences, this group is also very small. Apart from doctoral degree, several other factor do not show the expected effect. Again, I would recommend to re-investigate the effect on a larger subsample. However, this is not possible with the dataset at hand.

Table 17: Wage regressions for eight separate majors

	Arts	Humanities	Linguistics & cultural sciences	Social Sciences	Sports & health sciences	Agriculture & nutrition	Natural sciences	Engineering
Doctoral degree	0.212*	0.058	-0.041	-0.012	-0.085	0.330**	0.113**	0.112***
	(0.114)	(0.108)	(0.087)	(0.097)	(0.139)	(0.145)	(0.050)	(0.036)
Female	0.043	0.006	0.079	-0.123**	0.412**	-0.061	-0.052	-0.183***
	(0.081)	(0.084)	(0.074)	(0.052)	(0.161)	(0.083)	(0.045)	(0.037)
Marital status								
Without partner	Ref.cat.	Ref.cat.	Ref.cat.	Ref.cat.	Ref.cat.	Ref.cat.	Ref.cat.	Ref.cat.
With partner	0.190*	-0.070	-0.075	0.025	-0.296***	-0.273*	0.022	0.091**
	(0.113)	(0.151)	(0.086)	(0.056)	(0.100)	(0.155)	(0.054)	(0.039)
Married	0.005	-0.056	-0.177	0.126*	-0.382***	-0.323**	0.096	0.111**
	(0.109)	(0.170)	(0.108)	(0.069)	(0.107)	(0.144)	(0.068)	(0.044)
At least one child	0.063	-0.011	0.024	-0.087	0.214***	0.188*	-0.124**	-0.019
	(0.085)	(0.087)	(0.076)	(0.059)	(0.080)	(0.100)	(0.061)	(0.036)
Qualification adequate employment	0.370***	0.341***	0.308***	0.233***	-1.156***	0.008	0.056	0.225***
	(0.087)	(0.106)	(0.074)	(0.052)	(0.141)	(0.125)	(0.082)	(0.078)
Final college grade								
Satisfying or sufficient	Ref.cat.	Ref.cat.	Ref.cat.	Ref.cat.	Ref.cat.	Ref.cat.	Ref.cat.	Ref.cat.
Very good	0.146	0.243	0.094	0.072	0.959***	0.296	0.141	0.177**
	(0.104)	(0.193)	(0.096)	(0.072)	(0.191)	(0.334)	(0.100)	(0.073)
Good	0.256**	0.158	-0.052	0.125*	0.601***	0.204	0.016	0.095
	(0.102)	(0.194)	(0.088)	(0.069)	(0.085)	(0.321)	(0.105)	(0.070)
Total work experience in months	-0.006**	0.006**	0.005**	0.003	0.007***	0.007**	0.002	0.006***
	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)	(0.004)	(0.002)	(0.002)
Total working hours per week	0.012***	0.020***	0.019***	0.014***	-0.011*	0.001	0.009**	0.009***
	(0.003)	(0.006)	(0.003)	(0.003)	(0.006)	(0.007)	(0.004)	(0.002)
Form of employment								
Fixed-term contract	Ref.cat.	Ref.cat.	Ref.cat.	Ref.cat.	Ref.cat.	Ref.cat.	Ref.cat.	Ref.cat.
Unrestricted contract	0.267***	0.142	0.208***	0.059	0.346	0.254***	0.150**	0.229***
	(0.063)	(0.105)	(0.064)	(0.047)	(0.273)	(0.087)	(0.067)	(0.055)
Self-employed	-0.123	-0.020	-0.221**	0.326**	0.214	0.029	0.102	0.017
	(0.134)	(0.245)	(0.105)	(0.135)	(0.388)	(0.188)	(0.217)	(0.106)

(continued)

Table 17 *(continued)*

	Arts	Humanities	Linguistics & cultural sciences	Social Sciences	Sports & health sciences	Agriculture & nutrition	Natural sciences	Engineering
Public sector	-0.019	0.150	0.108	0.077	-0.566***	0.043	0.009	-0.120
	(0.089)	(0.163)	(0.081)	(0.058)	(0.153)	(0.104)	(0.061)	(0.098)
Working in large-scale	0.137	0.198	-0.081	0.101*	-0.732***	0.194*	0.143**	0.092**
enterprise	(0.085)	(0.128)	(0.072)	(0.061)	(0.139)	(0.107)	(0.058)	(0.036)
Industry								
Services	Ref.cat.	Ref.cat.	Ref.cat.	Ref.cat.	Ref.cat.	Ref.cat.	Ref.cat.	Ref.cat.
Primary or manufacturing	0.481***	0.073	-0.098	0.200***	-0.548*	0.231**	0.084	0.097***
sector	(0.154)	(0.125)	(0.173)	(0.063)	(0.326)	(0.092)	(0.058)	(0.033)
Public sector industry	0.075	-0.151	-0.295***	-0.027	-0.036	0.146	-0.162***	0.096
	(0.097)	(0.160)	(0.070)	(0.050)	(0.068)	(0.096)	(0.061)	(0.119)
Job location								
East-Germany	Ref.cat.	Ref.cat.	Ref.cat.	Ref.cat.	Ref.cat.	Ref.cat.	Ref.cat.	Ref.cat.
West-Germany	0.012	0.116	0.102	0.137**	0.756***	0.367***	0.042	0.124***
	(0.084)	(0.102)	(0.070)	(0.062)	(0.150)	(0.125)	(0.060)	(0.036)
Abroad	0.005	-0.140	0.414***	0.164	-1.080***	0.668***	0.067	0.150**
	(0.114)	(0.224)	(0.159)	(0.100)	(0.229)	(0.140)	(0.084)	(0.060)
Constant	6.844***	6.097***	6.558***	6.787***	8.148***	6.856***	7.260***	6.828***
	(0.215)	(0.418)	(0.188)	(0.171)	(0.251)	(0.374)	(0.239)	(0.198)
R^2	0.619	0.491	0.597	0.330	0.938	0.528	0.440	0.436
Observations	61	61	130	312	30	77	247	460

* p<0.10, ** p<0.05, *** p<0.01; linearized standard errors in parentheses
Own calculations based on DZHW Graduate Panel (2005).

In the preferred model specification (Table 13), I excluded graduates who attained a state examination degree. Due to mandatory internships, these individuals enter the labour market at a different point in time compared to Diplom or Magister graduates. However, even if I include these individuals in the regression – that is teachers and medical graduates – the results still show the expected effect (Table 18).

Table 18: Separate wage regressions for major groups (including state examination degrees)

	Time-durable majors	Time-erodible majors
Doctoral degree	-0.054	0.061**
	(0.045)	(0.024)
Female	-0.048*	-0.103***
	(0.026)	(0.020)
Marital status		
Without partner	Ref. cat.	Ref. cat.
With partner	0.040	0.026
	(0.030)	(0.026)
Married	0.051	0.082***
	(0.036)	(0.027)
At least one child	-0.034	-0.037*
	(0.028)	(0.022)
Qualification adequate employment	0.294***	0.122**
	(0.030)	(0.051)
Final college grade		
Satisfying or sufficient	Ref. cat.	Ref. cat.
Very good	0.038	0.088***
	(0.032)	(0.032)
Good	0.057*	0.039
	(0.030)	(0.028)
College major		
Arts	Ref. cat.	
Humanities	0.068	
	(0.051)	
Theology	0.103	
	(0.063)	
Linguistics and cultural sciences	0.096**	
	(0.040)	
Education sciences	0.094**	
	(0.040)	
Social sciences	0.141***	
	(0.044)	

(continued)

Table 18 *(continued)*

	Time-durable majors	Time-erodible majors
Mathematics		Ref. cat.
Sports and health sciences		-0.216***
		(0.065)
Agriculture and nutrition		-0.150***
		(0.055)
Natural sciences		-0.105***
		(0.035)
Engineering		-0.049
		(0.036)
Medicine		0.230***
		(0.047)
Total work experience in months	0.002***	0.006***
	(0.001)	(0.001)
Total working hours per week	0.014***	0.009***
	(0.001)	(0.001)
Form of employment		
Fixed-term contract	Ref. cat.	Ref. cat.
Unrestricted contract	0.187***	0.185***
	(0.026)	(0.027)
Self-employed	-0.025	0.305***
	(0.074)	(0.066)
Public sector	0.088**	0.040
	(0.037)	(0.032)
Working in large-scale enterprise	0.059	0.136***
	(0.039)	(0.029)
Industry		
Services	Ref. cat.	Ref. cat.
Primary or manufacturing sector	0.111*	0.085***
	(0.059)	(0.029)
Public sector industry	-0.094***	-0.086***
	(0.031)	(0.032)
Job location		
East-Germany	Ref. cat.	Ref. cat.
West-Germany	0.141***	0.096***
	(0.030)	(0.025)
Abroad	0.202**	0.144***
	(0.082)	(0.045)
Constant	6.616***	7.089***
	(0.091)	(0.108)
R^2	0.415	0.439
Observations	1008	1346

* p<0.10, ** p<0.05, *** p<0.01; linearized standard errors in parentheses
Own calculations based on DZHW Graduate Panel (2005).

Additionally, one might argue that the argument given above is developed from a private sector perspective as these employers feel more pressure to be innovative because they are surrounded by more competitors. I therefore run an additional robustness check where I exclude all individuals employed in the public sector (Table 19). The results regarding doctoral degree do not change qualitatively.

Table 19: Separate wage regressions for major groups (excluding public sector employees)

	Time-durable majors		Time-erodible majors	
Doctoral degree	-0.096	(0.071)	0.083**	(0.034)
Female	-0.041	(0.048)	-0.149***	(0.030)
Marital status				
Without partner	Ref.cat.		Ref.cat.	
With partner	0.007	(0.059)	0.082**	(0.037)
Married	0.054	(0.075)	0.114***	(0.043)
At least one child	-0.001	(0.051)	-0.028	(0.034)
Qualification adequate employment	0.286***	(0.040)	0.063	(0.057)
Final college grade				
Satisfying or sufficient	Ref.cat.		Ref.cat.	
Very good	0.127**	(0.055)	0.183**	(0.071)
Good	0.083	(0.057)	0.108	(0.067)
College major				
Arts	Ref.cat.			
Humanities	0.053	(0.076)		
Theology	0.329***	(0.121)		
Linguistics and cultural sciences	0.125**	(0.058)		
Education sciences	0.054	(0.065)		
Social sciences	0.159**	(0.063)		
Mathematics			Ref.cat.	
Sports and health sciences			-0.398***	(0.116)
Agriculture and nutrition			-0.266***	(0.081)
Natural sciences			-0.220***	(0.068)
Engineering			-0.148**	(0.059)
Total work experience in months	0.004**	(0.002)	0.007***	(0.002)
Total working hours per week	0.016***	(0.002)	0.009***	(0.002)
Form of employment				
Fixed-term contract	Ref.cat.		Ref.cat.	
Unrestricted contract	0.123***	(0.047)	0.154***	(0.060)
Self-employed	-0.059	(0.085)	0.046	(0.092)
Working in large-scale enterprise	0.042	(0.039)	0.117***	(0.031)
Industry				
Services	Ref.cat.		Ref.cat.	
Primary or manufacturing sector	0.084	(0.062)	0.095***	(0.030)
Public sector industry	-0.187***	(0.052)	-0.071	(0.055)
Job location				
East-Germany	Ref.cat.		Ref.cat.	
West-Germany	0.206***	(0.059)	0.198***	(0.038)
Abroad	0.229*	(0.120)	0.225***	(0.055)
Constant	6.409***	(0.133)	6.995***	(0.173)
R^2	0.462		0.478	
Observations	380		554	

* p<0.10, ** p<0.05, *** p<0.01; linearized standard errors in parentheses
Own calculations based on DZHW Graduate Panel (2005).

4.5 Conclusion

In this chapter, I investigated the effect of attaining a doctoral degree on wages five to six years after college graduation, separately for time-durable and time-erodible college major graduates. I hypothesised that doctoral degrees are remunerated for time-erodible major graduates, only. Based on considerations and findings in the literature, I argued that majors differ in two dimensions: their imparted skills (Kalmijn and Lippe 1997) and the durability of these skills (McDowell 1982). Further, I expect that an employer is primarily interested in certain types of skills (e.g. technical/analytical or communicative/caring) and that he will hire the respective graduates. Thus, he has to accept the knowledge durability affiliated with these skills (i.e. time-erodible and time-durable). However, as the employer is interested in always using the most current knowledge, he needs his employees to renew their knowledge constantly if this knowledge is time-erodible. I argue that this constant renewal is not necessary for time-durable major graduates, because knowledge in these fields is largely stable (McDowell 1982). I, further, argued that research skills imparted by doctoral studies allow their possessors to renew their knowledge on their own. Hence, I reasoned that research skills are important to employers of time-erodible major graduates but not important to employers of time-durable major graduates. Consequently, I expect doctoral degrees to be remunerated for time-erodible majors but not for time-durable major graduates.

The results in Section 4.4 support my hypotheses. Based on separate OLS regression for the subsamples of time-durable and time-erodible major gradates, I can show that holding a doctoral degree increases wages of time-erodible major graduates five to six years after college graduation by about 13 percent, controlling for individual, educational, and occupational characteristics. Among the time-durable major graduates, however, such a degree does not enhance wages. These findings are qualitatively robust to alternative major group categorisations, single major investigations, and sample exclusions (e.g. excluding public sector employees or including graduates of the state examination degree).

Regarding the theoretical explanation of the relationship of interest, however, there might be other valid mechanisms. One might argue, for example, that the root cause of differences in the doctoral wage premiums between major groups lies in the degree itself rather than in the research skills interlinked with the doctoral degree. Especially in consultancy or other occupations with high levels of client contact, the doctoral degree affixed to one's name signals competence and reliability. Thus, employers are willing to pay higher wages to doctoral degree holders if these individuals occupy respective positions with them. According to a German consultancy survey, consultancies are more interested in engineers and computer scientists than in humanities and arts graduates (Staufenbiel 2016, p. 21). Hence, significant returns to doctorates in time-erodible majors might be due the higher share of consultants or people with high levels of client contact. Since consultancies are, however, especially interested in graduates of business administration and economics (Staufenbiel 2016, p. 21), and since I assigned this group neither to the time-durable nor time-erodible majors, there is reason to believe that at least some part of the doctoral wage premium is due to the imparted research skills. Nonetheless, future studies should further investigate this aspect. Due to limited availability of information regarding detailed job descriptions, however, controlling for consultant or high-client-contact jobs was not possible in this study.

The results have multiple implications for educational institutions, firms, and individuals. Given the findings of this chapter, firms might realise not only their need for doctoral students – and hence research skills – when hiring time-erodible major graduates. They might also feel the importance of providing the appropriate research environment for these employees to utilise their research capabilities. Otherwise, they might fail to exploit their investment in doctoral graduates. If the argument of this chapter is true and it is not (only) the degree itself that is worth paying higher wages for but the research skills attached to this degree, failing to provide the environment to use these skills will result in a loss of competitive advantage while incurring high labour costs.

Given that the research skills employers of time-erodible major graduates need are provided by doctoral studies, it is important that these graduates are not only able to understand and create new knowledge and technologies but are also able to communicate ideas to others. Hence, it would be important that higher educational institutions provide doctoral education that trains doctoral students in these dimensions as well.

For the individual, the findings of this study might influence the individual doctoral enrolment decision. Given that – at least at the time of labour market entry – doctoral studies are only remunerated for time-erodible major graduates but not for time-durable major graduates, the latter might not rationally attend doctoral studies. Future research needs to investigate their motives in more detail. Although doctoral degrees in these majors do not pay off at labour market entrance according to this study, they might work as a door opener to the top management in later careers. Therefore, it would be of interest to investigate the effect of doctoral degrees on wages in both major groups 10 or 15 years after graduation. Regarding the graduation class of 2005, however, the respective data is unfortunately not yet available.

5 Do doctoral degrees signal female career orientation?[98]

5.1 Introduction

Women earn less than men do. This is true across various occupations (Hegewisch and Williams-Baron 2017), sectors (Hedija 2017), and countries (England et al. 2012). Literature analysing the gender wage gap, however, suggests that the wage gap decreases with higher educational levels (e.g. Dougherty (2005) and Pitts and Kroncke (2014) for the US, Livanos and Nunez (2012) for Greece and UK). According to Pitts and Kroncke (2014, pp. 148–149), for example, the gender wage gap is largest among those who did not complete high school (70.2 percent), while it is 40.8 percent for those with a high school diploma and reduces to 10.4 and even 4.8 percent for those with a bachelor or advanced degree, respectively.

One explanation for the decreasing gender wage gap might be that women use higher educational degrees to signal career orientation to the employer and therefore receive higher wage premiums than men (Dougherty 2005; Montgomery and Powell 2003). The most costly educational degree (at least on average – considering opportunity costs (Ampaw and Jaeger 2012, p. 641) as well as time (Enders 2002, p. 493; Kehm 2006, p. 70)) is the doctoral degree. Therefore, we raise the questions whether a woman can reduce (or even close) the gender wage gap by attaining a doctoral degree. Put differently, we ask whether the wage premium of a doctoral degree is higher for women than for men. We call this the gender premium gap.

But why do male and female wages differ in the first place? Economists believe labour markets to be characterised by information asymmetry (Phelps 1972), e.g. regarding an individual's career orientation. If the individual's career orientation is private knowledge to the individual, employers will alternatively use observable characteristics (e.g. gender) to assess an applicant's true career orientation (Noonan et al. 2005, p. 867). In many cases, men and women already signal their work attitudes through their choice of college major, with family-oriented individuals preferring majors that impart time-durable human capital, e.g. humanities and arts, and career-oriented individuals preferring better paid but more risky time-erodible human capital, e.g. engineering and natural sciences (Ochsenfeld 2014). Only when it comes to majors

[98] This chapter is based on Froehlich and Warning (2018) but presents some content in more detail. To this purpose, I extended the discussion of the literature in Section 5.2 by a more detailed presentation of the contribution of this chapter to the existing literature (Section 5.2.4) and included a more comprehensive explanation of the methodological approach (Section 5.4.5). In contrast to Froehlich and Warning (2018), this chapter discusses the dataset and empirical analysis in one common chapter (Section 5.4) instead of two separate chapters. As I already introduced some aspects discussed in Froehlich and Warning (2018) in Chapter 4, these paragraphs were extracted from Chapter 5 to avoid unnecessary repetition. This particularly applies to the theoretical part in Section 5.3 and the description of the dataset in Section 5.4.1.

that impart mixed human capital (e.g. business administration and economics), we expect employers to be still in the dark about the individuals career orientation. Hence, they will use gender and their previous experiences about average male and female career orientation to determine wage offers (Blau and Kahn 2007, p. 10). Assuming men to be career-oriented and women family-oriented (Fortin 2005, p. 417), they will offer lower wages to women than men. Under these circumstances, career-oriented women may want to distinguish themselves from the family-oriented majority. They may invest in human capital and thus signal career orientation, since investments in human capital go along with costs on which the women will probably want to receive a return on. Hence, we expect an additional signalling effect from doctoral degrees for women. For men, however, already expected to be career-oriented, there is no such effect. This results is what we call the gender premium gap, as we expect doctoral degrees to have a larger effect on female than male wages, allowing women to reduce discrimination they encounter in the labour market.

The empirical test is based on data of 1.918 graduates from German universities in 2005. Germany seems to be a good case to test the hypotheses for two reasons: First, after completing the doctoral thesis, the majority of students leaves academia and enters the “regular” labour market in the private sector comparatively free of compressed wages and collective agreements, allowing us to observe wage settings free from regulation. Second, parental leave arrangements in Germany are generous compared to most industrialized countries as mothers enjoy job protection for three years after birth and the flexibility of returning in part-time work within this period of time without losing their job protection (Fitzenberger et al. 2016, p. 806). Furthermore, they can ask for a regular part-time job after parental leave has expired (Fitzenberger et al. 2016, p. 806). Thus, employers who are interested in firm-committed employees who will stay with the employer and who prioritise work need to identify the career-oriented ones. Since employers cannot distinguish career-oriented from family-oriented female mixed major graduates, signalling career orientation is particularly important for career-oriented women.

Based on single equation estimations with interaction regarding gender and doctoral degree and Oaxaca-Blinder decomposition, the empirical analyses reveal that doctoral degrees help women who graduated in mixed majors to reduce discrimination and, thus, the gender wage gap. For time-durable and time-erodible majors, we find no difference in the doctoral effect between men and women, as expected.

The studies closest to us are Braakmann (2008) and Waite (2017), both investigating the effect of a doctoral degree on the gender wage gap. The effect proved insignificant (or even positive) in both studies. When we pool all major graduates into one sample and control for majors as Braakmann (2008) and Waite (2017) did before, we confirm this insignificant effect. We argue, however, that it is imperative to use separate subsamples reflecting the different major groups as we expect the discrimination reducing effect of doctoral degrees to be present only among the mixed major graduates. Controlling for majors within a common sample, instead, would mean that we erroneously assume the effect of doctoral degrees on the gender wage gap to be independent of the major group. To the best of our knowledge, we are the first to perform Oaxaca-Blinder decompositions on subsamples for distinct groups of time-durable, time-erodible, and mixed major graduates.

The remainder of this chapter is structured as follows: Section 5.2 provides a review of the literature on the gender wage gap in general and on gender differences in the doctoral wage premium in particular. In Section 5.3, we develop an argument based on Spence's (1973) signalling theory and derive the hypothesis. Section 5.4 describes the dataset, presents the estimations, and discusses the empirical findings. Section 5.5 concludes the chapter.

5.2 Literature on the gender wage gap

Differences in wages between men and women seem to exist since the dawn of time (Blau and Kahn 2000, p. 76). Since the late 1950s until about 1980 the gender wage gap was about 40 percent (Blau and Kahn 2017, p. 791). While the gender wage gap decreased during the 1980s to mid-1990s, it stabled at a lower degree since then (Blau and Kahn 2017, p. 791; Card and DiNardo 2002, p. 759). Hence, although it decreased to a lower level it is still present today[99] as more recent studies still testify to lower wages for women than men (see Blau and Kahn (2017) and Weichselbaumer and Winter-Ebmer (2005) for a discussion of the literature). And often, employers are blamed to cause this phenomenon.

However, differences in wages between men and women might not only result from employers discriminating certain groups of employees. In fact, economists tend to believe that there is actually no discrimination through employers, but that differences in wages between men and women result from their differences in educational choices and occupational preferences.

Thus, wage differences between men and women may result more from supply-side discrimination (occurring prior to the labour market) than from demand-side discrimination in the labour market.

[99] In Germany, for example, the raw gender wage gap in 2014 was 22 percent (Destatis 2016a) and in the US about 20 percent (Blau and Kahn 2017, p. 791).

5.2.1 Supply-side discrimination

The literature regarding these supply-side differences between men and women is mainly based on Becker's (1962) human capital theory. Individuals rationally choose how much work experience or education to attain or which kind of education to attend by trading off expected future returns on investment and expected educational costs. Therefore, differences in work experience (as a proxy for on-the-job training (Kilbourne et al. 1994, p. 690)) and educational attainment (off-the-job training) between men and women are based on differences in expected returns and/or costs (Blau and Kahn 2017, p. 813).

Traditionally, women engage in housework (Fortin 2005, p. 417) and, therefore, lack labour market experience compared to their male counterparts. Furthermore, men are more likely than women to work in lager firms, which are found to pay higher wages even in apparently similarly occupations (Anker 1997, p. 334). One reason for why firms pay higher wages is that these firms offer efficiency wages in order to attract the most talented individuals (Anker 1997, pp. 334–335).

Additionally, men and women select themselves into different occupations, horizontally as well as vertically[100] (Anker 1997, p. 335). An extreme version of vertical segregation is examined by the glass ceiling literature, arguing that at some point women are not promoted any further (e.g. Soleymanpour Omran et al. (2015)).

Women may choose to work in occupations where less on-the-job training (i.e. less firm-specific human capital) is needed (Blau and Kahn 2000, pp. 80–81; Leuze and Strauß 2016, p. 804; Triventi 2013, p. 566). Due to work life interruptions (e.g. child rearing) women are less likely than men to stay with the same employer for a long time. Therefore, they are less interested in acquiring firm-specific human capital that is not transferable to other firms. Occupations that require firm-specific human capital, however, are better paid. As it is not portable, individuals are reluctant to bear its cost on their own so that employers will pay at least a fraction of these costs. Consequently, as soon as these cost are sunk employers are in a weaker wage bargaining position against their employees, resulting in higher wages for the latter (Ochsenfeld 2014, p. 4). Employers may therefore be reluctant to invest in the firm-specific training of women as they might forego future returns on investment due to work life interruptions.

[100] Horizontal segregation refers to men and women being distributed unequally across occupations while vertical segregation refers to men and women working at different levels within the same occupation (Anker 1997, p. 335).

Moreover, as women prefer human capital that is long-lasting and that can be used in several occupations, they may prefer college majors that prepare for such jobs. Hence, they may choose time-durable majors that provide human capital that is more general[101], i.e. less in danger of atrophying in the future (Blakemore and Low 1984, p. 157; Schulze 2015, p. 601) or in other words majors that prepare for occupations that are less intensive in future on-the-job training (Ochsenfeld 2014, p. 9). Doing so might allow them to use their knowledge after work life interruptions or with other employers (Schulze 2015, p. 601). Hence, women might predominately choose majors such as education, arts, and humanities, while men prefer science and engineering (Ochsenfeld 2014, p. 8; Morgan 2008, p. 639; Schulze 2015, p. 601). As the latter provide time-erodible knowledge that may erode if work life is interrupted or the employer is changed, employers have to compensate for taking this risk by paying higher wages. Thus, if predominantly men choose these majors their future wages are expected to be higher than women's (Schulze 2015, p. 602).

Studies that use data on university graduates such as Bobbitt-Zeher (2007), Braakmann (2013), Machin and Puhani (2003), McDonald and Thornton (2007), or Morgan (2008) show that the differences in fields of study explain a large part of the gender wage gap. Using Oaxaca-Blinder decomposition on German graduate data, Braakmann (2013) shows that college majors can explain up to 70 percent of the gender wage gap 6 to 18 months after graduation, while McDonald and Thornton (2007) demonstrate that college majors can explain about 95 percent of differences in starting salaries of US graduates using simulation techniques. Again, the underlying consideration (though rarely explicitly elaborated) is that men and women rationally choose majors that differ with regard to specific (i.e. time-erodible) human capital. These, in turn, are differently remunerated at the labour market (Morgan 2008, p. 632). Eide (1994) shows based on US data that if women had the same major distribution as men, the gender wage gap would decrease by 27 percent, while it is 14 percent in Bobbitt-Zeher (2007). Machin and Puhani (2003) also testify to the effect of college majors on the gender wage gap for Germany and the UK, showing that up to 20 percent of the gender wage gap can be explained by differences in college major choices. The large differences in findings may result from the point in time when the effect was analysed: While Braakmann (2013) and McDonald and Thornton (2007) focus explicitly on wages at labour market entry, this is not the case in Eide (1994), Bobbitt-Zeher (2007), and Machin and Puhani (2003). While at labour market entrance, one's

[101] In contrast to classical human capital assumptions, and in line with Blakemore and Low (1984) and Polachek (1978), we believe college education not to be general all together but that some college major impart more specific human capital than others, or differ in terms of durability of knowledge as discussed in Section 4.3.

field of study might be very important for wage determination, factors such as work experience become more important for wage settings later with time. McDonald and Thornton (2007, p. 34) note that besides time also differences in the methodological approaches and control variables used may cause these differences in the detected effect.

