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Gender differences in promotion: A duration analysis of academic economists in Sweden

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Abstract

We located 1,041 doctoral graduates for the purpose of examining the determinants of gender differences in labour market outcomes. By compiling longitudinal data from CVs, we documented the careers of 572 academic economists in Sweden from graduation through the academic career ladder between 1990 and 2016. Duration analysis is used to estimate gender differences in the likelihood of promotion to associate and full professor. We find evidence of a gender promotion gap, accounted for in partial by publication differentials between men and women. An exploratory analysis shows that there has been a convergence in the publication differentials and that the promotion gap has narrowed—or even closed—for the young generation of academic economists. The results do not show any signs of discrimination or gender differences in the credit allocation of co-authored papers. By investigating co-authorship patterns closer, we do not find any gender differences in the propensity to solo-author or co-author with senior researchers, but that the female propensity to co-author with female colleagues is higher than the male. Finally, we have gathered a sub-sample of 359 researchers through a survey on parental factors. The evidence shows a negative correlation between children and the likelihood of promotion for both men and women, which appears to be related to having young children rather than parental leave.

Keywords: academic labour market, gender promotion gap, parenthood, co-authorship patterns, publication differentials
JEL: I23, J23, J24, J7

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1 Introduction

There is wide reporting of glass ceilings and glass doors in the labour market, describing the obstacles women face in their careers. The phenomena illustrate the effects of gender differences in labour market outcomes, which in theoretical work are categorised along two dimensions: horizontally and vertically. Horizontal gender differences—such as occupational segregation—can be understood in terms of glass doors, whereas vertical gender differences—portrayed as glass ceilings—describe how women are underrepresented at top positions within the labour market. In economic terms, these gender differences may be a sign of an inefficient labour market and hence a sub-optimal outcome, in that the full potential of the female workforce is not captured. Finding the determinants of these differences is crucial for the implementation of policies to close the gap and establish a gender-balanced labour market.

The academic labour market is suitable for investigating gender differences in labour market outcomes, given the formalisation of the promotion steps across universities and countries. In comparison to most non-academic labour markets, productivity can be estimated easily through research output, which the promotion decision usually is contingent on. The low share of female researchers within certain academic fields—most notably the STEM fields[1] and the field of economics—have been studied both horizontally and vertically (Ceci et al., 2014; Ginther and Kahn, 2014). Vertically, the gender promotion gap within academia has been conceptualised by the 'leaky pipeline', an expression used to describe how the representation of women deteriorates further up in the academic career ladder. A number of studies have established the existence of a leaky pipeline within the academic field of economics and found the phenomenon to be explained—fully or partially—by differences in publications (Ginther and Kahn, 2004) and family factors (Kahn, 2012; Takahashi and Takahashi, 2015). In relation to this, female researchers have been shown to be attributed less credit for co-authored publications in comparison to their male colleagues (Sarsons, 2017), implying that co-authorship can account for a part of the gender promotion gap.

The purpose of this paper is to study the determinants of gender differences in labour market outcomes. To this end, we have collected a unique data set of 1,041 doctoral graduates in Sweden between 1990 and 2016, out of which 572 have pursued an academic career in Sweden. There are at least three reasons for studying the Swedish field of economics: first of all, Sweden is considered one of the most gender equal countries in the world,[2] but the labour market is still characterised by gender differences in both the horizontal and vertical dimensions (Statistics Sweden, 2016). The academic field of economics is no exception—only 6% of the professors in economics were female in 2006 (Jonung and Ståhlberg, 2008). Secondly, an equal distribution of men and women within the field of economics is important in itself in terms of power and influence in society. Thirdly, most previous studies focus on the American academic labour market. There are differences in the institutional features of Sweden and USA, both in respect to the university system and family policies, which implies that the evidence on gender differences in the United States may not be applicable in a Swedish context. Most importantly, the 'up or out' tenure-track system is not as present in Sweden as in the United States, indicating that promotion

[1] Science, Technology, Engineering and Mathematics.

[2] Compared to the countries within the European Union, Sweden was ranked first in the Gender Equality Index by the European Institution for Gender Equality in 2017. The Global Gender Gap Report of 2017, presented by World Economic Forum, estimated the gender gap in Sweden as the fifth lowest in the world.

patterns may differ as well.

