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TUTKIMUKSIA / STUDIES

Returns to doctoral education in Finland

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ABSTRACT

This report examines the evolution of the economic status and role of PhD holders in Finland's labor market and firms using Statistics Finland's register and survey data. Special attention is paid to PhD graduates in the business, ICT, and engineering fields. The findings indicate a very tight labor market for PhD holders until the late 2000s, followed by rising unemployment and overeducation among them, as well as a stagnating wage premium for completing a PhD, in the 2010s. While PhDs have earned more than master's and bachelor's graduates on average, the PhD wage premium is found to be much higher for women than for men and to vary across fields of study. The firm-level analyses show no significant changes in productivity or profitability around the event of hiring the first PhD in a firm, whereas a higher share of PhD workers is found to be associated with increased wages and productivity. The results also provide suggestive evidence of PhDs, particularly those in the business, ICT, and engineering fields, playing a role in business-university collaboration.

JEL codes: I23, I26, J24, J31

Key words:
Higher education, Doctorate, Human capital, Labor markets, Wages, Firms, Research and development, Productivity, Business-university collaboration

TIIVISTELMÄ

Tutkijakoulutuksen tuotot Suomessa

Raportissa tarkastellaan tutkijakoulutettujen taloudellisen aseman ja roolin kehitystä Suomen työmarkkinoilla ja yrityksissä Tilastokeskuksen rekisteri- ja kyselyaineistoilla. Erityishuomiota kiinnitetään kauppatieteiden, ICT- ja tekniikan alojen tohtoreihin. Tulosten mukaan tutkijakoulutettujen työmarkkinat olivat kireät vielä 2000-luvun ensimmäisellä vuosikymmenellä. Tämän jälkeen tutkijakoulutettujen työttömyys ja työskentely koulutusta vastaamattomissa tehtävissä ovat lisääntyneet, samalla kun tutkijakoulutuksen palkkapreemion kasvu on pysähtynyt. Siinä missä tutkijakoulutettujen palkkatulot ovat keskimäärin ylittäneet ylemmän ja alemman korkeakoulututkinnon suorittaneiden palkkatulot, tutkijakoulutuksen palkkapreemion havaitaan olevan selvästi suurempi naisille kuin miehille sekä vaihtelevan koulutusalan mukaan. Yritystason tulokset eivät viittaa siihen, että yritysten tuottavuus tai kannattavuus muuttuisivat merkittävästi niiden palkatessa ensimmäisen tohtorinsa. Keskimäärin pienet lisäykset tutkijakoulutettujen osuudessa henkilökunnasta ovat kuitenkin yhteydessä isohkoihin parannuksiin yritysten keskipalkoissa ja tuottavuudessa. Tulosten mukaan erityisesti kaupallisten ja teknillisten alojen tohtoreilla voi myös olla merkitystä yritysten ja korkeakoulujen välisessä yhteistyössä.

JEL codes: I23, I26, J24, J31

Avainsanat:
Korkeakoulutus, tutkijakoulutus, inhimillinen pääoma, työmarkkinat, palkat, yritykset, tutkimus- ja kehitystoiminta, tuottavuus, korkeakoulujen yritysyhteistyö

SUMMARY

This report investigates the economic status and role of PhD holders in Finland, with a focus on PhDs' wage outcomes as well as their role in firms' performance and collaboration with higher education institutions. The study utilizes longitudinal population-wide register data on individuals and firms as well as survey data on firms' R&D resources and activities. While the data include all PhD holders who graduated and resided in Finland over the past several decades, special attention is paid to PhD graduates from the business, ICT, and engineering fields. The report's evidence of the associations between doctoral education and individual- and firm-level outcomes is based on regression and event study analyses and is mainly of descriptive nature.

The results regarding the evolution of PhDs' labor market outcomes suggest that, until the late 2000s, there was a significant imbalance in the demand and supply of PhDs in the labor market, as reflected by their low and largely acyclical unemployment, low overeducation rate, and rising relative annual wages. However, the increased supply of PhD graduates and Finland's prolonged economic problems evidently led to a cooling down of the PhD labor market in the 2010s, which showed up as PhDs holders' increased and procyclical unemployment and increased overeducation rate as well as a stagnation of the wage premium for completing a PhD and a less steep wage progression after doctoral graduation.

While PhDs have, on average, earned significantly higher annual wages compared to workers with only a master's or bachelor's degree during the past thirty years, the results reveal three types of interesting variation in the PhD wage premium. First, in terms of annual wages, women have benefited significantly more from completing a PhD after a master's degree than men. Second, the PhD wage premium varies across fields. For example, business and engineering PhDs have not, on average, earned higher annual wages than master's degree holders in these fields. Third, the results suggest that, after the early 2000s, newly graduated PhDs have earned a negative early-career wage premium relative to master's degree holders.

The results using firm-level data do not provide evidence of significant changes in firms' productivity or profitability around the event of recruiting the first PhD in a firm. However, the results suggest that, on average, small increases in the share of PhD workers are associated with significant increases in firms' mean wages and productivity. The share of PhDs is not, on average, found to be significant in terms of firms' profitability given the equal-size changes in wages and productivity. Finally, the analyses provide suggestive evidence that PhD workers, particularly those from the business, ICT, and engineering fields, may enhance cooperation between firms and higher education institutions.

YHTEENVETO

Tämä raportti tarkastelee tutkijakoulutuksen suorittaneiden taloudellista asemaa ja roolia Suomessa keskittyen tutkijakoulutettujen palkkakehitykseen sekä heidän rooliinsa yritysten suorituskyvyssä ja korkeakouluyhteistyössä. Tutkimusaineistona käytetään yksilö- ja yritystason rekisteritietoja sekä kyselyaineistoja yritysten tutkimus- ja kehitysresursseista ja -toiminnoista. Aineisto kattaa kaikki Suomessa tohtorintutkintonsa suorittaneet ja Suomessa asuneet henkilöt usean vuosikymmenen ajalta, mutta erityishuomiota kiinnitetään kauppatieteiden, ICT-alan ja tekniikan tohtoreihin. Raportissa esitetty tutkimusnäyttö tutkijakoulutuksen sekä yksilö- ja yritystason tulemien välisistä yhteyksistä on luonteeltaan pääasiassa kuvailevaa perustuen regressio- ja tapahtumatutkimusanalyysiin.

Tulokset tutkijakoulutettujen työmarkkinakehityksestä viittaavat siihen, että 2000-luvun loppupuolelle asti työmarkkinoilla vallitsi merkittävä epätasapaino tohtorien kysynnän ja tarjonnan välillä. Tämä näkyi tutkijakoulutettujen keskuudessa matalana työttömyysasteena, joka reagoi vain vähän suhdannevaihteluihin, ja alhaisena ylikoulutusasteena sekä tutkijakoulutettujen suhteellisten palkkatulojen kasvuna. Kuitenkin tutkijakoulutuksen suorittaneiden määrän kasvu ja Suomen pitkäaikaiset talousongelmat nähtävästi johtivat tohtorityömarkkinoiden jäähtymiseen 2010-luvulla. Tämä ilmeni tohtorien työttömyysasteen nousuna ja suhdanneherkkyytenä, ylikoulutuksen lisääntymisenä, tutkijakoulutuksen tuottaman palkkapreemion kasvun pysähtymisenä ja hitaampana valmistumisen jälkeisenä palkkakehityksenä.

Siinä missä tutkijakoulutettujen keskimääräiset palkkatulot ovat viimeisen kolmenkymmenen vuoden ajan ylittäneet ylemmän tai alemman korkeakoulututkinnon suorittaneiden keskimääräiset palkkatulot, tuloksista ilmenee myös kiinnostavaa vaihtelua tutkijakoulutuksen palkkapreemiossa. Tulosten mukaan naiset ovat hyötyneet merkittävästi miehiä enemmän tutkijakoulutuksen suorittamisesta ylemmän korkeakoulututkinnon päälle palkoilla mitattuna. Tutkijakoulutuksen palkkapreemion havaitaan vaihtelevan myös aloittain. Esimerkiksi kauppatieteiden ja tekniikan alojen tutkijakoulutetut eivät ole keskimäärin ansainneet enemmän kuin näiltä aloilta ylemmän korkeakoulututkinnon suorittaneet. Lisäksi tuloksista käy ilmi, että vastavalmistuneille tutkijakoulutetuille alku-uran palkkapreemio suhteessa ylemmän korkeakoulututkinnon suorittaneisiin on ollut negatiivinen 2000-luvun alun jälkeen.

Yritystason aineistoilla saadut tulokset eivät viittaa siihen, että yritysten tuottavuus tai kannattavuus muuttuisivat merkittävästi niiden rekrytoidessa ensimmäisen tutkijakoulutetun työntekijänsä. Tulokset viittaavat kuitenkin siihen, että pienet lisäykset tutkijakoulutettujen osuudessa yritysten henkilökunnasta ovat yhteydessä isohkoihin keskimääräisiin parannuksiin niiden keskipalkoissa ja tuottavuudessa. Tutkijakoulutettujen osuus ei kuitenkaan ole merkittävässä yhteydessä yritysten kannattavuuteen, koska palkkojen ja tuottavuuden muutokset ovat samansuuruisia. Lopuksi analyysit antavat viitteitä siitä, että tutkijakoulutetut – erityisesti kauppatieteiden, ICT-alan ja tekniikan tohtorit – voivat edistää yritysten ja korkeakoulujen välistä yhteistyötä.

1 Introduction

A vast body of literature, reviewed by Deming and Silliman (2024), has emphasized the economic importance of human capital, demonstrating that it can explain much of the variation in earnings across individuals and countries. However, the societal targeting of human capital investments is challenging, as the labor market returns to education and skills vary in many dimensions, for instance, across fields of study (e.g., Altonji et al., 2016; Altonji and Zimmerman, 2017; Altonji and Zhong, 2021) and across time (Deming, 2017; Edin et al., 2022; Izadi and Tuhkuri, 2024). This emphasizes the need for targeting human capital investments based on evidence that is both sufficiently granular and up to date.

The doctoral education pilot launched by the Finnish universities in 2024 is an interesting recent example of a large-scale human capital investment expected to entail significant economic benefits. The pilot, which involves training 1,000 new PhD holders within only three years (2024–2027), is supported by a government grant of 255 million euros. In addition to academic research, the pilot is expected to serve the R&D needs of businesses, as many of the doctoral graduates are expected to be employed in the business sector.[1]

However, the economic impact of the Finnish doctoral education pilot is currently difficult to anticipate given lack of evidence on some important questions, such as "To what extent is there unsatisfied demand for new PhD holders in the labor market?" and "Can investments in doctoral education boost firms' success?". While previous Finnish studies have examined income differences between PhD holders and lower-educated individuals (e.g., Uusitalo 1999; Suhonen and Jokinen 2018)[2] as well as PhD holders' employment, unemployment and sectoral sorting (Nuutinen, 2021; Holopainen, 2023; Gråsten, 2021; Helin et al., 2024), these studies lack many important aspects, such as PhDs' wage dynamics by field of study and the impacts of PhDs on firm-level outcomes.[3]

Public data sources provide certain pieces of information suggesting that there is room and need for additional PhDs in Finland. For example, based on the OECD data described in Figure 1, the share of PhD holders among 25—64-year-old residents was 1.4% in Finland in 2023 – which is

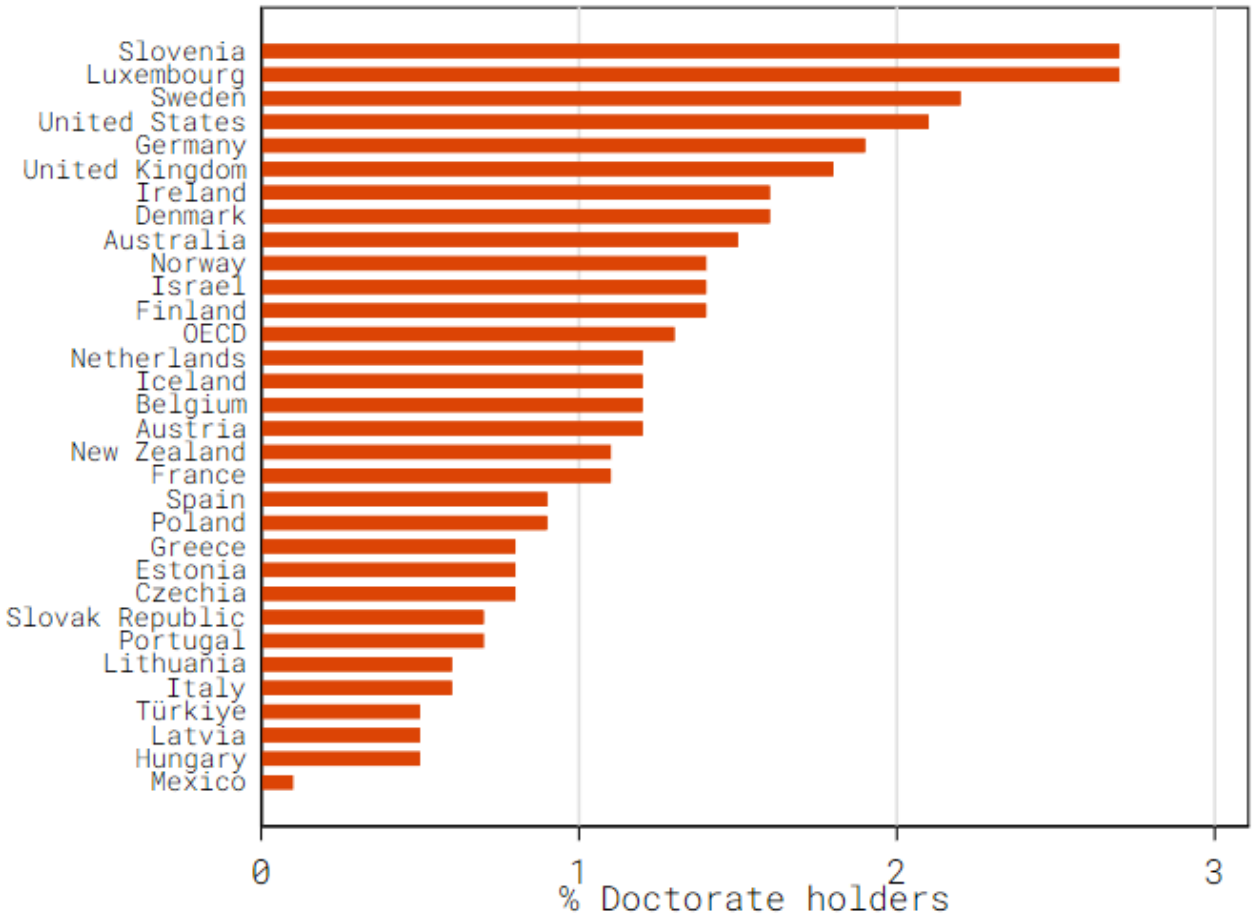
[1]Further information about the doctoral education pilot (in Finnish) is available at `https://okm.fi/tohtorikoulutuspilotti`.

[2]The prior Finnish evidence has suggested that the association between completing a PhD after a master's degree and later income is either small and positive (Suhonen and Jokinen, 2018) or small and negative (Uusitalo, 1999), while studies from abroad have often pointed towards positive individual-level returns (e.g., Mertens and Röbken 2013; Marini and Henseke 2023; Wouterse et al. 2017).