While controlling for educational characteristics seems to be imperative, Joy (2003) shows that it is also important to control for job related characteristics in addition to educational and socio-economic attributes. In fact, using data from US bachelor graduates in 1993/94, Joy (2003) finds that, while differences in job, socio-economic and educational characteristics explain only 25 percent of the gender wage gap, differences in industry and working hours contribute the most.

However, even after controlling for differences in educational and occupational characteristics, empirical studies still find significant differences in wages due to gender. Empirically, there are two possible reasons for this phenomenon: Either there are some unobserved characteristics or attitudes in which men and women differ that might cause wage differences but are not controlled for (i.e. unobservable heterogeneity), or there is demand-side discrimination by the labour market after all (or both).

5.2.2 Demand-side discrimination

According to economic literature, there are two major forms of demand-side discrimination. The first is taste-based discrimination arguing that some employers have a taste for discrimination and that dealing with certain individuals will cause disutility to the employer[102] (Becker 1971, p. 15). They will, therefore, prefer to keep their distance from the discriminated group or – in case of the discrimination against women – might desire socially appropriate roles, as Blau and Kahn (2007) point out. Hence, this form of discrimination is predominantly based on prejudges against certain groups, such as women. Blau and Kahn (2007, pp. 14–15) give examples for this form of discrimination, such as cases where employers tried to hire men, only[103]. As employers will not hire women for these jobs, workforce supply in other occupations is artificially increased resulting in lower wages in such "female" occupations (Kilbourne et al. 1994, p. 693).

[102] Becker (1971, p. 14) calls it a „taste for discrimination" as the respective individual acts as if he was willing to pay something in order to be associated with certain individuals instead of others.

[103] On a similar note, devaluation theory argues that majors and occupations predominantly chosen by women are paid worse because western culture devaluates women and everything that is stereotyped as female – including majors and occupations (England and Li 2006, p. 658; Leuze and Strauß 2016, pp. 805–806).

However, if higher wages for men only result from mere preferences but not from differences in productivity, discriminating firms might be driven out of the market by competitors that do hire less expensive but equally productive female employees (Blau and Kahn 2007, p. 13) and, therefore, erase taste-based discrimination eventually (Kilbourne et al. 1994, p. 693). Based on this train of thoughts, Becker's theory had to face some criticism by economists as it explains a phenomenon that it predicts not to exist (Guryan and Charles 2013, p. 418; Kilbourne et al. 1994, p. 694).

The second form of demand-side discrimination discussed in the literature is statistical discrimination (Arrow 1973; Phelps 1972). According to statistical discrimination theory future employers cannot observe the applicant's true productivity due to asymmetrically distributed information regarding unobservable characteristics of male and female applicants. Therefore, he will assign any applicant to certain productivity groups according to observable characteristics such as gender. If the employer assumes, based on previous experiences, that women are less productive than men, he will offer a lower wage to a woman than to a man. Thus, although a woman might have the same individual, educational, and occupational background, and even if employers account for these (Altonji and Blank 1999, p. 3180), a woman is still paid less than a comparable man because the employer assigns her to a less productive subgroup.

5.2.3 The gender wage gap among college graduates

Using the Oaxaca-Blinder decomposition (Blinder 1973; Oaxaca 1973), many studies focus on explaining the raw wage gap by decomposing it into two components: On the one hand wage differences that are caused by differences in endowments between men and women (i.e. supply-side discrimination) and on the other hand wage differences due to differences in coefficients. Assuming that no significant differences in endowments between men and women remain uncontrolled for, the differences in coefficients represent differences in the valuation of certain characteristics by the labour market, i.e. demand-side discrimination (e.g. Pitts and Kroncke (2014, p. 148)).

While earlier studies predominantly used linked employer-employee datasets (e.g. Belman and Heywood (1991), Machin and Puhani (2003)), detailed information on education was rare and, therefore, there was some accusation regarding the omission of significant differences in (educational) endowments. This point is quite crucial when aiming to detect the true size of discrimination: As analysing survey data only allows us to obverse discrimination as a residual, i.e. the unexplained part of the gender wage gap (Gerlach 1987, p. 590; Reimer and Schröder 2006, p. 238), omitting endowments that we believe to differ between men and women might bias the true size of discrimination.

Moreover, most labour market studies cover a wide range of individuals resulting in rather heterogeneous samples. Therefore, it might be possible to find combinations of characteristics which can only be found among men but not women (Bredtmann and Otten 2014, p. 292). The Oaxaca-Blinder decomposition, however, fails to account for these differences leading to a possibly overestimated unexplained component of the gender wage gap (Bredtmann and Otten 2014, p. 292).

Hence, more recent studies investigated more homogenous data using information on college graduates (e.g. Bredtmann and Otten (2014), Carvajal et al. (2000)). These datasets provide information on labour market entrances as well as detailed information regarding the educational background (e.g. Loury (1997)). Thus, they enable us to investigate a group of individuals that is (i) comparably low on previous work experience (before graduation), (ii) homogenous with regard to years of education, and allow us to (iii) control for educational characteristics beyond years of schooling or one's highest degree obtained (Weinberger 1998, pp. 68–69).

Surprisingly, compared to the vast literature on the gender wage gap in general, the literature discussing the gender wage gaps among the tertiary educated is rather small (Braakmann 2008, p. 2; Morgan 2008, p. 631; Pitts and Kroncke 2014, p. 125; Reimer and Schröder 2006, p. 236). Often, these studies either concentrate on college graduates – with a large part focussing on the effect of college major choices on the gender wage gap (e.g. Braakmann (2013), Eide (1994), Machin and Puhani (2003), Morgan (2008), and Reimer and Schröder (2006)), or on the gender wage gap among post-college graduates, both inside academia (e.g. Amilon and Persson (2013), Ginther and Hayes (2003) and Toutkoushian and Conley (2005)) as well as outside of academia (e.g. Amilon and Persson (2013) and Schulze (2015)).

Giving the evidence on the persistence of gender differences in pay among college graduates and (to a lower degree) among post-college graduates it surprises that studies aiming to focus on the different effect of academic degrees on male and female wages are rather scarce.

The existing literature can be divided into three groups regarding their estimation strategies: separate equations for men and women, single equations with interaction, and decomposition techniques, such as Oaxaca-Blinder decomposition.

5.2.3.1 Literature based on separate equations for men and women

Based on the coefficients of the education variables in separate equation estimations for men and women, the authors reveal whether education has a significant effect on wages in either group. Empirical evidence is mixed: Heineck and Matthes (2012) use data on German graduates of universities and universities of applied sciences to test for the effect of doctoral degrees on wages. Walker and Zhu (2011) use UK labour force data to test for the effect of post-graduate degrees (including master degree and doctorate) on wages. Pitts and Kroncke (2014), too, estimate the effect of an advanced degree beyond a bachelor degree using data drawn for the US National Longitudinal Survey of Youth (NLSY) in 1984 and 2007[104]. All find a positive education effect with different point estimates for men and women where the coefficient in the female regression is larger[105].

Contrary, Belman and Heywood (1991) show that while attending graduate school has a positive effect on wages of white and black women as well as black men, it has no significant effect on wages of white men using US labour force data of 1978. Moreover, Wouterse et al. (2017) even find a significant negative average annual return from gaining a doctoral degree for men using Dutch labour force information between 1987 and 2007 to test for the effect of doctoral degrees on wages within 20 years after master graduation. For women, the authors find a significant and positive effect. Braakmann (2013, 2008), however, using data on German graduates of universities and universities of applied sciences in 1997 testify to positive effects of doctoral degrees on wages for men, only, while he finds no effects on female wages five to six years after graduation.

For the US, Eide (1994), using two graduate surveys (National Longitudinal Study of the High School Class of 1972 and the High School and Beyond Survey) and Monks (2000) using the NLSY data between 1979 and 1993 find larger point estimates of postgraduate degrees for men than women[106]. Morikawa (2015) confirms this finding for the Japanese labour force in 2007. However, due to the estimation strategy, these studies are not able to test whether male and female wage premiums differ significantly as they cannot simply compare coefficients across models.

[104] Following a similar idea, Ohsfeldt et al. (1987) examine the effects of board certification on wages separately for male and female physicians using information on US non-federal patient care physicians in 1982/83. Although board certification in this example is no degree (Ohsfeldt et al. 1987, p. 344), the basic idea is the same.

[105] In Pitts and Kroncke (2014), this is at least true for individuals in 1984, for 2007 the effects are less clear.

[106] Eide (1994) also perform Oaxaca-Blinder decomposition but does not report the coefficients regarding postgraduate degree. In Monks (2000), the results of a Chow test indicate that the relationship between wage and the regressors differ between men and women.

There are different theoretical ideas why the gender wage gap at higher educational levels should be smaller than at lower levels. On the one hand, Montgomery and Powell (2003, p. 398) argue that taste-based discrimination is lower or not existent among the highly educated as “higher education promotes tolerance”. They argue that if there was something like prejudice or a taste against employing women, we would expect these to be lower among more educated individuals if we believe the highly educated ones to work for and with highly educated people.

On the other hand, there is also reason to believe that statistical discrimination is lower among the higher educated. Borjas and Goldberg (1978) and Golbe (1985) argue that if signalling costs[107], i.e. obtaining an advanced educational degree, are higher for the minority group (women) than for the majority group (men), only the most productive members of the minority group will obtain the degree. Consequently, only productive men and (even more) productive women will hold such advanced degrees. Assuming that wages are paid according to their marginal productivity, the gender wage gap among degree holders is smaller or possibly in favour of women. Furthermore, as employers can use degrees as a base for wage decisions, wage offers at higher educational levels might be more standardized and independent of gender (Dougherty 2005, p. 973; Morgan 2008, p. 634).

While separate wage regression estimations for men and women do not enable us to compare the effect of doctoral degrees on wages between the two groups, single-estimation equations with interaction regarding gender and degree (Belman and Heywood 1991, p. 723) or the application of decomposition techniques such as Oaxaca-Blinder decomposition do the trick. Studies that test whether a “’positive’ signal such as advanced education [can] overcome a ‘negative’ [indicator] such as being female” (Montgomery and Powell 2003, p. 396) and, hence, investigate whether additional degrees help women to reduce the gender wage gap (i.e. statistical discrimination) are rare.

5.2.3.2 Literature based on single equation regressions with interaction

Studies that use single equation regression with interaction are Engelage and Hadjar (2008), Mumford and Smith (2007), and Waite (2017). Engelage and Hadjar (2008) use data on Swiss graduates between 1983 and 2001 to test (i) whether there is a difference in the effect of doctoral degrees on labour market outcomes for men and women and (ii) whether this difference changed over time. Looking at different major groups[108] separately, they find lower doctoral

[107] In Borjas and Goldberg (1978, p. 919), these higher signaling costs are represented by a biased test that favors the majority group (men) in a sense that an equally productive female would perform worse on the test than a comparable male person.

[108] Business administration and economics; humanities and social sciences; exact and natural sciences; engineering; and law.

wage premiums for women than men for all majors but engineering. Focussing on the development of doctoral effects on wages over time the authors do not control for individual characteristics (except for age), educational characteristics (except for doctoral degree), or occupational characteristics. With regard to the latter, they control for differences in working hours by calculating full-time equivalent yearly gross wages (Engelage and Hadjar 2008, p. 81). They point out that doing so might cause biased results[109]. Given the literature on the gender wage gap, however, it seems imperative to control for individual, educational, and occupational characteristics in more detail when investigating gender differences in educational premiums. Angle and Wissmann (1981), using US information on the young labour force and controlling for individual and educational characteristics such as major finds no significant gender difference in the doctoral wage premium. Mumford and Smith (2007) use data from the British Workplace Employee Relations Survey 1998 to examine the gender wage gap among British employees. The authors use different model specifications. Within one of these specifications, they control for individual, occupational, and educational factors (including postgraduate degree) and model gender differences in the effects of postgraduate education on wages through interaction with gender. Based on this model specification, Mumford and Smith (2007) testify to a significantly larger effect of postgraduate degrees on wages for women than men[110]. Waite (2017) uses Canadian labour force information to investigate gender differences in the effect of doctoral degrees on wages. Interacting gender and doctoral degree, the author finds no significant gender difference in the effect of doctoral degrees on wages relative to a bachelor degree after controlling for educational and occupational characteristics.

A major drawback from single equation regression with interaction is that this approach implicitly expects all coefficients to be equal for men and women except those that are interacted with gender. With regard to the literature on the gender wage gap, this is not what we expect. We rather anticipate male and female characteristics to be valued differently by the labour market (Ñopo 2008, p. 290). Decomposition techniques such as Oaxaca-Blinder enable us to model such gender specific wage structures (as in separate regressions) while still investigating gender differences in the effects of certain factors on wages (as in interaction regressions). Hence, the Oaxaca-Blinder technique became the standard procedure for

[109] Due to differences in the structures of full- and part-time jobs, a part-time employee (50 percent) would not just earn twice as much if (s)he was employed full-time (Engelage and Hadjar 2008, p. 90).

[110] Mumford and Smith (2007) also use Oaxaca-Blinder decomposition to further investigate the gender wage gap (including controls for occupational and workplace segregations), they do not report on the effects of postgraduate degrees on the gender wage gap.

investigating gender wage differences (Elder et al. 2010, p. 284; Kunze 2008, p. 68; Weichselbaumer and Winter-Ebmer 2005, p. 481).

5.2.3.3 Literature based on Oaxaca-Blinder decomposition of the gender wage gap

Studies that use the Oaxaca-Blinder decomposition technique to investigate the effect of doctoral degrees on the gender wage gap are Braakmann (2008), Dougherty (2005), Livanos and Nunez (2012), Montgomery and Powell (2003), Pitts and Kroncke (2014) and Waite (2017). Dougherty (2005) and Pitts and Kroncke (2014) perform Oaxaca-Blinder wage decomposition for each year of schooling or educational level, respectively. Both studies pool observations drawn from NLSY survey of two (1984 and 2007 in Pitts and Kroncke (2014)) or four waves (between 1988–2000 in Dougherty (2005)). Both confirm that the gender wage gap decreases with higher educational level. However, while Dougherty (2005) concludes that the unexplained gender wage gap decreases with more years of schooling, Pitts and Kroncke (2014) point to an increasing unexplained part, arguing that women with higher education are not necessarily exposed to less demand-side discrimination.

Livanos and Nunez (2012) use Greek and UK labour force data in 2004 to investigate the effect of a tertiary degree (including doctoral degrees) over secondary education on the gender wage gap. Based on Oaxaca-Blinder decomposition they show that while tertiary education reduces the unexplained gender wage gap in Greece it has no effect in the UK.

Possibly due to their quite heterogeneous datasets regarding educational qualification (all include individuals with secondary education or less), Pitts and Kroncke (2014), Livanos and Nunez (2012), and Dougherty (2005) do not control for one's major. As argued before, however, previous studies showed that majors matter when analysing the gender wage gap (Morgan 2008). Studies that use more educational homogeneous datasets and control for college major are Braakmann (2008), Montgomery and Powell (2003), and Waite (2017).

Montgomery and Powell (2003) use data from a longitudinal survey of registrants for the Graduate Management Admission Test (GMAT) in 1990/91 to compare the gender wage gap among MBA recipients (Master of Business Administration) and the gap among non-MBA recipients. In a first step, the authors estimate a two-stage full-information maximum likelihood tobit model[111] and show that while the female dummy coefficient is insignificant for the subsample of MBA completers it is significant and negative for the subgroup of non-completers. Montgomery and Powell (2003, p. 406) argue that these results "support [their]

[111] Where they estimate on the first stage the probability of completing a MBA and on second stage the hourly ln wage based on tobit regression.

hypothesis that the gender wage gap is smaller among GMAT registrants who have an MBA […] than among those who do not have an MBA". Due to the large difference in observation numbers regarding both subsamples (MBA completers: 862, non-completers: 3431), such comparison is rather difficult. To further investigate the unexplained part of the gender wage gaps among MBA completers and non-completers, Montgomery and Powell (2003) conduct Oaxaca-Blinder decompositions separately for both subsamples in a second step. Comparing these, they conclude based on the t-statistic that, depending on their assumptions regarding the distribution of the error terms, the unexplained part of the gender wage gap is significantly smaller among MBA completers than non-completers. Like Dougherty (2005) and Pitts and Kroncke (2014), their methodological approach does not allow them to quantify the effect of the advanced degree on the (unexplained) gender wage gap. Braakmann (2008) and Waite (2017), however, are able to by pooling both, degree holders and non-holders, in one sample.

Waite (2017) uses Canadian labour force information in 2011 to investigate the effect of doctoral degrees on the gender wage gap. In a subsample specification, he restricts the dataset to master and doctoral graduates. Based on Oaxaca-Blinder decomposition he finds that a doctorate has no significant effect on the unexplained gender wage gap (discrimination).

Based on data of German graduates of the examination cohort of 1997, Braakmann (2008) reports the effect of doctoral degrees on the unexplained gender wage gap to have either no effect or a significantly positive (i.e. wage gap increasing) effect, depending on the model specification.

Apart from whether these studies pool degree-holders and non-degree holders into a common sample, all three studies (Braakmann (2008), Montgomery and Powell (2003), and Waite (2017)) pool all major graduates into common samples and control for the majors that occur in their respective samples (4 majors in Montgomery and Powell (2003) and about 30 majors in Braakmann (2008)[112] and Waite (2017)). By simply controlling for one's major, however, one implicitly assumes the effect of doctoral degrees on the gender wage gap to be independent of major. This is not what we expect. Instead, we expect the reducing effect of doctoral degrees on the gender wage gap to be present in majors of mixed human capital (e.g. business administration and economics), only. Hence, we argue that is it imperative to analyse distinct subsamples regarding major groups.

[112] Braakmann (2008) gives no information on the exact number of controlled majors but analyses in Braakmann (2013) suggest 33 majors.

A study that performs separate Oaxaca-Blinder decompositions for distinct major groups is O'Leary and Sloane (2005). The authors investigate the mark-up of a doctoral degree over a bachelor degree in ten broad majors using UK labour force data between 1994 and 2002. The authors investigate the premium of having a doctoral degree over a bachelor degree in a given major, separately for men and women. They do so by performing separate Oaxaca-Blinder decompositions for men and women and comparing the size of the unexplained wage gaps which they argue to constitute the respective doctoral premiums. Finding mostly larger point estimates for women than men, they conclude that "women have more to gain than men" from a doctoral degree (O'Leary and Sloane 2005, p. 85). Their methodological approach does not allow to compare male and female doctoral mark-ups as coefficients cannot be compared across models. Estimating the difference in doctoral wage premiums between men and women, however, is the focus of this study.

5.2.4 Contribution to the literature

Rarely, there is so much agreement in economic literature than when it comes to the existence of the gender wage gap. The above literature review shows, however, that researchers are less eye to eye when it comes to the reasons for this phenomenon. Previous studies suggest that there are two reasons for gender wage differences. On the one hand, there is supply-side discrimination arguing that men and women differ in their educational and occupational choices and that these differences explain wage differences. On the other hand, there is demand-side discrimination with its two manifestations, taste-based discrimination and statistical discrimination. With the former, employers indulge a taste for discrimination against women resulting in them preferably hiring men. This in turn leads to lower wages for women due to labour oversupply in occupations where employers do not discriminate against women. Statistical discrimination, however, results from the employer's inability to (perfectly) observe an applicant's true level of productivity. Without this knowledge, the employer will use observable indicators he believes to be correlated with productivity. With gender as such an indicator, the employer will offer lower wages to women compared to men if he believes women to be – on average – less productive than men.

In order to be paid in accordance with their true productivity, we argue that women can use a high academic degree such as a doctoral degrees to signal their true career-orientation to the employer and, hence, reduce demand-side and particularly statistical discrimination (i.e. differences in the valuation of male and female endowments by the labour market).

Thus, this chapter contributes, first, to the literature on educational signalling. In accordance with Spence's (1973) signalling theory, we argue that women can use doctoral degrees to gain higher wages and higher wage premiums than men, eventually.

Second, this chapter contributes to the vast literature on the gender wage gap. In contrast to other studies in gender wage gap literature, however, we do not focus on isolating the true size of discrimination in the labour market. Instead, our aim is to better understand the possibilities of discriminated groups, such as women, to overcome or at least reduce discrimination against themselves from a supply-side perspective.

Third, it contributes to the literature on gender differences in the educational wage premium. To the best of our knowledge, the studies closest to us are Braakmann (2008) and Waite (2017). Both studies investigate the effect of a doctoral degree on the unexplained part of the gender wage gap (demand-side discrimination). By pooling degree-holders and non-degree holders into one sample, they are able to quantify the discrimination reducing effect. In both studies, the effect is insignificant (or the discrimination is even increasing as in one specification in Braakmann (2008)). We argue that a possible reason for this finding is that the authors pool all major graduates in one sample. As the authors control for majors, they implicitly assume that the effect of doctoral degrees on the gender wage gap is independent of the major group. This is not what we expect. According to our argumentation we expect the discrimination reducing effect to be present in majors of mixed human capital, only. We therefore argue, that it is imperative to perform separate Oaxaca-Blinder decomposition for different forms of human capital (time-erodible, time-durable, and mixed). To the best of our knowledge, we are the first to provide such evidence.

5.3 The relationship between doctoral degrees and the gender wage gap

In what follows, we will argue that the doctoral degrees are signals of female career-orientation and as such help women to reduce the gender wage gap among graduates of mixed (heterogeneous) majors. To this aim, we will, first, differentiate between heterogeneous and homogeneous majors regarding the imparted human capital[113]. Then, we will explain the concept of statistical discrimination, the resulting gender wage gap, and how women can use

[113] Note that in line with human capital theory and the argumentation in Section 4.3, we still expect time-durable, time-erodible, and mixed majors to impart major-specific human capital that enhances productivity with the employer. Similarly, I argued that doctoral degrees enhance a graduate's productivity with an employer who is in need of research skills. Furthermore, due to its durability nature, individuals with certain work attitudes (e.g. career orientation) choose certain types of college majors (e.g. time-erodible majors), resulting in one's major choice also serving as a signal for certain work attributes. Depending on the context (as we will elaborate in this chapter) doctoral degrees can be signals of female career-orientation, too.

doctoral degrees to reduce these wage differences between men and women in heterogeneous majors. As before, we expect employers to be in need of certain skills. Hence, they will hire graduates of majors that impart the respective skills.

5.3.1 Homogenous and heterogeneous major groups

Section 4.3, claimed that majors differ with regard to the nature of imparted knowledge (e.g. communicative/caring and technical/analytical skills) and the durability of this knowledge (time-durable and time-erodible majors). Based on Kalmijn and Lippe (1997) and McDowell (1982), I grouped communicative/caring majors such as linguistics, cultural and social sciences into the time-durable major category, where knowledge and skills can still be productively put to use after some time and technical/analytical majors such as engineering and natural sciences into the time-erodible category, where knowledge has to be renewed constantly.

Furthermore, we expect family-oriented individuals to tend to choose time-durable majors precisely because these skills and knowledge do not erode over time and are of a rather general nature in the sense that they are more portable (i.e. transferable to other employers) (Ochsenfeld 2014). If knowledge does not erode over time and/or is easily transferable to other employers, a family-oriented person will not lose her knowledge during the time off or can switch to an employer who allows her to better link family and labour market work.

We see a family-oriented person as an individual whose first priority is family work, e.g. child rearing. This individual might choose to not work in order to commit to family work (for some time or altogether) or try to find a job that allows her to support her family financially but would not interfere with her family duties. This is why one might expect especially women to choose time-durable majors due to traditional gender roles and preferences for respective imparted skills (Leuze and Strauß 2009, p. 806). On a similar note, Leuze and Strauß (2016, p. 807) argue that women prefer occupation arrangements (e.g. part-time and telework) that allow them to combine family and household responsibilities.

A career-oriented individual, however, is a person whose first priority is labour market work and who finds self-fulfilment in such occupations. This does not necessarily imply that these individuals choose not to have children but to wish for successfully combining family and career without forgoing career opportunities.

In what follows, we will understand career orientation as a characteristic that employers prefer over family orientation. Hence, they will remunerate this favourable characteristic. Employers are interested in career-oriented employees because “turnover is costly for firms“ (Carter and Lynch 2004, p. 92). It takes time to find sufficiently qualified personnel, to train the new employee, and for the latter to become acquainted with the new tasks (Staw 1980, pp. 255–256). This is especially true for higher level or more complex occupations (Staw 1980, p. 255). Career-oriented individuals are committed to their careers and to the organisation, and will stay with the employer for a long time and are hence more productive. With career-oriented personnel, the employer is able to reduce costs which targets his profit-maximising objective.

We expect career-oriented individuals to predominantly choose time-erodible majors. As these majors impart comparably large parts of specific human capital (Blakemore and Low 1984, p. 159) that decays rapidly over time (McDowell 1982), there is the risk that one's knowledge becomes obsolete if it is not constantly refreshed. Due to this risk, time-erodible human capital is better paid than time-durable human capital (Ochsenfeld 2014, p. 4; Polachek 1978, pp. 500–501). An individual's expected returns on investment in time-erodible human capital, however, will only be higher than from an investment in time-durable human capital if she anticipates not to take a longer break from work and does plan to refresh her knowledge regularly. Hence, only career-oriented individuals will choose to invest in time-erodible human capital and hence study time-erodible majors. Family-oriented individuals, on the contrary, will opt for time-durable majors as they allow them to better align family and labour market work later on as argued above.

Consequently, we understand both major groups (time-durable and time-erodible majors) to be homogenous within themselves with regard to work attitudes, with time-durable majors chosen by family-oriented and time-erodible majors chosen by career-oriented people.

Furthermore, understanding time-durable and time-erodible majors as two (homogeneous) extremes of a spectrum of knowledge durability, there are also majors that are neither predominantly time-durable nor time-erodible but impart both elements of knowledge and skills. Such heterogeneous majors are business administration, economics, and law. Following the idea of work attitudes, we would expect these majors neither to be chosen by mainly family- nor career-oriented individuals, but both. Note that in this context, career orientation does not imply that these individuals do not thrive for high incomes. We rather understand career orientation as an opponent to family orientation, and as such reflecting an individual's wish to stay attached to the labour market rather than to sacrifice career ambitions for family work[114].

[114] We therefore deviate from Bredtmann and Otten 's (2014, p. 294) definition of career orientation, understanding "generating a high income" as an important part of career orientation.

Given the reasoning of individuals to choose time-erodible or time-durable majors, future employers might have a clear idea about the true work attitude of an individual who majored in one of these homogenous majors. Hence, the fact of having chosen either a time-erodible or time-durable major is a signal of career (or family) orientation in itself, fulfilling all of Spence's (1973) signalling requirements: College major choices are observable by the employer (e.g. in the form of certifications) and deliberately taken by the individual. As argued above, they inform the employer about relevant characteristics, i.e. career orientation (or the lack of career orientation that is family orientation). Furthermore, there is a negative cost relationship: The expected returns from attending a time-erodible major are lower for the family-oriented person than for the career-oriented, such that only the career-oriented person will choose time-erodible majors. For a career-oriented individual, on the contrary, the expected returns from attaining a time-erodible major are larger than from attaining a time-durable major. Hence, any risk-neutral career-oriented individual will choose a time-erodible major over a time-durable major. As long as individuals do not deviate from their decisions (that is time-durable majors are chosen by family-oriented individuals and time-erodible majors by career-oriented ones), employers will believe time-durable major graduates to be family-oriented and time-erodible major graduates to be career-oriented.