Developing the work of Boström and Sundberg (2016), we study gender differences in promotion within the field of economics, alongside three potential factors explaining the under-representation of women. These determinants—publications, co-authorship and parenthood—have been selected based on their importance in explaining gender differences in labour market outcomes in previous literature. We estimate the promotion gap through the use of duration analysis, by investigating gender differences in the likelihood of promotion to associate and full professor. Research output in the form of publications serves as a proxy for productivity in the labour market for academic economists. The role of co-authorship is examined two-fold: by studying the direct effects of co-authorship on promotion through credit allocation of jointly written papers, and moreover, by examining the gender composition of research collaborations as an initial step in analysing the indirect effects of co-authorship on promotion. Finally, the effects of parenthood—measured through children and parental leave take-up—are added to our models on promotion. The motivation of the determinants and the research question are further discussed and presented in Sections 3 and 4.

The main finding of the thesis is the existence of a gender promotion gap in the Swedish labour market for academic economists, which can be partially explained by publication differentials between men and women. By dividing the sample into two cohorts, an exploratory analysis of the data implies that these publication differentials appear in the early—but not in the late—cohort.[3] Furthermore, duration analyses of the sub-samples indicate that there is no gender promotion gap in the late cohort. An interpretation is that the gender promotion gap found in the main analysis can be explained by historical differences in publications. There is no evidence suggesting any discrimination or gender differences in the credit allocation of co-authored papers. By closer examining publications through co-authorship patterns, we find that female researchers have a higher propensity to co-author with other women in comparison to male researchers. In contrast to our hypotheses, we do not find any gender differences in co-authorship patterns with respect to solo-authorship or co-authorship with senior researchers. Finally, we observe a negative correlation between having children and the likelihood of promotion for both men and women. This relationship is not contingent on parental leave take-up, but seems to work partly through the role of publications.

The remainder of the paper is organised as follows: we begin by outlining important background information on the Swedish labour market for academic economists in Section 2. A literature review is provided in Section 3, followed by a presentation of the identified gap in the literature alongside research questions and hypotheses in Section 4. We proceed by describing the data in Section 5. In Section 6, we explain of the method of duration analysis and continue with an outline of the empirical strategy in Section 7. The results are presented in Section 8, followed by sensitivity and exploratory analyses in Sections 9 and 10. A discussion of our findings is presented in Section 11, and finally, the paper is concluded in Section 12.

[3] The cohorts of PhD graduates are divided into two groups: the early cohort between 1990 and 2004 and the late cohort between 2005 and 2016.

2 Background

The purpose of this section is to provide the information needed for understanding the labour market under study, highlighting the gender differences in the aggregated labour market in Sweden. Moreover, we outline the labour market for academic economists in Sweden by presenting the statistics on doctoral graduates in economics alongside a description of the academic career ladder in Sweden.

2.1 Labour market for female workers in Sweden

There have been improvements over the last decades in the Swedish labour market, yet there are still gender differences in several areas. The high level of occupational segregation is one aspect: out of the Swedish employees, only 16% of the women and 15% of the men had an occupation with an even gender distribution in 2015, while 70% of the women and 67% of the men had an occupation that was dominated by their own gender. This occupational segregation is one of the factors explaining the gender wage gap, which was estimated at 13% in 2014. By adjusting for gender differences in occupation, sector, educational background, full-time/part-time and age, the weighted gender wage gap was at 6%. Furthermore, women in Sweden work less than men do along the extensive as well as the intensive margin in the public sphere (Statistics Sweden, 2016).

In regard to the extensive margin, the female labour force participation rate in 2015 was 88% for women aged 25 to 44, and 83% for women aged 45 to 64. The corresponding numbers for men were 93% and 88%. In the age group 20 to 64, the employment rate was somewhat lower: 78% and 83% for women and men respectively. Along the intensive margin, women work 30 hours, and men 37 hours, per week on average in the public sphere. The fraction of part-time work also differs between the genders. Although the share of women has decreased from 45% in 1987 to 29% in 2015, the share of men working part-time was 11% the same year—up from 6% in 2015. Moreover, the reasons for doing so vary. The most common reason out of the top 3 choices for working part-time in 2015 was 'Cannot find suitable full-time work' for both genders. For women, the other two were 'Care of children' and 'Do not want to work full-time'. For men, they were 'Studies' and 'Illness/Reduced work capacity'. In relation to part-time work, the gender difference in the intensive margin of the private sphere is relevant: here, women work on average five hours more per week than men do—26 hours compared to 21 hours. Considering paid and unpaid work, both women and men work 8 hours per day on average (Statistics Sweden, 2016).