[3]The existing international evidence of the effects of PhD holders on firm outcomes is also scarce and mainly descriptive. Studies using Spanish data suggest that the availability of doctoral workers is positively associated with a firm's probability of starting basic research activities (Barge-Gil et al., 2021) and cooperation with scientific partners, including universities (Segarra-Blasco, 2011; Garcia-Quevedo et al., 2012). Garcia-Quevedo et al. (2012) further found that the cooperation between firms and universities is positively associated with the demand for workers with a doctoral degree. Shao et al. (2025) reports that Chinese companies with more PhDs exhibit stronger innovation performance. Furthermore, Urquhart and Zhang (2022) find, using data on FTSE 350 firms, that a CEO with a PhD is positively correlated with firm performance.

slightly above the OECD average (1.3%) and falls behind those measured in Finland's most important comparison countries: Sweden, Denmark, and Germany.[4] This suggests that, to catch up with the education level of its competitors, Finland needs additional investments in researcher training and/or international recruitment.

FIGURE 1: SHARE OF DOCTORATE HOLDERS AMONG 25–64-YEAR-OLDS IN OECD COUNTRIES (2023)



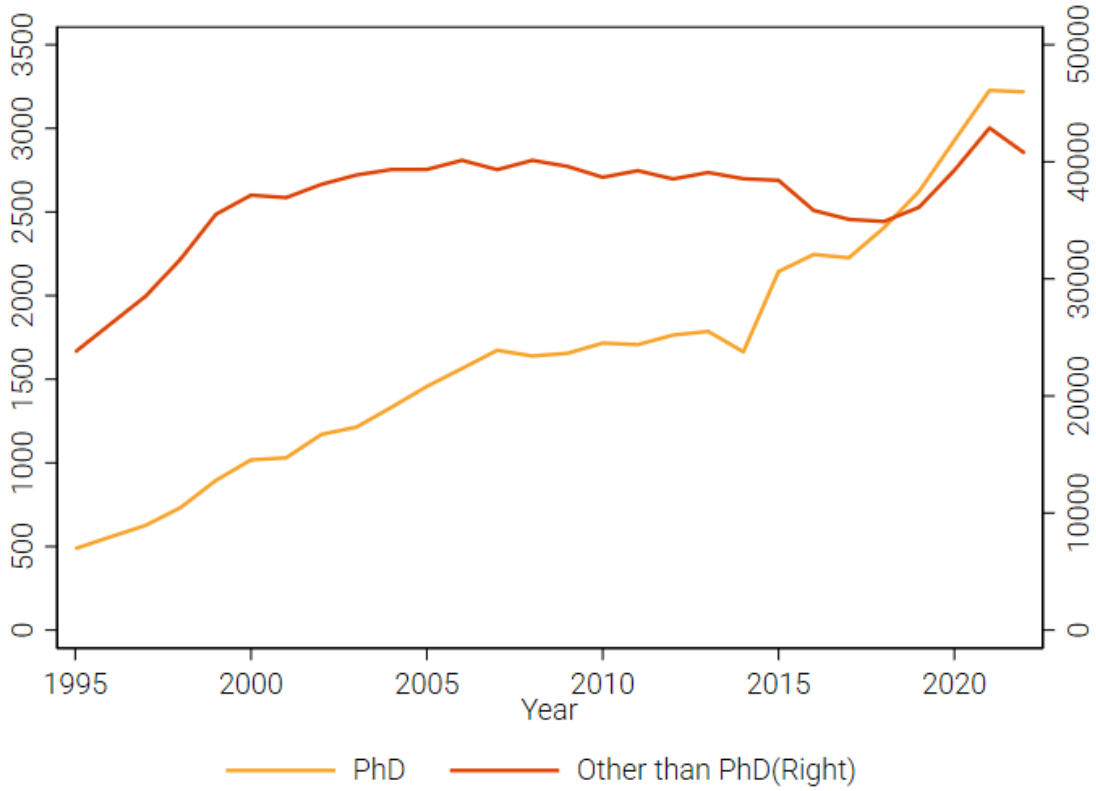
Source: OECD (2024)

Furthermore, Statistics Finland's R&D statistics provide some indication of growth in the business sector's demand for PhDs. Figure 2 shows that, after a period of slow growth in 2008–2014, the number of PhD holders working in firms' R&D positions has been growing rapidly, while the number of other R&D personnel has remained close to the early 2000s level.

To obtain a more comprehensive view of the demand for and economic contribution of PhDs in Finland, the current study moves beyond aggregated statistics and analyses microdata combining

[4]Figure B2 shows a steady increase, from 0.4% to 1.4%, in the share of PhDs among the 25—64-year-old population in Finland between 1987 and 2022.

FIGURE 2: R&D PERSONNEL IN FIRMS BY LEVEL OF EDUCATION



Source: Authors' own calculations based on Statistics Finland's research and development statistics

various types of individual- and firm-level information. We examine the following main research questions:

1. How have the wage incomes of PhDs from a particular field of study evolved over time relative to lower-educated workers within the same field?
2. How are the increases in the number of workers with a PhD reflected in firm performance?
3. What is the role of PhDs in cooperation between firms and universities?

While all Finland-based PhD holders are included in our empirical analyses, we pay special attention to PhDs graduated from the business and administration, ICT, and engineering fields—that is, the three broad fields closest to the sponsors of this research: KAUTE Foundation, TEK, and Suomen Ekonomit. The analyses rely primarily on Statistics Finland's register data, which covers all Finnish residents and firms over a long period of time. We also use nationally representative survey data from Statistics Finland's Innovation survey, particularly, to shed light on the third research question.

Although the analyses presented in this report are based on rich data, the results are to be interpreted with caution. While the data enable controlling for many of the background characteristics

of individuals and firms, including firms' time-invariant unobserved attributes, the results are not based on research designs that would identify causal effects in a highly credible manner. Moreover, it should be emphasized that our analysis focuses on direct returns from having a PhD degree (for individuals) or PhD-educated workers (for firms), dismissing possible wider social returns from doctoral education emerging, e.g., through the creation of general purpose technologies. Nevertheless, by providing descriptive evidence on associations that have not been extensively studied in the past, the report is hoped to pave the way for more rigorous and comprehensive studies on returns to doctoral education in Finland and elsewhere.

2 Data

The study utilizes Statistics Finland's longitudinal population-wide register data on Finnish individuals and firms, as well as firm-level survey data on R&D resources and activities. The employed datasets and key variables are listed in Table 1.

Given the availability of comprehensive educational records, all PhDs residing in Finland who obtained their doctoral degree from a Finnish university, as well as a portion of Finnish residents who earned their doctoral degree abroad, can be identified in the data. In many of the analyses, PhD holders are divided into four groups based on the field of their doctoral degree, following the 2016 national educational classification[5]: business and administration[6] (field 041), ICT (field 06), engineering (fields 071 and 072), and other fields (fields 01, 02, 03, 042, 05, 073, 08, 09, and 10).

The data allow for linking individual-level information on firms' employees to firm-level information, which makes it possible to separate PhD workers graduated in the fields of interest (business, ICT, and engineering) from others in the firm-level analyses.

[5]The educational classification is available at `https://stat.fi/en/luokitukset/koulutusala/koulutusala_1_20160101.`

[6]For conciseness, we mainly use the term *business* to refer to the field of business and administration throughout this report.

TABLE 1: DATASETS UTILIZED IN THE STUDY

Dataset	Description	Key variables used
FOLK Basic data	Basic data on Finland's residents, including information on their families and employment, at the end of each year between 1987 and 2023	year and region of birth, gender, origin, first language, education level, labor market status
FOLK Income	Data on persons' factor income, current transfers received, current transfers paid, wealth, and debts from 1987 to 2023	wage income, disposable income
FOLK Employment	Data on persons' employment based on the employment relationship during the last week of the year (TVM) and the longest employment relationship of the year (ATV) from 1987 to 2022	occupation, employer characteristics
EDUC Degrees and qualifications module	Data on all post-compulsory degrees and qualifications completed in Finland since 1971 and some information on education completed abroad	highest education completed: level, field and year
FIRM Financial statement data panel	Profit and loss account and balance sheet data for Finnish enterprises from 1986 to 2022	number of full-time equivalent employees, sum of wages, turnover, value added, profit
FIRM Research and development	Annual survey data (1985–2022) on resources used by enterprises for research and product and process development	number of R&D personnel
Innovation survey (2018, 2020, 2022)	Survey data on innovation activity carried out by enterprises, the potential of innovation activity and themes and phenomena closely linked to innovation activity	cooperation with universities, cooperation with universities of applied sciences

3 Descriptive analysis of Finnish PhD holders

This section describes the population of Finnish PhD holders from the late 1980s to the early 2020s, focusing on the number and composition of new PhD graduates as well as PhDs' employment statistics.

Figure 3 shows that, in the late 1980s, there were only around 500 PhD graduations per year in Finland. The number of PhD graduations increased rapidly during the 1990s, to around 1,500 yearly graduations, whereas the growth has been markedly slower and less steady after the turn of the century. The highest number of PhD graduates (1,806) was recorded in 2016, after which the number of PhD graduations has been on a slightly declining trend.

FIGURE 3: NUMBER OF PHD GRADUATIONS IN FINLAND

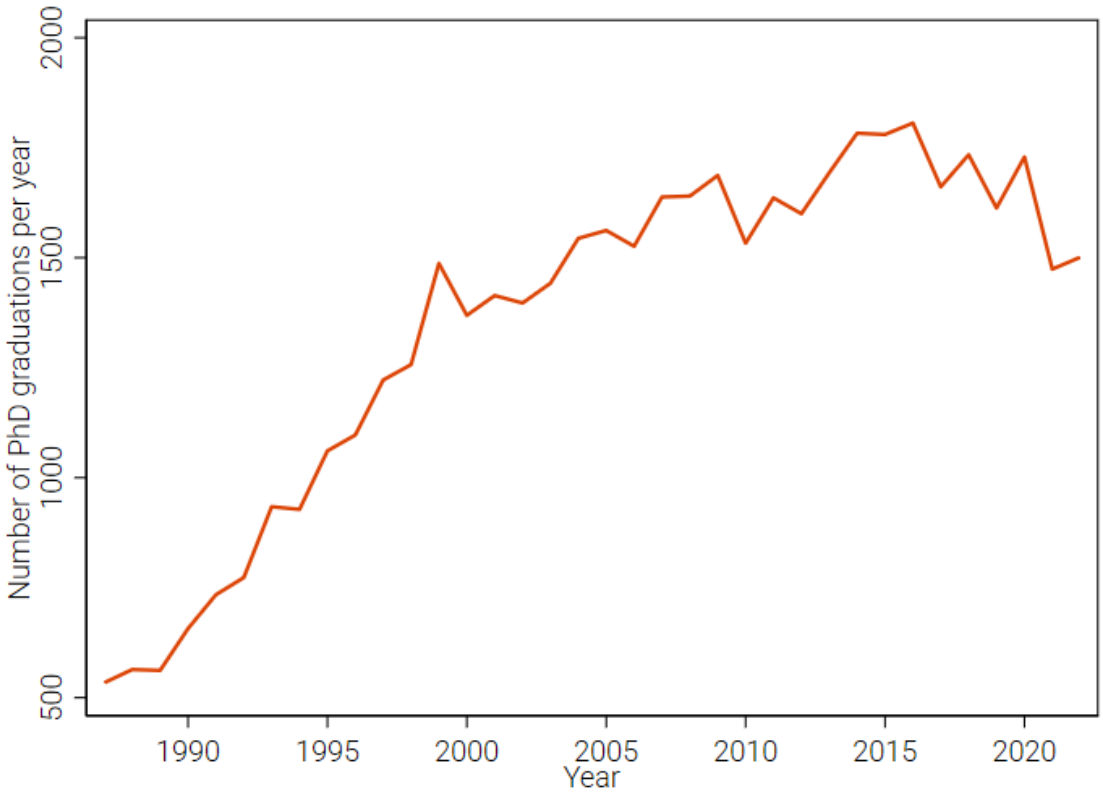
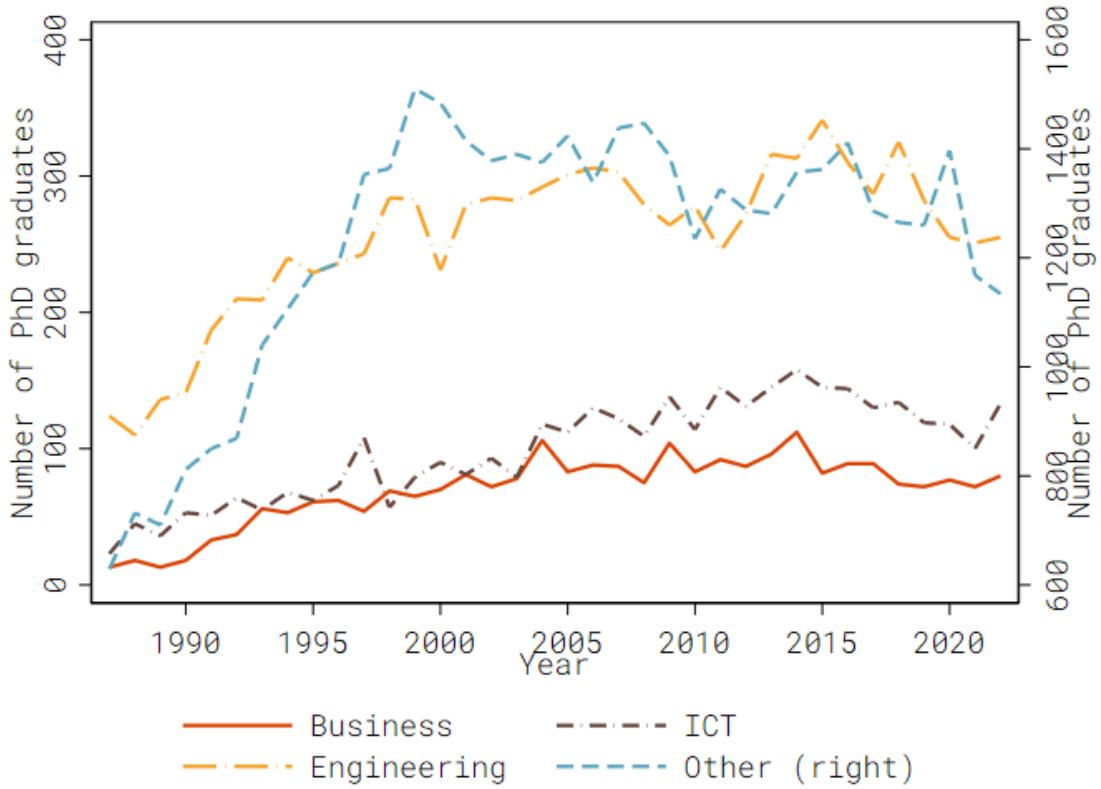


Figure 4 reports the number of PhD graduates by field of study. Of the three fields of interest (business, ICT, and engineering), engineering had the highest number of graduates throughout the observation period, increasing from around 100 to close to 300 graduates per year during the 1990s and remaining relatively steady ever since. In the two remaining fields, PhD graduations were still somewhat uncommon in the early period. For example, in 1987, only 13 doctoral degrees in business and 23 doctoral degrees in ICT were awarded in Finland. Over the observation period, the number of PhD graduations in these fields grew slowly, varying around 80 graduations in the business

field and around 120 graduations in the ICT field in the last years.

FIGURE 4: NUMBER OF PHD GRADUATIONS BY FIELD OF STUDY



The register data further show that, while the number of PhD graduates has increased, the composition of the graduates has also changed significantly in terms of the graduates' gender and origin. Figure 5 demonstrates that, still in the 1980s, women were highly underrepresented among PhD graduates in all four field-of-study categories (business, ICT, engineering, and other). However, the female participation in doctoral programs increased rapidly during the 1990s and early 2000s. Since the late 2000s, the yearly number of female graduates has commonly exceeded that of male graduates in the business field and many other fields of study. However, the ICT and engineering fields have remained highly male dominated. Furthermore, Figure 6 shows that the share of PhD degrees awarded to persons of Finnish origin—including people who were born in Finland or whose parent was born in Finland—has been on a clear decline. In the late 1980s and early 1990s, virtually all PhD graduates in Finland had Finnish roots. The following growth in the share of foreign-origin graduates has been fastest in the ICT field where just above 70% of the graduates were of Finnish origin in 2021.