With regard to heterogeneous major graduates, however, employers might be uncertain about an applicant's true work attitudes as heterogeneous majors impart neither predominantly time-durable nor time-erodible human capital, but a combination of both which, in turn, attracts both career- and family-oriented individuals. Put differently, here the mere choice of studying such heterogeneous majors does not serve as a signal of career orientation.

5.3.2 Gender premium differences in heterogeneous majors

With uncertainty about the true work attitude of applicants as in the case of heterogeneous major graduates, employers might turn to other observable indicators that they believe to provide them with an idea about the true hidden characteristic. This leads to the concept of statistical discrimination. In the following, we will explain the phenomenon of statistical discrimination and how it explains wage differences between men and women.

5.3.2.1 Statistical discrimination and the gender wage gap

In line with the concept of statistical discrimination, we assume employers to be profit maximising and to have less knowledge about an individual's true endowments than the individual herself (Phelps 1972, p. 659). Moreover, it would be excessively costly for the employer to sufficiently learn about the individual's true endowments, so he uses the individual's gender as a proxy, instead (Arrow 1973, p. 24). Any employer will, therefore, discriminate against women if he believes women to be on average less favourably endowed than men (Arrow 1973, pp. 23–24; Phelps 1972, p. 659). As argued before, career orientation is such a favourable characteristic.

In line with Aigner and Cain (1977, p. 184), Arrow (1973, p. 25), and Phelps (1972, p. 660), we assume employers to have different expectations regarding the mean work attitude of men and women. Based on past experiences[115], employers believe men to be predominantly career-oriented (Schulze 2015, p. 600) while women are expected to be predominantly family-oriented (Fortin 2005, p. 147). This reflects the breadwinner idea where men are the main earner in the family, while women are mainly responsible for family work and therefore less attached to the labour market (Fortin 2005, p. 147). Thus, although a woman might attend the labour market in the beginning, she might step out of it for a longer period of time e.g. when she becomes a mother.

Without any further information on the woman's true work attitude, any rational risk-neutral employer will offer a wage that reflects the expected mean work attitude of all individuals within the respective gender group. As men are assumed to be – on average – more career-oriented, the employer will offer higher wages to a man than to a woman.

5.3.2.2 Doctoral degrees as signals of female career orientation

In what follows, we will now show how a career-oriented women who graduated in a heterogeneous field can use a doctoral degree to signal her true career orientation, reduce statistical discrimination, and thus, gender wage differences. We therefore argue that signals are context specific (Handy et al. 2010, p. 503) as it depends on the field of college major whether a doctoral degree is a signal of female career orientation and, hence, remunerated by the employer.

As discussed before, without any further information, employers might expect men to be predominately career-oriented while they expect women to be predominantly family-oriented. At the point of application, they will recognise a female applicant as a member of the female i.e. family-oriented group and will therefore offer a lower wage than to a male applicant.

In order to be paid according to her true level of career orientation, a career-oriented women needs to validly distinguish herself from the family-oriented ones. We argue that

[115] We want to stress the point that in accordance with Aigner and Cain (1977, p. 184), we assume that these believes about differences in mean career orientation are solely based on experiences and not on prejudices against women as employers who base their wages on false assumptions would not survive in a competitive labour market.

attaining a doctoral degree is one possibility to signal her career orientation. As with productivity (see Chapter 3), a doctoral degree is a valid signal for female career orientation. It is observable by the employer, informative with regard to one's career orientation and modifiable by the individual. Moreover, only those who anticipate to engage in the labour market in the future and plan to make a career expect to receive the returns on this educational investment. Hence, only the career-oriented women will pursue doctoral studies as family-oriented women anticipate to engage in family work with no or just little return on educational investments. Put differently, doctoral education imposes higher costs on the family-oriented women than on the career-oriented one (i.e. negative cost correlation). With only the career-oriented women attaining doctoral degrees, employers will be willing to remunerate these signals as they allow them to tell career- and family-oriented women apart.

Section 4.3 argues that while doctoral degrees are remunerated for (male and female) time-eroding major graduates, while they are not for time-durable major graduates, we so far did not comment on the effect of doctoral degrees on wages of mixed-major graduates. As these majors impart both time-durable and time-erodible knowledge, it depends on the respective composition of a certain major: The larger the part of time-erodible knowledge, the more important are research skills to keep the respective knowledge up-to-date and the more willing are employers to remunerate these research skills and therefore doctoral degrees.

For women who majored in heterogeneous majors, however, we expect an additional signalling function of doctoral degrees. In contrast to men who are already assumed to be career-oriented, the doctorate allows career-oriented women to distinguish themselves from the family-oriented ones. Men, on the contrary, are already assumed to be career-oriented (even without a doctoral degree). Attaining a doctoral degree has, therefore, no additional signalling function for them. In other words, while gathering a doctoral degree might increase male wages due to increased productivity, gathering a doctoral degree as a woman signals career orientation on top[116].

Due to this additional signalling function of doctoral degrees for women, we assume the doctoral wage premium to be larger for women than for men in heterogeneous majors. Consequently, we believe that doctoral degrees in heterogeneous majors enable women to reduce the gender wage gap (i.e. statistical discrimination).

[116] Additionally, while due to cultural conditions the Ph.D. might be more expected from men then from women, pursuing a Ph.D. degree as a woman might even signal additional commitment. For similar considerations see Montgomery and Powell (2003) who look at the effect of pursuing a MBA for women in order to reduce the gender wage gap.

Within homogeneous majors, however, we expect no additional signalling function of doctoral degrees for women, as they, as well as their male counterparts, already signalled their work attitudes through their choice of college major. This argumentation leads to the following hypothesis:

H 3: The doctoral wage premium among heterogeneous major graduates is higher for women than for men. Doctoral degrees therefore help women to reduce the gender wage gap in these majors. Among homogeneous major graduates, there is no gender difference in doctoral wage premiums.

5.4 Empirical evidence on the relationship between doctoral degrees and gender wage gap

5.4.1 Sample

As in Section 4.4, the empirical analysis in this study uses data from the DZHW Graduate Panel of the examination cohort 2005 (Baillet et al. 2016). Again, we use individual information drawn from the first and second wave of the survey as well as sample weights provided by the DZHW to adjust the survey sample to the underlying population. All further results are adjusted accordingly.

Among the 11,789 individuals sampled, we focus on the 4,352 university graduates who attained one of the following college degrees: Diplom or Magister. Again, we excluded Diplom graduates from universities of applied sciences (3,554 individuals) and bachelor graduates (1,622 individuals) as these are not immediately entitled to attain doctoral degrees. Further, we also remove those graduates from our sample who gained a *Staatsexamen* (state examination degree, 2,204 individuals). Not only differ Diplom and Magister graduates from those with state examination degrees with regard to their point of labour market entry as discussed in Section 4.4.1.2; also the information asymmetry between the graduate and the potential employer might be reduced for the latter due to the compulsory traineeship. Hence, further indicators regarding one's work attitudes are less important in studies that award state examination degrees. As before, we also excluded graduates of studies with church, artistic, and other degrees (57 individuals).

As in Section 4.4.1.2, we drop individuals that report very low gross wages (below 1,000 per month) as well as those with wages above 15,000 € per month (Braakmann 2013). Hubbard (2011) points out that such top coding causes the difference in gender wage premiums to be overestimated because those who report those very large values are predominantly men.

We, therefore, run a robustness check using all wage observations (Table 38). The results regarding the variable of interest do not change qualitatively.

Due to missing responses (in total or on wages) in the second wave (i.e. five to six years after graduation), or missing values in the variables used in the full model specification, our sample arrives at 1,918 observations.

5.4.2 Central variables

As in Section 4.4.2, the natural logarithm of the gross monthly total income reported five to six years after graduation (i.e. the second wave of the survey) is used as a proxy for the dependent variable *wage (ln).* It includes additional compensation components such as variable payments or a 13th or 14th month of pay.

The independent variables of interest are the dummy variables *female* and *doctoral degree*. The dummy variable female is 1 if a person is female and 0 otherwise. Within the sample 47.19 percent of the individuals are women. The variable doctoral degree indicates whether an individual has completed her doctoral studies within five to six years after graduation[117]. In total, 14.95 percent of the individuals in the sample attained a doctoral degree by the second survey wave. Men attain doctoral degrees more often than women do[118] (17.97 percent of men and 11.58 percent of women attained doctoral degrees). In order to test whether there is a difference in the doctoral wage premium of men and women, we use an interaction of the variables female and doctoral degree within a single equation regression.

5.4.3 Control variables

Literature suggest that there are several factors we should account for when investigating the gender wage gap. In the following, we will group these factors into individual, educational, and occupational characteristics. Section 4.4.3 already introduced these factors as determinants of wages. This section, however, will focus on explaining why we should expect these factors to influence the wage gap between men and women as they affect male and female wages differently and, hence, should be controlled for in gender wage gap regressions. As this study also includes graduates of majors that impart mixed human capital[119], the sample is larger than the sample described in Section 4.4.

[117] Individuals who are still within their doctoral studies are assigned to the group of those who have not yet gained a degree.

[118] A t-test confirms statistical difference in doctoral degree possession of men and women (coef. = 0.064, linearized std. err. = 0.019).

[119] Business administration, economics, as well as administrative sciences and economic law

5.4.3.1 Individual characteristics

Among the individual characteristics, we control for one's *marital status*. As before, we distinguish between individuals without partners, ones with permanent partners, and married individuals. Within the sample 19.07 percent were without partner at the time of the second wave, while 40.38 percent were in a steady partnership. Further 40.55 percent were married. Due to the traditional roles performed by men and women, and in line with Becker (1985), Killewald and Gough (2013), and Reimer and Schröder (2006, p. 237), we believe predominantly women to engage in household work within the family. Hence, regardless of their marital status, we expect women to take responsibility of household work. Thus, while married women might not earn (much) more than single women[120], as they are still in charge of (a large part of) household work, married men might gain higher wages than single men as they specialise in labour market work while their wives specialise in household work[121].

We use a dummy variable, which is 1 if the individual has *at least one child* five to six years after graduation and 0 otherwise. Within the sample, 29.72 percent have at least one child at the time of the second wave. We expect especially women to be in charge of child care. As they have to interrupt their work life for at least a little while during maternity leave anyways, mothers rather than fathers will focus on family instead of career duties. Thus, we expect the negative effect of having children on wages to be larger for women than for men.

In line with Barron (2003) and Janssen et al. (2015), we further assume men in contrast to women to better negotiate with employers. A possible reason is that women compare themselves with other (low paid) women and hence do not expect to earn higher wages (Auspurg et al. 2017). Hence, we might be able to explain some of the differences in wages between men and women by controlling for wage negotiation affinities. As there is no question in the survey that explicitly asks for someone's negotiation skills, we use one's self-assessment of whether one is *adequately employed regarding their academic qualifications.* The dummy variable is 1 if someone believes to be (to some degree) adequately employed and 0 otherwise[122]. Within the sample 85.94 percent believe to be adequately employed.

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[120] This expected result is contrary to Becker (1985, p. 54) who assumes "earnings of single women to exceed those of married women".

[121] Killewald and Gough (2013) even expect a marriage wage penalty for women. However, their empirical findings support the idea that, while both men and women gain marriage wage premiums, the male wage premium is significantly larger.

[122] In the survey, employment adequacy is measured on a 5-point-scale (1: "very much", 5: "not at all") (DZHW 2005). We grouped 1, 2 and 3 as qualification adequately employed and 4 and 5 as not adequately employed.

5.4.3.2 Educational characteristics

To control for one's ability, we use one's *grade of university degree*. As mentioned before, this allows us to further isolate the effect of doctoral degrees on wages as it enables us to control for the ability of doctoral studies to attract the more productive individuals[123]. Montgomery and Powell (2003, pp. 396–397) argue that this is important as lower gender wage gaps at higher educational levels might result from higher degrees of motivation, ambition, and intelligence, all being merely impossible to measure and therefore possible discrimination effect reducers which we may mistakenly ascribe to the degree effect. Additionally, assuming that only the best students will attend doctoral studies, it allows us to control for self-selection into doctoral programmes, Montgomery and Powell (2003, p. 401) argue to exist. Moreover, as Montgomery and Powell (2003) point out, due to cultural conditions it might be more expected for men to do doctoral studies than for equally productive women. Hence, the average marginal productivity of male doctorates might be lower than the average marginal productivity of female doctorates. Thus, without controlling for ability and, therefore, this potential self-selection, we might mistakenly understand the additional doctoral degree effect on wages for women as an additional signalling effect rather than higher levels of productivity.

We use three categories of university grade: "very good" if the individual has a final grade of 1.5 or better, "good" if one's final grade is worse than 1.5 but better than or equal to 2.5, and "satisfying or sufficient" if one's final grade is worse than 2.5 but equal or better than 4.0. Within the sample 36.59 percent finished their university degree with "very good" grades, 53.62 percent achieved "good" marks and 9.79 percent obtained "satisfying or sufficient" results. As with our variable of interest, we might expect the positive effects of good grades on wages to be larger for women than for men. We reason that while good grades might signal higher productivity for men, it might signal higher commitment, i.e. career-orientation, for women on top.

To test for the effect of a doctoral degree on wages separately within different manifestations of human capital as hypothesised in Section 5.3, we use three different subsamples. As introduced in Section 4.4.1.2, we distinguish between university graduates of time-erodible majors[124], graduates of time-durable majors[125], and university graduates of mixed

[123] For a similar idea regarding the relationship between one's ability and choice of major see O'Leary and Sloane (2005, p. 77).

[124] University graduates who majored in agriculture and nutritional sciences, mathematics, natural sciences, engineering, or sports and health sciences.

[125] University graduates who majored in the fields of arts, humanities, theology, linguistic and cultural sciences, social sciences, or educational sciences.

majors (e.g. graduates of business administration, economics, and administrative sciences and economic law). As Blakemore and Low (1984), Ochsenfeld (2014), and Polachek (1978) before, we argue that individuals who anticipate less labour market attachment in the future will prefer time-durable over time-erodible human capital and will, therefore, prefer a major within the first group over a major within the second group. Furthermore, we believe the third group of majors to impart neither predominantly time-durable nor time-erodible human capital but a combination of both. In line with this idea, we refer to time-durable or time-erodible majors as homogeneous majors with regard to imparted human capital, on the one hand, and to the mixed major group as heterogeneous majors, on the other hand. Within our sample, 36.56 percent of the university graduates majored in time-durable majors, 39.26 percent in time-erodible majors, and 24.18 percent in mixed majors.

Furthermore, we also control for one's *university major* (in the complete sample as well as within each major group subsample) to control for different manifestations of knowledge durability (McDowell 1982) within different majors. We assign each of the 204 different majors registered in the dataset to one of 14 major categories (fractions of students in the sample in parentheses, categorisation follows in large parts Destatis (2016b, pp. 454–456)): arts (5.90 percent), humanities (2.99 percent), theology (0.99 percent), linguistic and cultural sciences (8.51 percent), social sciences (12.95 percent), educational sciences (5.22 percent), business administration (17.48 percent), economics (5.00 percent), administrative sciences and economic law (1.71 percent), agricultural and nutritional sciences (2.21 percent), mathematics (2.05 percent), natural sciences (11.89 percent), engineering (20.83 percent), and sports and health sciences (2.28 percent). We do not create more detailed major groups (e.g. separate major groups for agricultural and nutritional sciences) as these groups would consist of only a small number of observation. Furthermore, according to Weinberger (1998), controlling for more detailed major categories does not increase explanatory power. Using information from US bachelor graduates in 1985, she finds that while carefully increasing the specification of quality and type of education increases the explained part of the gender wage gap[126], increasing the specification further by introducing 246 college major dummy variables has only little effect on the gender dummy variable. She concludes that within broad college majors, women do not choose the less remunerated ones (Weinberger 1998, p. 79).

[126] Using an indicator variable indicating whether an individual is female, its coefficient is smaller, almost half as large when controlling for twelve broad college majors. The remaining gender gap is still significant (Weinberger 1998).

5.4.3.3 Occupational characteristics

Again, we control for one's *work experience* (in months), defining employment, self-employment, service contracts, casual work, and internships to reflect employment relationships where work experience is accumulated. Within the sample, individuals have accumulated on average 60.83 months (roughly five years) of work experience by the second wave. We expect former job experience to further reduce information asymmetry between the employer and the employee. Either because the employer was able to observe the individual's true productivity first hand or because of respective documents (e.g. job references) issued by other employers (whose assessment he trusts). These signals might help especially women to reduce discrimination and, therefore, to receive higher wages.

As before, we need to control for one's *working hours*, which we define as one's average weekly working hours spent in the main occupation and possible secondary employments. In the dataset, individuals work on average 43.97 hours per week. Triventi (2013, p. 567) and Leuze and Strauß (2016, p. 807) argue that women are paid less because they predominantly engage in flexible work arrangements that allow them to combine family and work responsibilities, hence, preferring, e.g. part-time work. Thus, one might argue that there is an additional signalling effect to working hours for women regarding productivity.

We further control for one's *form of employment*, i.e. whether someone is self-employed, employed based on a fixed-term contract (incl. apprenticeship and service contract), or has an unrestricted contract. The variable is operationalised as before. The majority of individuals in the sample is employed based on an unrestricted contract (64.90 percent). 27.83 percent are employed based on a fixed-term contracts and 7.27 percent are self-employed. We expect women to be more often employed on non-permanent contracts. Fixed-term contracts allow employers to evaluate the employee's true productivity. In line with discrimination theory (Arrow 1973; Phelps 1972), one might argue that employers are less sure about the true characteristics of women compared to men. They might, therefore, offer fixed-term contracts particularly to women in order to assess their true productivity. As argued before, wages differ across different forms of employment. Hence, differences in the gender distribution across the different employment forms might explain at least some fraction of the overall gender wage gap.

We further control whether someone is employed in the *public sector* or whether her wage is adjusted to the remuneration in the public sector. As public sector employers should act as "model employer[s]" (Melly 2005, p. 506) and because wages in the public sector are bound to collective agreements, we might expect to observe less discrimination against women compared to the private sector. We, therefore, use a dummy variable that is 1 if someone is working in the public sector or payed accordingly, and 0 otherwise. 33.45 percent of the wages in the sample are paid by or according to public sector terms.

Moreover, we control whether someone works in a subsidiary that is part of a corporate structure. The variable is 1 if the individual is employed in such a *large-scale company* and 0 otherwise. Among the sampled individuals 34.69 percent are employed in large-scale companies. Large-scale enterprises are more often subject to public awareness than small-scale firms (Mahadeo et al. 2011, p. 549). They might, therefore, feel the pressure to install non-discrimination policies resulting in lower wage gaps between men and women in equal positions. Moreover, the likelihood of similar or equal positions within the same enterprise is higher in larger firms. Remunerating these positions differently is more likely to attract attention and to cause negative publicity both within the firm as well as in public. We, therefore, expect wage gaps in large-scale enterprises to be smaller than in small-scale companies.

Controlling for *industry*, we distinguish between (i) predominantly primary[127] and manufacturing[128] sector industries, (ii) public sector industries[129], and (iii) services. Within the sample 18.37 percent of the individuals are engaged in the primary or manufacturing sector, 34.48 percent work in public sector industries and 47.15 percent work in the service sector. Due to their interest in time-durable human capital and communicative and caring occupations, we expect women to predominantly work in the public and service sector industries which are paid less compared to, e.g. manufacturing industries. Hence, we expect this self-selection into industries to explain some part of the gender wage gap.

Finally, we control for one's *job location*, distinguishing between East-Germany, West-Germany, and abroad (European and non-European countries). The operationalisation is performed as in Section 4.4.3.3 , resulting in 19.15 percent of the individuals working in East-Germany, 73.99 percent in West-Germany, and 6.86 percent out of Germany. Given the cultural background of East-Germany rooting in the times of the German Democratic Republic (GDR), we might expect male and female wages to be more aligned in East- than in West-Germany. While in the GDR, working full-time as a wife and mother was the norm, in West-Germany wives and mothers specialised in household work, choosing not to engage in the labour market (Kreyenfeld and Geisler 2006, p. 333). Culturally, these roles of women might

[127] Agriculture, fishing, mining, energy and water management
[128] Manufacturing, industry, and construction
[129] Public administrations and not-for-profit organisations as well as industries in the field of education, research, and culture. Compared to primary, manufacturing and service sector industries, we believe these industries to have predominantly socio-cultural responsibilities.

have manifested in the minds of today's societies in East- and West-Germany, reflecting on West-German employers to be more sceptical about female career orientation than East-German employers.

5.4.4 Descriptive statistics

Table 20 and Table 21 present the descriptive statistics of the variables discussed above separately for men and women for the complete sample (Table 20) and for the three major groups (Table 21).

There are significant gaps between the wages of men and women both in total and in all three subsamples. According to Table 20, men earn on average 999.67 € more than women in the sample. This is in line with other studies that used similar datasets (Braakmann 2013, 2008). Furthermore, men attain significantly more doctoral degrees than women: 18.0 percent of the male and 11.6 percent of the female university graduates sampled attained a doctorate.

Table 20: Descriptive statistics and t-test for differences between men and women (complete sample)

	Women[a]		Men[a]		Difference[b]	
Wage	3264.985	(1465.545)	4264.652	(1769.174)	999.668***	(88.833)
(ln) wage	8.000	(0.430)	8.272	(0.430)	0.272***	(0.024)
Doctoral degree	0.116	(0.320)	0.180	(0.384)	0.064***	(0.019)
Marital status						
Without partner	0.178	(0.382)	0.202	(0.402)	0.025	(0.021)
With partner	0.436	(0.496)	0.375	(0.484)	-0.061**	(0.026)
Married	0.386	(0.487)	0.423	(0.494)	0.036	(0.026)
At least one child	0.296	(0.457)	0.299	(0.458)	0.003	(0.024)
Qualification adequate employment	0.828	(0.378)	0.888	(0.316)	0.060***	(0.020)
Final college grade						
Very good	0.388	(0.487)	0.347	(0.476)	-0.041	(0.026)
Good	0.527	(0.499)	0.544	(0.498)	0.017	(0.027)
Satisfying or sufficient	0.085	(0.279)	0.109	(0.312)	0.024	(0.016)
College major						
Arts	0.073	(0.261)	0.046	(0.210)	-0.027	(0.017)
Humanities	0.032	(0.175)	0.028	(0.166)	-0.003	(0.008)
Theology	0.007	(0.083)	0.012	(0.111)	0.006	(0.004)
Linguistics and cultural sciences	0.148	(0.356)	0.029	(0.167)	-0.120***	(0.016)
Education sciences	0.091	(0.288)	0.017	(0.131)	-0.074***	(0.011)
Social sciences	0.177	(0.382)	0.087	(0.282)	-0.091***	(0.016)
Sports and health sciences	0.022	(0.148)	0.023	(0.150)	0.001	(0.012)
Business admin	0.166	(0.372)	0.183	(0.387)	0.017	(0.022)
Economics	0.022	(0.146)	0.075	(0.264)	0.054***	(0.011)
Economic law and administrative sciences	0.016	(0.127)	0.018	(0.132)	0.001	(0.006)
Agriculture and nutrition	0.027	(0.162)	0.018	(0.132)	-0.009	(0.006)
Mathematics	0.014	(0.119)	0.026	(0.159)	0.012	(0.008)
Natural sciences	0.118	(0.323)	0.120	(0.325)	0.002	(0.016)
Engineering	0.086	(0.280)	0.318	(0.466)	0.232***	(0.019)
Total work experience in months	58.312	(12.823)	63.072	(11.025)	4.760***	(0.646)
Total working hours per week	41.916	(9.784)	45.803	(8.548)	3.887***	(0.502)

(continued)

Table 20 *(continued)*

	Women[a]		Men[a]		Difference[b]	
Form of employment						
unrestricted contract	0.606	(0.489)	0.687	(0.464)	0.081***	(0.026)
fixed-term contract	0.325	(0.469)	0.237	(0.425)	-0.088***	(0.024)
self-employed	0.069	(0.253)	0.076	(0.265)	0.007	(0.015)
Public sector	0.393	(0.489)	0.282	(0.450)	-0.111***	(0.025)
Working in large-scale enterprise	0.303	(0.460)	0.386	(0.487)	0.082***	(0.026)
Industry						
primary or manufacturing sector	0.126	(0.332)	0.235	(0.424)	0.109***	(0.019)
public sector industry	0.392	(0.489)	0.302	(0.459)	-0.090***	(0.025)
services	0.481	(0.500)	0.463	(0.499)	-0.018	(0.027)
Job location						
East-Germany	0.208	(0.406)	0.177	(0.382)	-0.031	(0.020)
West-Germany	0.720	(0.449)	0.758	(0.429)	0.039*	(0.023)
abroad	0.072	(0.259)	0.065	(0.247)	-0.007	(0.013)
Observations	1041		877		1918	

[a] Means with standard deviations in parentheses
[b] * p<0.10, ** p<0.05, *** p<0.01; linearized standard errors in parentheses
Source: Own calculations based on DZHW Graduate Panel (2005).

Regarding the individual characteristics in the dataset, we find no difference between men and women in having children or being married, i.e. women do not postpone their family-founding wishes (getting married and having children) compared to men. These results differ from the results in Braakmann (2013) who use the examination cohort of 2001. A possible explanation might be that Braakmann (2013) uses all graduates (university and university of applied sciences) while we focused on university graduates with Diplom and Magister. Our sample might, therefore, be more homogenous with regard to individual characteristics. We do, however, find women to be more often in stable relationships than men five to six years after graduation. This suggests that women try to implement future family structures.

Men and women in our sample differ with regard to the job adequacy of their academic qualifications. Men more often work in occupations that suit their qualifications than women five to six years after graduation. This indicates that women do worse in job and wage negotiations than men do.

Among educational characteristics, men and women differ with regard to their choice of major: While women prefer linguistics, cultural, educational, and social sciences compared to men, men prefer economics and engineering. This fits in large parts what we might expect based on Morgan (2008), Ochsenfeld (2014), and Schulze (2015).

With regard to the occupational characteristics, we observe many differences between men and women: Men work longer hours, have more work experience, and are more often employed based on an unrestricted contract than women. Moreover, they more often work for large-scale companies and in primary and manufacturing sector industries than women. Women, on the other hand, work more often in the public sector as well as in public sector industries. They are also more often employed on fixed-term contracts than men. This hints to the argument that employers are less sure about the work attitudes of women and therefore hire them on fixed-term contracts where it is easier to lay them off in the future. Furthermore, in West-Germany the labour market participation of men is higher than that of women. This supports the idea that in West-Germany the traditional gender roles still hold.

Where applicable, these results fit the results in Braakmann (2013). Furthermore, these descriptive results suggest, in line with Joy (2003), that it is imperative to control for occupational characteristics when investigating the gender wage gap, as we observe large differences between men and women regarding these factors.

Moreover, we argued that we should use separate samples for the three major groups of time-durable, time-erodible, and mixed major graduates. Table 21 depicts the descriptive statistics of men and women in these three subsamples.