Another aspect of the Swedish labour market is the institutional features relating to childcare. By entering parenthood, the working life of an individual is affected in at least two ways: the short-term interruption in the form of parental leave, and the long-term effect of child rearing. Institutions such as parental leave and publicly funded daycare for children are meant to deal with both of these dimensions and provide opportunities for women to continue their work and careers. As regulated by law since 1974, Swedish parents may share the parental allowance, extending to 480 days of paid leave (corresponding to 16 months). Moreover, any of the parents are entitled to stay at home full-time during the first 18 months of each new child birth using job-protected paid parental leave. After these initial 18 months, either or both of the parents can work part-time (with a minimum of 75%) until the child turns 8 years old (Parental Leave Act [1995:584]). With the purpose of promoting a gender-equal division of parental allowance, a month of non-transferable

paid parental leave was introduced in 1995, and later extended to two and three months in 2002 and 2016 respectively. By comparison, the European Parliament passed a directive in 2010 that included a non-transferable paternity quota of four weeks (European Union: Council Directive 2010/18/EU). Although the gender balance in parental allowance has steadily increased since 1974, women still account for most of the leave. In 2015, women accounted for 74% of the days of parental allowance. The latest data on the average gender division of parental allowance stretching until the child turns 8 years reports that parents on average had attained 431 days of parental leave, where men accounted for 22% of the days (Statistics Sweden, 2016).

Other aspects of parenthood which can have long-term effects on the working life include child care after the parental leave and temporary absence due to child-illness. The system of publicly funded daycare centres for children is an institution which alleviates the long-term effect of child rearing on the career of parents. 85% of children in the age 1 to 5 and 84% of children in the age 6 to 9, were enrolled in some form of pre-school, leisure time centres or pedagogical care in 2014. In regard to illness, 62% of the temporary parental allowance (previously sickness benefit for care of sick children and parental allowance for care of children) were accounted for by women (Statistics Sweden, 2016).

2.2 Labour market for academic economists in Sweden

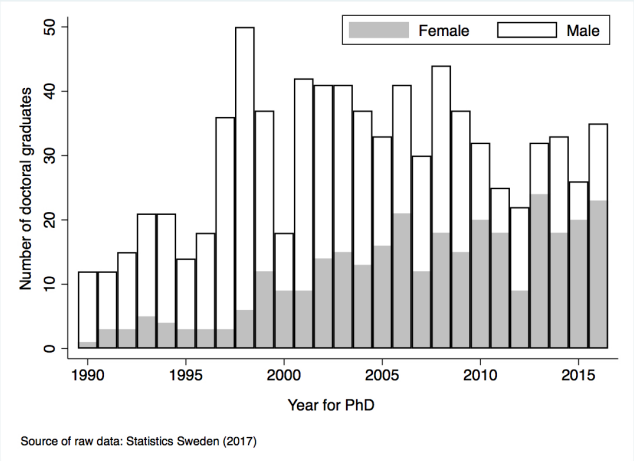
This study focuses on the career ladder in the labour market of academic economist in Sweden, where the initial step is receiving the doctoral degree. In brief, the Swedish doctoral programme is generally preceded by four or five years of university studies, generally ending with one of three degrees: the Degree of Master of Science in Business & Economics (*civilekonomexamen*), the Degree of Master of Science (One Year) in Economics (*magisterexamen i nationalekonomi*) and the Degree of Master of Science (Two Year) in Economics (*masterexamen i nationalekonomi*). Figure 1 displays the distribution of the 1,121 doctoral graduates in economics between 1990 and 2016, issued from 14 universities and university colleges.[4] 89% of the doctoral graduates has a degree from one of the following six universities: Lund University, Stockholm School of Economics, Stockholm University, Umeå University, University of Gothenburg and Uppsala University. There is a total of 805 men and 316 women, hence a female share of 28% across the population. In a given year between 1990 and 2016, the share of women varies from 8% to 43%.

A large share of the academic labour force in Sweden have positions based on the employment categories of regulation (the Swedish Higher Education Act [1992:1434] and the Swedish Higher Education Ordinance) preceding the *autonomy reform* (Bill 2009/10:149). At the time, the employment categories regulated by law were post-doctoral researcher (*forskarassistent*), lecturer (*adjunkt*), senior lecturer (*lektor*), associate senior lecturer (*biträdande lektor*) and professor (*professor*). Changes in light of the reform have been implemented during the last years, however. As of 2012, there are three employment categories codified by law within Swedish academia: professor (*professor*), senior lecturer (*lektor*) and the 'employment for career development positions' (*meriteringsanställning*). The latter employment category is a fixed-term position with a contract on a maximum of four years unless reasons specific calls for an extended period of two additional years,