FIGURE 5: SHARE OF FEMALE PHD GRADUATES

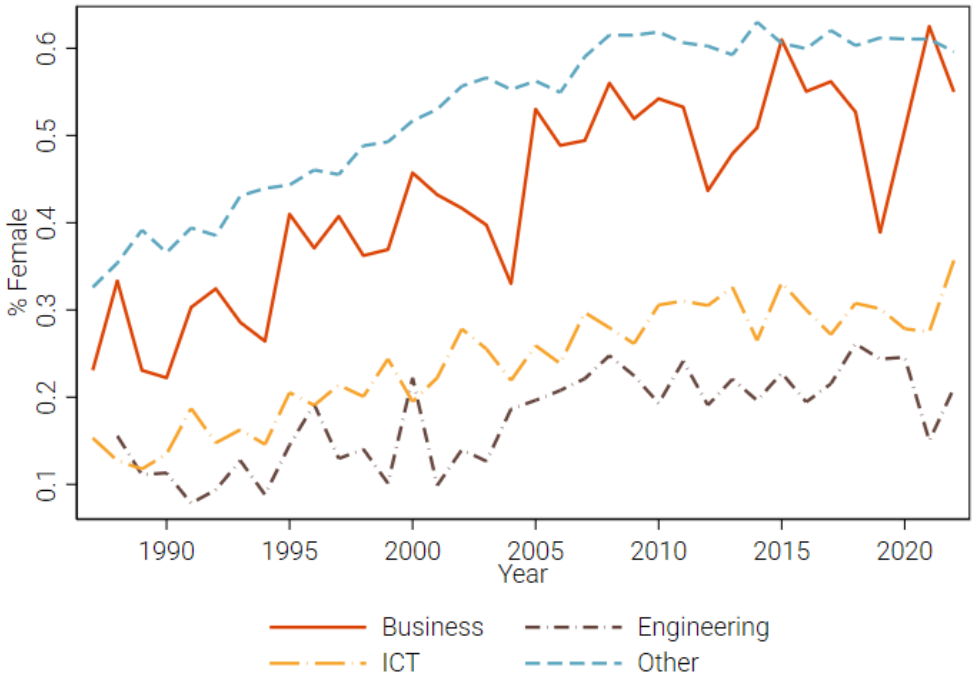
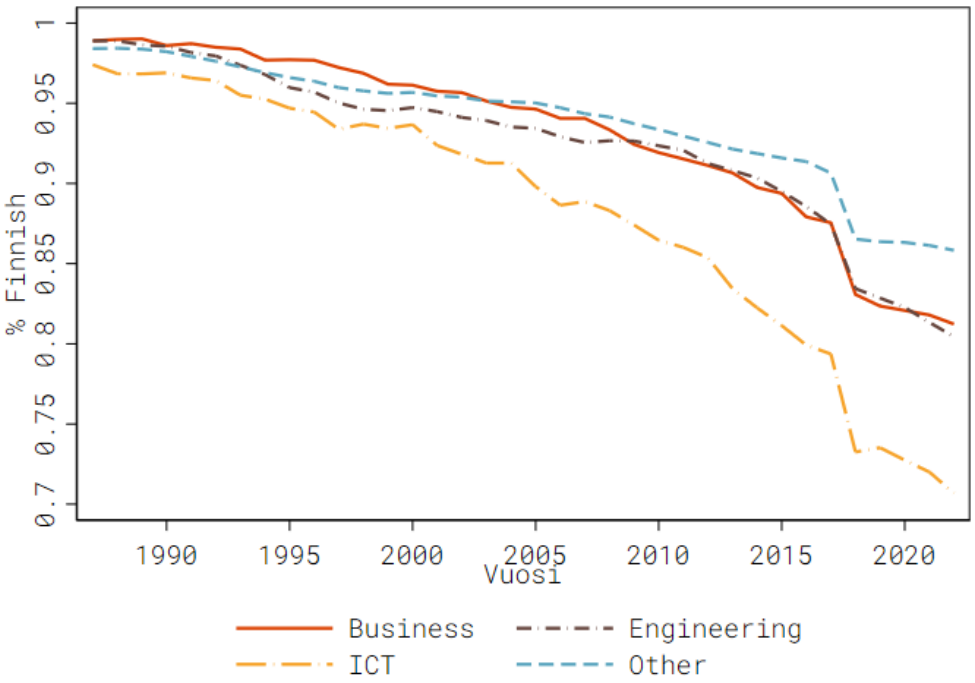


FIGURE 6: SHARE OF PHD GRADUATES OF FINNISH ORIGIN



Note: Here, persons of Finnish origin include all persons of Finnish background (at least one parent born in Finland) and all persons born in Finland.

Since the number of PhD graduates has increased significantly over the past decades, it is interesting to assess how the balance between the supply and demand of PhDs has evolved in the labor market during the same period. The PhD unemployment rate—the share of unemployed PhDs of all PhDs in the workforce—is a key indicator of this balance.

Figure 7 depicts the development of the PhD unemployment rate, measured at the end of each year, and the corresponding unemployment rates for master's and bachelor's degree holders between 1987 and 2022. The figure shows that, throughout the period, there has been a negative relationship between education level and the probability of unemployment, as the unemployment rate has been consistently highest for bachelor's degree holders and lowest for PhDs. Although there was a rise in the PhD unemployment rate in the early 1990s, it remained highly stable, between 2% and 3%, and even somewhat unresponsive to business cycle fluctuations until the early 2010s. This would suggest that the demand for workers with a doctoral degree significantly exceeded their supply during this period. However, following the euro crisis and the collapse of the Nokia mobile phone cluster in the early 2010s, the PhD unemployment rate began to increase, reaching 6% in 2015–2016. The PhD unemployment rate also began to exhibit a more cyclical behavior, moving in parallel with the unemployment rates for bachelor's and master's degree holders. Figure 8 further shows that the development of the PhD unemployment rate has been highly similar in all fields of study, particularly since the early 2010s.[7]

Besides unemployment, changes in the balance of labor supply and demand can be reflected in PhDs' likelihood of working in positions that do not match their education level, that is, the probability of overeducation. Figure 9 shows the development of the PhD overeducation rate by field of study. Here, overeducation is simply defined as the share of PhD holders that do not work in managerial or professional occupations.[8] The graph shows that, since around 2005, there has been a steady increase in overeducation. Around 14% of engineering PhDs and 10% of other PhDs were overeducated for their position in 2021.

Table 2 lists the 10 most common 3-digit-level occupations among PhD holders in 2021. All the occupations, except the category 'unknown' (3.1% of PhDs) belong to professional occupations. These occupations represent two thirds of all PhD holders' jobs. By far, the most common occupational groups are 'university and higher education teacher' and 'medical doctor' with 17.8% and 11.3% of PhDs working in these occupations, respectively.

[7]Figure B4 in the Appendix shows that the unemployment rate for foreign-origin PhDs has mainly varied between 10% and 20%, significantly exceeding that of Finnish-origin PhDs. Furthermore, the average annual wage income of Finnish-origin PhDs has exceeded that of foreign-origin PhDs by around €20,000.

[8]The classification of occupations is available at `https://stat.fi/en/luokitukset/ammatti/ammatti_1_20100101`.

FIGURE 7: UNEMPLOYMENT RATE BY EDUCATION LEVEL

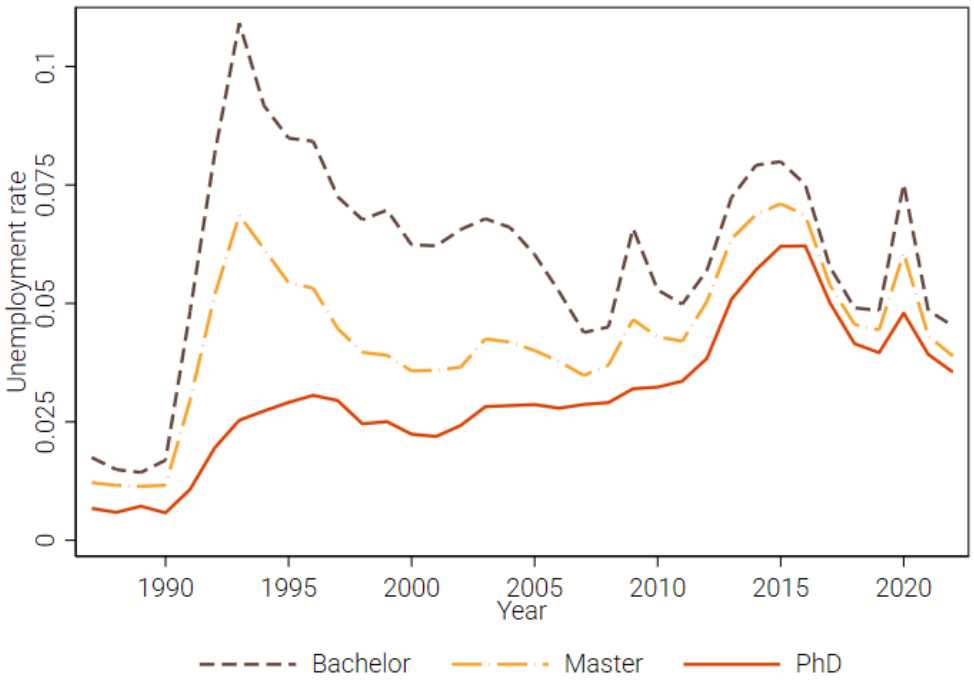


FIGURE 8: PHD UNEMPLOYMENT RATE BY FIELD OF STUDY

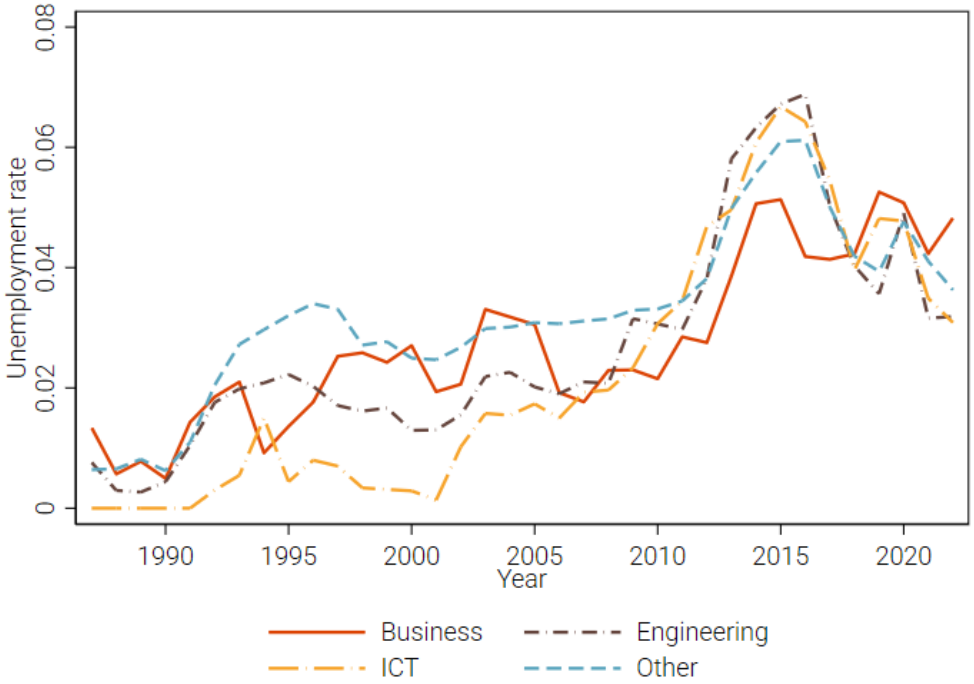
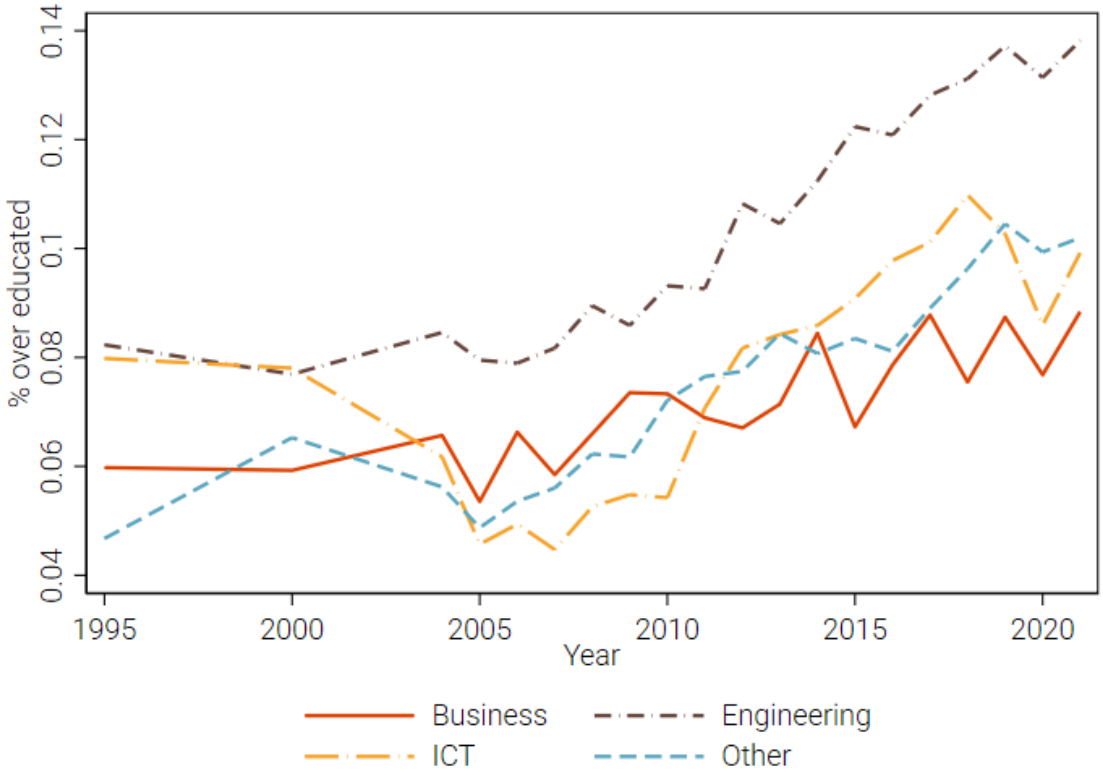


FIGURE 9: OVEREDUCATION AMONG PHDS



Note: Here, overeducated are those who do not work in managerial or professional occupations.

TABLE 2: 10 MOST COMMON 3-DIGIT LEVEL OCCUPATIONS HELD BY PHD HOLDERS IN FINLAND IN 2021

Occupation	ISCO code	N	%
University and higher education teachers	231	6950	17.8
Medical doctors	221	4407	11.3
Social and religious professionals	263	2368	6.1
Life science professionals	213	2057	5.3
Engineering professionals (excluding electrotechnology)	214	2013	5.2
Administration professionals	242	1743	4.5
Physical and earth science professionals	211	1452	3.7
Unknown	XXX	1198	3.1
Electrotechnology engineers	215	1155	3.0
Software and applications developers and analysts	251	1124	2.9
Other teaching professionals	235	968	2.5

4 Returns to doctoral education for individuals

This section complements the descriptive evidence of PhDs' labor market outcomes, presented in Section 3, by assessing the wage premium for completing a PhD degree. We conduct two types of analyses: wage regression analyses comparing all PhD employees to employees with only a master's or bachelor's degree in different years and event study analyses examining the dynamics of PhDs' annual wages before and after graduation.