Table 21: Descriptive statistics and t-tests for differences between men and women in different major groups

	Time-durable majors			Time-erodible majors			Mixed majors		
	Women[a]	Men[a]	Difference[b]	Women[a]	Men[a]	Difference[b]	Women[a]	Men[a]	Difference[b]
Wage	2835.242	3190.910	355.668**	3411.122	4210.262	799.140***	4187.705	5220.139	1032.434***
	(1264.454)	(1426.588)	(137.121)	(1459.601)	(1473.581)	(114.332)	(1501.675)	(1985.232)	(197.447)
ln wage	7.867	7.973	0.106**	8.054	8.281	0.227***	8.274	8.494	0.220***
	(0.406)	(0.446)	(0.045)	(0.405)	(0.375)	(0.031)	(0.375)	(0.368)	(0.042)
Doctoral degree	0.054	0.121	0.067*	0.290	0.267	-0.023	0.048	0.067	0.019
	(0.226)	(0.327)	(0.036)	(0.454)	(0.443)	(0.036)	(0.215)	(0.251)	(0.025)
Marital status									
Without partner	0.204	0.204	0.0001	0.164	0.204	0.041	0.127	0.198	0.071*
	(0.403)	(0.404)	(0.042)	(0.370)	(0.404)	(0.030)	(0.334)	(0.399)	(0.042)
With partner	0.411	0.381	-0.031	0.482	0.381	-0.101**	0.441	0.359	-0.081
	(0.493)	(0.487)	(0.049)	(0.500)	(0.486)	(0.039)	(0.498)	(0.481)	(0.056)
Married	0.384	0.415	0.031	0.354	0.415	0.061	0.433	0.443	0.010
	(0.487)	(0.494)	(0.050)	(0.479)	(0.493)	(0.039)	(0.497)	(0.498)	(0.057)
At least one child	0.300	0.314	0.014	0.280	0.286	0.006	0.304	0.309	0.005
	(0.459)	(0.465)	(0.045)	(0.450)	(0.452)	(0.035)	(0.461)	(0.463)	(0.053)
Qualification adequate	0.771	0.818	0.047	0.899	0.908	0.008	0.880	0.907	0.027
employment	(0.420)	(0.387)	(0.041)	(0.301)	(0.290)	(0.024)	(0.326)	(0.291)	(0.036)
Final college grade									
Very good	0.464	0.457	-0.008	0.423	0.424	0.001	0.141	0.116	-0.025
	(0.499)	(0.499)	(0.050)	(0.495)	(0.495)	(0.039)	(0.350)	(0.321)	(0.036)
Good	0.485	0.456	-0.029	0.516	0.501	-0.015	0.652	0.693	0.041
	(0.500)	(0.499)	(0.051)	(0.500)	(0.501)	(0.040)	(0.478)	(0.463)	(0.054)
Satisfying or	0.051	0.087	0.036	0.061	0.074	0.014	0.207	0.191	-0.015
sufficient	(0.220)	(0.282)	(0.024)	(0.239)	(0.262)	(0.022)	(0.406)	(0.394)	(0.047)

(continued)

Table 21 *(continued)*

	Time-durable majors			Time-erodible majors			Mixed majors		
	Women[a]	Men[a]	Difference[b]	Women[a]	Men[a]	Difference[b]	Women[a]	Men[a]	Difference[b]
College major									
Arts	0.139	0.210	0.072						
	(0.346)	(0.409)	(0.051)						
Humanities	0.060	0.129	0.069**						
	(0.237)	(0.336)	(0.029)						
Theology	0.013	0.057	0.044***						
	(0.114)	(0.232)	(0.016)						
Linguistics and	0.281	0.130	-0.150***						
cultural sciences	(0.450)	(0.337)	(0.038)						
Educational sciences	0.172	0.079	-0.093***						
	(0.378)	(0.271)	(0.027)						
Social sciences	0.336	0.395	0.059						
	(0.473)	(0.490)	(0.047)						
Sports and health				0.084	0.046	-0.038			
sciences				(0.278)	(0.209)	(0.028)			
Agriculture and				0.101	0.035	-0.065***			
nutritional sciences				(0.301)	(0.185)	(0.017)			
Mathematics				0.053	0.052	-0.002			
				(0.225)	(0.221)	(0.019)			
Natural sciences				0.441	0.237	-0.204***			
				(0.497)	(0.426)	(0.037)			
Engineering				0.321	0.630	0.309***			
				(0.467)	(0.483)	(0.038)			
Business							0.813	0.663	-0.150***
administration							(0.391)	(0.474)	(0.047)
Economics							0.106	0.273	0.167***
							(0.309)	(0.447)	(0.041)
Admin. sciences and							0.081	0.064	-0.017
economic law							(0.273)	(0.245)	(0.027)
Total work experience in	57.149	58.515	1.366	59.059	64.258	5.199***	60.347	64.534	4.188***
months	(13.005)	(14.176)	(1.370)	(13.009)	(9.578)	(0.956)	(11.793)	(9.626)	(1.257)

(continued)

Table 21 *(continued)*

	Time-durable majors			Time-erodible majors			Mixed majors		
	Women[a]	Men[a]	Difference[b]	Women[a]	Men[a]	Difference[b]	Women[a]	Men[a]	Difference[b]
Total working hours per	40.254	44.351	4.097***	42.766	45.263	2.497***	45.111	47.947	2.837***
week	(10.409)	(9.764)	(1.043)	(8.378)	(7.913)	(0.630)	(8.887)	(8.264)	(0.977)
Form of employment									
Unrestricted contract	0.545	0.572	0.027	0.564	0.646	0.082**	0.821	0.854	0.033
	(0.498)	(0.496)	(0.051)	(0.497)	(0.479)	(0.039)	(0.384)	(0.354)	(0.044)
Fixed-term contract	0.356	0.272	-0.084*	0.403	0.298	-0.105***	0.142	0.097	-0.046
	(0.479)	(0.446)	(0.045)	(0.491)	(0.458)	(0.038)	(0.350)	(0.296)	(0.037)
Self-employed	0.100	0.156	0.057	0.033	0.056	0.023	0.036	0.049	0.013
	(0.300)	(0.364)	(0.039)	(0.179)	(0.230)	(0.018)	(0.188)	(0.217)	(0.024)
Public sector	0.441	0.387	-0.054	0.388	0.302	-0.086**	0.275	0.162	-0.113**
	(0.497)	(0.488)	(0.049)	(0.488)	(0.460)	(0.037)	(0.448)	(0.369)	(0.047)
Working in large-scale	0.246	0.236	-0.010	0.323	0.374	0.051	0.426	0.527	0.101*
enterprise	(0.431)	(0.426)	(0.045)	(0.468)	(0.484)	(0.038)	(0.496)	(0.500)	(0.057)
Industry									
Primary or	0.046	0.037	-0.008	0.212	0.284	0.072**	0.223	0.303	0.081
manufacturing sector	(0.209)	(0.190)	(0.017)	(0.409)	(0.451)	(0.032)	(0.417)	(0.461)	(0.049)
Public sector industry	0.453	0.485	0.032	0.414	0.300	-0.114***	0.207	0.161	-0.046
	(0.498)	(0.501)	(0.051)	(0.493)	(0.459)	(0.038)	(0.407)	(0.368)	(0.044)
Services	0.501	0.478	-0.023	0.374	0.416	0.042	0.570	0.536	-0.034
	(0.500)	(0.501)	(0.051)	(0.485)	(0.493)	(0.039)	(0.497)	(0.500)	(0.057)
Job location									
East-Germany	0.230	0.212	-0.018	0.195	0.175	-0.020	0.168	0.153	-0.016
	(0.421)	(0.410)	(0.040)	(0.396)	(0.380)	(0.028)	(0.375)	(0.360)	(0.038)
West-Germany	0.727	0.752	0.024	0.685	0.749	0.064*	0.744	0.779	0.035
	(0.446)	(0.433)	(0.044)	(0.465)	(0.434)	(0.034)	(0.438)	(0.416)	(0.046)
Abroad	0.042	0.036	-0.007	0.121	0.076	-0.044*	0.088	0.068	-0.019
	(0.202)	(0.186)	(0.023)	(0.326)	(0.266)	(0.023)	(0.284)	(0.253)	(0.031)
Observations	508	189	697	363	480	843	170	208	378

[a] Means with standard deviations in parentheses

[b] * p<0.10, ** p<0.05, *** p<0.01; linearized standard errors in parentheses

Source: Own calculations based on DZHW Graduate Panel (2005).

First, men earn significantly more than women in all three subsamples. Second, while there are still various factors in which men and women differ within these subsamples, their characteristics are more alike (especially regarding individual characteristics). This supports the common idea that gender wage differences are to a large part caused by gender differences in occupational and educational choices (e.g. Anker (1997), Braakmann (2013), Joy (2003), Machin and Puhani (2003), McDonald and Thornton (2007), and Morgan (2008)).

While men and women in the complete sample differ with regard to nearly every occupational factor, they are more alike within the three subsamples. Here, gender differences are most severe among the time-erodible major graduates.

We still observe that men and women differ with regard to their college major choices in all three subsamples. Note that knowledge durability is not discrete but continuous. Although the three major groups formed in this study are similar with regard to knowledge durability, there is still at least some variability regarding knowledge decay rates within these major groups (although to a lesser degree). As we can see from Table 21, within major groups, men tend to prefer majors that one would expect to be comparatively more time-erodible (e.g. economics and engineering) while women opt for comparably more time-durable majors (e.g. agriculture and nutritional sciences, linguistics and cultural sciences)[130]. Interestingly, only in time-durable majors, men hold more doctoral degrees than women. With regard to the other two major groups, there is no significant difference. This could suggest that in majors that signal family orientation, men might use doctoral degrees as a signal of their career orientation. However, wage analyses in the following do not support this idea.

5.4.5 Methodological approach

Within the econometric literature on the gender wage gap, there are two frequently used methods to isolate the demand-side discrimination effect: (i) estimation of a single equation multiple linear regression including a gender dummy variable (e.g. Wooldridge 2016, p. 207) and (ii) decomposition methods such as Oaxaca-Blinder decomposition (Blinder 1973; Oaxaca 1973) that are based on separate equation multiple linear regressions for both gender groups.

Due to its simplicity, estimating single equation models that pool male and female observations and use a female dummy in order to measure the unexplained part of the gender wage gap “is the most commonly-used method” (Toutkoushian and Conley 2005, p. 17). Using models with a gender dummy variable implicitly assumes that all coefficients of the regressors

[130] Not all gender differences between majors within major groups, however, can be explained with knowledge durability. In theology, for example, high male rates might be due to persistent gender roles in the church.

in the model are equal for men and women. In this case, all discrimination is assigned to the gender coefficient, which therefore reflects the unexplained part of the gender wage gap (Elder et al. 2010, p. 285),

$$y_i = \beta_0 + \beta_F * female_i + \sum_{k=1}^{K} X_{k,i}\beta_k + \varepsilon_i, \tag{35}$$

with y as (ln) wage, female as gender dummy variable, and X as a vector of regressors (e.g. doctoral education) controlling for K variables besides gender (female), β for the coefficients and ε for the error term. Graphically, this means that male and female wage regression areas are parallel and differ only with regard to their intersection with the vertical axis.

Within the theoretical part of this chapter, we argued that we assume returns on doctoral education to differ between men and women in heterogeneous majors. We are, therefore, not interested in isolating the demand-side discrimination effect as thoroughly as possible but – assuming that demand-side discrimination exists – to investigate whether doctoral degrees help to reduce this discrimination.

One possibility to embed this idea econometrically is to introduce an interaction between female and doctoral degree to estimate the simultaneous effect of being female and having a doctoral degree. Hence,

$$y_i = \beta_0 + \beta_F * female_i + \beta_{Ph.D.} * Ph.D._i + \beta_I * female_i * Ph.D._i + \sum_{k=2}^{K} X_{k,i}\beta_k + \varepsilon_i, \tag{36}$$

with Ph.D. as a dummy variable that is 1 if the individual has a doctoral degree and 0 otherwise.

Thus, male and female wage regression areas do not only differ with regard to their intersection with the vertical axis but also with regard to their slope representing the effect of doctoral education on wages. Within the regression equation, the coefficient of the interaction, β_I, stands for the gender difference in the effect of doctoral degrees on wages. Regarding the effect of doctoral degrees on wages for men (M), we observe

$$\left.\frac{\partial y}{\partial Ph.D.}\right|_M = \beta_{Ph.D.}. \tag{37}$$

Hence, the effect of doctoral degrees on wages for men is represented by the doctoral coefficient alone, while the effect of doctoral degrees on wages for women (F) includes the interaction coefficient,

$$\left.\frac{\partial y}{\partial \text{Ph.D.}}\right|_F = \beta_{\text{Ph.D.}} + \beta_I. \tag{38}$$

A single equation regression model with interaction as in (36) is commonly used within the treatment literature in order to examine the effect of a certain treatment (e.g. policy change) on a group of observations exposed to the treatment (treatment group) in contrast to those not exposed to the treatment (control group) and, thus, is often referred to as treatment model (Wooldridge 2016, p. 210).

In the gender wage gap setting, as in many econometric applications, however, we assume both groups (i.e. men and women) to be affected by the treatment and to differ with regard to the size of the treatment effect. Furthermore, in line with demand-side discrimination literature, we assume the labour market to differently value endowments of men and women beyond the doctoral degree (i.e. treatment). That is we expect not only the doctoral degree coefficient to vary between men and women but also the coefficients of other endowments. Moreover, in line with supply-based discrimination arguments, we expect men and women to differ with regard to their mean endowments as shown in the descriptive statistics.

Although the model specification in (36) allows wage regressions of men and women to differ with regard to the wage effect of doctoral degrees, it assumes equal effects for both groups (i.e. men and women) with regard to the other regressors. It therefore does not allow for different coefficients for men and women regarding the other regressors. With decomposition techniques, this strong assumption of equal coefficients for men and women is relaxed (Fortin et al. 2011, p. 6).

A simple way to allow for all coefficients to differ for both gender groups is to run separate wage regressions,

$$y_i^F = \beta_0^F + \beta_{\text{Ph.D.}}^F * \text{Ph.D.}_i^F + \sum_{k=2}^{K} X_{k,i}^F \beta_k^F + \varepsilon_i^F, \tag{39}$$

$$y_i^M = \beta_0^M + \beta_{\text{Ph.D.}}^M * \text{Ph.D.}_i^M + \sum_{k=2}^{K} X_{k,i}^M \beta_k^M + \varepsilon_i^M, \tag{40}$$

with y^F and y^M as (ln) wages of women and men, respectively. This is frequently done in the literature as shown in Section 5.2.3.1. However, when explicitly interested in the differences in effects of certain regressors on wages as in this study, one would need to compare the coefficients of doctoral degrees on male and female wages, $\beta_{\text{Ph.D.}}^M$ and $\beta_{\text{Ph.D.}}^F$ Comparing coefficients across different subsamples is not straight forward, though, as standard errors vary with different sample sizes.

Furthermore, in view of our argument developed in Section 5.3, we are particularly interested in how doctoral degrees affect demand-side discrimination. Decomposition techniques such as Oaxaca-Blinder decompositions allow to investigate this relationship. As mentioned before, gender differences in wages are often explained through supply- and demand-side discrimination. When using decomposition techniques to analyse the gender wage gap, we essentially divide the raw gender wage gap (differences in mean wages) into the explained and the unexplained gender wage gap[131]. The explained gender wage gap is the part of the wage gap that is due to differences in endowments, i.e. educational choices, occupational preferences, and/or personal traits between men and women. It therefore depicts supply-side discrimination. The unexplained gender wage gap, on the contrary, refers to differences in coefficients (i.e. valuation) of these endowments and is often called the demand-side discrimination part. However, one should be careful when using this terminology as the unexplained part of the gender wage gap is merely an upper bound to this discrimination effect (Cattaneo and Wolter 2015, p. 9): If certain variables that might affect wages of men and women differently are omitted from the model specification (either due to observability or availability), their effects might be included in the unexplained part of gender wage gap causing biased results (Cotton 1988, p. 237). Furthermore, the regressors included in the analysis could be affected by discrimination themselves resulting in an underestimated discrimination (Weichselbaumer and Winter-Ebmer 2005, p. 481). In what follows, we will address this part of the gender wage gap as the unexplained part rather than discrimination by the employer but keep in mind that the true demand-side discrimination (if any) is embedded in this part.

The Oaxaca-Blinder decomposition determinates how much of the gender wage gap is due to differences in coefficients (i.e. valuation) and how much due to differences in mean endowments based on separate wage regression for men and women (Neumark 1988, p. 280):

$$y_i^M = \beta_0^M + \sum_{k=1}^{K} X_{k,i}^M \beta_k^M + \varepsilon_i^M, \tag{41}$$

$$y_i^F = \beta_0^F + \sum_{k=1}^{K} X_k^F \beta_k^F + \varepsilon_i^F, \tag{42}$$

with $y^G, G \in (M, F)$, representing the (ln) wage of a male (M) or female (F) individual (Fortin et al. 2011, pp. 4–5) . Here, the differences in wages between men and women are not only represented in a single dummy variable (represented in different intersections with the vertical

[131] Sometimes, there is a third term, i.e. interaction term (e.g. Blinder (1973)). We will address this issue at a later point.

axis, only) but in different coefficients regarding possibly all regressors (i.e. different slopes for men and women regarding certain endowments/characteristics).

The estimated overall gender difference in average wages (i.e. raw gender wage gap) is the difference in mean wages between both groups (Fortin et al. 2011, p. 5),

$$\overline{y^M} - \overline{y^F} = \widehat{\beta_0^M} + \sum_{k=1}^{K} \overline{X_k^M}\,\widehat{\beta_k^M} - \left[\widehat{\beta_0^F} + \sum_{k=1}^{K} \overline{X_k^F}\,\widehat{\beta_k^F}\right] = \widehat{\beta_0^M} - \widehat{\beta_0^F} + \sum_{k=1}^{K} \overline{X_k^M}\,\widehat{\beta_k^M} - \sum_{k=1}^{K} \overline{X_k^F}\,\widehat{\beta_k^F}. \tag{43}$$

Basically, there are two common used forms of decomposition: a three-fold and a two-fold version. While within the three-fold version, an interaction term is explicitly formulated in addition to the explained and unexplained part of the gender wage gap, it is included in one of the latter ones within the two-fold version (Jones and Kelley 1984).

The three-fold decomposition can be accomplished by simultaneously adding and subtracting additional terms,

$$\overline{y^M} - \overline{y^F} = \widehat{\beta_0^M} - \widehat{\beta_0^F} + \sum_{k=1}^{K} \overline{X_k^M}\,\widehat{\beta_k^M} - \sum_{k=1}^{K} \overline{X_k^F}\,\widehat{\beta_k^F} + \sum_{k=1}^{K} \overline{X_k^M}\,\widehat{\beta_k^F} - \sum_{k=1}^{K} \overline{X_k^M}\,\widehat{\beta_k^F} + \sum_{k=1}^{K} \overline{X_k^F}\,\widehat{\beta_k^M} - \sum_{k=1}^{K} \overline{X_k^F}\,\widehat{\beta_k^M} + \sum_{k=1}^{K} \overline{X_k^F}\,\widehat{\beta_k^F} - \sum_{k=1}^{K} \overline{X_k^F}\,\widehat{\beta_k^F} = \tag{44}$$

such that

$$\overline{y^M} - \overline{y^F} = \widehat{\beta_0^M} - \widehat{\beta_0^F} + \sum_{k=1}^{K} \overline{X_k^F}\left(\widehat{\beta_k^M} - \widehat{\beta_k^F}\right) + \sum_{k=1}^{K}\left(\overline{X_k^M} - \overline{X_k^F}\right)\widehat{\beta_k^F} + \sum_{k=1}^{K}\left(\overline{X_k^M} - \overline{X_k^F}\right)\left(\widehat{\beta_k^M} - \widehat{\beta_k^F}\right), \tag{45}$$

with $\widehat{\beta_0^M}$ and $\widehat{\beta_0^F}$ as the estimated intercepts in the male and female wage regression models in (41) and (42), respectively, while $\widehat{\beta_k^M}$ and $\widehat{\beta_k^F}$ with $k = 1, \dots, K$, are the estimated coefficients of the regressors in these models (Fortin et al. 2011, p. 5). The first term on the right side in (45) reflects differences due to group membership. Together with the second term it is the coefficient effect, reflecting differences in wages due to differences in the valuation of individual characteristics by the labour market. The third term represents differences in endowments and is, therefore, called endowment effect. The last term is called interaction effect. It refers to the endowment and coefficient effects occurring simultaneously, e.g. assuming that women increase their endowments to those of men and that the labour market appreciates this rise with the male wage structure (Jones and Kelley 1984). Obviously, one drawback from using this decomposition is the less strait forward interpretation of the interaction term.

Within the two-fold decomposition this interaction term is allocated to one of the other two components of the gender wage gap (Jones and Kelley 1984). One possibility is to alter (45) in such ways that the interaction term is either assigned to (i) the endowment part

$$\overline{y^M} - \overline{y^F} = \widehat{\beta_0^M} - \widehat{\beta_0^F} + \sum_{k=1}^{K} \overline{X_k^F}\left(\widehat{\beta_k^M} - \widehat{\beta_k^F}\right) + \left[\sum_{k=1}^{K}\left(\overline{X_k^M} - \overline{X_k^F}\right)\widehat{\beta_k^F} + \sum_{k=1}^{K}\left(\overline{X_k^M} - \overline{X_k^F}\right)\left(\widehat{\beta_k^M} - \widehat{\beta_k^F}\right)\right] =$$
$$\widehat{\beta_0^M} - \widehat{\beta_0^F} + \sum_{k=1}^{K} \overline{X_k^F}\left(\widehat{\beta_k^M} - \widehat{\beta_k^F}\right) + \left[\sum_{k=1}^{K} \overline{X_k^M}\,\widehat{\beta_k^F} - \overline{X_k^F}\widehat{\beta_k^F} + \overline{X_k^M}\widehat{\beta_k^M} - \overline{X_k^F}\widehat{\beta_k^M} - \overline{X_k^M}\widehat{\beta_k^F} + \overline{X_k^F}\widehat{\beta_k^F}\right] = \tag{46}$$

$$\overline{y^M} - \overline{y^F} = \widehat{\beta_0^M} - \widehat{\beta_0^F} + \sum_{k=1}^{K} \overline{X_k^F}\left(\widehat{\beta_k^M} - \widehat{\beta_k^F}\right) + \sum_{k=1}^{K}\left(\overline{X_k^M} - \overline{X_k^F}\right)\widehat{\beta_k^M} \tag{47}$$

or (ii) to the coefficient part (Jones and Kelley 1984):

$$\overline{y^M} - \overline{y^F} = \left[\widehat{\beta_0^M} - \widehat{\beta_0^F} + \sum_{k=1}^{K} \overline{X_k^F}\left(\widehat{\beta_k^M} - \widehat{\beta_k^F}\right) + \sum_{k=1}^{K}\left(\overline{X_k^M} - \overline{X_k^F}\right)\left(\widehat{\beta_k^M} - \widehat{\beta_k^F}\right)\right] + \sum_{k=1}^{K}\left(\overline{X_k^M} - \overline{X_k^F}\right)\widehat{\beta_k^F} =$$
$$\widehat{\beta_0^M} - \widehat{\beta_0^F} + \sum_{k=1}^{K} \overline{X_k^F}\,\widehat{\beta_k^M} - \overline{X_k^F}\widehat{\beta_k^F} + \overline{X_k^M}\widehat{\beta_k^M} - \overline{X_k^F}\widehat{\beta_k^M} - \overline{X_k^M}\widehat{\beta_k^F} + \overline{X_k^F}\widehat{\beta_k^F} + \sum_{k=1}^{K}\left(\overline{X_k^M} - \overline{X_k^F}\right)\widehat{\beta_k^F} = \tag{48}$$

$$\overline{y^M} - \overline{y^F} = \widehat{\beta_0^M} - \widehat{\beta_0^F} + \sum_{k=1}^{K} \overline{X_k^M}\left(\widehat{\beta_k^M} - \widehat{\beta_k^F}\right) + \sum_{k=1}^{K}\left(\overline{X_k^M} - \overline{X_k^F}\right)\widehat{\beta_k^F}. \quad (49)$$

In both equations, (47) and (49), the first two terms represent the unexplained part of the gender wage gap, while the third part represents the explained part[132].

From the women's point of view the difference between these two parts of the gender wage gap is, that in (i) the unexplained part asks how mean wages of women would change if female endowments would be paid according to the male wage structure (i.e. valued as if they were men) (Blau and Kahn 2017, p. 800; Jones and Kelley 1984, p. 327). Furthermore, the explained part asks how mean female wages would change if they increase their endowments to the level of mean male endowments and if this rise was paid according to the male wage structure (Brown and Corcoran 1997, p. 450; Jones and Kelley 1984, p. 329).

In contrast, (ii) is rather formulated from a male point of view: the unexplained part asks how mean male wages would change if male endowments would be valued with the female wage structure. The explained part asks how mean male wage would change if they reduced their endowments to the level of female endowments and if this drop was weighted with the female wage structure.

Therefore, while (i) explains how the wage gap would change if female endowments and coefficients were adjusted to those of men, (ii) investigates how the wage gap would change if male endowments and coefficients were adjusted to those of women. Thus, this implicitly assumes that in (i) men are the non-discriminated sex while women are discriminated by the labour market. Whereas in (ii) women are the non-discriminated sex while men are positively discriminated by the labour market. Hence, in the two decompositions presented above, we assume either men (i) or women (ii) to be not discriminated while the other sex is[133]. Oaxaca (1973, p. 697) refers to the decision which one to choose (either the male or the female coefficient) as the "index number problem" where the true discrimination share of the gender wage gap lies between these two. As Elder et al. (2010, p. 284) and Neumark (1988, p. 281) point out, both approaches will generally yield different results which, according to Neumark

[132] Referring to the unexplained and explained part rather than the coefficient and endowment effect should emphasize the difference between the two- and three-fold decompositions. When adding the interaction term to the endowment effect (as in (i)) the unexplained part equals the coefficient effect but the explained part is larger than the endowment effect.

[133] Neumark (1988) points out that in (i) it is assumed that in the absence of discrimination, the difference in coefficients would be zero and that differences in wages would be explained by differences in endowments between men and women, weighted with the (non-discriminatory) coefficients of men. The same applies to (ii) with the female coefficients being the non-discriminated ones.

(1988, p. 281), are far apart in some cases. Hence, it is important to decide on the discriminated group.

Based on the argument developed in this chapter, we assume the male coefficients to be non-discriminating. First, doing so refers to the idea that women are discriminated by the labour market while men are not. Second, it allows us to investigate how mean wages of women would change, if their doctoral degrees were valued as doctoral degrees of men. In line with our hypothesis derived above, we would assume the effect of a doctoral degree on the unexplained part of the gender wage gap or on mean female wages, $\overline{X^{F}_{Ph.D.}}\left(\widehat{\beta^{M}_{Ph.D.}} - \widehat{\beta^{F}_{Ph.D.}}\right)$, to be negative in heterogeneous majors and insignificant in homogeneous majors.