[4] The universities and university colleges are (in alphabetical order): KTH Royal Institute of Technology, Jönköping University, Linköping University, Linnaeus University, Luleå University of Technology, Lund University, Stockholm School of Economics, Stockholm University, Swedish University of Agricultural Sciences, Växjö University, Umeå University, University of Gothenburg, Uppsala University and Örebro University.

established for the purpose of offering doctoral graduates an opportunity to qualify for an academic career. Titles used for this 'employment for career development positions' vary across the universities, but include postdoctoral researcher, assistant professor and associate senior lecturer (Swedish Higher Education Authority [UKÄ], 2017). Moreover, some of the Swedish universities have implemented versions of the American tenure-track system, which includes the use of American titles: assistant professor, associate professor and full professor. Assistant professors on the Swedish tenure-track are on special fixed-term contracts of two three-year periods, and apply to become associate professors at the end of the contract. Additional to the professional titles are the academic qualification *docent*, which corresponds to four years of full-time research and can be compared to the academic qualification *habilitation* commonly used in continental Europe. In translation to English, *docent* is in general translated to the professional title associate professor.

Figure 1: Swedish doctoral graduates in economics 1990–2016



3 Literature review

Gender differences in labour market outcomes have been widely studied within the field of labour economics. While some of the gender differences—such as labour force participation, educational attainment and hours spent on paid work in respect to work at home—have narrowed substantially (Goldin, 2014), there are still mechanisms at play yielding differences between men and women in terms of allocation of capital and power in society. The economic theory behind these mechanisms have been categorised into five classes of explanations: skill differences, discrimination, preferences, identity and psychological attributes (Altonji and Blank, 1999; Bertrand, 2010). The two latter have emerged during the last decades, incorporating theories from sociology and psychology into the economics framework for the purpose of capturing human elements beyond homo economicus. In this study, the existence of gender differences in labour market outcomes is explored by studying *discrimination* and the interaction of *preferences* and *gender identity* through the roles of publications, co-authorship and parenthood.

Models of discrimination theory are often divided into collective and competitive models, where competitive models in turn are categorised into taste-based models and models of statistical discrimination (Altonji and Blank, 1999). The taste-based models

stem from the work by Becker (1957) and were further developed by Cain (1986). These theories assume that the employer has a 'distaste' for a particular minority group, implying that a worker of the minority group needs to be more productive than a comparable worker of the majority group. The models on statistical discrimination were later developed by Phelps (1972) and Arrow (1973) and focused on information asymmetry. When there is no clear signal of the productivity of a worker, the firm makes a judgment based on other characteristics, such as the worker's gender, if they believe that this characteristic is correlated with productivity. In contrast to the taste-based discrimination models, statistical discrimination can therefore be fully rational from the employer's perspective, given the limited amount of information on the worker's productivity. Additionally, these models of statistical discrimination assume that the workers, being rational, also incorporate the employers' discrimination into their decision on whether to invest in certain skills or educational attainments or not.

Gender differences in labour market outcomes may also be the result of women spending more time on family obligations than men do. While some interpret this as a female preference for family formation and care-taking, there may be underlying mechanisms explaining these preferences. Akerlof and Kranton (2000) constructed an identity model of behaviour, in which the concept of identity is added in the form of preferences to the standard utility function of the economic agent. Through this framework, the distinct preferences of men and women can be analysed in terms of social norms. Women are expected to be the primary caregivers to children and defying this norm may consequently yield disutility. There is, however, a direct conflict in the division of resources between the career and the household: any time spent on household chores affects the time a person can spend at work, and vice versa (Becker, 1991). As follows, by complying to the social norm, women are likely to spend less time on their careers. The effect of parenthood would therefore have a greater adverse effect on the careers of women (as a group) than on men's. The theories on discrimination and gender identity are not mutually exclusive but can also work together—the identity of being a primary caregiver may be the cause for discrimination as women are *expected* to devote less time to the career.

The existence of glass ceilings in labour markets is an outcome portraying gender promotion gaps, a measure of the extent to which women are under-represented at top positions within the labour market. The promotion gap captures the vertical dimension of factors explaining the gender earnings and wage gaps. Hence, these gender gaps are closely related and the determinants of the gender differences in promotion are pivotal in understanding the gender wage gap. In the academic labour market, gender differences in promotion have been shown to largely explain the wage differentials between male and female researchers (Ginther and Hayes, 2003; Ginther, 2006). In the remainder of the literature review, we present empirical studies supporting the existence of a gender promotion gap alongside factors shown to have an impact on the distinct labour market outcomes for men and women. We discuss the role of two of these factors—co-authorship patterns and parenthood—in detail, for the purpose of highlighting the research gap we have identified in the literature, which will be further discussed in Section 4.