4.1 Doctoral wage premium

To assess the wage premium for completing a doctoral degree, we estimate Mincer-style wage regressions separately for each year between 1995 and 2021. The estimation sample includes all Finnish residents who had at least a bachelor's degree and were 25 to 65 years old in one of the observation years. The total number of individual-by-year observations exceeds 13 million. The analysis is conducted by regressing individual i's annual wage income in year t, $Wage_{it}$, on their education level as follows:

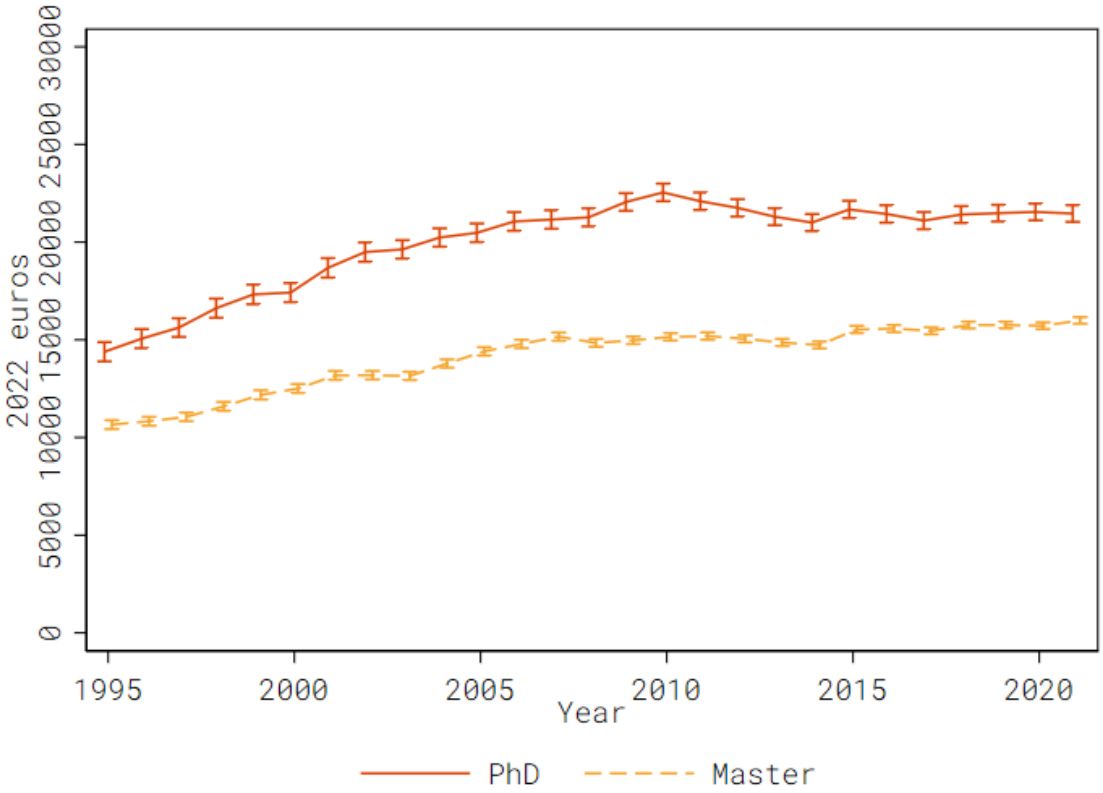
$$Wage_{it} = \alpha_t + \beta_{1t} PhD_{it} + \beta_{2t} Master_{it} + \gamma_t X_{it} + \varepsilon_{it}, \quad (1)$$

where α_t is a year-specific constant term, and coefficients β_{1t} and β_{2t} capture the average wage premia for having completed a PhD degree (PhD_{it}) or a master's degree ($Master_{it}$), respectively, by year t versus only a bachelor's degree; the set of control variables X_{it} includes region of birth, age, gender, first language, and 3-digit field of education; and ε_{it} is the error term. To avoid distortions from extremely high incomes, especially due to the early 2000s dot-com bubble, the wage income distribution is censored from the top by replacing incomes above the 99.5th percentile with the average wage income of this top-income group (€235,000).

Figure 10 shows the estimated yearly wage premia for a master's degree and a PhD degree, using those with only a bachelor's degree as the reference group. According to the results, the average wage premium for a PhD increased from €14,000 to €21,000 between 1995 and 2010 but has been relatively stable ever since. However, the premium for master's degrees has been steadily increasing throughout the observation period. Nonetheless, the PhD wage premium was 34% higher than the master's wage premium both at the beginning and the end of the period.

The results in Figure 11 have been obtained by dividing the yearly samples of highly educated workers by gender. These results indicate that, throughout the observation period (1995–2021), women have gained a significantly higher average labor market return to completing a PhD degree than men—this observation holds regardless of whether the return is expressed relative to bachelor's or master's degree holders. Moreover, the results suggest that the gender gap in the PhD wage premium has increased over time. This increase stems from a steady growth in women's wage

FIGURE 10: AVERAGE WAGE PREMIA FOR A PHD DEGREE AND A MASTER'S DEGREE BY YEAR



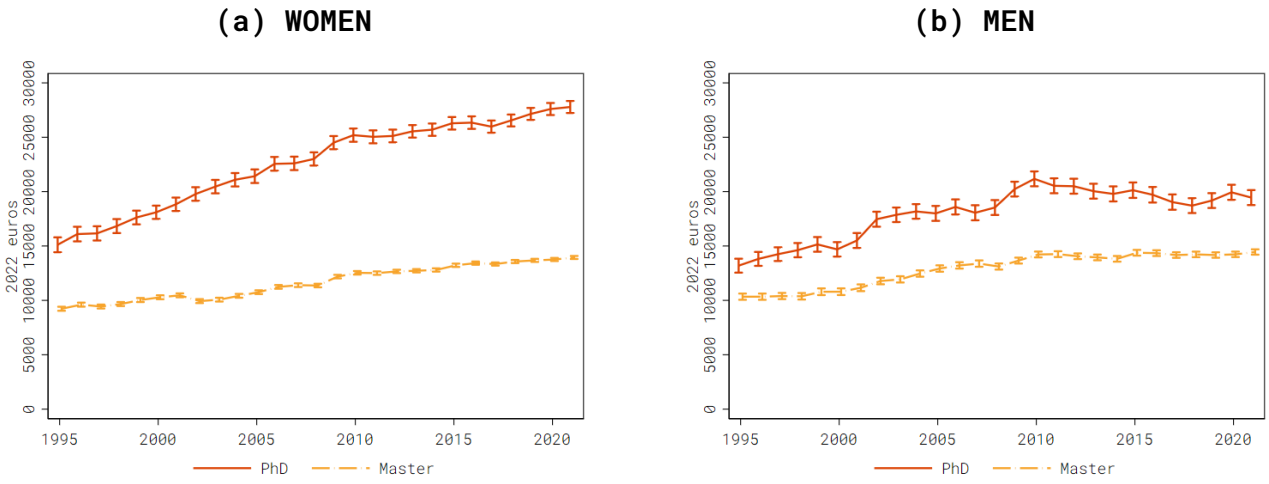
Notes: The results are from yearly regression models controlling for region of birth, age, gender, first language, and 3-digit field of education. Individuals with a bachelor's degree are used as the reference group. The vertical lines describe the 95% confidence intervals.

premium combined with a sluggish development in men's wage premium. At the end of the period, in 2021, the PhD wage premium, relative to bachelor's degree holders, was already €8,000 higher for women than for men. These results suggest that completing a PhD may be an effective way for women to catch up with men's life-cycle earnings.[9]

Figure B7 describes the yearly PhD and master's wage premia estimated separately for different fields of study. Figure 12a shows that, after a clear increase between 1995 and 2001, the average PhD wage premium for the business, ICT, and engineering fields, in relation to bachelor's degree holders, has remained roughly stable at around €24,000. However, the average wage premium of *other* doctoral degrees has been increasing throughout the observation period, being initially significantly lower than that for the business, ICT, and engineering fields (at €13,000) and catching up

[9]Figure B5 in the Appendix shows that the gender gap in the PhD wage premium holds for both PhDs in business/ICT/engineering and other PhDs. These results show a remarkable decrease in the relative wage income of male PhDs in business/ICT/engineering after the early 2000s dot-com boom.

FIGURE 11: AVERAGE WAGE PREMIA FOR A PHD DEGREE AND A MASTER'S DEGREE BY YEAR AND GENDER



Notes: The results are from yearly regression models estimated separately for men and women. The models include controls for region of birth, age, first language, and 3-digit field of education. Individuals with a bachelor's degree are used as the reference group. The vertical lines describe the 95% confidence intervals.

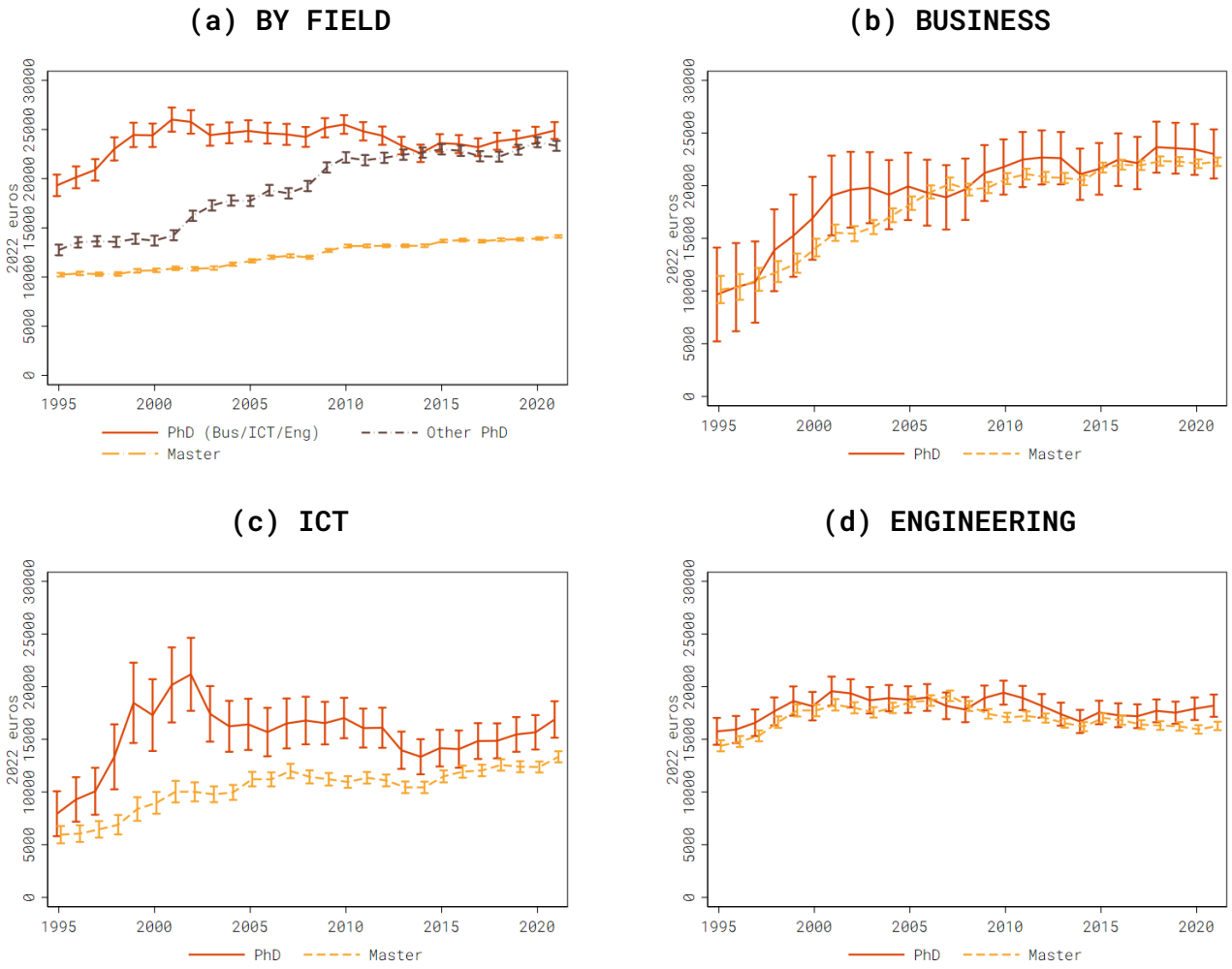
these fields by the early 2010s.[10]

Figures 12b, 12c, and 12d show certain interesting differences in the level and development of the PhD wage premium across fields of study. In all three fields, the PhD wage premium relative to bachelor's degree holders has been significant. However, only for the business field, there was a steady increase in this wage premium over the observation period, from around €10,000 in 1995 to €23,000 in 2021. For the ICT field, a rapid increase in the PhD wage premium from around €8,000 to above €20,000 coincided with the dot-com boom of the late 1990s and early 2000s. After the early 2000s, the PhD wage premium for this field has been relatively stable, varying around €15,000. Likewise, the PhD wage premium for the engineering field has been quite stable at around €18,000 since the 2000s.

Perhaps the most striking observation in Figure B7 is that, within the business and engineering fields, the average wage premia for a PhD degree and a master's degree have been approximately similar throughout the observation period. That is, in these fields, there has been no significant wage premium for completing a PhD after a master's on average. In the ICT field, PhDs have again constantly earned higher annual wages than master's degree holders. However, this difference di-

[10]Figure B1 in the Appendix describes the evolution of PhDs' average income by field of study, showing that, both in terms of gross wage income and disposable income (*käytettävissä oleva rahatulo*), PhDs from the business field have earned more than PhDs from other fields.

FIGURE 12: AVERAGE WAGE PREMIA FOR A PHD DEGREE AND A MASTER'S DEGREE BY YEAR AND FIELD OF EDUCATION



Notes: The results are from yearly regression models controlling for region of birth, age, gender, first language, and 3-digit field of education. Individuals with a bachelor's degree are used as the reference group. The vertical lines describe the 95% confidence intervals.