Above, we argued that the valuation of female doctoral degrees by the labour market, $\beta^{F}_{Ph.D.}$, is larger than the valuation of male doctoral degrees, $\beta^{M}_{Ph.D.}$, because of the additional signalling function of doctoral degrees for women compared to men in heterogeneous majors. Hence, if doctoral degrees of women in these majors were equally valued by the labour market as male doctoral degrees (i.e. valued as if there was no discrimination), mean wages of women would decrease and, therefore, the gender wage gap increase.

5.4.6 Empirical analysis

5.4.6.1 Descriptive analysis

Correspondingly, Table 22 and Table 23 depict (i) wages of men and women with and without a doctoral degree, (ii) the resulting doctoral wage premiums for men and women as well as (iii) the gender gap in doctoral wage premiums, both separately for each major group (Table 23) and in total (Table 22). They, therefore, complement Table 20 and Table 21 which depicted the mean wages of all male and female graduates but not separately for doctorate and non-doctorate holders.

Table 22: Wage differences between men and women with and without doctoral degrees (complete sample)

	All major graduates		
	Men	Women	Difference
Wage without doctoral degree	4271.58[a] (1682.54)	3219.04[a] (1519.44)	1052.54***[b] (98.95)
Wage with doctoral degree	4233.03[a] (1340.95)	3615.85[a] (1722.98)	617.18***[b] (209.94)
Doctoral wage premium	-38.55[b] (159.40)	396.81**[b] (168.69)	435.36*[c] (232.09)

[a] Means with standard deviations in parentheses
[b] Results based on t-test on wages between (i) people with and without doctoral degree or (ii) men and women with the same highest educational level. Linearized standard errors in parentheses.
[c] Results based on OLS regression, regressing "wage" on "female" and "doctoral degree" and the respective interaction. Linearized standard errors in parenthesis.
* p<0.10, ** p<0.05, *** p<0.01
Source: Own calculations based on DZHW Graduate Panel (2005).

Pooling all major graduates into a common sample (Table 22), we detect a smaller gender wage gap among those holding a higher educational degree than among those without such a degree: The gender wage gap among those with a doctoral degree is smaller (617.18 €) than among those who do not hold a doctoral degree but hold a Diplom or Magister as highest university degree (1,052.54 €). Moreover, the doctoral wage premium is significantly positive for women, only (there is an insignificant doctoral penalty of 38.55 € for men and a significant doctoral premium of 396.81 € for women). Together, these numbers suggest a significant gender wage premium gap (435.36 €)[134]. Hence, while the gender wage gap usually reflects an advantage for men, the gender premium gap mirrors an advantage for women.

The absent doctoral wage premium for men might be surprising, at first. Note, however, that we only observe wages five to six years after college graduation. During this time, men without a doctoral degree might have collected substantial work experience outside of academia which the labour market might value more than additional academic qualifications such as a doctoral degree or they might have entered higher and thus better paid positions that doctoral graduates do not occupy at their labour market entry.

Before, we argued that there are distinct labour markets for different major groups and that the effect of doctoral degrees on the gender wage gap differs across these major groups. Therefore, we argued that we should investigate distinct subsamples. This is done in Table 23.

[134] Regressing wage on female, doctoral degree, and the respective interaction based on OLS estimation indicates that the doctoral wage premiums differ significantly between men and women.

As one can see for the subsample of time-durable majors, the doctoral wage premium (i.e. the difference between wages with and without doctoral degrees) is neither significant for men nor women (98.96 € and -234.94 €). Furthermore, the difference between these two premiums is also not significant (-333.89 €). This indicates that the doctoral wage premiums do not differ significantly between men and women who studied time-durable majors. Consequently, a wage gap between men and women exists for both educational groups, those without and those with a doctoral degree (331.10 € and 664.99 €, respectively) with no significant difference between these two gaps.

For the subsample of time-erodible major graduates, there is also no significant doctoral wage premium for men (122.43 €). Women however benefit significantly from gaining a doctoral degree (515.04 €). Nonetheless, the difference between these two premiums is not significant (392.61 €). Put differently, one can see from Table 23 that gender wage gaps exist at both educational stages among the time-erodible graduates (with and without doctoral degree, 523.10 € and 915.72 €, respectively) and that these gaps do not differ significantly.

The subsample of mixed major graduates draws a different picture: Here, Table 23 indicates a significant wage gap between men and women without doctoral degree (1,093.43 €), but no significant gender wage gap among those with a doctorate (-121.33 €). This drop in the wage gap (1,214.76 €), however, is insignificant. One might conclude from Table 23 that – as neither men nor women gain significant doctoral wage premiums (-114.17 € and 1,100.60 €) – doctoral degrees do not enable women to reduce the gender wage gap.

Hence, the descriptive analysis in Table 23 does not fully support our hypothesis. While doctoral wage premiums do not differ between men and women among homogeneous major graduates as expected, there is also no significant gender difference between the doctoral wage premiums among mixed major graduates. There might be various factors, however, that affect the effect of doctoral degrees on the gender wage gap.

Regarding Table 22, we argued that the negative wage trend regarding doctoral degrees for men might be due to the relatively high wages of men who entered the labour market right after college graduation. An advantage, men with doctoral degrees are not able to catch up at their labour market entrance. This seems to be especially true for the subgroup of mixed major graduates, where the trend towards a doctoral wage penalty seems to be highest.

To investigate the gender wage premium gap in more detail, the following analyses will not only consider control variables but also apply a standard decomposition approach (Oaxaca-Blinder).

Table 23: Wage differences between men and women with and without doctoral degrees in different major groups

	Time-durable major graduates			Time-erodible major graduates			Mixed major graduates		
	Men	Women	Difference	Men	Women	Difference	Men	Women	Difference
Wage without Ph.D.	3178.95[a] (1297.50)	2847.86[a] (1289.22)	331.10**[b] (147.31)	4177.60[a] (1521.96)	3261.88[a] (1784.04)	915.72***[b] (134.61)	5227.83[a] (1635.95)	4134.40[a] (1370.88)	1093.43***[b] (200.34)
Wage with Ph.D.	3277.91[a] (1246.10)	2612.92[a] (1146.71)	664.99*[b] (380.86)	4300.02[a] (1083.80)	3776.92[a] (1617.84)	523.10**[b] (207.43)	5113.66[a] (2317.99)	5234.99[a] (1955.63)	-121.33[b] (918.47)
Ph.D. wage premium	98.96[b] (316.22)	-234.94[b] (258.38)	-333.89[c] (408.36)	122.43[b] (170.54)	515.04***[b] (179.07)	392.61[c] (247.28)	-114.17[b] (655.08)	1100.60[b] (674.24)	1214.76[c] (940.07)

[a] Means with standard deviations in parentheses

[b] Results based on t-test on wages between (i) people with and without doctoral degree or (ii) men and women with the same highest educational level. Linearized standard errors in parentheses.

[c] Results based on OLS regression, regressing "wage" on "female" and "doctoral degree" and the respective interaction. Linearized standard errors in parenthesis.

* p<0.10, ** p<0.05, *** p<0.01

Source: Own calculations based on DZHW Graduate Panel (2005).

5.4.6.2 Multiple regression analysis

In the following, we present empirical evidence on our hypothesis theoretically derived in Section 5.3. We will have a closer look at the gender wage gaps among time-durable, time-erodible, and mixed major graduates and test whether the doctoral wage premium is higher for women than for men and, thus, whether doctoral degrees help women to reduce the (unexplained part of the) gender wage gap in these three subsamples.

In a first step, we use single equation estimations with interactions to test for differences in effects of doctoral degrees on wages between men and women. Table 24 shows the respective regression results for the total sample as well as for the three subsamples (time-durable, time-erodible, and mixed majors). The variable of interest is the interaction of female and doctoral degree indicating whether there is a significant difference between the male and female doctoral wage premium. All coefficients are interpreted in percentage changes.

According to the total sample (all majors), after controlling for individual, educational, and occupational characteristics, women earn $\left(\left(e^{(-0.090)} - 1\right) * 100 =\right)$ 8.61 percent less than men without a doctoral degree. Gaining a doctoral degree significantly increases male wages by 6.61 percent, and female wages by 8.44 percent[135]. There is, however, no significant difference in the doctoral wage premium across gender (1.83 percent-points[136]). Hence, the results confirm findings in the literature, as women earn less than men do (Blau and Kahn 2017) and that this is true with and without doctoral degree[137]. The doctoral degree does not reduce the gender wage gap in the complete sample.

With regard to the control variables, the model specification tested in Table 24 assumes no gender differences in the effects of these factors on wages. Except for public sector, all significant coefficients show the expected signs. Being employed in the public sector has a positive effect on wages (4.50 percent). This is rather surprising. In line with Melly (2005, p. 506), we might expect wages in the public sector to be more compressed compared to the private sector. However, one might argue that – as we observe wages closely to the labour market entry (i.e. five to six years after graduation) – the sampled individuals are still in

[135] The marginal effect of holding a doctoral degree is $\left(e^{(0.064)} - 1\right) * 100 = 6.61$ percent for men and $\left(e^{(0.064+0.017)} - 1\right) * 100 = 8.44$ percent for women. Both marginal effects are significant (for men: linearized std. err. = 0.030; for women: linearized std. err. = 0.038).

[136] The difference in the doctoral degree effect sizes between women and men is $\left(e^{(0.064+0.017)} - 1\right) * 100 - \left(e^{(0.064)} - 1\right) * 100 = 8.44 - 6.61 = 1.83$ percent-points (linearized std. err. = 0.045).

[137] Women with doctoral degree earn $\left(e^{(-0.09+0.017)} - 1\right) * 100 = 7.04$ percent less than men with a doctoral degree. This marginal effect is significant (linearized std. err. = 0.042). Without a doctoral degree, women earn $\left(e^{(-0.09)} - 1\right) * 100 = 8.61$ percent less than wenn without a doctorate (linearized std. err. = 0.020).

positions that are not considered as (top) management positions and, thus, not negatively affected by wage compression.

Table 24: Single-equation estimations for differences in the doctoral wage premium between men and women

	All majors	Time-durable majors	Time-erodible majors	Mixed majors
Female	-0.090***	-0.037	-0.117***	-0.147***
	(0.020)	(0.036)	(0.030)	(0.034)
Attained doctoral degree	0.064**	0.011	0.103***	-0.106
	(0.030)	(0.072)	(0.034)	(0.104)
Female * Attained doctoral degree	0.017	-0.059	0.056	0.364***
	(0.045)	(0.095)	(0.056)	(0.138)
Marital status				
Without partner	Ref.cat.	Ref.cat.	Ref.cat.	Ref.cat.
With partner	0.052**	0.025	0.056*	0.090*
	(0.023)	(0.041)	(0.031)	(0.047)
Married	0.084***	0.032	0.096***	0.126**
	(0.027)	(0.052)	(0.034)	(0.050)
At least one child	-0.041*	-0.035	-0.032	-0.058
	(0.022)	(0.038)	(0.028)	(0.042)
Qualification adequate employment	0.221***	0.269***	0.107**	0.274***
	(0.026)	(0.031)	(0.052)	(0.065)
Final college grade				
Satisfying or sufficient	Ref.cat.	Ref.cat.	Ref.cat.	Ref.cat.
Very good	0.099***	0.109**	0.179***	0.050
	(0.030)	(0.045)	(0.061)	(0.056)
Good	0.056**	0.110**	0.091	-0.014
	(0.027)	(0.045)	(0.056)	(0.042)
College major				
Arts	Ref.cat.	Ref.cat.		
Humanities	0.086	0.080		
	(0.061)	(0.060)		
Theology	0.191**	0.208**		
	(0.094)	(0.093)		
Linguistics and cultural sciences	0.166***	0.150***		
	(0.053)	(0.050)		
Education sciences	0.090*	0.078		
	(0.050)	(0.048)		
Social sciences	0.202***	0.191***		
	(0.049)	(0.048)		
Business administration	0.391***			Ref.cat.
	(0.048)			
Economics	0.429***			0.031
	(0.051)			(0.036)
Economic law and administrative sciences	0.301***			-0.076
	(0.066)			(0.051)

(continued)

Table 24 *(continued)*

	All majors	Time-durable majors	Time-erodible majors	Mixed majors
Mathematics	0.437***		Ref.cat.	
	(0.061)			
Sports and health sciences	0.133		-0.280***	
	(0.085)		(0.090)	
Agriculture and nutrition	0.194***		-0.206***	
	(0.062)		(0.065)	
Natural sciences	0.173***		-0.238***	
	(0.048)		(0.050)	
Engineering	0.289***		-0.101**	
	(0.046)		(0.045)	
Total work experience in months	0.005***	0.003***	0.005***	0.009***
	(0.001)	(0.001)	(0.001)	(0.002)
Total working hours per week	0.013***	0.015***	0.009***	0.013***
	(0.001)	(0.001)	(0.002)	(0.003)
Form of employment				
Fixed-term contract	Ref.cat.	Ref.cat.	Ref.cat.	Ref.cat.
Unrestricted contract	0.178***	0.129***	0.235***	0.245***
	(0.021)	(0.030)	(0.037)	(0.044)
Self-employed	-0.0005	-0.063	0.104	0.172
	(0.053)	(0.074)	(0.081)	(0.117)
Public sector	0.044*	0.044	-0.012	0.064
	(0.026)	(0.038)	(0.041)	(0.063)
Working in large-scale enterprise	0.083***	0.045	0.123***	0.036
	(0.022)	(0.039)	(0.031)	(0.044)
Industry				
Services	Ref.cat.	Ref.cat.	Ref.cat.	Ref.cat.
Primary or manufacturing sector	0.109***	0.121*	0.099***	0.114***
	(0.021)	(0.065)	(0.028)	(0.037)
Public sector industry	-0.102***	-0.111***	-0.014	-0.018
	(0.026)	(0.033)	(0.047)	(0.072)
Job location				
East-Germany	Ref.cat.	Ref.cat.	Ref.cat.	Ref.cat.
West-Germany	0.137***	0.147***	0.137***	0.153***
	(0.021)	(0.036)	(0.029)	(0.044)
Abroad	0.200***	0.198**	0.162***	0.326***
	(0.039)	(0.083)	(0.047)	(0.085)
Constant	6.531***	6.510***	7.060***	6.606***
	(0.085)	(0.108)	(0.136)	(0.186)
R^2	0.535	0.420	0.455	0.494
Observations	1918	697	843	378

* p<0.10, ** p<0.05, *** p<0.01; linearized standard errors in parentheses
Own calculations based on DZHW Graduate Panel (2005).

Table 24 further depicts the regression results of the same model specification as for the total sample (all majors) separately for the three major subsamples (time-durable majors, time-erodible majors, and mixed majors).

Focusing on the variables of interest, all three subsamples show the expected results. For time-durable majors, gaining a doctoral degree does not increase wages, neither for men nor women (both the male wage premium of 1.11 percent as well as the female wage penalty of 4.69 percent are not significant). This is in line with expectations in Section 4.3 arguing that employers will not remunerate research skills of time-durable major graduates (regardless of gender). Furthermore, the insignificant interaction between gender and doctoral degree shows no significant difference in the doctoral wage premium between men and women. This is in line with our expectation that there is no additional signalling effect for women in time-durable majors.

Among time-erodible major graduates, both men and women gain wage premiums when attaining doctoral degrees (10.85 percent for men and 17.23 percent for women). However, these doctoral wage premiums do not differ significantly (as indicated by the insignificant interaction coefficient). Thus, as with time-durable majors, there is no additional signalling effect of doctoral degrees for women. Again, this is in line with our expectations formulated before.

The group of mixed major graduates draws a different picture: While there is no significant doctoral wage premium for men (-10.06 percent), women gain a significant doctoral wage premium of 29.43 percent. Moreover, the difference in wage premiums is significant (39.49 percent-points). This, too, confirms our expectations. The significant interaction of female and doctoral degree supports the idea that women gain an additional signalling effect compared to men, which results in a significantly larger doctoral wage premium for women.

Regarding the control variables, we might not expect contradicting effect directions within the three major groups. However, due to distinct labour markets and different types of individuals choosing the respective majors, we expect some factors that have a significant effect on wages for one major group not to have any effect on wages in another group. According to Table 24, only half of the control variables show qualitatively equal effects in all three subsamples: Being negotiation affine increases wages of all graduates. Similarly, having more work experience, working longer hours, outside of East-Germany, with an unrestricted contract and in the primary or manufacturing sector has also a significantly positive effect on wages regardless of major group. Having children, however, has no effect on wages in all subsamples.

For the remaining eight control variables, we find either differences in whether an effect is significant or in the sign of the respective coefficient. While one's marital status affects wages in time-erodible and mixed majors, it does not affect wages of time-durable major graduates. This is in line with the idea that family-oriented individuals prefer time-durable majors and respective occupations. Employers of such graduates might have introduced work arrangements such as home office or working part-time that allow individuals to better align household and labour market work. Hence, individuals who are single are not less productive than couples and will therefore not earn less.

Regarding one's final grade in college, only in time-durable majors both good and very good students get a wage premium compared to graduates who have only done satisfying or worse. This is in line with our expectation that better students are more productive later on and, hence, earn more money. In time-erodible majors, however, only very good students get a wage premium, while there is no significant college grade wage premium in mixed majors. The result in time-erodible majors might be due to the nature of imparted human capital in these majors. As human capital decays rapidly, it needs to be constantly renewed which better students might be more capable of. The results in mixed majors, however, is rather surprising. One might expect at least very good students to gain a wage premium.

Working in an enterprise with a corporate structure seems to increase wages only within the group of time-erodible major graduates. For the other two major groups, there is no significant effect. Again, one might believe the nature of imparted human capital to cause the difference: With knowledge decaying rapidly, employers interested in these skills need the best graduates to constantly renew the firm's knowledge pool and to create new business ideas to stay competitive. Hence, these employers might be more willing to pay efficiency wages to first attract these graduates and then to hold them. Efficiency wages, however, are more likely to be paid by large firms (Schmidt and Zimmermann 1991, p. 706).

As discussed in Section 5.4.5, one may argue that estimating single equation models with interaction neglects the true nature of the data. Based on the literature on wage differences between men and women, we might assume men and women to differ with regard to their endowments as well as to the effect of these endowments on their wages. Table 20 and Table 21 already testify to differences in the endowments (individual characteristics, educational, and occupational preferences) between men and women.

Thus, instead of pooling men and women in one common sample (as in Table 24), we run separate regressions for men and women (Table 25 and Table 26) and decompose the raw gender wage gap as suggested by Blinder (1973) and Oaxaca (1973) (Table 27). Doing so enables us to investigate the effect of doctoral degrees on the (unexplained) gender wage gap more sophisticatedly (Table 28 and Table 29) than with single equation regressions (Table 24).

Table 25 suggests that holding a doctoral degree has a significant and positive effect on wages for men, only (8.87 percent wage increase). For women, the effect is insignificant. Hence, according to these results, men gain a doctoral wage premium, while women do not. These results confirm findings in Braakmann (2008) and Braakmann (2013).

Table 25: Separate wage equation estimations for men and women (complete sample)

	All major (men)	All major (women)
Doctoral degree	0.085***	0.056
	(0.031)	(0.041)
Individual factors	yes	yes
Educational factors	yes	yes
Occupational factors	yes	yes
Constant	6.437***	6.606***
	(0.118)	(0.110)
R^2	0.565	0.457
Observation	877	1041

* p<0.10, ** p<0.05, *** p<0.01; linearized standard errors in parentheses
Own calculations based on DZHW Graduate Panel (2005).

When we take a closer look at the subsamples for time-durable, time-erodible, and mixed major graduates (Table 26), we see important differences in the effect of doctoral degrees on wages for men and women between these major groups.

First, there is no significant effect of doctoral degrees on wages in time-durable majors neither for men nor women. On the one hand, this is in line with hypothesis H 2b in Section 4.3 arguing that research skills imparted by doctoral studies are not remunerated for time-durable major graduates. On the other hand, we argued that employers expect time-durable majors to be chosen by family-oriented individuals, only. Hence, within this group of graduates, they believe to know an applicant's true level of work attitude so that additional signalling regarding career orientation is not needed.

Second, in time-erodible majors, doctoral degrees raise both male and female wages significantly (14.57 percent wage increase for men and 10.74 percent for women). Again, this is in line with hypothesis H 2a in Section 4.3 arguing that time-erodible major graduates can put their research skills productively to use with future employers. Further, with employers expecting time-erodible majors to be chosen by career-oriented individuals, only, they believe respective graduates to be homogeneous with regard to their work attitude. Hence, as with time-durable majors, we expect that there is no need for additional signals of career orientation for time-erodible major graduates, resulting in no additional remuneration of doctoral degrees for women.

This is different, however, for mixed major graduates. Due to the nature of imparted knowledge (a combination of both time-durable and time-erodible knowledge) we argue that both family- and career-oriented individuals will choose these majors. As employers cannot distinguish between career- and family-oriented individuals, we expect them to pay lower wages to women because – based on previous experiences – they more often believe women than men to be family-oriented. With doctoral degrees, however, women can validly signal their career orientation to employers, resulting in higher wages for such women compared to women without doctorates. This is what Table 26 suggests in form of a significant doctoral wage premium for women (33.51 percent wage increase) but no significant doctoral effect for men.

Table 26: Separate wage equation estimations for men and women in different major groups

	Homogeneous majors				Heterogeneous majors	
	Time-durable majors		Time-erodible majors		Mixed majors	
	Men	Women	Men	Women	Men	Women
Doctoral degree	0.045 (0.076)	-0.060 (0.061)	0.136*** (0.035)	0.102* (0.053)	-0.087 (0.099)	0.289*** (0.094)
Individual factors	yes	yes	yes	yes	yes	yes
Educational factors	yes	yes	yes	yes	yes	yes
Occupational factors	yes	yes	yes	yes	yes	yes
Constant	6.271*** (0.171)	6.607*** (0.127)	7.069*** (0.149)	7.261*** (0.287)	6.774*** (0.233)	6.372*** (0.256)
R^2	0.500	0.422	0.508	0.347	0.477	0.551
Observations	189	508	480	363	208	170

* p<0.10, ** p<0.05, *** p<0.01; linearized standard errors in parentheses
Own calculations based on DZHW Graduate Panel (2005).

Table 27 depicts the decomposition of the gender wage gap (i.e. difference in mean male and female (ln) wages). According to Table 27, there are significant gender wage gaps, both in the complete sample (all majors[138]) as well as in each of the three subsamples (time-durable, time-erodible, and mixed major group).

[138] The raw gender wage gap across all majors reported in this study is of similar size as in Braakmann (2013) and Pitts and Kroncke (2014).

Table 27: Oaxaca-Blinder wage differentials in (ln) monthly wages

	All majors	Time-durable majors	Time-erodible majors	Mixed majors
(ln) wage (men)	8.272***	7.973***	8.281***	8.494***
	(0.018)	(0.038)	(0.021)	(0.028)
(ln) wage (women)	8.000***	7.867***	8.054***	8.274***
	(0.015)	(0.020)	(0.022)	(0.032)
Gender wage gap	0.272***	0.106**	0.227***	0.220***
	(0.023)	(0.043)	(0.031)	(0.042)
Explained	0.206***	0.070*	0.147***	0.096***
	(0.022)	(0.038)	(0.026)	(0.033)
	[76%]	[66%]	[65%]	[44%]
Unexplained	0.066***	0.035	0.080***	0.124***
	(0.021)	(0.036)	(0.028)	(0.038)
	[24%]	[33%]	[35%]	[56%]

* p<0.10, ** p<0.05, *** p<0.01; linearized standard errors in parentheses
Own calculations based on DZHW Graduate Panel (2005).

With demand-side discrimination embedded in the unexplained part of the gender wage gap and in light of the argument developed above, we are interested in the effect of doctoral degrees on the unexplained part. According to Table 27, the largest unexplained part among the subsamples seems to be within the group of mixed major graduates (56 percent of the gender wage gap). This hints to our expectation that demand-side discrimination is particularly present in these majors[139]. In time-durable and time-erodible majors, which are more homogenous in themselves with regard to imparted knowledge, employers expect these majors to be chosen by family- or career-oriented individuals, respectively. Regarding mixed major graduates, however, they are more in the dark about the applicants' true work attitudes, resulting in higher demand-side discrimination (i.e. larger unexplained part of the gender wage gap). As employers of mixed major graduates may find it difficult to assess their applicants' true attitudes, they base their wage offers on their beliefs about the work attitude of men and women resulting in different valuations of equal characteristics.

In what follows, we will investigate whether a doctoral degree helps women to reduce this demand-side discrimination using detailed Oaxaca-Blinder decomposition. The results are shown in Table 28 and Table 29. As explained in the methodological Section 5.4.5, the effect of doctoral degree on the explained part of the gender wage gap is $(\overline{X^{M}_{Ph.D.}} - \overline{X^{F}_{Ph.D.}})\widehat{\beta^{M}_{Ph.D.}}$, while the effect on the unexplained part can be calculated as $\overline{X^{F}_{Ph.D.}}\left(\widehat{\beta^{M}_{Ph.D.}} - \widehat{\beta^{F}_{Ph.D.}}\right)$, with $\overline{X^{M}_{Ph.D.}}$ and $\overline{X^{F}_{Ph.D.}}$ as mean Ph.D. rates of men and women in the sample (Table 20 and Table 21) and $\widehat{\beta^{M}_{Ph.D.}}$

[139] For similar considerations regarding interpretation see Pitts and Kroncke (2014, pp. 149–150).

and $\widehat{\beta^{F}_{Ph.D.}}$ as the coefficients of doctoral degree in separate male and female wage regressions (Table 25 and Table 26).

Table 28: Detailed Oaxaca-Blinder decomposition of the gender wage gap (complete sample)

	Explained		Unexplained	
Doctoral degree	0.005**	(0.003)	0.003	(0.006)
Marital status	0.002	(0.003)	0.009	(0.007)
At least one child	-0.00005	(0.0004)	0.019	(0.012)
Qualification adequate employment	0.012**	(0.005)	-0.026	(0.045)
Final grade of college degree	-0.003	(0.002)	-0.021	(0.013)
Major of first college degree	0.075***	(0.015)	0.009	(0.018)
Total work experience in months	0.021***	(0.006)	0.083	(0.087)
Total working hours per week	0.048***	(0.009)	-0.014	(0.092)
Form of employment	0.018***	(0.006)	-0.015	(0.026)
Public sector	-0.0001	(0.005)	-0.028	(0.022)
Working in large-scale enterprise	0.006*	(0.003)	-0.009	(0.013)
Industry	0.019***	(0.006)	0.013	(0.009)
Job location	0.004	(0.003)	0.015	(0.018)
Constant			0.027	(0.139)

* p<0.10, ** p<0.05, *** p<0.01; linearized standard errors in parentheses
Own calculations based on DZHW Graduate Panel (2005).
Notes:
Results of regressors regarding certain sets of variables are combined (e.g. categories of marital status are grouped under the term “marital status” in this output). Analogously, all categorical variables with more than two categories are grouped respectively (i.e. marital status, college grade, college major, industry, form of employment, and job location). Furthermore, their coefficients are transformed such that the results of the detailed decomposition is unaffected by the choice of reference category (Jann 2008, p. 462). Using untransformed coefficients would not affect the effect of the category on the explained part but is of consequence when analysing the effect of variables with no natural zero point (e.g. categorical variables) on the unexplained part (Fortin et al. 2011, p. 43; Gardeazabal and Ugidos 2004; Jann 2008, p. 461). While using a different reference category does not alter the regressors' means, it alters the coefficients. This, in turn, causes some transfer of effects between the group membership (i.e. constant) and the remaining unexplained part of the gender wage gap (Fortin et al. 2011, p. 44; Jann 2008, p. 461). This means that because the estimated coefficients of the categorical variable in the separate equation regression change when the reference category is altered, the category's contribution to the unexplained part alters as well (Gardeazabal and Ugidos 2004). We, therefore, use a transformation that causes all coefficients of a certain categorical variable to sum up to zero and, thus, reflect deviations from the grand mean as suggested by Jann (2008, p. 462).