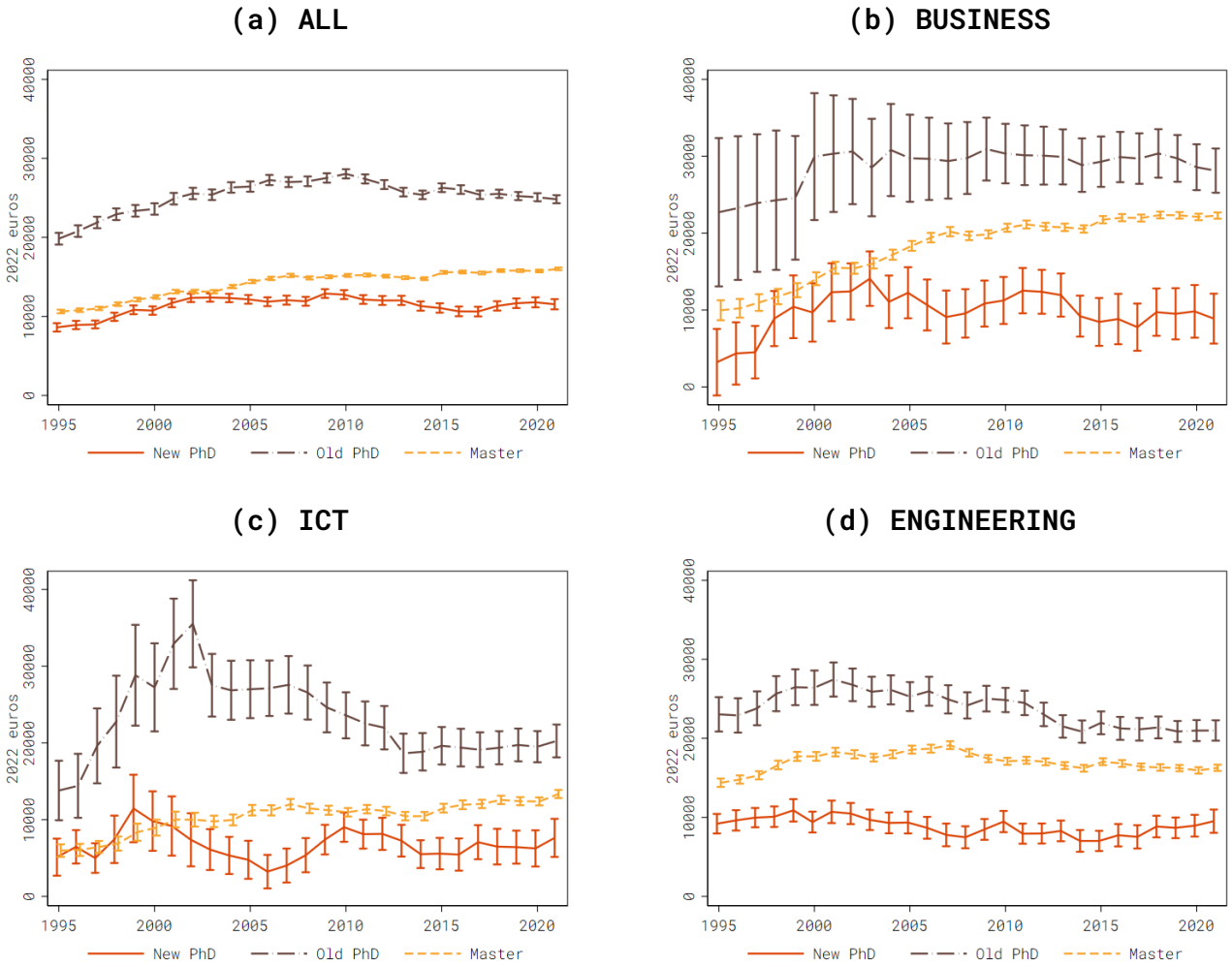
minished significantly between the early 2000s and early 2010s, from around €10,000 to €3,000.[11]

Apart from examining the average annual wages of PhDs, it is relevant, from a policy perspective, to monitor recently graduated PhDs' wages, as the early-career labor market performance can be predictive of the later career. Figure 13 shows the wage regression results obtained by splitting the sample of PhDs based on the number of years from graduation in the observation year into new PhDs (graduated no more than five years ago) and old PhDs (graduated over five years ago). The results show that, in general, recent PhD graduates' average annual wage has been lower than that

[11] Figure B6 in the Appendix further shows that the share of PhDs working in the private sector varies notably across fields of study. After the early 2010s, the private sector's employment share has increased particularly among ICT and engineering PhDs, exceeding 50% in recent years, while this share has remained below 30% among business PhDs. The results in Figure B7 further suggest that, both among private- and public-sector workers, the PhD wage premium has significantly exceeded the master's wage premium.

of master's degree holders. However, given the steep wage-experience gradient for PhDs (which is further analyzed in the next subsection), the wage premium for old PhDs has significantly exceeded the wage premium for a master's degree. When the wage premia are averaged across all fields of education, the results suggest that the gap between the wage premia for old and new PhDs remained roughly stable across the observation period, the wage premium for old PhDs being constantly more than double of that for new PhDs (e.g., €25,000 vs. €11,500 in 2021). Interestingly, the average wage income gap between master's degree holders and new PhDs was rather negligible in the late 1990s and early 2000s but grew significant subsequently.

FIGURE 13: AVERAGE WAGE PREMIA FOR A PHD DEGREE AND A MASTER'S DEGREE BY YEAR AND FIELD OF EDUCATION (COMPARISON OF OLD AND NEW PHDS)



Note: The results are from yearly regression models controlling for region of birth, age, gender, first language, and 3-digit field of education. Individuals with a bachelor's degree are used as the reference group. The vertical lines describe the 95% confidence intervals. New PhDs are those that graduated no more than five years before the reference year, while old PhDs graduated over five years ago.

The field-specific sub-figures of Figure 13 demonstrate that, within the three fields of education of interest, the development of new PhDs' relative wage incomes has been, overall, somewhat poor.

This is perhaps most visible in Figure 13b, showing that, in the case of the business field, the initially small gap in the wage premium between master's degree holders and new PhDs (15% in 2003), widened significantly towards the end of the observation period. In 2021, the wage premium for old business PhDs was more than three times that of new business PhDs, while master's degree holders earned a 2.5 times higher wage premium. Figure 13c further suggests that the labor market returns to a PhD in ICT decreased significantly for both old and new PhD graduates during the aftermath of the dot-com bubble. The wage premium for new ICT PhDs relative to bachelor's degree holders reached the bottom in 2006, amounting to only €3,000, and stabilized at around €6,000 in the 2010s, remaining below the master's degree premium until the end of the period. Finally, Figure 13d shows that the differences between the wage premia remained more stable in the engineering field compared to the two other fields. Notably, the master's degree premium has gradually converged towards the wage premium for old PhDs, while remaining significantly larger compared to the wage premium for new PhDs throughout the period.

4.2 PhD wage dynamics

In this section, we study PhDs' post-graduation wage dynamics by using an event study approach which is based on comparing PhDs' annual wages in the post-graduation years to those of the not-yet graduated ones in the same years. The analysis is conducted using the approach proposed of Callaway and Sant'Anna (2021) which is designed for studying cases where different groups receive a treatment at different points in time. In our case, these groups consist of PhDs who graduated in different years. The method involves estimating the treatment effect for each group at each point in time, rather than assuming the effect is the same for everyone. Unlike traditional two-way fixed effects regressions that rely on comparing treated units to those already treated—potentially introducing bias—this method only uses appropriate comparison groups that have not yet received the treatment. This makes it more robust to changes in treatment effects over time. It also avoids the hidden weighting problems that can occur in standard two-way fixed effects models. Overall, it offers a flexible and transparent way to estimate treatment effects in settings with multiple time periods and a staggered treatment.[12] The sample for this analysis consists of everyone who completed a doctoral degree in Finland between 1995 and 2021 and includes around 41,000 individuals.

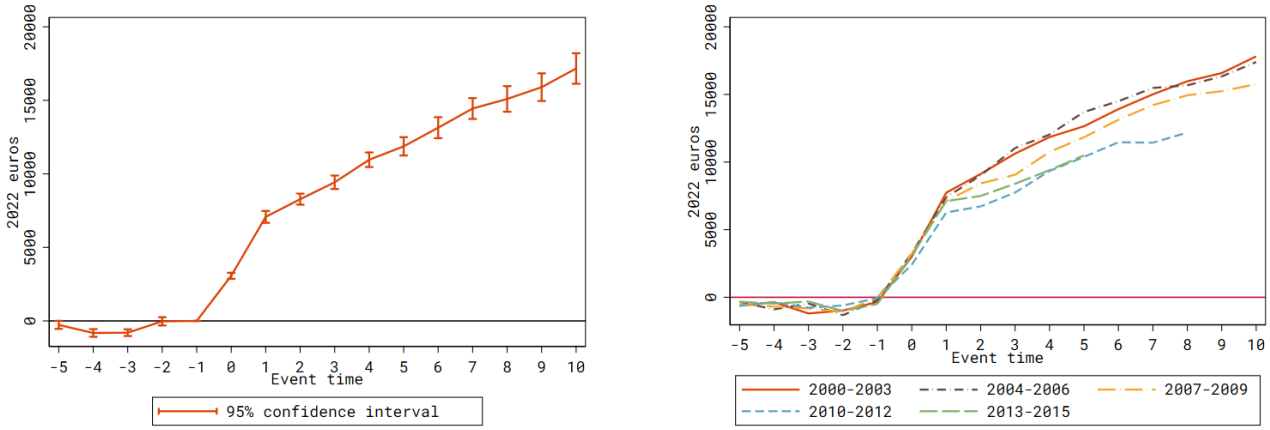
Figure 14a depicts the estimated wage income growth after receiving a doctoral degree. According to the results, PhD graduation is followed by a steady and rapid increase in annual wage, leading, on average, to a €17,000 higher annual wage 10 years after graduation compared to the pre-graduation period. Figure 14b breaks down the results by graduation year, comparing graduates from years 2000–2003, 2004–2006, 2007–2009, 2010–2012, and 2013–2015. All of these

[12]Recently, Jabbari et al. (2024) have used the method of Callaway and Sant'Anna (2021) to study the earnings premiums associated with completing educational degrees and credentials in the U.S. Their estimates indicate that PhD graduation is followed by an over $50,000 average increase in earnings within five years from graduation.

cohorts experience a significant increase in annual wage after graduation. However, the early-career wage progression is notably steeper for the cohorts that graduated before 2010 compared to those that graduated later. For example, 8 years after graduation, the 2010–2012 cohort earned around a €12,000 wage premium, which is around €3,000 less than the wage premium for the cohorts that graduated in the previous decade.

FIGURE 14: WAGE PROGRESSION BEFORE AND AFTER GRADUATION: ANY PHD

(a) ALL GRADUATION YEARS **(b) BY GRADUATION YEAR**



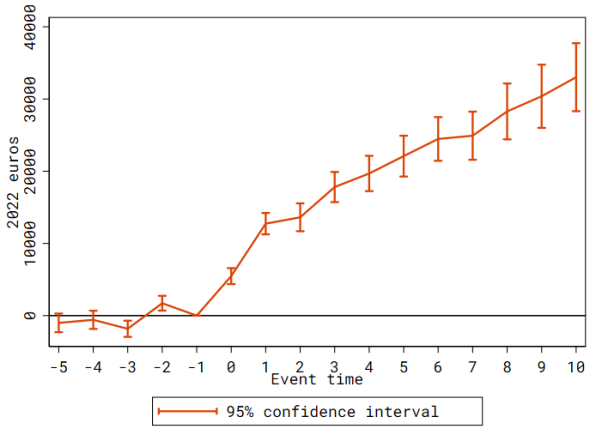
Notes: Results have been obtained using the event study approach of Callaway and Sant'Anna (2021). The vertical lines describe the 95% confidence intervals.

According to the field-specific event study results reported in Figure 15, the post-graduation wage progression is faster in the business field compared to the two other fields of interest. After 10 years from graduation, the business PhDs earn, on average, €33,000 more compared to the last pre-graduation year, whereas the corresponding wage premiums for ICT PhDs and engineering PhDs are €22,000 and €15,000, respectively. Figure 15 also reports the field-specific wage progression by cohort. These results indicate that, particularly in the case of the ICT field, the post-doctoral wage progression is faster for the pre-2010 cohorts than for the post-2010 cohorts. However, in the longer run, within 8 years from graduation, the post-graduation wage premium is, in all three fields, highly similar for PhDs graduated in the early 2010s (2010–2012) compared to the earlier cohorts.

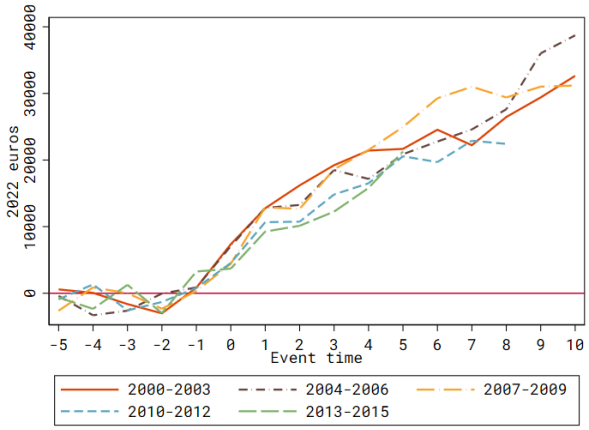
FIGURE 15: WAGE PROGRESSION BEFORE AND AFTER GRADUATION BY FIELD

BUSINESS

(a) ALL GRADUATION YEARS

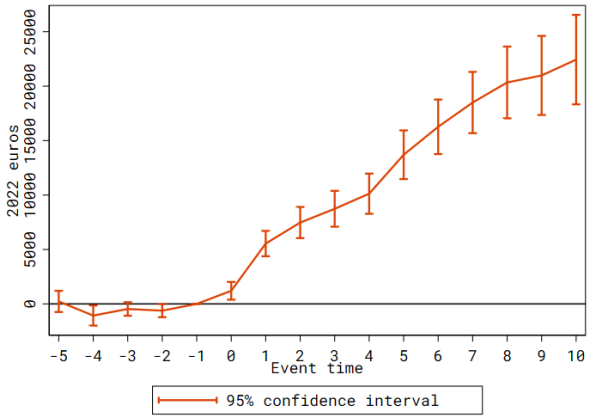


(b) BY GRADUATION YEAR

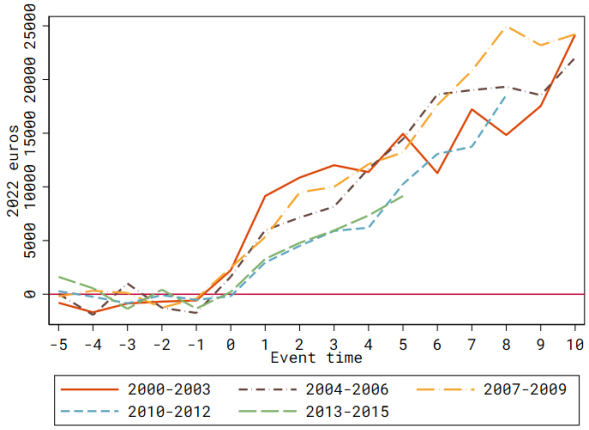


ICT

(c) ALL GRADUATION YEARS

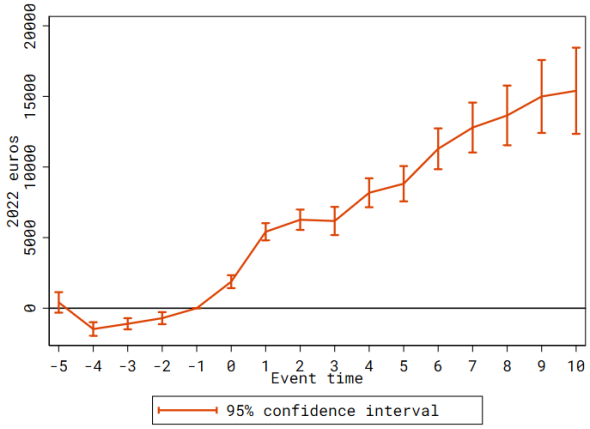


(d) BY GRADUATION YEAR

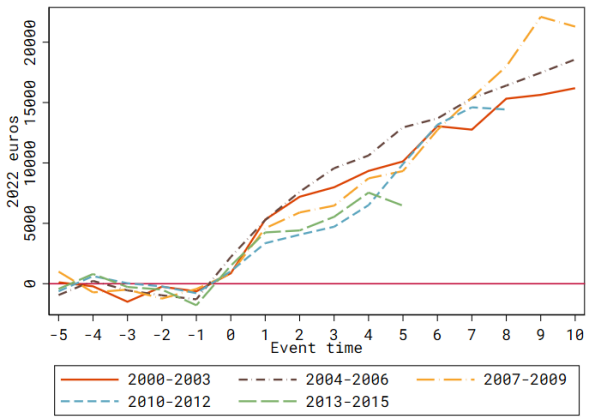


ENGINEERING

(e) ALL GRADUATION YEARS



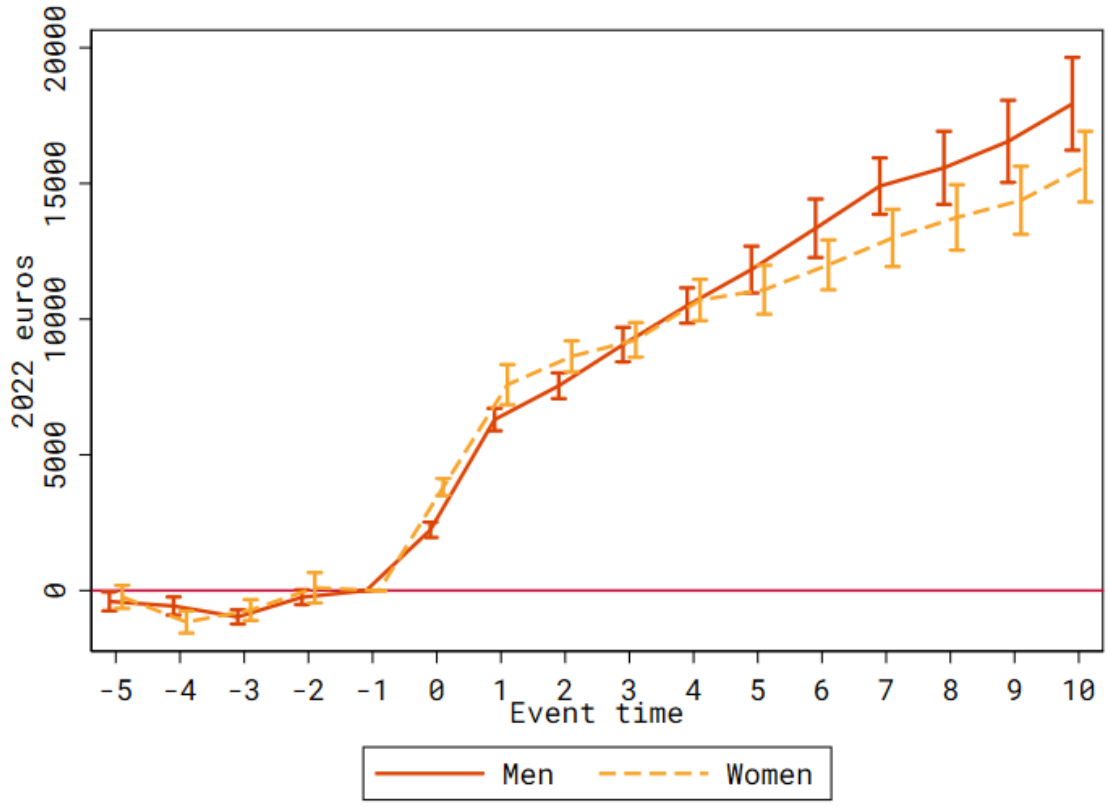
(f) BY GRADUATION YEAR



Notes: Results have been obtained using the event study approach of Callaway and Sant'Anna (2021). The vertical lines describe the 95% cc

Figure 16 depicts the event study results by gender. These results suggest that the average increase in annual wage within two years from graduation is slightly higher for women than for men. However, overall, the post-doctoral wage progression is more rapid for men than for women. After 10 years from graduation, there is a gender gap of €2,300 in favor of men in the post-graduation wage premium. However, based on the overlapping confidence intervals, this gap is not statistically very significant.

FIGURE 16: WAGE PROGRESSION BEFORE AND AFTER GRADUATION BY GENDER



Notes: The results have been obtained using the event study approach of (Callaway and Sant'Anna, 2021). The vertical lines describe the 95% confidence intervals.

5 Returns to doctoral education for firms

This section complements the evidence of returns to doctoral education by examining these returns from the perspective of firms. Specifically, we examine how changes in the number of doctoral workers within a firm are associated with changes in the firm's performance, measured in terms of its productivity and profitability. We first investigate changes in firm outcomes taking place around the event of a firm hiring a PhD for the first time–that is, an investment in PhDs at the extensive margin. In the second step, we examine how the extensive- and intensive-margin changes in the

number of PhDs, on average, relate to changes in firm outcomes. Although the methods employed in these analyses control for many factors, including time-invariant firm-level heterogeneity, the results should be interpreted with caution for several reasons. In particular, firms with similar time-invariant characteristics could be exposed to different financial shocks that generate spurious correlations between changes in worker composition and other outcomes. Furthermore, the results could be confounded by reverse causality, as changes in a firm's performance might affect its decisions to hire PhDs.

5.1 Hiring the first PhD and changes in firm outcomes

In this section, we adopt the event study approach of Callaway and Sant'Anna (2021) to examine how hiring a PhD graduate is associated with a firm's performance. This analysis is based on the year when the firm is observed to recruit its first worker with a PhD. To construct a reasonable control group for the firms that began hiring PhDs between 2006 and 2021, we exclude firms that either 1) never employed a PhD graduate during these years or 2) employed PhDs every year—that is, the never-treated and always-treated firms—from the estimation sample. Additionally, we restrict our analysis to firms engaged in at least some types of R&D activities by excluding firms without any R&D personnel from the sample. The final sample consists of 354 firms observed between 2006 and 2021.

TABLE 3: SUMMARY STATISTICS FOR THE FIRMS USED IN THE ANALYSIS

Variable	Mean	SD
Number of employees (FTE)	187.08	502.21
Employee composition		
Age	40.07	4.87
Male	0.7316	0.1974
Bachelor's degree	0.2553	0.2700
Master's degree	0.2718	0.2579
PhD	0.0317	0.0849
PhD (Bus/ICT/Eng)	0.0165	0.0457
PhD (Other)	0.0152	0.0678
Financial outcomes (€/employee)		
Profit	29,587	215,393
Turnover	391,803	1,561,942
Value added	101,577	232,282
Salaries	54,637	54,311

Note: The financial outcomes have been deflated by Statistics Finland's industry-level output deflator with baseline in 2015 and divided by the number of full-time equivalent employees.

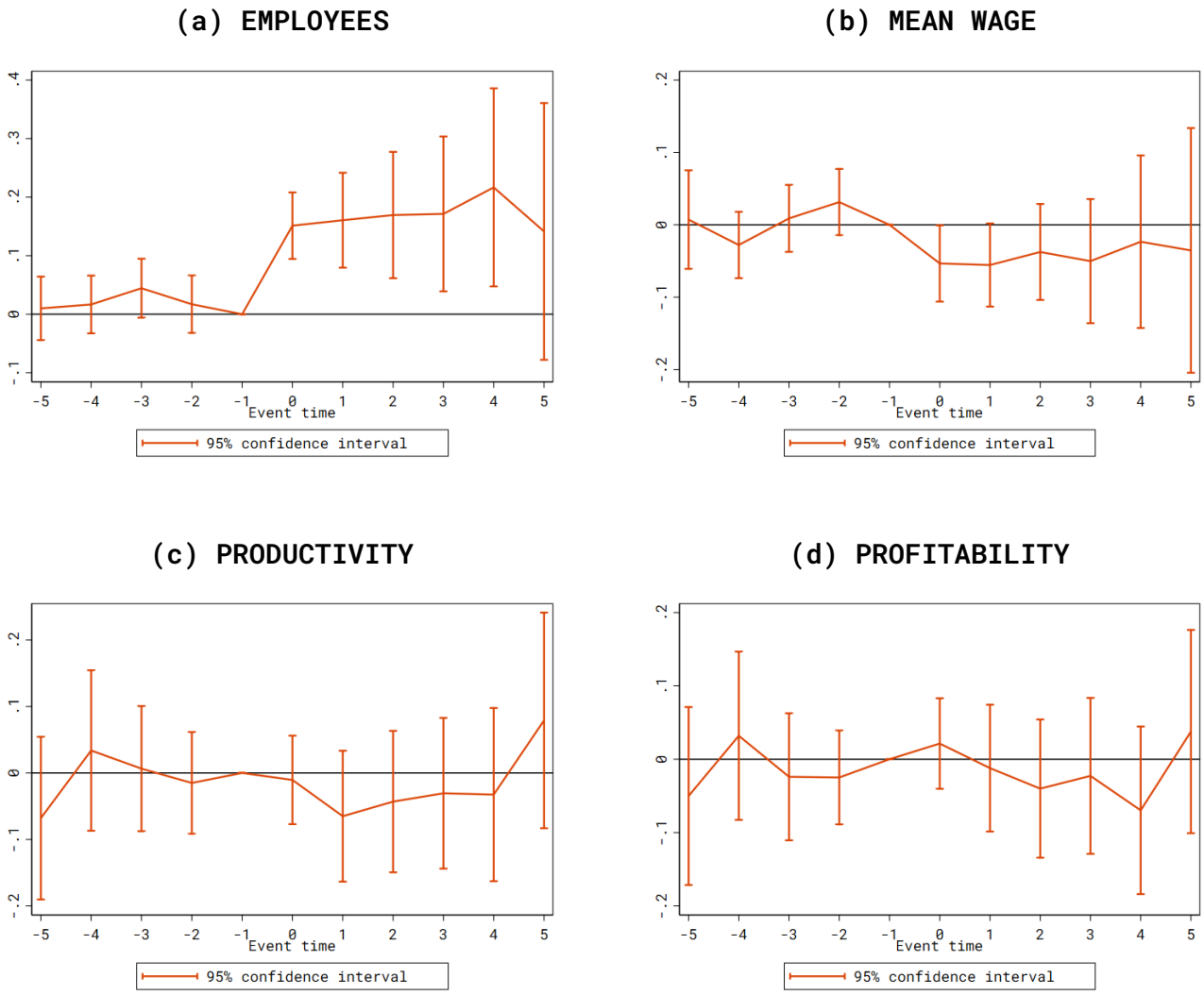
The summary statistics in Table 3 describe the firms used in the analysis from 2007 to 2021.

The table shows that the firms in the sample are relatively large, having 187 full-time equivalent employees on average. The firms are also highly male-dominated, as 73% of their employees are men. Furthermore, the employees of these firms are relatively highly educated, with the share of employees having at least a bachelor's degree being around 55%. However, only 3% of the employees have a doctoral degree. Around half of the PhDs are from business, ICT, or engineering fields. The table further shows that the sample is concentrated towards relatively high-value and high-paying firms with the average profit per employee of €30,000 and the average wage of €55,000. The average productivity (value-added per full-time employee), is €102,000.

Figure 17 describes the event study results regarding the effects of hiring a doctoral worker on four selected firm outcomes: the number of employees (FTE), mean wage, productivity (value added per FTE employee) and profitability (the ratio of value added and wages). All the outcomes are used in the logarithmic form, and therefore, the estimates can be used to approximate percentage changes in the outcomes.[13] The pre-trends in all four regressions indicate a balance between the treated and not-yet-treated firms. The results suggest that hiring the first PhD coincides with a significant 0.15-log-point average increase in the number of employees within a firm, while no significant change in firm size is observed after the initial increase. Furthermore, the hiring of a PhD coincides with a 0.05-log-point decrease in mean wage. However, this effect is only significant for the first two years. None of the estimated effects on productivity or profitability are statistically significant. However, it is worth noting that, while the point estimates for these effects are mainly negative in the first four years after the event, they turn into positive in the fifth year, pointing towards possible benefits from the educational investment in the longer term.

[13]The percentage changes can be roughly approximated by calculating $100\% * (exp(estimate) - 1)$.

FIGURE 17: EVENT STUDY RESULTS. HIRING THE FIRST PHD.



Note: The results have been obtained using the method of Callaway and Sant'Anna (2021). The vertical lines represent the 95% confidence intervals.

5.2 Share of PhDs and firm performance

To study how employees' educational composition, including the share of workers with a PhD, is, on average, associated with firm performance, we use a panel regression approach resembling that of Kampelmann et al. (2018). Our main results rely on the following two-way fixed effects specification:

$$logY_{it} = \alpha + \beta_1 PhD_{it} + \beta_2 Master_{it} + \beta_3 Bachelor_{it} + \gamma X_{it} + \delta_i + \mu_t + \varepsilon_{it},$$

where $logY_{it}$ is the log-transformed outcome variable, and α is a constant term; PhD_{it} is the percentage share of PhDs of firm i's total workforce in year t; $Master_{it}$ and $Bachelor_{it}$ control for the shares of master's and bachelor's degree graduates, respectively; X_{it} is a set of other control variables, in-

cluding the natural logarithm of the number of employees (FTE) and dummy variables controlling for employees' age and gender distributions; δ_i and μ_t are the firm and year fixed effects, respectively; and ε_{it} is the error term. In an alternative specification, PhD_i is replaced with two variables which break down the share of PhDs into 1) the share of workers with a PhD from the business, ICT, and engineering fields and 2) the share of workers with a PhD from other fields.[14] The estimation sample includes 40,000 Finnish firms that were in operation between 2006 and 2022. To make the firms in the estimation sample more comparable in terms of workers' educational attainment, firms without any masters or doctoral graduates are excluded from the sample.

Tables 4 and 5 describe the estimated associations between workers' educational attainment and three firm outcomes: mean wage, productivity, and profitability. Overall, the results in Table 4 indicate a strong positive relationship between education and firm performance. According to the estimates, a one-percentage-point increase in the share of PhD holders within a firm is associated with a 0.09-log-point (≈10%) increase in both workers' mean wage and productivity. Given the approximately equal change in wages and productivity, the corresponding change in profitability is logically close to zero and insignificant. The results suggest that the share of master's degree graduates is likewise positively associated with mean wage and productivity, but these associations are markedly smaller (0.04 and 0.05 log points, respectively) than those related to the share of PhDs. However, unlike the share of PhDs, the share of master's degree graduates is also statistically significantly associated with a firm's profitability. The associations between the share of bachelor's degree graduates and firm outcomes are positive and statistically significant but negligible in magnitude.

Table 5 breaks down the associations between the share of PhDs and firm outcomes by PhDs' fields of study. These results indicate that both PhDs from business/ICT/engineering and PhDs from other fields are positively associated with mean wage and productivity. However, the share of PhDs from other fields is more strongly linked to positive firm outcomes, being also positively associated with profitability, unlike the share of business/ICT/engineering PhDs. A one-percentage-point increase in the share of these non-business/ICT/engineering PhDs relates to around 10%, 11%, and 2% increases in mean wage, productivity and profitability, respectively. For the share of business/ICT/engineering PhDs, the corresponding associations are 8%, 7%, and -1%.

[14]We further experimented with specifications that allow the share of PhDs to have lagged effects on firm outcomes. In most cases, the estimated lagged effects were not significantly different from zero. The results are available from the authors by request.

TABLE 4: ASSOCIATION BETWEEN WORKERS' EDUCATIONAL COMPOSITION AND A FIRM'S FINANCIAL OUTCOMES.

	Mean wage	Productivity	Profitability
PhD	0.0920***	0.0923***	0.0069
	(0.0054)	(0.0082)	(0.0077)
Master	0.0403***	0.0509***	0.0065***
	(0.0011)	(0.0017)	(0.0015)
Bachelor	0.0002**	0.0004***	0.0002**
	(0.0001)	(0.0001)	(0.0001)
Observations	427,238	406,685	405,245

Notes: The results are from regression models controlling for firm and year fixed effects, log number of employees (FTE) as well as employees' age and gender distributions. The standard errors in parentheses are clustered at the firm level. Statistical significance: * p<0.1, ** p<0.05, *** p<0.01.