For the complete sample, Table 28 shows the respective effect of doctoral degrees on the explained[140] $\left(\left(\overline{X^{M}_{Ph.D.}} - \overline{X^{F}_{Ph.D.}}\right)\widehat{\beta^{M}_{Ph.D.}} = (0.180 - 0.116) * 0.085 = 0.005\right)$ and unexplained gender wage gap[141] $\left(\overline{X^{F}_{Ph.D.}}\left(\widehat{\beta^{M}_{Ph.D.}} - \widehat{\beta^{F}_{Ph.D.}}\right) = 0.116 * (0.085 - 0.056) = 0.003\right)$. Only the doctoral degree effect on the explained part of the gender wage gap is

[140] $\overline{X^{M}_{Ph.D.}}$ and $\overline{X^{F}_{Ph.D.}}$ are taken from Table 20 and $\widehat{\beta^{M}_{Ph.D.}}$ from Table 25.
[141] $\overline{X^{F}_{Ph.D.}}$ is taken from Table 20 and $\widehat{\beta^{M}_{Ph.D.}}$ and $\widehat{\beta^{F}_{Ph.D.}}$ from Table 25.

significant, meaning that – if women attained doctoral degrees as often as men did, their wages would raise by 0.005 ln-wage-points (0.50 percent). Put differently, the gender wage gap would decrease by 0.50 percent. This result contradicts Braakmann (2013) and Braakmann (2008) where the doctoral degree is found to have no significant effect on neither the explained nor unexplained gender wage gap. However, although significant the effect is quite small compared to e.g. major (0.075 ln-wage points, i.e. 7.79 percent)[142]. The insignificant effect of doctoral degrees on the unexplained gender wage gap, however, confirms the respective findings in Braakmann (2008).

In line with other studies investigating the gender wage gap of the highly educated (e.g. Leuze and Strauß (2016), Triventi (2013)), occupational characteristics contribute the most to the explained part of the gender wage gap with working hours as the single most relevant factor. The second most important endowments are educational characteristics with college major as the single most important factor within this category (see also Braakmann (2013) and Triventi (2013)). For the overall sample, we can therefore conclude that attaining doctoral degrees does not affect the gender wage gap.

In Section 5.3, however, we argued that it depends on the major group, whether doctoral degrees have effects on male and female wages and therefore reduce the unexplained gender wage gap. Hence, Table 29 presents the detailed Oaxaca-Blinder decompositions for the three major groups (time-durable, time-erodible, and mixed majors).

As one can see, doctoral degrees have no significant effects on the explained parts of the gender wage gaps in any of the three major groups. That is, if women would – on average – attain doctoral degrees as often as men do, their mean wages would not change significantly. For time-erodible and mixed majors, this is not surprising given that men do not significantly attain more doctorates in these majors (see Table 21). In time-durable majors, however, men do attain significantly more doctoral degrees than women (Table 21), but as a doctoral degree does not significantly increase wages among the time-durable major graduates, neither for men nor women (Table 26), an increase in the mean doctoral degree rate of women would not increase female mean wages.

[142] If women had the same major distribution as men, their wages would rise by 7.79 percent.

Doctoral degrees have an effect on the unexplained wage gap within heterogeneous majors. The respective coefficient in Table 29 can be calculated as follows[143]: $\overline{X^F_{Ph.D.}}\left(\widehat{\beta^M_{Ph.D.}} - \widehat{\beta^F_{Ph.D.}}\right) = 0.048 * (-0.087 - 0.289) = -0.018$ ln-wage points, that is -1.78 percent. Hence, because the labour market for mixed major graduates values doctoral degrees of men and women differently (i.e. values female doctorates more), women can significantly reduce the gender wage gap.

Put differently, if employers valued female doctoral degrees in mixed majors as they value male doctoral degrees, female mean wages would decrease significantly by 1.78 percent (effectively widening the gender wage gap). However, because doctoral degrees of men and women are in fact valued differently in mixed majors, the gender wage gap is 1.78 percent smaller as it would be when degrees were equally valued. This lends support to our expectation of an additional signalling effect of doctoral degrees for women, which is represented by the effect of the doctoral degree on the unexplained gender wage gap in mixed majors. Due to this signalling effect for women, we argue doctoral degrees to reduce wage differences and therefore discrimination, too. Although significant, this effect is small compared to, e.g. the public sector effect (-10.06 percent).

If female work in the public sector was valued the same as male public sector work, female wages would decrease by 10.06 percent, effectively widening the gender wage gap. This confirms to some extent the idea that there is less discrimination against women in the public sector.

As we detect a significant effect of doctoral degrees on the unexplained part of the gender wage gap in mixed majors but find no evidence for the effect of doctoral degrees on the explained part in the homogenous majors, we conclude that the gender difference in doctoral wage premiums is present in heterogeneous majors, only. We therefore confirm our hypothesis formulated above. The result suggests that women in heterogeneous majors can significantly reduce the gender wage gap (and thus demand-side discrimination) by attaining doctoral degrees.

[143] $\overline{X^F_{Ph.D.}}$ is taken from Table 21 and $\widehat{\beta^M_{Ph.D.}}$ and $\widehat{\beta^F_{Ph.D.}}$ from Table 26.

Table 29: Detailed Oaxaca-Blinder decomposition of the gender wage gap in different major groups

	Time-durable majors		Time-erodible majors		Mixed majors	
	Explained	Unexplained	Explained	Unexplained	Explained	Unexplained
Doctoral degree	0.003	0.006	-0.003	0.010	-0.002	-0.018**
	(0.005)	(0.005)	(0.005)	(0.018)	(0.003)	(0.009)
Marital status	0.002	0.018	0.001	0.003	-0.003	0.003
	(0.006)	(0.013)	(0.004)	(0.011)	(0.010)	(0.020)
At least one child	-0.0003	0.012	-0.00005	0.032*	-0.0003	-0.014
	(0.001)	(0.024)	(0.0003)	(0.017)	(0.003)	(0.024)
Qualification adequate employment	0.011	-0.030	0.001	0.082	0.007	-0.012
	(0.010)	(0.061)	(0.003)	(0.099)	(0.009)	(0.097)
Final grade of college degree	-0.003	-0.016	-0.001	-0.044	-0.003	-0.038*
	(0.004)	(0.028)	(0.003)	(0.028)	(0.005)	(0.021)
Major of first college degree	-0.006	0.028	0.057***	0.037	0.007	-0.054
	(0.019)	(0.029)	(0.014)	(0.029)	(0.007)	(0.033)
Total work experience in months	0.005	0.095	0.021**	0.026	0.031**	-0.062
	(0.006)	(0.138)	(0.009)	(0.140)	(0.013)	(0.190)
Total working hours per week	0.067***	0.079	0.028***	0.353**	0.032**	-0.125
	(0.020)	(0.124)	(0.009)	(0.154)	(0.015)	(0.229)
Form of employment	0.013	-0.050	0.024**	-0.037	0.009	0.076
	(0.011)	(0.033)	(0.011)	(0.042)	(0.010)	(0.057)
Public sector	-0.010	0.072*	0.011	-0.087***	0.014	-0.106***
	(0.010)	(0.037)	(0.007)	(0.033)	(0.010)	(0.033)
Working in large-scale enterprise	-0.0005	0.005	0.005	-0.026	0.001	-0.037
	(0.002)	(0.022)	(0.004)	(0.020)	(0.006)	(0.036)
Industry	-0.012	-0.065*	-0.001	0.022**	0.004	-0.007
	(0.017)	(0.039)	(0.010)	(0.011)	(0.006)	(0.019)
Job location	0.001	-0.045	0.002	0.006	0.001	0.054
	(0.008)	(0.041)	(0.004)	(0.021)	(0.010)	(0.042)
Constant		-0.072		-0.296		0.464
		(0.188)		(0.254)		(0.340)

* p<0.10, ** p<0.05, *** p<0.01; linearized standard errors in parentheses
Notes: Categorical variables marital status, college grade, college major, industry, form of employment, and job location are grouped. Their coefficients are transformed such that the results of the detailed decompositions are unaffected by the choice of reference category.
Own calculations based on DZHW Graduate Panel (2005).

5.4.7 Robustness of results

In this section, we present the regression results of all model specifications given above based on unweighted data as well as additional robustness checks as mentioned above. To this aim, Table 30 presents the descriptive analysis previously performed in Table 22 but with unweighted data. The results do not differ qualitatively. In both setups, men do not gain a significant doctoral wage premium, while women do (395.47 €). Furthermore, the difference between these premiums (376.25 €) is significant and in favour of women. Nonetheless, there is still a gender wage gap among those with doctoral degrees (756.50 €), although it is significantly smaller than the gender wage gap among those with only Diplom or Magister degree (1,132.75 €).

While using unweighted data does not change the results qualitatively, it is still interesting to note that the point estimates suggest that using unweighted data tends to overestimate male wages (especially those of male doctorate holders) while it underestimates female wages. A possible explanation is that women in general take part in surveys more often than men (Sax et al. 2003). Possibly due to traditional gender roles, women with lower wages (and possibly more time to take part in surveys) do not mind to answer questions about their income. With men seen as breadwinners (Fortin 2005, p. 147) and questions regard income being sensitive (Tourangeau and Yan 2007, p. 860), especially those with lower incomes might refrain from answering wage questions as it is more expected of men to earn higher wages.

Table 30: Wage differences between men and women with and without doctoral degree (unweighted data)

	All major graduates		
	Men	Women	Difference
Wage without doctoral degree	4306.16[a] (1749.34)	3173.41[a] (1432.83)	1132.75***[b] (78.48)
Wage with doctoral degree	4325.38[a] (1703.46)	3568.89[a] (1484.41)	756.50***[b] (193.65)
Doctoral wage premium	19.22[b] (159.69)	395.47***[b] (134.08)	376.25*[c] (208.24)

* p<0.10, ** p<0.05, *** p<0.01
[a] Means with standard deviations in parentheses
[b] Results based on t-test on wages between (i) people with and without doctoral degree or (ii) men and women with the same highest educational level. Standard errors in parentheses.
[c] Results based on OLS regression, regressing "wage" on "female" and "doctoral degree" and the respective interaction. Robust standard errors in parenthesis.
Source: Own calculations based on DZHW Graduate Panel (2005).

Table 31 presents the descriptive analysis performed in Table 23 based on unweighted data. Again, all results are qualitatively equal as when weighted data is used. In all subsamples, the point estimates of male wages are overestimated with unweighted data, while female wages are underestimated (except for female doctorate holders).

Table 31: Wage differences between men and women with and without doctoral degrees in different major groups (unweighted data)

	Time-durable major graduates			Time-erodible major graduates			Mixed major graduates		
	Men	Women	Difference	Men	Women	Difference	Men	Women	Difference
Wage without Ph.D.	3371.08[a] (1383.06)	2837.25[a] (1224.55)	533.83***[b] (113.38)	4190.13[a] (1468.33)	3219.72[a] (1510.07)	970.41***[b] (118.67)	5355.26[a] (1990.18)	4109.60[a] (1463.20)	1245.66***[b] (189.91)
Wage with Ph.D.	3445.74[a] (1896.84)	2716.15[a] (1064.05)	729.60*[b] (429.35)	4310.26[a] (1233.76)	3702.03[a] (1462.37)	608.23***[b] (191.15)	5525.12[a] (3081.45)	4613.85[a] (1652.91)	911.27[b] (1020.62)
Ph.D. wage premium	74.66[b] (341.37)	121.11[b] (236.51)	-195.77[c] (474.93)	120.14[b] (156.26)	482.31***[b] (180.12)	362.17[c] (226.67)	169.86[b] (543.57)	504.25[b] (459.91)	334.39[c] (908.18)

* p<0.10, ** p<0.05, *** p<0.01
[a] Means and standard deviations
[b] Results based on t-test on wages between (i) people with and without doctoral degree or (ii) men and women with the same highest educational level. Standard errors in parentheses.
[c] Results based on OLS regression, regressing "wage" on "female" and "doctoral degree" and the respective interaction. Robust standard errors in parenthesis.
Source: Own calculations based on DZHW Graduate Panel (2005).

In Table 24, we performed single equation regressions with interaction regarding gender and doctoral degree. Table 32 shows the respective results when unweighted data is used. The results regarding the effect of interest change qualitatively for one out of four models. In the time-erodible subsample, the doctoral wage premium for women is significantly larger than it is for men. Furthermore, women without a doctoral degree in time-durable majors earn significantly less (7.50 percent) than their male counterparts when unweighted data is used. A possible explanation could be that standard errors are usually smaller when unweighted data is used (Bell et al. 2012, p. 1400). Regarding the control variables, there are only minor changes. As results based on unweighted data might be biased as discussed in Section 4.4.1.1, the results in Table 24 should be preferred.

Table 32: Single equation estimations for differences in the doctoral wage premium between men and women (unweighted data)

	All majors	Time-durable majors	Time-erodible majors	Mixed majors
Female	-0.122***	-0.078**	-0.150***	-0.150***
	(0.017)	(0.031)	(0.027)	(0.034)
Attained doctoral degree	0.050*	0.012	0.077**	-0.051
	(0.029)	(0.081)	(0.032)	(0.101)
Female * Attained doctoral degree	0.048	-0.053	0.091*	0.248*
	(0.042)	(0.102)	(0.050)	(0.126)
Marital status				
Without partner	Ref.cat.	Ref.cat.	Ref.cat.	Ref.cat.
With partner	0.037*	0.015	0.038	0.079*
	(0.020)	(0.035)	(0.029)	(0.045)
Married	0.071***	0.031	0.084**	0.090*
	(0.024)	(0.041)	(0.035)	(0.046)
At least one child	-0.046**	-0.027	-0.062**	-0.035
	(0.019)	(0.031)	(0.028)	(0.038)
Qualification adequate employment	0.199***	0.259***	0.072	0.301***
	(0.027)	(0.030)	(0.056)	(0.065)
Final college grade				
Satisfying or sufficient	Ref.cat.	Ref.cat.	Ref.cat.	Ref.cat.
Very good	0.119***	0.093**	0.195***	0.093*
	(0.026)	(0.045)	(0.048)	(0.053)
Good	0.078***	0.116***	0.103**	0.007
	(0.025)	(0.045)	(0.046)	(0.041)

(continued)

Table 32 *(continued)*

	All majors	Time-durable majors	Time-erodible majors	Mixed majors
College major				
Arts	Ref.cat.	Ref.cat.		
Humanities	0.083	0.078		
	(0.056)	(0.057)		
Theology	0.180**	0.151*		
	(0.083)	(0.086)		
Linguistics and cultural sciences	0.140***	0.131***		
	(0.050)	(0.050)		
Education sciences	0.063	0.056		
	(0.047)	(0.046)		
Social sciences	0.169***	0.164***		
	(0.045)	(0.046)		
Business administration	0.372***			Ref.cat.
	(0.045)			
Economics	0.425***			0.051
	(0.049)			(0.036)
Economic law and administrative sciences	0.288***			-0.073
	(0.063)			(0.052)
Mathematics	0.396***		Ref.cat.	
	(0.066)			
Sports and health sciences	0.186**		-0.176*	
	(0.090)		(0.096)	
Agriculture and nutrition	0.160**		-0.185**	
	(0.063)		(0.076)	
Natural sciences	0.152***		-0.220***	
	(0.047)		(0.061)	
Engineering	0.252***		-0.091	
	(0.043)		(0.057)	
Total work experience in months	0.004***	0.002**	0.005***	0.008***
	(0.001)	(0.001)	(0.001)	(0.002)
Total working hours per week	0.012***	0.015***	0.006***	0.013***
	(0.001)	(0.001)	(0.002)	(0.003)
Form of employment				
Fixed-term contract	Ref.cat.	Ref.cat.	Ref.cat.	Ref.cat.
Unrestricted contract	0.178***	0.140***	0.199***	0.245***
	(0.019)	(0.028)	(0.034)	(0.046)
Self-employed	0.035	0.029	0.034	0.166
	(0.048)	(0.066)	(0.080)	(0.114)
Public sector	0.054**	0.061*	0.038	0.076
	(0.024)	(0.037)	(0.036)	(0.059)
Working in large-scale enterprise	0.118***	0.076**	0.169***	0.034
	(0.020)	(0.036)	(0.029)	(0.040)
Industry				
Services	Ref.cat.	Ref.cat.	Ref.cat.	Ref.cat.
Primary or manufacturing sector	0.116***	0.149***	0.094***	0.115***
	(0.020)	(0.054)	(0.029)	(0.034)
Public sector industry	-0.074***	-0.067**	-0.044	-0.078
	(0.023)	(0.030)	(0.039)	(0.068)

(continued)

Table 32 *(continued)*

	All majors	Time-durable majors	Time-erodible majors	Mixed majors
Job location				
East-Germany	Ref.cat.	Ref.cat.	Ref.cat.	Ref.cat.
West-Germany	0.133***	0.144***	0.131***	0.142***
	(0.018)	(0.031)	(0.027)	(0.039)
Abroad	0.209***	0.211***	0.176***	0.328***
	(0.035)	(0.074)	(0.046)	(0.078)
Constant	6.647***	6.551***	7.221***	6.639***
	(0.083)	(0.110)	(0.155)	(0.196)
R^2	0.508	0.409	0.433	0.530
Observation	1918	697	843	378

* p<0.10, ** p<0.05, *** p<0.01; robust standard errors in parentheses
Own calculations based on DZHW Graduate Panel (2005).

In Table 25 and Table 26, we run separate regressions for men and women. In Table 33, we re-run these regressions based on unweighted data. The effect of interest (doctoral degree) varies for the female subpopulation in the complete sample as the doctoral wage premium is significant for women, too. Again, this might be because of the smaller standard errors, when unweighted data is used. This is not the case when weighted data is used (see Table 25). For the three subsamples of interest, however, the effect of interest does not change qualitatively when unweighted data is used (Table 33 compared to Table 26).

Table 33: Separate wage equation estimations for men and women (unweighted data)

	All majors		Homogeneous majors				Heterogeneous majors	
			Time-durable majors		Time-erodible majors		Mixed majors	
	Men	Women	Men	Women	Men	Women	Men	Women
Doctoral degree	0.073**	0.082**	0.072	-0.056	0.106***	0.137***	-0.054	0.257***
	(0.031)	(0.038)	(0.088)	(0.064)	(0.033)	(0.050)	(0.095)	(0.085)
Individual characteristics	yes	yes	yes	Yes	yes	yes	yes	yes
Educational characteristics	yes	yes	yes	Yes	yes	yes	yes	yes
Occupational characteristics	yes	yes	yes	Yes	yes	yes	yes	yes
Constant	6.527***	6.633***	6.422***	6.507***	7.079***	7.374***	6.816***	6.422***
	(0.117)	(0.110)	(0.182)	(0.127)	(0.152)	(0.291)	(0.275)	(0.245)
R^2	0.522	0.420	0.476	0.399	0.448	0.347	0.506	0.552
Observations	877	1041	189	508	480	363	208	170

* p<0.10, ** p<0.05, *** p<0.01; robust standard errors in parentheses
Own calculations based on DZHW Graduate Panel (2005).

With regard to the decomposition of the gender wage gap, both weighted (Table 27) and unweighted data (Table 34) show qualitatively the same results with exception of the unexplained gender wage gap in the time-durable subsample which is significant when unweighted data is used. In both settings, complete and subsamples show significant wage differences between men and women caused by significant differences in characteristics across gender (i.e. explained part of the gender wage gap) and in the valuation of these characteristics by the labour market (i.e. unexplained part). Moreover, regardless whether or not weighted data is used, the subsample of mixed majors shows the largest unexplained part of the gender wage gap.

Table 34: Oaxaca-Blinder wage differentials in (ln) monthly wages (unweighted data)

	All majors	Time-durable majors	Time-erodible majors	Mixed majors
(ln) wage (men)	8.288***	8.038***	8.288***	8.516***
	(0.014)	(0.032)	(0.016)	(0.028)
(ln) wage (women)	7.989***	7.868***	8.029***	8.264***
	(0.013)	(0.018)	(0.022)	(0.029)
Gender wage gap	0.299***	0.169***	0.259***	0.252***
	(0.019)	(0.037)	(0.028)	(0.040)
Explained	0.207***	0.095***	0.165***	0.126***
	(0.018)	(0.033)	(0.024)	(0.034)
	[69%]	[56%]	[64%]	[50%]
Unexplained	0.092***	0.075**	0.094***	0.126***
	(0.019)	(0.034)	(0.029)	(0.038)
	[31%]	[44%]	[36%]	[50%]

* p<0.10, ** p<0.05, *** p<0.01; robust standard errors in parentheses
Own calculations based on DZHW Graduate Panel (2005).

With regard to the detailed decomposition, we also find the effect of interest to be independent of whether weighted or unweighted data are used, except for the complete sample. Here, while doctoral degree significantly influences the explained gender wage gap when using weighted data (Table 28), we do not detect such an effect when unweighted data is used (Table 35).

Table 35: Detailed Oaxaca-Blinder decompositions of the gender wage gaps (unweighted data)

	All majors		Time-durable majors		Time-erodible majors		Mixed majors	
	Explained	Unexplained	Explained	Unexplained	Explained	Unexplained	Explained	Unexplained
Doctoral degree	0.003	-0.001	0.004	0.007	-0.004	-0.008	-0.001	-0.020**
	(0.002)	(0.006)	(0.005)	(0.006)	(0.003)	(0.015)	(0.002)	(0.010)
Marital status	0.002	0.007	0.001	0.009	0.004	0.007	-0.004	0.009
	(0.003)	(0.006)	(0.004)	(0.011)	(0.004)	(0.010)	(0.007)	(0.019)
At least one child	0.0003	0.012	0.000002	0.014	-0.0004	0.021	0.001	-0.008
	(0.001)	(0.012)	(0.0001)	(0.023)	(0.002)	(0.018)	(0.003)	(0.024)
Qualification adequate	0.011***	0.023	0.008	-0.007	0.005	0.143	0.005	-0.011
employment	(0.004)	(0.046)	(0.009)	(0.062)	(0.004)	(0.102)	(0.009)	(0.107)
Final grade of college degree	-0.004*	-0.023*	-0.001	-0.046*	-0.004	-0.013	0.001	-0.039**
	(0.002)	(0.012)	(0.003)	(0.025)	(0.003)	(0.027)	(0.006)	(0.020)
Major of first college degree	0.073***	0.033*	0.006	0.049*	0.055***	0.044	0.017	-0.045
	(0.012)	(0.017)	(0.015)	(0.029)	(0.014)	(0.033)	(0.012)	(0.030)
Total work experience in	0.023***	0.083	0.005	0.044	0.030***	0.095	0.031**	-0.019
months	(0.006)	(0.082)	(0.005)	(0.125)	(0.010)	(0.142)	(0.015)	(0.206)
Total working hours per week	0.044***	-0.028	0.070***	0.027	0.024***	0.199	0.035**	-0.148
	(0.008)	(0.088)	(0.019)	(0.136)	(0.007)	(0.156)	(0.015)	(0.214)
Form of employment	0.025***	-0.008	0.012	-0.047	0.038***	-0.015	0.011	0.065
	(0.006)	(0.025)	(0.009)	(0.031)	(0.011)	(0.047)	(0.009)	(0.060)
Public sector	-0.002	-0.024	-0.002	0.045	0.005	-0.061**	0.014	-0.102***
	(0.005)	(0.021)	(0.006)	(0.043)	(0.006)	(0.031)	(0.010)	(0.033)
Working in large-scale	0.009***	-0.010	-0.0003	0.002	0.009*	-0.016	-0.001	-0.043
enterprise	(0.003)	(0.012)	(0.003)	(0.021)	(0.005)	(0.020)	(0.007)	(0.034)
Industry	0.021***	0.009	-0.008	-0.065**	0.004	0.015	0.008	-0.00001
	(0.006)	(0.008)	(0.011)	(0.033)	(0.009)	(0.010)	(0.007)	(0.017)
Job location	0.003	-0.005	-0.00001	-0.067	-0.0004	-0.010	0.007	0.024
	(0.003)	(0.017)	(0.008)	(0.041)	(0.003)	(0.020)	(0.012)	(0.037)
Constant		0.022		0.110		-0.306		0.462
		(0.139)		(0.197)		(0.261)		(0.353)

* p<0.10, ** p<0.05, *** p<0.01; robust standard errors in parentheses
Notes: Categorical variables marital status, college grade, college major, industry, form of employment, and job location are grouped. Their coefficients are transformed such that the results of the detailed decompositions are unaffected by the choice of reference category.
Own calculations based on DZHW Graduate Panel (2005).

Table 25 did not report the coefficients of control variables. We comply with this in Table 36.

Table 36: Separate wage equation estimations for men and women with all control variables (complete sample)

	All majors: Men		All majors: Women	
Doctoral degree	0.085***	(0.031)	0.056	(0.041)
Marital status				
Without partner	Ref.cat.		Ref.cat.	
With partner	0.056*	(0.032)	0.038	(0.032)
Married	0.140***	(0.036)	0.009	(0.038)
At least one child	-0.016	(0.029)	-0.079***	(0.030)
Qualification adequate employment	0.207***	(0.045)	0.238***	(0.031)
Final college grade				
Satisfying or sufficient	Ref.cat.		Ref.cat.	
Very good	0.085**	(0.040)	0.131***	(0.042)
Good	0.019	(0.036)	0.115***	(0.039)
College major				
Arts	Ref.cat.		Ref.cat.	
Humanities	0.189*	(0.098)	0.038	(0.072)
Theology	0.266**	(0.126)	0.195*	(0.113)
Linguistics and cultural sciences	0.200**	(0.096)	0.123**	(0.055)
Education sciences	0.249***	(0.092)	0.027	(0.051)
Social sciences	0.354***	(0.089)	0.120**	(0.051)
Business administration	0.532***	(0.080)	0.325***	(0.052)
Economics	0.571***	(0.079)	0.325***	(0.070)
Economic law and admin. sciences	0.499***	(0.101)	0.195**	(0.079)
Sports and health sciences	0.140	(0.124)	0.177**	(0.086)
Agriculture and nutrition	0.308***	(0.089)	0.124	(0.084)
Mathematics	0.578***	(0.082)	0.355***	(0.102)
Natural sciences	0.304***	(0.077)	0.114**	(0.055)
Engineering	0.447***	(0.075)	0.135***	(0.050)
Total work experience in months	0.004***	(0.001)	0.003***	(0.001)
Total working hours per week	0.012***	(0.002)	0.013***	(0.001)
Form of employment				
Fixed-term contract	Ref.cat.		Ref.cat.	
Unrestricted contract	0.212***	(0.033)	0.146***	(0.025)
Self-employed	0.070	(0.078)	-0.055	(0.067)
Public sector	0.001	(0.044)	0.073**	(0.033)
Working in large-scale enterprise	0.070**	(0.030)	0.099***	(0.032)
Industry				
Services	Ref.cat.		Ref.cat.	
Primary or manufacturing sector	0.067**	(0.028)	0.148***	(0.032)
Public sector industry	-0.130**	(0.051)	-0.064**	(0.030)
Job location				
East-Germany	Ref.cat.		Ref.cat.	
West-Germany	0.153***	(0.030)	0.118***	(0.028)
Abroad	0.199***	(0.049)	0.206***	(0.054)
Constant	6.437***	(0.118)	6.606***	(0.110)
R^2	0.565		0.457	
Observations	877		1041	

* p<0.10, ** p<0.05, *** p<0.01; linearized standard errors in parentheses
Own calculations based on DZHW Graduate Panel (2005).