TABLE 5: ASSOCIATION BETWEEN WORKERS' EDUCATIONAL COMPOSITION AND A FIRM'S FINANCIAL OUTCOMES (THE SHARE OF PHDS BROKEN DOWN BY FIELD OF STUDY)

	Mean wage	Productivity	Profitability
PhD (Bus/ICT/Eng)	0.0787***	0.0719***	-0.0093
	(0.0081)	(0.0117)	(0.0110)
PhD (other)	0.1026***	0.1120***	0.0226**
	(0.0072)	(0.0114)	(0.0108)
Master	0.0403***	0.0509***	0.0064***
	(0.0011)	(0.0017)	(0.0015)
Bachelor	0.0002**	0.0004***	0.0002**
	(0.0001)	(0.0001)	(0.0001)
Observations	427,238	406,685	405,245

Notes: The results are from regression models controlling for firm and year fixed effects, log number of employees (FTE) as well as employees' age and gender distributions. The standard errors in parentheses are clustered at the firm level. Statistical significance: * p<0.1, ** p<0.05, *** p<0.01.

6 The role of PhDs in university-business cooperation

Cooperation between universities and businesses is considered to be an important driver of knowledge-based economies and societies (Davey et al., 2018), and part of the potential economic benefits from doctoral education may stem from this type of cooperation. Previously, Garcia-Quevedo et al. (2012) have shown that hiring PhDs is positively related to firms' cooperation with universities in Spain. This section examines whether such a relationship can also be found using Finnish data.

Our analysis utilizes data from Statistics Finland's EU-harmonized Innovation survey (*Innovaatiotutkimus*) from the years 2018, 2020, and 2022. For each survey year, the data include around 2,400 sampled firms. Our analysis utilizes the survey items asking if the firms cooperated with universities or with universities of applied sciences. Table 6 shows that, in 2018, 20.5% of the firms in the sample cooperated with either type of university. This share decreased to 18.8% in 2020 and to 15% in 2022.

TABLE 6: COOPERATION WITH UNIVERSITIES

	2018	2020	2022
University	0.175	0.163	0.126
University of applied sciences	0.143	0.124	0.093
Either	0.205	0.188	0.150
Observations	2,256	2,406	2,434

To study the relationship between the number of PhD graduates within a firm and the firm's probability of cooperation with universities, our main approach is to estimate a linear probability model with year and firm fixed effects. This method can only be implemented using the subsample of firms that appear in at least two of the survey samples. Our regression model specification is given by:

$$Cooperation_{it} = \alpha + \beta PhD_{it} + \gamma X_{it} + \delta_i + \mu_t + \varepsilon_{it}, \quad (2)$$

where α is a constant term, and β describes the association between the number of PhD holders working in a firm (PhD_{it})[15] and the probability of cooperation with universities; X_{it} is a set of control variables including the number of workers with a master's degree and the natural logarithm of the number of employees (FTE); δ_i and μ_t are the firm and year fixed effects, respectively; and ε_{it} is the error term.

Tables 7 and 8 present the results of the linear probability model with firm fixed effects. Table 7 indicates that hiring an additional PhD is associated with a 0.9-percentage-point increase in the probability of a firm cooperating with universities of applied sciences, whereas there is no statistically

[15] Whereas the analyses in subsection 5.2 used the percentage share of PhDs as the explanatory variable, the current subsection uses the absolute number of PhDs, as this approach provided more precise estimates.

significant relationship between the number of PhDs and cooperation with research universities. The average association between the number of PhDs and the probability of any type of university cooperation is likewise insignificant.

Table 8 divides the PhD graduates into those from the business, ICT, and engineering fields and those from other fields of study. The results suggest that the positive relationship between PhDs and cooperation with universities of applied sciences in Table 7 is driven by PhDs from the business, ICT, and engineering fields. An additional worker with a PhD from these fields is associated with a 2.4-percentage-point increase the probability of a firm cooperating with universities of applied sciences, while there are no statistically significant associations between the number of PhDs from other fields and the cooperation indicators.[16]

TABLE 7: ASSOCIATION BETWEEN THE NUMBER OF PHDS IN A FIRM AND THE PROBABILITY OF COOPERATION WITH UNIVERSITIES

	(1) University	(2) UAS	(3) Either
PhD	0.0041	0.0092*	0.0063
	(0.0065)	(0.0050)	(0.0066)
Master	0.0001	-0.0003	0.0000
	(0.0005)	(0.0004)	(0.0005)
Employees	0.0337**	-0.0067	0.0132
	(0.0164)	(0.0175)	(0.0195)
2020	-0.0186	-0.0175	-0.0259**
	(0.0114)	(0.0119)	(0.0125)
2022	-0.0513***	-0.0464***	-0.0581***
	(0.0126)	(0.0127)	(0.0140)
Constant	0.0679	0.2004***	0.1908**
	(0.0703)	(0.0732)	(0.0823)
Observations	3,557	3,557	3,557

Notes: The results are from regression models controlling for firm fixed effects. The dependent variables are indicators for whether the firm cooperates with 1) a university, 2) a university of applied sciences (UAS) or 3) an institution of either type. Statistical significance: * p<0.1, ** p<0.05, *** p<0.01.

[16] Tables A1 and A2 in the Appendix show the results using a random effects model, that is, without firm's fixed effects. The advantage of this method is that the sample size is larger. However, the random effects model does not control for unobserved time-invariant firm characteristics. The results in Table A1, to some extent, contradict those in Table 7 by showing a statistically significant positive association between the number of PhDs and cooperation with research universities, while no significant connection to cooperation with universities of applied sciences. However, similar to the main results, the alternative results suggest that the number of PhDs from the business, ICT, and engineering fields is more strongly related to the probability of cooperation than the number of other PhDs.

TABLE 8: ASSOCIATION BETWEEN THE NUMBER OF PHDS IN A FIRM AND THE PROBABILITY OF COOPERATION WITH UNIVERSITIES (NUMBER OF PHDS BROKEN DOWN BY FIELD OF STUDY)

	(1) University	(2) UAS	(3) Either
PhD(Bus/ICT/Eng)	0.0134	0.0239***	0.0173
	(0.0106)	(0.0089)	(0.0109)
PhD (other)	-0.0058	-0.0066	-0.0055
	(0.0088)	(0.0069)	(0.0091)
Master	-0.0000	-0.0005	-0.0001
	(0.0005)	(0.0005)	(0.0005)
Employees	0.0353**	-0.0041	0.0151
	(0.0165)	(0.0176)	(0.0195)
2020	-0.0186	-0.0176	-0.0259**
	(0.0114)	(0.0119)	(0.0124)
2022	-0.0510***	-0.0459***	-0.0578***
	(0.0126)	(0.0126)	(0.0139)
Constant	0.0641	0.1944***	0.1863**
	(0.0706)	(0.0732)	(0.0827)
Observations	3,557	3,557	3,557

Notes: The results are from regression models controlling for firm fixed effects. The dependent variables are indicators for whether the firm cooperates with 1) a university, 2) a university of applied sciences (UAS) or 3) an institution of either type. Statistical significance: * p<0.1, ** p<0.05, *** p<0.01.

7 Concluding remarks

The descriptive analyses presented in this report provide certain interesting insights into the evolution of the population of Finnish PhDs as well as into individual- and firm-level returns to doctoral education in Finland. The statistics show that, in the 1990s and early 2000s, Finland significantly increased investments in doctoral education, which roughly tripled the number of PhD graduations compared to the late 1980s level. However, after the mid-2010s, the supply of new PhD graduates has been on a slightly declining trend.

The analyses of PhDs' labor market outcomes suggest that, until the late 2000s, there was a high level of demand for PhDs relative to their supply in the labor market. This imbalance was reflected as a low and largely acyclical unemployment rate, a low overeducation rate, and a rising wage premium for PhDs. However, evidently, the increased supply of PhD graduates together with the prolonged problems in Finland's economic growth led to a cooling down of the PhD labor market in the 2010s, which showed up as an increased and procyclical unemployment rate, increased overeducation rate, a stagnation of the PhD wage premium, and a less steep wage progression after doctoral graduation.

While PhDs have, on average, earned significantly higher annual wages compared to workers with only a master's or bachelor's degree during the past thirty years, our results reveal three types of interesting variation in the PhD wage premium. First, the results suggest that, in terms of annual wages, women have benefited significantly more from completing a PhD after a master's degree than men. The gender gap in the PhD wage premium appears to have even significantly increased over time due to the notable positive trend in women's wage premium. Second, we found significant variation across fields. In the business and engineering fields, PhDs have not, on average, earned higher annual wages than master's degree holders, whereas, in the ICT field, the positive PhD-master wage gap has decreased significantly after the early 2000s dot-com boom. Third, the results suggest that, after the early 2000s, newly graduated PhDs have earned a negative early-career wage premium relative to master's degree holders. That is, the growth in the number of new PhDs graduates has, to some extent, coincided with a weakening of their relative labor market position.

Our results using firm-level data suggest that the benefits from doctoral education may extend beyond PhD graduates' own income. We do not find evidence of significant changes in firms' productivity or profitability around the event of recruiting the first PhD in a firm. However, we find that, on average, small increases in the share of PhD workers are associated with significant increases in firms' mean wages and productivity. Then again, the share of PhDs is not, on average, found to be significant in terms of firms' profitability given the equal-size changes in wages and productivity. Finally, our results using the Innovation survey data provide suggestive evidence that PhD workers, particularly those from the business, ICT, and engineering fields, may enhance cooperation between firms and higher education institutions—which can be important for the functioning of the Finnish innovation system.

Coming back to the Finnish doctoral education pilot (2024–2027) discussed in the introduction, what type of economic impacts can we expect from the pilot based on our findings? First, there are obvious risks involved in an attempt to rapidly increase the supply of PhDs in the labor market, especially, as our results suggest that the relative labor market position of PhDs, particularly those at the post-doctoral stage, has weakened during the last twenty years. Therefore, if the Finnish unemployment rate will remain high in the coming years, for instance, due to prolonged problems in the global market, the new PhD graduates are expected to encounter difficulties in finding employment in the business sector. However, if the overall labor market situation will improve, the investment could—based on our firm-level results—pay off by enhancing firms' innovation capabilities and productivity.

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Appendix

A Additional tables

TABLE A1: COOPERATION WITH UNIVERSITIES

	(1) University	(2) UAS	(3) Either
PhD	0.0073***	0.0015	0.0070***
	(0.0021)	(0.0018)	(0.0020)
Master	0.0002	0.0003***	0.0001
	(0.0001)	(0.0001)	(0.0001)
Employees	0.0802***	0.0674***	0.0875***
	(0.0046)	(0.0040)	(0.0047)
2020	0.0003	-0.0081	-0.0023
	(0.0102)	(0.0094)	(0.0110)
2022	-0.0266***	-0.0321***	-0.0318***
	(0.0098)	(0.0089)	(0.0105)
Constant	-0.1539***	-0.1318***	-0.1504***
	(0.0162)	(0.0141)	(0.0168)
Observations	6,682	6,682	6,682

Notes: The results are from random-effects regression models. The dependent variables are indicators for whether the firm co-operates with 1) a university, 2) a university of applied sciences (UAS) or 3) an institution of either type. Statistical significance: * p<0.1, ** p<0.05, *** p<0.01.

TABLE A2: COOPERATION WITH UNIVERSITIES

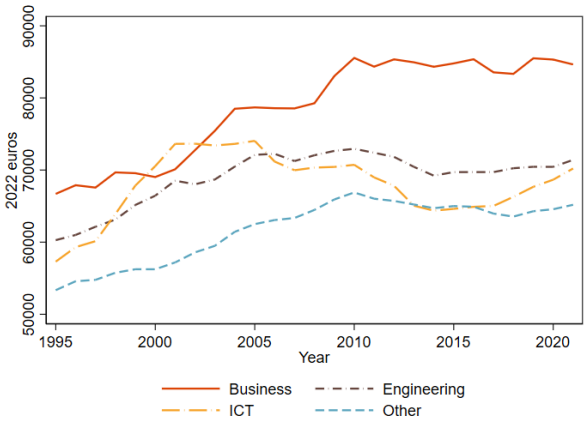
	(1) University	(2) UAS	(3) Either
PhD (Bus/ICT/Eng)	0.0111**	0.0070**	0.0107**
	(0.0047)	(0.0031)	(0.0044)
PhD (other)	0.0053***	-0.0013	0.0051***
	(0.0018)	(0.0014)	(0.0018)
Master	0.0001	0.0002	0.0000
	(0.0001)	(0.0001)	(0.0001)
Employees	0.0812***	0.0687***	0.0884***
	(0.0046)	(0.0041)	(0.0046)
2020	0.0004	-0.0080	-0.0023
	(0.0102)	(0.0094)	(0.0110)
2022	-0.0261***	-0.0314***	-0.0313***
	(0.0097)	(0.0089)	(0.0105)
Constant	-0.1569***	-0.1359***	-0.1532***
	(0.0160)	(0.0144)	(0.0167)
Observations	6,682	6,682	6,682

Notes: The results are from random-effects regression models. The dependent variables are indicators for whether the firm cooperates with 1) a university, 2) a university of applied sciences (UAS) or 3) an institution of either type. Statistical significance: * p<0.1, ** p<0.05, *** p<0.01.

B Additional figures

FIGURE B1: PHDS' ANNUAL WAGE INCOME AND DISPOSABLE INCOME BY FIELD

(a) WAGE INCOME



(b) DISPOSABLE INCOME

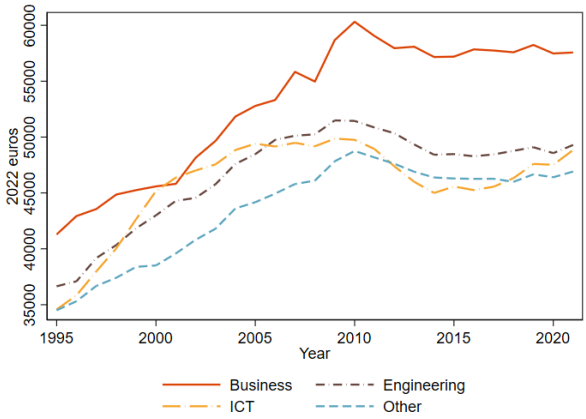


FIGURE B2: SHARE OF PHD HOLDERS AMONG 25--64-YEAR-OLDS

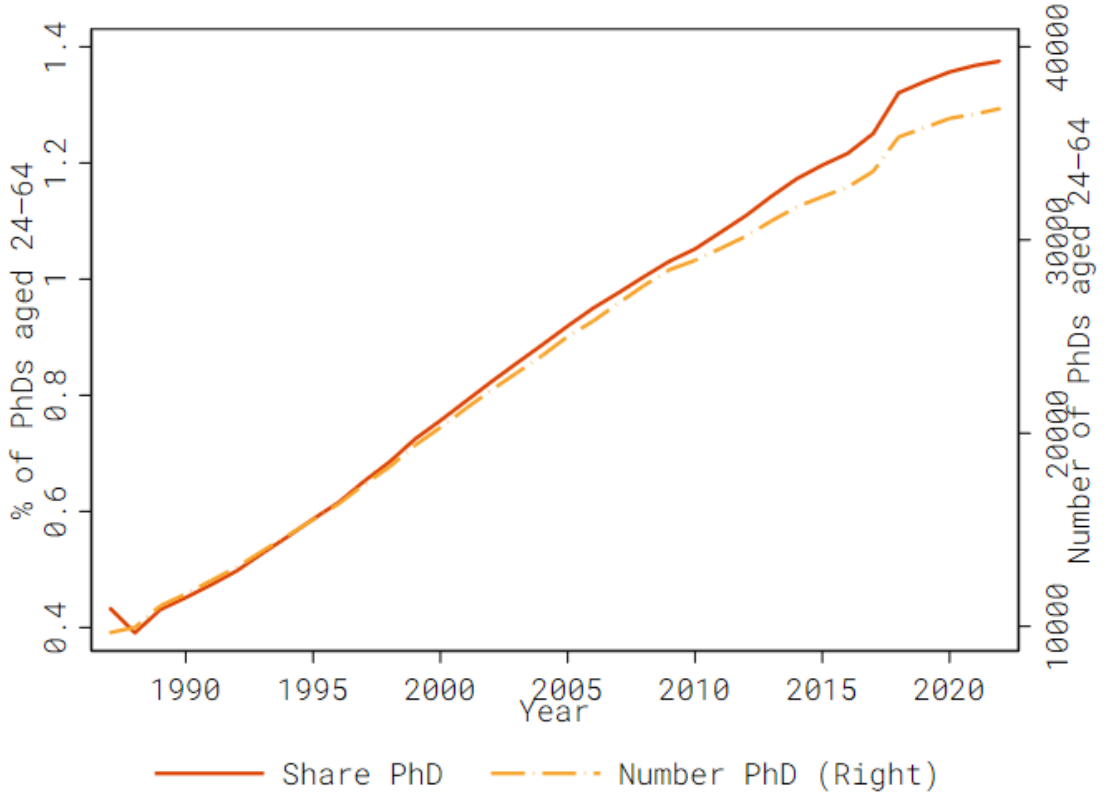


FIGURE B3: NUMBER OF FOREIGN-ORIGIN PHD HOLDERS IN FINLAND'S LABOR FORCE BETWEEN 1987 AND 2022

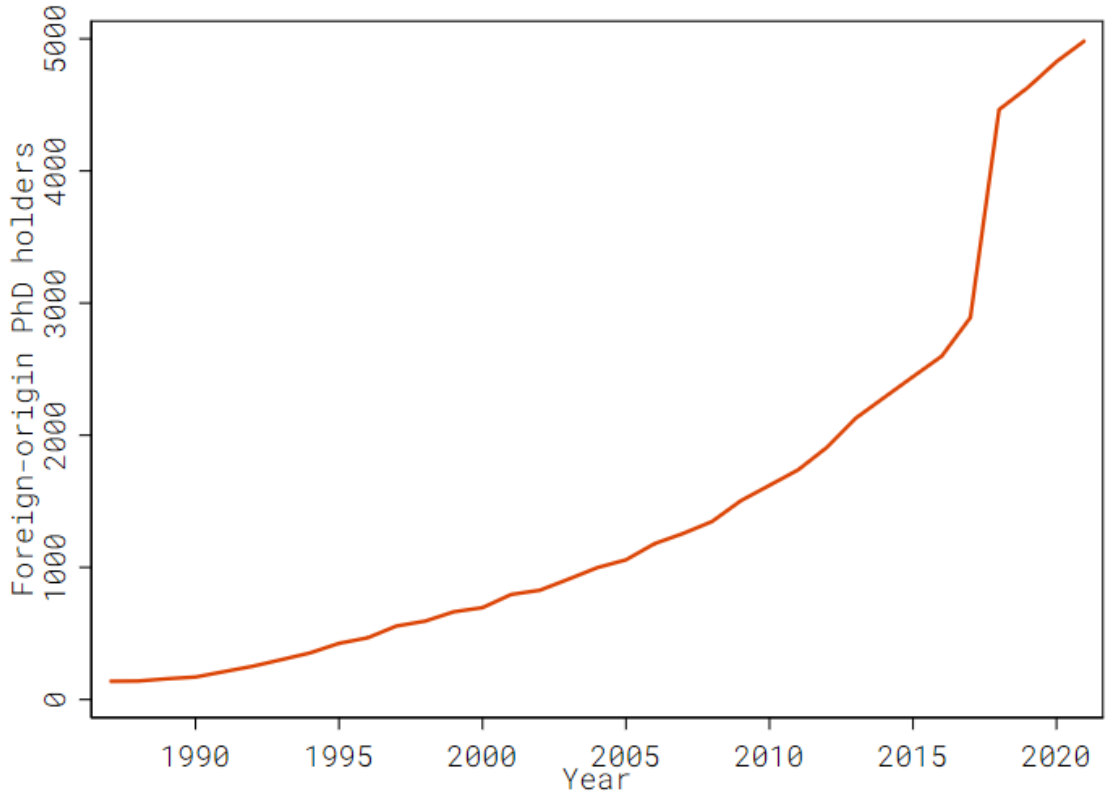
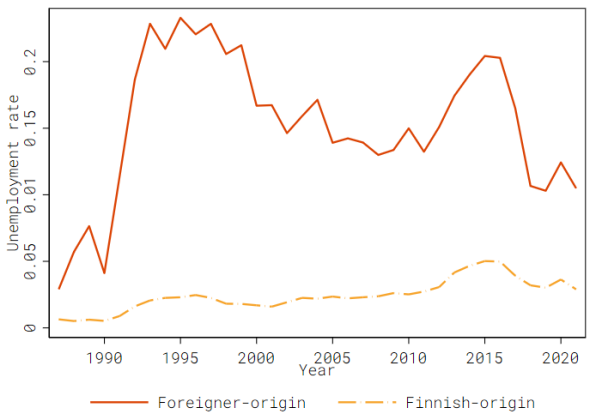


FIGURE B4: UNEMPLOYMENT RATE AND AVERAGE ANNUAL WAGE INCOME FOR PHDS OF FOREIGN-ORIGIN AND FINNISH-ORIGIN

(a) UNEMPLOYMENT



(b) WAGE INCOME

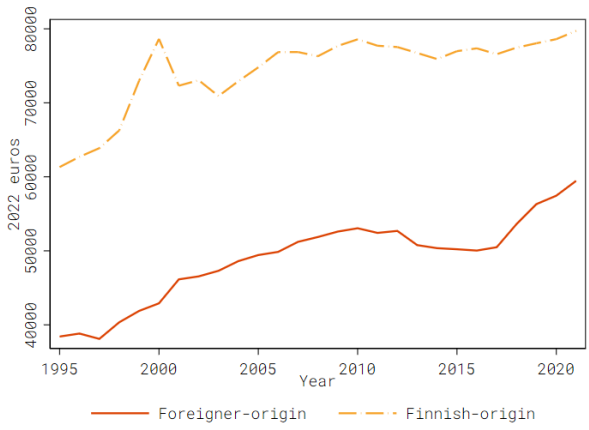
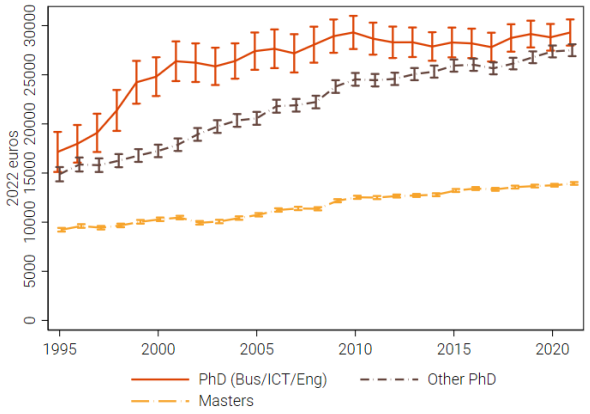
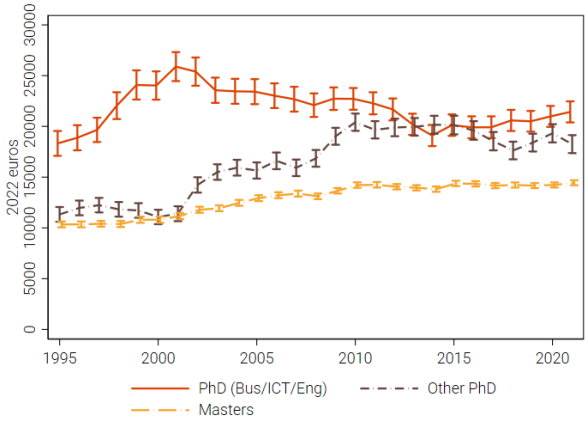


FIGURE B5: AVERAGE WAGE PREMIA FOR A PHD DEGREE AND A MASTER'S DEGREE BY YEAR AND GENDER

(a) WOMEN



(b) MEN



Notes: The results are from yearly regression models estimated separately for men and women. The models include controls for region of birth, age, first language and 3-digit field of education. Individuals with a bachelor's degree are used as the reference group. The vertical lines describe the 95% confidence intervals.

FIGURE B6: SHARE OF PHD HOLDERS WORKING IN THE PRIVATE SECTOR

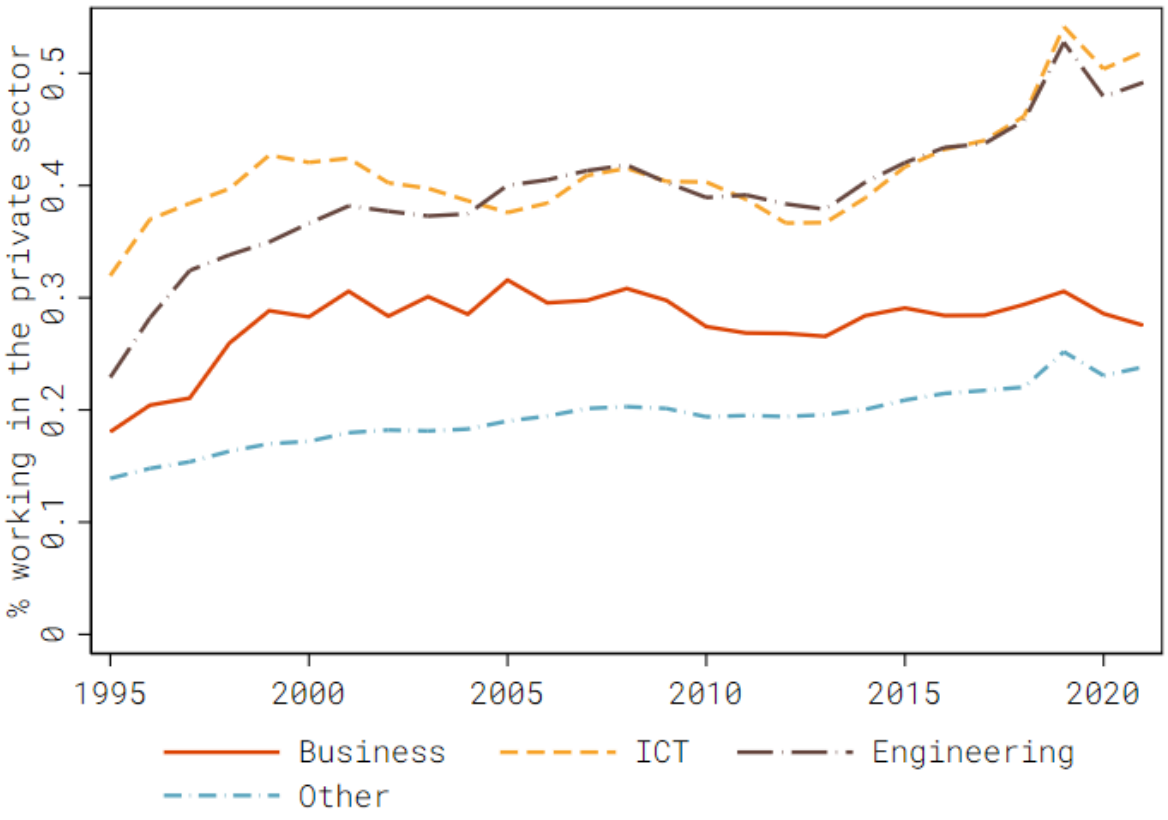
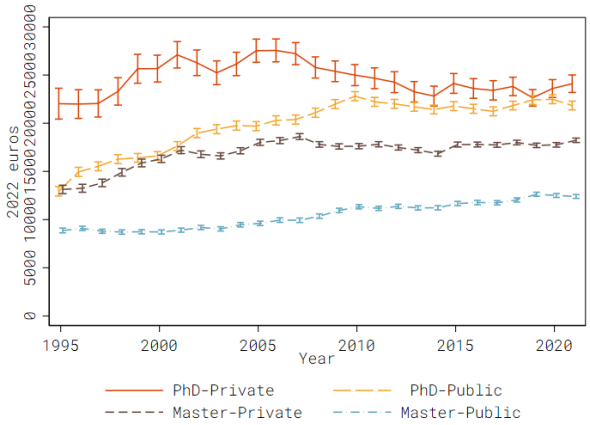
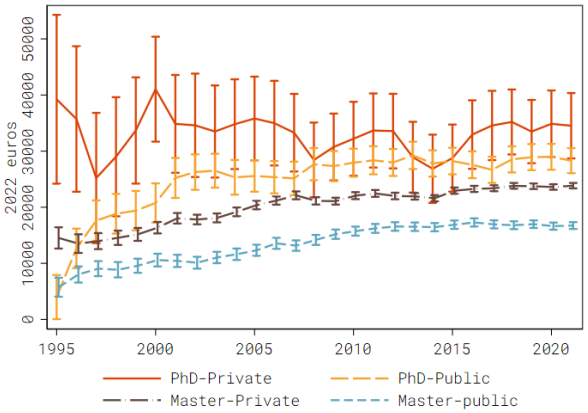


FIGURE B7: AVERAGE WAGE PREMIA FOR A PHD DEGREE AND A MASTER'S DEGREE BY YEAR, FIELD OF EDUCATION, AND EMPLOYER SECTOR (PUBLIC/PRIVATE)

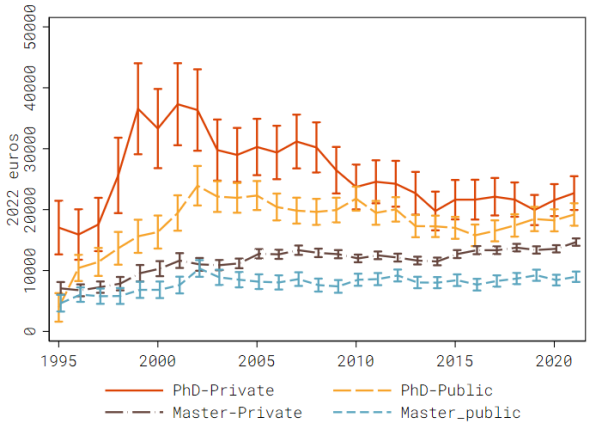
(a) ALL FIELDS



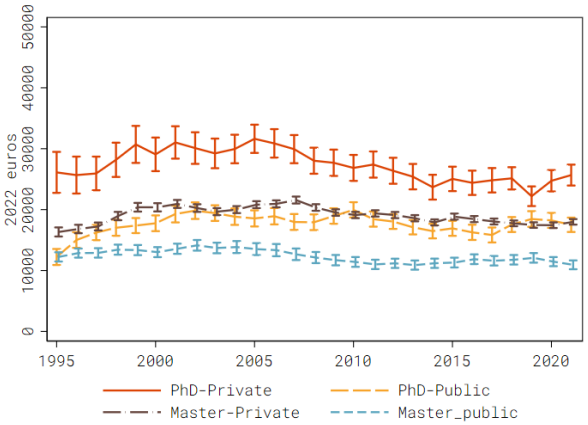
(b) BUSINESS



(c) ICT



(d) ENGINEERING



Notes: The results are from sector- and year-specific regression models controlling for region of birth, age, gender, first language, and 3-digit field of education. Individuals with a bachelor's degree working in the same sector are used as the reference group. The vertical lines describe the 95% confidence intervals.

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