Where applicable, the coefficients of control variables shown above largely confirm findings in Braakmann (2013). Regarding the individual characteristics, both models in Table 36 confirm our expectations: While men profit from being married (15.03 percent) or being in a stable partnership (5.76 percent) because they can specialise in labour market work, women do not profit significantly from not being single because they are still in charge of household work regardless of their marital state. Furthermore, with women being predominantly in charge of child rearing, having a child negatively affects their wages (-7.60 percent), while it does not affect male wages. Being a good negotiator, however, pays off for both men and women (23.00 percent for men and 26.87 percent for women).

As expected, both men and women profit from gaining very good grades in college (8.87 percent for men and 14.00 percent for women). Finishing college with "just" good grades, however, pays off for women, only (12.19 percent). To some degree, this meets our expectations that having (very) good grades works as an additional signalling effect for women. The results regarding returns on majors is in line with O'Leary and Sloane (2005, p. 86) arguing that degrees in arts show the lowest returns. According to Table 36, almost all other majors offer higher returns than arts and only a few show no significant major wage premiums.

Being more experienced and working longer hours pays off for both men and women. However, there seem to be no gender differences in these positive effects, neither for work experience (0.40 percent for men and 0.30 percent for women) nor for working hours (1.21 percent for men and 1.31 percent for women). As expected, working in the public sector results in higher wages for women (7.57 percent) as there is less discrimination in the public sector. For men, working in the public sector does not affect wages. Furthermore, both men and women profit from working in large-scale companies (7.25 percent for men and 10.41 for women). Also as expected, working in the primary or manufacturing sector is better payed than the service sector (6.93 percent wage increase for men and 15.95 percent for women), while working in public sector industries is paid worse. This is true for both gender groups (12.19 percent wage penalty for men and 6.20 for women). Also, wages in East-Germany are lower than wages in West-Germany (16.53 percent for men and 12.52 percent for women) or abroad (22.02 percent for men and 22.88 percent for women).

Table 37 presents the coefficients of the control variables which we did not report on in Table 26. All significant coefficients show the expected sign, expect for the public sector among male time-durable graduates. Here, the effect of working in the public sector is positive (while there is no significant effect on female wages).

Table 37: Separate wage equation estimations for men and women with all control variables in different major groups

	Homogenous majors				Heterogeneous majors	
	Time-durable majors		Time-erodible majors		Mixed majors	
	Men	Women	Men	Women	Men	Women
Doctoral degree	0.045	-0.060	0.136***	0.102*	-0.087	0.289***
	(0.076)	(0.061)	(0.035)	(0.053)	(0.099)	(0.094)
Marital status						
Without partner	Ref. cat.	Ref. cat.	Ref. cat.	Ref. cat.	Ref. cat.	Ref. cat.
With partner	0.102	-0.013	0.052	0.045	0.063	0.153**
	(0.092)	(0.042)	(0.038)	(0.052)	(0.056)	(0.073)
Married	0.152	-0.029	0.109***	0.034	0.192***	0.059
	(0.109)	(0.053)	(0.040)	(0.064)	(0.062)	(0.073)
At least one child	-0.018	-0.060	-0.008	-0.122**	-0.060	-0.013
	(0.070)	(0.041)	(0.033)	(0.050)	(0.056)	(0.056)
Qualification adequate employment	0.240***	0.280***	0.136**	0.045	0.244***	0.257***
	(0.071)	(0.036)	(0.064)	(0.090)	(0.090)	(0.064)
Final college grade						
Satisfying or sufficient	Ref. cat.	Ref. cat.	Ref. cat.	Ref. cat.	Ref. cat.	Ref. cat.
Very good	0.109	0.150**	0.114*	0.299***	0.091	0.025
	(0.084)	(0.060)	(0.069)	(0.086)	(0.072)	(0.075)
Good	0.089	0.162***	0.044	0.195**	-0.026	0.052
	(0.086)	(0.059)	(0.065)	(0.082)	(0.052)	(0.060)
College major						
Arts	Ref. cat.	Ref. cat.				
Humanities	0.134	0.045				
	(0.097)	(0.071)				
Theology	0.202	0.236**				
	(0.131)	(0.099)				
Linguistics and cultural sciences	0.151*	0.132**				
	(0.092)	(0.055)				
Educational sciences	0.206**	0.030				
	(0.097)	(0.051)				
Social sciences	0.303***	0.130**				
	(0.084)	(0.052)				

(continued)

Table 37 *(continued)*

	Homogenous majors				Heterogeneous majors	
	Time-durable majors		Time-erodible majors		Mixed majors	
	Men	Women	Men	Women	Men	Women
Mathematics			Ref. cat.	Ref. cat.		
Sports and health sciences			-0.422***	-0.100		
			(0.117)	(0.113)		
Agriculture and nutritional sciences			-0.290***	-0.203*		
			(0.061)	(0.123)		
Natural sciences			-0.273***	-0.217**		
			(0.053)	(0.109)		
Engineering			-0.109**	-0.143		
			(0.045)	(0.106)		
Business administration					Ref. cat.	Ref. cat.
Economics					0.040	-0.046
					(0.042)	(0.059)
Administrative sciences and economic law					-0.018	-0.154**
					(0.070)	(0.073)
Total work experience in months	0.004*	0.002	0.004**	0.004**	0.007***	0.008***
	(0.002)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)
Total working hours per week	0.016***	0.014***	0.011***	0.003	0.011***	0.014***
	(0.003)	(0.002)	(0.002)	(0.003)	(0.003)	(0.004)
Form of employment						
Fixed-term contract	Ref. cat.	Ref. cat.	Ref. cat.	Ref. cat.	Ref. cat.	Ref. cat.
Unrestricted contract	0.177***	0.115***	0.256***	0.153***	0.235***	0.256***
	(0.059)	(0.033)	(0.054)	(0.048)	(0.051)	(0.063)
Self-employed	0.142	-0.128	0.124	-0.079	0.072	0.361***
	(0.121)	(0.082)	(0.101)	(0.113)	(0.150)	(0.139)
Public sector	0.181**	0.017	-0.130*	0.094*	-0.125*	0.260***
	(0.071)	(0.045)	(0.066)	(0.050)	(0.075)	(0.076)
Working in large-scale enterprise	0.050	0.032	0.104***	0.183***	0.007	0.094
	(0.075)	(0.047)	(0.035)	(0.050)	(0.058)	(0.062)

(continued)

Table 37 *(continued)*

	Homogenous majors				Heterogeneous majors	
	Time-durable majors		Time-erodible majors		Mixed majors	
	Men	Women	Men	Women	Men	Women
Industry						
Services	Ref. cat.	Ref. cat.	Ref. cat.	Ref. cat.	Ref. cat.	Ref. cat.
Primary or manufacturing sector	0.220**	0.105	0.070**	0.163***	0.063	0.154***
	(0.106)	(0.079)	(0.032)	(0.050)	(0.053)	(0.043)
Public sector industry	-0.316***	-0.046	0.054	-0.077	0.025	-0.106
	(0.076)	(0.036)	(0.084)	(0.049)	(0.087)	(0.078)
Job location						
East-Germany	Ref. cat.	Ref. cat.	Ref. cat.	Ref. cat.	Ref. cat.	Ref. cat.
West-Germany	0.149**	0.121***	0.120***	0.164***	0.219***	0.061
	(0.073)	(0.037)	(0.035)	(0.050)	(0.066)	(0.048)
Abroad	0.367***	0.173*	0.121**	0.221***	0.341***	0.295***
	(0.106)	(0.097)	(0.057)	(0.075)	(0.120)	(0.113)
Constant	6.271***	6.607***	7.069***	7.261***	6.774***	6.372***
	(0.171)	(0.127)	(0.149)	(0.287)	(0.233)	(0.256)
R^2	0.500	0.422	0.508	0.347	0.477	0.551
Observations	189	508	480	363	208	170

* p<0.10, ** p<0.05, *** p<0.01; linearized standard errors in parentheses
Own calculations based on DZHW Graduate Panel (2005).

Addressing Hubbard's (2011) remark that top coded wages might cause differences in gender wage premiums to be overestimated, we run a robustness check in Table 38 using all wage observations (resulting in a complete sample of 1,973 observations). As shown in Table 38, the results regarding the variable of interest do not change qualitatively.

Table 38: Detailed Oaxaca-Blinder decompositions of the gender wage gaps with alternative dependent variable

	All majors		Time-durable majors		Time-erodible majors		Mixed majors	
	Explained	Unexplained	Explained	Unexplained	Explained	Unexplained	Explained	Unexplained
Doctoral degree	0.006**	0.001	0.003	0.003	-0.003	0.014	-0.001	-0.017*
	(0.003)	(0.006)	(0.005)	(0.005)	(0.005)	(0.022)	(0.002)	(0.009)
Marital status	-0.00004	0.008	0.0004	0.016	0.0001	-0.003	-0.005	0.005
	(0.003)	(0.008)	(0.006)	(0.015)	(0.004)	(0.012)	(0.010)	(0.020)
At least one child	-0.0001	0.032**	0.00003	0.030	-0.0003	0.041*	-0.0001	-0.012
	(0.001)	(0.015)	(0.0004)	(0.028)	(0.001)	(0.022)	(0.003)	(0.025)
Qualification adequate	0.016***	-0.074	0.017	-0.042	0.003	-0.139	0.006	0.049
employment	(0.006)	(0.050)	(0.013)	(0.071)	(0.003)	(0.106)	(0.011)	(0.104)
Final grade of college degree	-0.003	-0.023*	-0.002	-0.020	-0.001	-0.042	-0.003	-0.033
	(0.002)	(0.014)	(0.003)	(0.029)	(0.004)	(0.031)	(0.004)	(0.021)
Major of first college degree	0.080***	-0.005	0.010	0.025	0.048***	0.020	0.009	-0.046
	(0.017)	(0.021)	(0.020)	(0.032)	(0.016)	(0.032)	(0.007)	(0.037)
Total work experience in	0.033***	0.163	0.007	0.164	0.047**	0.244	0.027**	-0.128
months	(0.010)	(0.120)	(0.009)	(0.164)	(0.020)	(0.220)	(0.013)	(0.195)
Total working hours per week	0.067***	-0.093	0.080***	-0.048	0.045***	0.070	0.043**	-0.045
	(0.011)	(0.114)	(0.023)	(0.157)	(0.013)	(0.208)	(0.018)	(0.239)
Form of employment	0.019***	-0.010	0.011	-0.051	0.021*	-0.044	0.004	0.099*
	(0.007)	(0.031)	(0.012)	(0.034)	(0.012)	(0.068)	(0.010)	(0.059)
Public sector	-0.001	-0.044*	-0.008	0.052	0.007	-0.088**	0.019	-0.122***
	(0.005)	(0.024)	(0.010)	(0.048)	(0.006)	(0.035)	(0.012)	(0.034)
Working in large-scale	0.006**	-0.017	-0.001	-0.005	0.006	-0.042*	0.001	-0.040
enterprise	(0.003)	(0.013)	(0.003)	(0.022)	(0.005)	(0.022)	(0.006)	(0.036)
Industry	0.019***	0.010	-0.011	-0.076**	0.002	0.014	0.004	-0.008
	(0.007)	(0.010)	(0.017)	(0.039)	(0.009)	(0.011)	(0.006)	(0.020)
Job location	0.005	0.015	0.003	0.003	0.003	0.005	0.002	0.060
	(0.003)	(0.021)	(0.006)	(0.077)	(0.004)	(0.023)	(0.010)	(0.043)
Constant		0.095		-0.027		0.041		0.346
		(0.182)		(0.260)		(0.360)		(0.345)

* p<0.10, ** p<0.05, *** p<0.01; linearized standard errors in parentheses
Notes: Categorical variables marital status, college grade, college major, industry, form of employment, and job location are grouped. Their coefficients are transformed such that the results of the detailed decompositions are unaffected by the choice of reference category.
Own calculations based on DZHW Graduate Panel (2005).

5.5 Conclusion

In this chapter, we investigated the effect of doctoral degrees on wages as well as on the gender wage gap in three distinct labour markets regarding three distinct major groups: time-durable, time-erodible, and mixed major graduates.

We argue that prior to labour market entrance, employers cannot observe an applicant's true work attitude: family or career orientation. One source of information about an individual's work attributes, however, is her choice of college major. Based on Blakemore and Low (1984), Ochsenfeld (2014), and Polachek (1978), we argued that only career-oriented individuals will self-select into time-erodible majors (i.e. majors that predominantly impart human capital that erodes over time), while family-oriented individuals prefer time-durable majors. Hence, employers interested in respective graduates have a clear idea about the work attitudes of these graduates.

With majors that we refer to as heterogeneous (i.e. mixed majors that impart neither predominantly time-durable nor time-erodible human capital, but both), employers are in the dark regarding the true nature of an individual's work attitude. In lack of any signal, the employer will, therefore, use the applicant's gender to infer her hidden characteristics. Expecting women to be on average more family-oriented than men, they will offer higher wages to men than to women. By attaining a doctoral degree, a career-oriented woman can validly signal her career orientation to the employer and gain higher wages compared to women without a doctoral degree as well as a higher wage premium compared to men and hence reduce the gender wage gap in heterogeneous majors.

The results of both, a single equation estimation with interaction term as well as an Oaxaca-Binder decomposition based on separate-equation estimations controlling for individual, educational, and occupational characteristics support our hypothesis.

There are some limitations to this study. While we control to some extend for horizontal segregation of men and women via field of study, we are not able to control for vertical segregation, i.e. men being more likely to occupy top managerial positions. However, according to Schulze (2015, p. 602) this usually does not occur before one's mid-40s. Hence, while there might be some reason to believe vertical segregation to start as early as five to six years after graduation, we expect it to be rather small.

Furthermore, there might be alternative mechanisms that explain the observed results. For instance, highly educated women such as female doctorates might be of particular interest for employers who want to signal to the public and politics that they do not discriminate against women by explicitly employing women for (top) management positions. Hence, women are not put into higher positions (and hence receive higher wages) because they successfully signalled their high level of career orientation but because the firm wants to set a statement. This explanation refers to Belman and Heywood (1991, p. 723) idea of different labour markets for majorities and minorities, men and women respectively.

The results of this study have multiple implications for individuals and politics. First, our findings suggest that career-oriented women who graduated in heterogeneous majors should attain doctoral degrees.

Second, as we concluded that female doctoral degrees are more valued by the labour market than male doctoral degrees (in heterogeneous majors), one might argue that doctoral studies should be more promoted among women. However, this is only true as long as only career-oriented women will do their doctoral degrees, but not family-oriented ones. Otherwise, the potential signalling effect would be distorted. Nonetheless, it would be important to guarantee that women are not discouraged from pursuing doctoral degrees. Due to cultural conditions, however, it is more common for or expected of men to do their Ph.Ds. (Montgomery and Powell 2003). Educational institutions might prefer men over women when filling vacancies. Hence, professors might follow the same reasoning as employers in the private sector, believing (based on previous experiences) that women are on average less career-oriented than men. Fearing that a woman opts for family founding during her time at the chair, it would be rational for a professor to employ a man instead of an equally endowed woman. A possible solution could be to extend scholarships and/or to encourage professors to employ women so that women can attain their doctoral degrees and, hence, signal their career orientation to future employers.

This study was conducted based on data from Germany. In international comparison, Germany is comparably strong in maternal leave programs. Thus, it is even more important for German employers to employ individuals that are career-oriented and committed to the organisation. Consequently, it would be interesting to investigate, whether we find this additional signalling effect of doctoral degrees for women in countries that are less strong in providing parental leave programs. Future research could investigate whether there is a difference in the signalling effect of doctoral degrees across countries, i.e. in different manifestations of family protection programs.

6 Final remarks

6.1 Summary

With its Europe 2020 strategy, the EU set itself ambitious goals with increasing the average European percentage of the GDP dedicated to research and development to 3 percent to become and stay a knowledge-based economy (Eurostat 2017a, 2016b, p. 15). Achieving this goal requires to have the highly skilled personnel – that is researchers – necessary to create new ideas and to absorb and process new knowledge (European Commission 2017a).

A call for more researchers implies a call for more doctoral graduates (Pedersen 2014). Dedicating themselves to original research during their doctoral studies, these students not only learn how to create new knowledge and pass it on to others but also become the drivers behind knowledge commercialisation and distribution in their later careers (Eurostat 2016a). Governments, however, cannot simply force more people to attend doctoral studies but need to understand the driving forces behind individual doctoral enrolment decisions. Thus, understanding these drivers is crucial when trying to steer future numbers of doctorates. While previous studies already identified various important determinants that affect doctoral enrolment decisions, Chapter 3 investigates a new factor: the curricular structure at college level.

With the Bologna Process, Europe's higher educational landscape was changed on an unprecedented scale (European Commission et al. 2012, p. 15). Introducing the curricular structure of a two-cycle system in all member countries of the European Higher Education Area initially aimed at satisfying Europe's increasing demand for college graduates. Hoping for more students to enrol in higher education, once the study duration is shortened, Europe's higher education ministers put less focus on the potential threats the introduction of a two-cycle system might oppose on the number of doctoral graduates in former one-cycle countries. However, the results in Chapter 3 suggest that doctoral enrolments might drop once the two-cycle system is fully implemented.

I argue that with two college level degrees as in the two-cycle system, students in second cycle studies (master) have already validly distinguished themselves from the less productive ones who left college after their first college level degree (bachelor). Hence, I expect second cycle graduates less often to choose to continue to doctoral studies compared to college graduates in one-cycle systems (e.g. German Diplom) who have no chance to distinguish from the less productive college graduates but by attaining a doctoral degree. Estimating a random effects model based on 23 European countries between 1995 and 2005, I discovered that the doctoral enrolment rate in former one-cycle countries was 0.086 percent-points higher than in two-cycle countries after controlling for factors of educational institutions, labour market conditions, and a population's socio-economic characteristics. Thus, while introducing a two-cycle structure might in fact increase college enrolment rates (Di Pietro 2012), the analysis in Chapter 3 suggests that it also decreases doctoral enrolment rates which would contradict the Bologna goals and the goals of the Europe 2020 strategy.

Targeting its 2020 strategy, the EU especially needs researchers in the so called STEM fields (Eurostat 2017a; Pedersen 2014, p. 636). Chapter 4 explains that research skills are particularly important in these fields because they impart predominantly time-erodible human capital that decays over time if not constantly renewed. Hence, in these majors, research skills imparted by doctoral studies that help its possessor to refresh and create new knowledge on her own help to keep one's knowledge up to date. This constant creation of knowledge and ideas enables Europe's firms to create new and secure existing jobs and to stay internationally competitive (Eurostat 2017a). Thus, research skills should be important for employers who are in need of knowledge and skills imparted by time-erodible college majors and who are, therefore, willing to remunerate doctoral degrees of those major graduates. Employers of time-durable major graduates however, whose human capital is rather stable and does not erode over time, do not need their employees to constantly refresh their knowledge. Therefore, they will not remunerate doctoral degrees and the accompanying research skills of time-durable major graduates.

To investigate the effects of doctoral degrees on wages in both major groups five to six years after college graduation, I use data from the German DZHW Graduate Panel of the examination cohort 2005 (DZHW 2016). Germany is almost predestined for observing these doctoral wage premium differences, because it exhibits a large number of doctoral graduates employed in the private sector. This allows me to evaluate how the labour market values doctoral degrees largely in the absence of compressed wage structures and collective agreements. Furthermore, Germany ranks high on employment protection impeding employers from laying-off employees and, thus, yielding a wider impact on employment decisions than firms in countries with a 'hire and fire' mentality might face. Hence, employers cannot easily get rid of employees when their productivity decreases, increasing their demand for research skills for time-erodible major graduates.

The results of separate OLS regressions for the subsamples of time-durable and time-erodible major graduates show that holding a doctoral degree increases monthly wages of time-erodible major graduates by about 13 percent controlling for individual, educational, and occupational characteristics. For time-durable major graduates, however, there is no such effect.

Chapter 5 investigates the gender differences in the doctoral wage premium in heterogeneous majors with respect to imparted knowledge. Heterogeneous majors are majors that impart neither predominantly time-erodible nor time-durable human capital but a combination of both. Again, the national context of Germany is used to investigate this effect.

Apart from its strong employment protection legislations, Germany also has strong parental leave legislations and is at the same time characterised by traditional gender roles (Leuze and Strauß 2016, p. 804). This combination might contribute to employers' reluctance to hire women or at least results in a comparatively large gender wage gap even among the highly educated (Leuze and Strauß 2016, p. 804).

Assuming that only career-oriented people will self-select into time-erodible majors, while family-oriented individuals prefer time-durable ones, we expect the mere graduation from these majors as a signal for career orientation (in case of time-erodible majors) or family orientation (time-durable majors) in themselves. Hence, employers interested in respective graduates have a clear idea about the career orientation of these graduates. With heterogeneous major graduates, however, employers are unsure about the true nature of an individual's work attitude. In lack of any signal, the employer will use one's gender to infer her work attitude, assuming women to be – on average – family-oriented and men to be career-oriented. Attaining a doctoral degree, thus, allows a career-oriented woman to validly signal her career orientation to the employer and, therefore, gain higher wages compared to women without a doctoral degree. For men, however, who are already assumed to be career-oriented, having a doctoral degree does not hold such signalling effect, resulting in higher doctoral wage premiums for women than men in heterogeneous majors. The results of a single equation OLS estimation with interaction between gender and doctoral degree as well as an Oaxaca-Binder decomposition for the subsample of mixed major graduates support our hypothesis. According to our Oaxaca-Blinder decomposition, a doctoral degree reduces the gender wage gap by 1.78 percent.

To some degree, this finding is in favour of the EU's goal to increase average employment rates to 75 percent of the labour force (European Commission 2017a) at least in the long run, as it targets the determinants of female labour market participation as a by-product. If these doctoral wage premiums for women mean that more women occupy positions at (top) management level, than these women might encourage other women to join the labour market or actively reduce labour market discrimination against women (Cardoso and Winter-Ebmer 2010; Cohen and Huffman 2007), causing a "ripple effect" (Cohen and Huffman 2007, p. 699) that may result in increased overall female labour market participation.

6.2 Implications and future research

All findings in this book have major implications at individual, political, and firm level. Results in Chapter 3 suggest that doctoral enrolment rates are higher if education at college level is structured in a one-cycle structure in lieu of a two-cycle structure. Apart from its potential negative effect on EU objectives, this result holds major implications for universities: With fewer doctoral students today, there might be less (potential) teaching personnel in the future. With doctoral students supporting academic teaching and with future academic teaching personnel originating from these students, politicians and educational institutions might feel pressured to promote academic careers more actively early on or might even consider to restructure doctoral education in order to fit the new situation.

In Chapter 4, I showed that while research skills are remunerated for time-erodible major graduates, they are not remunerated for time-durable major graduates in Germany. These findings in themselves have important implications for firms and individuals: First, individuals might question their doctoral enrolment decisions. With no doctoral wage premium for time-durable major graduates, these individuals would rationally refrain from doctoral education. Nonetheless, we observe doctoral graduates in these majors (although at a lesser degree than in time-erodible majors). The argument in Chapter 4, however, fails to explain their enrolment decision. A potential motivator is the pure interest in a certain field or the prospect of career steps in a more distant future. Hence, future research should investigate the doctoral wage premium in time-erodible and time-durable majors 10 or 15 years after graduation to test for their potential doctoral wage premiums in later work life. As of today, however, the corresponding data is not yet available for the class of 2005.

Second, employers that hire time-erodible major graduates should realise that time-erodible knowledge needs to be constantly renewed and that research skills imparted by doctoral studies might be one way to do so. If employers fail to provide the research environment necessary to elaborate on their human capital stock, they could fail to exploit the competitive advantage their investment in doctoral graduates provides.

With Germany as a former one-cycle country which changed its curricular structure to a two-cycle structure in accordance with the Bologna objectives, I expect doctoral graduates to become scarcer while – in order to stay competitive – future firms might need to be more and more innovative and thus require more research skills especially in technology and sciences, i.e. doctoral graduates in time-erodible majors. Hence, we might expect the future demand to be even higher than today while research findings in Chapter 3 suggest future doctoral supply to drop. This could result in even higher wage premiums for doctoral graduates in time-erodible majors in the future. Given this prognosis, future research should investigate (i) whether the number of doctoral graduates will actually drop in former one-cycle countries and (ii) depending on this outcome whether the doctoral wage premium for time-erodible major graduates increases further.

Additionally, the remuneration of doctorates in time-durable majors might also change in the future. With fewer doctoral students as a consequence of decreased doctoral enrolment rates and less personnel to support academic teaching, more fixed-term employees (with doctoral degrees) might be needed in higher educational institutions, possibly leading to increased demand and hence wage premiums for doctorate holders in time-durable majors, too. Again, it is up to future research to investigate this effect given that future doctoral supply actually drops. As of today, however, we would not yet be able to recognise this potential decrease in supply as present doctoral graduates in Germany attended college during a time when the one-cycle structure was still the predominant system.

Results in Chapter 5 suggest that in heterogeneous majors, doctoral degrees reduce the unexplained gender wage gap. We interpret this result such that women can use doctoral degrees to signal their career orientation to reduce demand-side discrimination. Therefore, it is still important to ensure that women are not deterred from attaining doctoral studies so that they are able to signal their inherent career orientation to the labour market. Promoting doctoral education among women or even introducing mechanisms such as scholarships for women to enhance female enrolment should be considered with caution as this could deter the potential signalling effect of doctoral degrees.

While as of today, our results indicate that there is no doctoral wage premium for men in mixed majors, this result might change once doctoral enrolments decrease. As speculated above, demand for doctorates might exceed its supply leading to higher wages for both men and women. Whether the gender difference in the doctoral wage premium will change once doctoral enrolment rates decrease is less clear. It depends on whether male and female enrolment rates decrease equally or whether one decreases more drastically. If there is an even reduction across gender, the effect on the gender wage gap might not change, ceteris paribus. If especially women refrain from doing their doctoral degrees, those who still enrol are presumably the most career-oriented ones, resulting in an even larger doctoral wage premium for women (in the private sector where wages are less restricted to collective agreements). Hence, it would be interesting to investigate this question in the future.

As the discussion above shows, the changes due to the Bologna Process provides us with various interesting future research questions regarding the determinants and effects of doctoral degrees in general but especially in former one-cycle countries such as Germany. With an eye on the Europe 2020 strategy, these developments are of major interest for politicians as well. However, as the two-cycle structure in Germany and various other European countries was not fully implemented before 2013, it is still too early to fully observe these effects.

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Appendix

A Theoretical appendix

A.1 Assumptions regarding the cost function in the signalling framework

This part of the appendix presents further assumptions regarding the educational cost function as used in Section 3.3 in order to give a better idea of its shape and characteristics. As in the standard signalling model, educational costs increase with educational levels, e (higher levels of education may encompass higher levels of study effort) and decrease with ability, θ (attending a given educational level causes lower costs for the more than for the less productive individual) (Spence 1973), so that

$$\frac{\partial c(e,\theta)}{\partial e} > 0, \tag{50}$$

$$\frac{\partial c(e,\theta)}{\partial \theta} < 0. \tag{51}$$

Moreover, the marginal costs of gaining the next educational degree are lower, the more productive an individual is (Mas-Colell et al. 1995, p. 453), so that

$$\frac{\partial c(e,\theta)}{\partial e\,\partial \theta} < 0. \tag{52}$$

Hence, it is easier for the more productive individual than for the less productive one to further extend her education. This property implies that the education-wage-indifference curves of two differently productive individuals cross only once and that, at this point, the indifference curve of the less productive individual is steeper than the more productive one's (Mas-Colell et al. 1995, p. 453; Riley 2001). Given this cost function, it might be rational for the more productive individual to acquire further education, while it is not for the less productive one: The wage premium from attaining further education (which is equal for both individuals as wages reflect the expected average marginal productivity of all individuals with the respective educational degree) might compensate for the marginal costs of the more productive individual but not for the marginal costs of the less productive one (Mas-Colell et al. 1995, p. 455). Hence, this 'single crossing condition' is central in signalling models as it gives rise to the separation of groups or individuals (Riley 2001).

The individual aims to maximise her lifetime income. Therefore, she maximises the difference between the expected wage with a certain educational degree and the costs of attaining this degree. The individual's objective function with different educational levels is

$$w(e_0) - c(e_0, \theta) \quad \text{, with educational level } e_0, \tag{53}$$

$$w(e_1) - c(e_0, \theta) - c(e_1, \theta) \quad \text{, with educational level } e_1, \tag{54}$$

$$w(e_2) - c(e_0, \theta) - c(e_1, \theta) - c(e_2, \theta) \quad \text{, with educational level } e_2. \tag{55}$$

Note that individuals at higher educational levels have to bear the costs at lower levels, too (Bedard 2001, p. 752; Ryan 2001, p. 194).

A.2 Semi-pooling equilibria in one- and two-cycle systems

Following Franaszek (2012), this section proves the existence of a semi-pooling equilibrium in the one-cycle system and two semi-pooling equilibria in the two-cycle system, respectively. In order to do so, assume that at the edges of the productivity interval $[\underline{\theta}; \overline{\theta}]$ the cost function converges to infinity (Franaszek 2012, p. 4),

$$\lim_{\theta \to \underline{\theta}} c(e, \theta) = \infty, \tag{56}$$

and to zero, respectively,

$$\lim_{\theta \to \overline{\theta}} c(e, \theta) = 0. \tag{57}$$

The least productive individual is inflicted with infinitely high educational costs while the most productive one bears no educational costs at all.

A.2.1 Semi-pooling equilibrium in one-cycle countries

Assume that productivity, θ, is continuously and equally distributed over the interval $[\underline{\theta}; \overline{\theta}]$[144]. Furthermore, there are two educational levels, e_1 and e_2, with $e_1 < e_2$. It has to be shown that there is a semi-pooling equilibrium at θ^* so that all individuals with productivity θ, $\theta > \theta^*$, choose e_2, those with $\theta, \theta < \theta^*$, choose e_1, and all individuals with θ^* are indifferent between e_1 and e_2, given $\theta \in [\underline{\theta}; \overline{\theta}]$ (Franaszek 2012, pp. 5–6).

With a semi-pooling equilibrium at θ^*, the set of strategies followed by the actors is a Nash equilibrium. In a Nash equilibrium the individual only chooses a higher educational level if she is sufficiently productive (i.e. if the returns exceed the costs of acquiring the degree). The employer offers wages equal to the marginal productivity of individuals with a certain educational degree (Riley 2001, p. 444). Such an equilibrium exists if both individual rationality and incentive compatibility conditions are satisfied (Franaszek 2012, p. 6).

[144] Franaszek (2012) shows that this is possible without any loss of generality.

Individual rationality implies that an individual will rationally choose the educational level for which the return on investment exceeds educational costs, yielding (Franaszek 2012, p. 6):

$$w(e_2) - c(e_2, \theta) - c(e_1, \theta) \geq 0, \text{if } \theta > \theta^*, \quad (58)$$
$$w(e_1) - c(e_1, \theta) \geq 0, \text{if } \theta < \theta^*.$$

The incentive compatibility conditions reflect that the employer correctly assesses the effect of the wage premium, yielding for the more productive individuals with $\theta > \theta^*$ (Franaszek 2012, p. 6):

$$w(e_2) - c(e_2, \theta) - c(e_1, \theta) > w(e_1) - c(e_1, \theta), \quad (59)$$
$$w(e_2) - w(e_1) > c(e_2, \theta),$$

and for the less productive ones with $\theta < \theta^*$:

$$w(e_2) - c(e_2, \theta) - c(e_1, \theta) < w(e_1) - c(e_1, \theta), \quad (60)$$
$$w(e_2) - w(e_1) < c(e_2, \theta).$$

Note that the wage premium $w(e_2) - w(e_1)$ "is simply a number" (Franaszek 2012, p. 6). Moreover, as $c(e, \theta)$ is continuous and differentiable in θ, so are the additional costs from attaining e_2, $c(e_2, \theta)$ (Franaszek 2012, pp. 6–7). With an increase in θ, the marginal costs form attaining further education decrease. That is, the net income from attaining further education increases in θ (Bergh and Fink 2009, p. 380). Moving closely to θ^* from both edges of the interval (Franaszek 2012, pp. 6–7), yields

$$w(e_2) - w(e_1) = c(e_2, \theta^*). \quad (61)$$

Hence, to prove the existence of a semi-pooling equilibrium at θ^*, one has to show that an individual with θ^* exists for whom the wage premium from attaining e_2 equals the additional costs of doing so (Franaszek 2012, p. 7).

Note that θ is equally distributed over $[\underline{\theta}; \overline{\theta}]$. The wage offers according to the observed educational levels e_1 and e_2 are (Franaszek 2012, p. 4)

$$w(e_1) = \frac{\underline{\theta} + \theta^*}{2}, \quad (62)$$

$$w(e_2) = \frac{\theta^* + \overline{\theta}}{2}. \quad (63)$$

Therefore, the wage premium from attaining e_2 is

$$w(e_2) - w(e_1) = \frac{\theta^* + \overline{\theta}}{2} - \frac{\underline{\theta} + \theta^*}{2} = \frac{\overline{\theta} - \underline{\theta}}{2}. \quad (64)$$

Additionally, for the right hand side of (64) it holds that (Franaszek 2012, p. 7)

$$\lim_{\theta \to \underline{\theta}} c(e_2, \theta) = \infty, \quad (65)$$

$$\lim_{\theta \to \overline{\theta}} c(e_2, \theta) = 0. \quad (66)$$

As long as the wage premium $w(e_2) - w(e_1)$ is positive, an individual's utility function $w(e_2) - w(e_1) - c(e_2, \theta)$ has two different signs at the edges of the interval $[\underline{\theta}; \overline{\theta}]$ (Franaszek 2012, p. 7), as expressed by

$$\lim_{\theta \to \underline{\theta}} [w(e_2) - w(e_1) - c(e_2, \theta)] < 0, \quad (67)$$

$$\lim_{\theta \to \overline{\theta}} [w(e_2) - w(e_1) - c(e_2, \theta)] > 0. \quad (68)$$

With regard to the intermediate value theorem there exists a solution to (61) which is unique, as $c(e_2, \theta)$ is increasing in θ (Franaszek 2012, p. 7). In other words, as an individual's utility from gaining higher education, $w(e_2) - w(e_1) - c(e_2, \theta)$, is strictly increasing in θ, there is exactly one productivity level θ^* where the wage premium equals the costs of attaining further education. Furthermore, with θ^* being indifferent between e_1 and e_2, and with (67) and (68) it can be shown that all individuals with $\theta < \theta^*$ choose e_1, while all individuals with $\theta > \theta^*$ choose e_2.

A.2.2 Semi-pooling equilibria in two-cycle countries

Consider the two-cycle system with three distinct educational levels, e_0, e_1, and e_2. Again, θ is continuously and equally distributed over the interval $[\underline{\theta}; \overline{\theta}]$ (Franaszek 2012). It has to be shown that an individual with productivity θ, chooses educational level e_0 if $\underline{\theta} < \theta < \theta'$, and educational level e_1 if $\theta' < \theta < \theta''$, and educational level e_2 if $\theta'' < \theta < \overline{\theta}$. An individual with θ' is indifferent between e_0 and e_1 and an individual with θ'' is indifferent between e_1 and e_2, given $\theta \in [\underline{\theta}; \overline{\theta}]$ (Franaszek 2012, p. 7).

With semi-pooling equilibria at θ' and θ'', all sets of strategies followed by the actors are Nash equilibria that satisfy individual rationality as well as incentive compatibility conditions (Franaszek 2012, p. 14). The individual rationality condition can be expressed as (Franaszek 2012, p. 14)

$$w(e_b) - c(e_b, \theta) \geq 0, \text{ if } \theta \in [\theta_b; \theta_{b+1}], \quad (69)$$

$$\text{with } b = 0,1,2;\ \theta_0 = \underline{\theta}, \theta_1 = \theta', \theta_2 = \theta'', \theta_3 = \overline{\theta}.$$

The educational level chosen depends on the individual's productivity, θ. As educational levels are discrete, the optimal educational level, $e(\theta)$, is locally constant and increases only weakly in θ (Franaszek 2012, p. 14). Educational costs, however, decrease monotonically in θ. Thus, an individual can only be indifferent between neighbouring educational levels (if at all) (Franaszek 2012, p. 14). Hence, the incentive compatibility conditions are

$$w(e_1) - w(e_0) < c(e_1, \theta), \text{ if } \theta \in (\underline{\theta}; \theta'), \tag{70}$$

$$w(e_1) - w(e_0) > c(e_1, \theta), \text{ if } \theta \in (\theta'; \theta''), \tag{71}$$

$$w(e_2) - w(e_1) < c(e_2, \theta), \text{ if } \theta \in (\theta'; \theta''), \tag{72}$$

$$w(e_2) - w(e_1) > c(e_2, \theta), \text{ if } \theta \in (\theta''; \overline{\theta}). \tag{73}$$

As $c(e, \theta)$ is continuous and differentiable in θ, moving closely to θ' and θ'' from both sides in each case (Franaszek 2012), there have to be individuals for whom it is true that (Franaszek 2012, p. 14)

$$w(e_1) - w(e_0) = c(e_1, \theta'), \tag{74}$$

$$w(e_2) - w(e_1) = c(e_2, \theta''). \tag{75}$$

Furthermore, as $c(e, \theta)$ continuously decreases in θ, the utility functions from gaining the next educational level, $w(e_1) - w(e_0) - c(e_1, \theta)$ and $w(e_2) - w(e_1) - c(e_2, \theta)$, respectively, increase in θ. Thus, there is only one solution to the maximization of each of the two functions.

B Definitions and descriptions of variables

Table 39: Definitions and descriptions of variables in Chapter 3

Variable *(name in do-file)*	Type	Definition	Source
Ph.D. rate *(PhDtoPopB)*	Continuous	Ratio of ISCED 6 graduations in all fields of study in year $(t + 3)$ to the population of the corresponding age cohort (25 to 34 years of age) in thousands in $(t + 3)$.	Eurostat (2014a)
One-cycle country *(Hist1Cycle)*	Binary	Dummy variable indicating whether curricula are organised in a one-cycle structure: 1 if curricula at ISCED 5 level are organised in a one-cycle structure and 0 if curricula are organised in a two-cycle structure.	Westerheijden et al. (2012), European Commission (1998), and Eurydice (2003)
Public spending on tertiary education (% of GDP) *(ExpendEduc56)*	Continuous	Public spending on tertiary education as a percentage of a country's gross domestic product.	Eurostat (2014a)
Students enrolled in private college level education (%) *(RPrivatA5)*	Continuous	Ratio of students enrolled in ISCED 5A studies in private institutions to those enrolled in ISCED 5A studies in any form of college level institution.	Eurostat (2014a)
Ratio of graduations from practically to theoretically based college studies *(RatioGrad51_BtoA)*	Continuous	Ratio of students graduating from practically oriented first degree studies to those graduating from theoretically based first degree programs at ISCED 5 level.	Eurostat (2014a)
Corruption Perceptions Index *(CPI)*	Continuous	A country's ranking on the Corruption Perceptions Index.	Transparency International (2014b)

(continued)

Table 39 *(continued)*

Variable *(name in do-file)*	**Type**	**Definition**	**Source**
Students graduating in 'high income' college majors (%) *(RM_MajorA51)*	Continuous	Ratio of graduations in engineering, manufacturing, construction, mathematics, computer sciences, and natural sciences to those in any field of study in theoretically based first degree ISCED 5 programs.	Eurostat (2014a)
Unemployment among people with college level education (%) *(Unemp_ISCED5)*	Continuous	Ratio of unemployed people to the population aged 15 and older, with ISECD 5 as highest educational level.	European Union Labour Force Survey, Eurostat (2014a)
Ratio of female to male college graduates *(RGrad5A1_FtoM)*	Continuous	Ratio of first degree ISCED 5A graduations of women to those of men.	Eurostat (2014a)
GDP per capita (log) *(lnGDP_PPP)*	Continuous	Logarithmic version of GDP per capita (measured in purchasing power standards).	Eurostat (2014a)
People aged 65 years or older (%) *(PropPop65plus)*	Continuous	Proportion of people in a country aged 65 years or older.	Eurostat (2014a)

Table 40: Definitions and descriptions of variables in Chapter 4 and 5[145]

Variable *(name in do-file)*	**Type**	**Definition**	**Wave**	**Question number**	**Original survey question in German** (DZHW 2005)	**Original variable**
w2_surveydate	Continuous	Date of second survey wave	2	–	–	x2dateinja x2dateinmo
ln wage *(w2_lnwage_tot)*	Continuous	Logarithmic version of gross monthly income reported in the second wave (i.e. 5 to 6 years after graduation).	2	4.15 4.17	"Wie hoch ist Ihr Brutto-Monatseinkommen?" "Welche zusätzlichen (Brutto-) Gehaltsbestandteile bekommen Sie?"	c2brutto c2zufixge c2zuvarge
Female *(female)*	Binary	Dummy variable for being female: 1 if individuals is female, 0 otherwise.	1	6.8	"Ihr Geschlecht?"	geschl
Attained doctoral degree *(w2_phdcompleted)*	Binary	Dummy variable indicating whether individual holds a doctoral degree 5 to 6 years after graduation: 1 if individual obtained a doctoral degree, 0 otherwise.	2	2.1	"Haben Sie eine Promotion begonnen oder abgeschlossen?"	d2wsppromo
Degree provides direct access to doctoral studies *(phddesigned)*	Binary	Dummy variable for providing direct access to doctoral studies: 1 if degree provides direct access to doctoral programs (i.e. Diplom and Magister studies), 0 otherwise.	1	1.2	"Welche Studienabschlüsse und welche Examina haben Sie erlangt?"	absart1

(continued)

[145] Data extracted from DZHW (2005) via remote access. For excess to the data and questionnaires of the graduate panel of the examination cohort of 2005 which were used in Chapter 4 and 5 of this book, please contact dataservice@dzhw.eu. To re-estimate the results in Chapter 4 and 5, please request access to the variables listed in column „Original variable".

Table 40 *(continued)*

Variable *(name in do-file)*	**Type**	**Definition**	**Wave**	**Question number**	**Original survey question in German** (DZHW 2005)	**Original variable**
Marital status *(w2_familystat)*	Categorical		2	8.1	"Sind Sie zurzeit … ohne feste/n Partner/in [,] in fester Partnerschaft [,] verheiratet?"	k2famstand
Without partner (Ref. cat.) *(w2_familystat_1)*	Binary	Dummy variable indicating whether individual is single 5 to 6 years after graduation: 1 if individual is single, 0 otherwise.				
With partner *(w2_familystat_2)*	Binary	Dummy variable indicating whether individual is in a stable relationship (but not married) 5 to 6 years after graduation: 1 if individual is in a stable relationship, 0 otherwise.				
Married *(w2_familystat_3)*	Binary	Dummy variable indicating whether individual is married 5 to 6 years after graduation: 1 if individual is married, 0 otherwise.				
Has at least one child *(w2_child)*	Binary	Dummy variable indicating whether individual has at least one child 5 to 6 years after graduation: 1 if individual has at least one child, 0 otherwise.	2	8.3	"Haben Sie Kinder?"	k2kinder
Qualification adequately employed *(w2_qualiadeqemployment)*	Binary	Dummy variable indicating whether individual believes to be qualification adequately employed 5 to 6 years after graduation: 1 if someone believes to be (to some degree) adequately employed and 0 otherwise.	2	4.21	"Würden Sie sagen, dass Sie Ihrer Hochschulqualifikation entsprechend beschäftigt sind?"	c2qualpos

(continued)

Table 40 *(continued)*

Variable *(name in do-file)*	**Type**	**Definition**	**Wave**	**Question number**	**Original survey question in German** (DZHW 2005)	**Original variable**
Grade of university degree *(collegegrade_cat)*	Categorical		1	1.3	"Wann haben Sie im Rahmen Ihres Examens Ihre letzte Prüfungsleistung […] erbracht und welche Gesamtnote […] haben Sie erzielt?"	examnote
Very good *(collegegrade_cat1)*	Binary	Dummy variable indicating whether someone has "very good" final university grades (i.e. 1.5 or better): 1 if the individual's final university grade is very good, 0 otherwise.				
Good *(collegegrade_cat2)*	Binary	Dummy variable indicating whether someone has "good" final university grades (i.e. worse than 1.5 but better or equal 2.5): 1 if the individual's final university grade is good, 0 otherwise.				
Satisfying or sufficient (Ref. cat.) *(collegegrade_cat3)*	Binary	Dummy variable indicating whether someone has "satisfying or sufficient" final university grades (i.e. worse than 2.5): 1 if the individual's final university grade is satisfying or sufficient, 0 otherwise.				
College major *(majorB)*	Categorical		1	1.2	"Welche Studienabschlüsse und welche Examina haben Sie erlangt?"	fach1ab1
Major in arts (Ref. cat.) *(majorB_cat1)*	Binary	Dummy variable indicating whether someone's college major is in arts: 1 if the individual majored in arts, 0 otherwise.				
Major in humanities *(majorB_cat2)*	Binary	Dummy variable indicating whether someone's college major is in humanities: 1 if the individual majored in humanities, 0 otherwise.				

(continued)

Table 40 *(continued)*

Variable *(name in do-file)*	**Type**	**Definition**	**Wave**	**Question number**	**Original survey question in German** (DZHW 2005)	**Original variable**
Major in theology *(majorB_cat3)*	Binary	Dummy variable indicating whether someone's college major is in theology: 1 if the individual majored in theology, 0 otherwise.	1	1.2	"Welche Studienabschlüsse und welche Examina haben Sie erlangt?"	fach1ab1
Major in linguistics and cultural sciences *(majorB_cat4)*	Binary	Dummy variable indicating whether someone's college major is in linguistics or cultural sciences: 1 if the individual majored in linguistics or cultural sciences, 0 otherwise.				
Major in educational sciences *(majorB_cat5)*	Binary	Dummy variable indicating whether someone's college major is in educational sciences: 1 if the individual majored in educational sciences, 0 otherwise.				
Major in social sciences *(majorB_cat6)*	Binary	Dummy variable indicating whether someone's college major is in social sciences: 1 if the individual majored in social sciences, 0 otherwise.				
Major in sports and health sciences *(majorB_cat7)*	Binary	Dummy variable indicating whether someone's college major is in sports or health sciences: 1 if the individual majored in sports or health sciences, 0 otherwise.				
Major in business administration *(majorB_cat8)*	Binary	Dummy variable indicating whether someone's college major is in business administration: 1 if the individual majored in business administration, 0 otherwise.				

(continued)

Table 40 *(continued)*

Variable *(name in do-file)*	**Type**	**Definition**	**Wave**	**Question number**	**Original survey question in German** (DZHW 2005)	**Original variable**
Major in economics *(majorB_cat9)*	Binary	Dummy variable indicating whether someone's college major is in economics: 1 if the individual majored in economics, 0 otherwise.	1	1.2	"Welche Studienabschlüsse und welche Examina haben Sie erlangt?"	fach1ab1
Major in administrative sciences and economic law *(majorB_cat10)*	Binary	Dummy variable indicating whether someone's college major is in administrative sciences or economic law: 1 if the individual majored in administrative sciences or economic law, 0 otherwise.				
Major in agricultural and nutritional sciences *(majorB_cat12)*	Binary	Dummy variable indicating whether someone's college major is in agriculture or nutritional sciences: 1 if the individual majored in agriculture or nutritional sciences, 0 otherwise.				
Major in mathematics *(majorB_cat13)*	Binary	Dummy variable indicating whether someone's college major is in mathematics: 1 if the individual majored in mathematics, 0 otherwise.				
Major in natural sciences *(majorB_cat14)*	Binary	Dummy variable indicating whether someone's college major is in natural sciences: 1 if the individual majored in natural sciences, 0 otherwise.				
Major in engineering *(majorB_cat15)*	Binary	Dummy variable indicating whether someone's college major is in engineering: 1 if the individual majored in engineering, 0 otherwise.				

(continued)

Table 40 *(continued)*

Variable *(name in do-file)*	**Type**	**Definition**	**Wave**	**Question number**	**Original survey question in German** (DZHW 2005)	**Original variable**
Total sum of work experience in months *(w2_totworkexp)*	Continuous	Number of month spent in employment relationships such as regular employment, self-employment, service contracts, casual work, and internships until 5 to 6 years after graduation.	2	1.7	"Um die Wege beim Übergang aus dem Studium in das Berufsleben und in andere Lebensbereiche besser verstehen zu können, bitten wir Sie, Ihre seit Anfang 2006 ausgeübten Tätigkeiten in den folgenden Kalender einzutragen."	mo01jobs-mo85jobs mo01srer-mo85srer mo01usre-mo85usre mo01werk-mo85werk mo01prak-mo85prak
Total working hours per week *(w2_workhours_tot)*	Continuous	Average number of weekly working hours spent in main occupation and possible secondary employments 5 to 6 years after graduation.	2	4.19	"Wie viele Arbeitsstunden verwenden Sie insgesamt pro Woche durchschnittlich für Ihre berufliche Tätigkeit? Haupttätigkeit (einschließlich Überstunden, Mehrarbeit) [, g]gf. zweite Beschäftigung oder Nebentätigkeit"	c2wazhau c2wazneb

(continued)

Table 40 *(continued)*

Variable *(name in do-file)*	**Type**	**Definition**	**Wave**	**Question number**	**Original survey question in German** (DZHW 2005)	**Original variable**
Form of employment *(w2_jobstatus)*	Categorical		2	4.3	"Im Folgenden bitten wir Sie um eine nähere Beschreibung der verschiedenen beruflichen Tätigkeiten, die Sie im Jahr 2006 und danach ausgeübt haben."	c2job1lnoc-c2job9lnoc c2job1manf-c2job9manf c2job1janf-c2job9janf c2job1mend-c2job9mend c2job1jend-c2job9jend c2job1std-c2job9std c2job1arve-c2job9arve
Unrestricted contract *(w2_jobstatus_1)*	Binary	Dummy variable indicating whether one's current (or last) "main job" is based on an unrestricted contract 5 to 6 years after graduation: 1 if the employed based on an unrestricted contract, 0 otherwise.				
Fixed-term contract (incl. apprenticeship/service contract) (Ref. cat.) *(w2_jobstatus_2)*	Binary	Dummy variable indicating whether one's current (or last) "main job" is based on a fixed-term contract (incl. apprenticeship/service contract) 5 to 6 years after graduation: 1 if the employed based on a fixed-term contract, 0 otherwise.				
Self-employed *(w2_jobstatus_3)*	Binary	Dummy variable indicating whether someone is currently (or was in her last) "main job" self-employed 5 to 6 years after graduation: 1 if the person is self-employed, 0 otherwise.				
Public sector *(w2_publicsector)*	Binary	Dummy variable indicating whether the individual is employed in the public sector or whether her wage is adjusted to the remuneration in the public sector 5 to 6 years after graduation: 1 if someone is working in the public sector or payed accordingly, 0 otherwise.	2	4.6	"Sind Sie im öffentlichen Dienst bzw. in einem dem öffentlichen Dienst tariflich angeglichenen Arbeitsverhältnis beschäftigt?"	c2oeffdi

(continued)

Table 40 *(continued)*

Variable *(name in do-file)*	**Type**	**Definition**	**Wave**	**Question number**	**Original survey question in German** (DZHW 2005)	**Original variable**
Employed in large-scale enterprise *(w2_concern)*	Binary	Dummy variable indicating whether someone works in a subsidiary that is part of a corporate structure 5 to 6 years after graduation: 1 if the individual is employed in a large-scale company, 0 otherwise.	2	4.7	"Arbeiten Sie in einem Betrieb, der Teil eines größeren Unternehmens ist?"	c2konzern
Industry *(w2_industry)*	Categorical		2	4.9	"Welchem Wirtschaftsbereich gehört der Betrieb bzw. die Einrichtung schwerpunktmäßig an, in dem/der Sie arbeiten?"	c2branche
Primary or manufacturing sector industries *(w2_industry_1)*	Binary	Dummy variable indicating whether someone is working in the primary or manufacturing sector 5 to 6 years after graduation: 1 if the individual works in a predominantly in primary or manufacturing sector industry, 0 otherwise.				
Public sector industries *(w2_industry_2)*	Binary	Dummy variable indicating whether someone is working in a public sector industry 5 to 6 years after graduation: 1 if the individual works in public sector industry, 0 otherwise.				
Services (Ref. cat.) *(w2_industry_3)*	Binary	Dummy variable indicating whether someone is working in the service sector 5 to 6 years after graduation: 1 if the individual works in the service sector, 0 otherwise.				

(continued)

Table 40 *(continued)*

Variable *(name in do-file)*	**Type**	**Definition**	**Wave**	**Question number**	**Original survey question in German** (DZHW 2005)	**Original variable**
Location of job *(w2_region)*	Categorical		2	4.3	"Im Folgenden bitten wir Sie um eine nähere Beschreibung der verschiedenen beruflichen Tätigkeiten, die Sie im Jahr 2006 und danach ausgeübt haben."	c2job1land-c2job9land
East-Germany (Ref. cat.) *(w2_region_1)*	Binary	Dummy variable indicating whether someone's job is located in East-Germany 5 to 6 years after graduation: 1 if the job is located in East-Germany, 0 otherwise.				
West-Germany *(w2_region_2)*	Binary	Dummy variable indicating whether someone's job is located in West-Germany 5 to 6 years after graduation: 1 if the job is located in West-Germany, 0 otherwise.				
Abroad *(w2_region_3)*	Binary	Dummy variable indicating whether someone's job is located in a foreign country (Europe and non-European countries) 5 to 6 years after graduation: 1 if the job is located out of Germany, 0 otherwise.				