3.1 The gender promotion gap

There are various studies establishing the existence of a gender promotion gap within the field of economics (Kahn, 1993; Jonung and Ståhlberg, 2003; Ginther and Kahn, 2004; Kahn, 2012), although some evidence points toward diminishing promotion gaps over

time (McDowell et al., 1999; Ceci et al., 2014). From the cohort of PhD graduates of 1980 to 1999, Ginther and Kahn (2014) found that the gender differences in tenure award had disappeared in most social sciences with the exception of the field of economics, where there was a 20% difference between men and women. Moreover, the likelihood of promotion to full professor differed by 26.6 percentage points.

A range of explanations have been studied in order to comprehend the existence of glass ceilings in the academic career ladder, including productivity, researcher mobility and discrimination (Wolfinger et al., 2008; Ginther and Kahn, 2004). Studies on scientific productivity—in terms of research output—have shown that male researchers in general publish to a higher extent than female researchers do. This gender gap has been referred to as a 'productivity puzzle' (Cole and Zuckerman, 1984; Mairesse and Pezzoni, 2015), and while some evidence suggests that the gap has narrowed considerably for the most recent cohorts of researchers (Arensbergen et al., 2012), there are also studies showing that the gender publication gap within the field of economics have increased over time (Ceci et al., 2014). Parenthood and co-authorship patterns are two factors which may have an impact on productivity, and hence affect the gender promotion gap indirectly, which will be discussed more in detail in Sections 3.2 and 3.3. Kahn (1995) contributed a part of the productivity gap to gender differences in research affiliation: male researchers were found to be more likely to be employed at higher ranked institutions. Male researchers have also been found to spend more time on research, while women spend time on other obligations such as teaching and mentoring, implying that these gender differences in time allocation may have an impact on research output (Misra et al., 2011; Manchester and Barbezat, 2013).

Another aspect of gender differences in promotion is the existence of 'sticky floors': female academic economists in Japan have been found to stay longer as lecturers—the lowest academic rank—which the authors suggest explains a large part of the promotion gap over the entire academic career (Takahashi and Takahashi, 2015). There is also evidence suggesting that female researchers have a lower propensity to apply for promotion both in academia in general, as well as within the field of economics (De Paola et al., 2017; Bosquet et al., 2017). Wolfinger et al. (2008) argued the mobility of women is limited in comparison to men due to family-related factors, implying that female researchers do not relocate to other universities in light of a tenure denial, which in turn results in a lower likelihood of promotion. Finally, the unexplained gender promotion gap have in some studies been interpreted as discrimination (Kahn, 1995; Ginther and Kahn, 2004).

3.2 Entering parenthood: parental leave and family factors

Entering parenthood may yield gender differences in the labour market through two possible effects: directly affecting the likelihood of promotion or the duration at each promotion step, and indirectly through factors accounting for the promotion gap, for instance publication differentials. Women have been shown to be adversely affected by being married and having children in comparison to men—an effect denoted the 'motherhood penalty'—accounting for a substantive part of the gender differences in the labour market outcomes. These differences are particularly accentuated in more highly educated and high-skilled occupations (Bertrand et al., 2010; Barth et al., 2017; Goldin et al., 2017; Blau and Kahn, 2017). Goldin (2014) also showed that the gender wage gap is mostly dependent on the importance of long working hours, which is relevant in light of the labour market for academic economists. As shown by Kleven et al. (2017), women

tend to reduce their hours worked to a substantively higher extent than men do after entering parenthood—a difference that is also amplified by the number of children. In an academic context there is also evidence of women choosing not to have children due to incompatibilities with their career in research (Finkel and Olswang, 1996).

Many academic researchers enter parenthood shortly after receiving their doctoral degree—during a time period when lower productivity may have decisive consequences for the advancement to higher ranks. A slowdown in scientific output might also have an amplifying effect, assuming that early advancement is important in order to establish research networks and 'make a name' for oneself. If female researchers are more prone to interrupt their careers for parental leave, or have more responsibility in parenthood in some other way, this is likely to affect their productivity and dim their prospects of advancement to higher academic ranks relative to men.

Results from estimations of the effects of parenthood on promotion and productivity within academia have been ambiguous. Amilon and Persson (2013) studied the effect of family factors on doctoral graduates within as well as outside of academia and found children-related variables only to negatively affect the wages of the latter group. Marriage, however, had a positive effect on wages for both genders regardless of being in academia or not. Some evidence indicates that having children accounts for a part—though not all—of the gender promotion gap (Ginther, 2006). Wolfinger et al. (2008) found that women were penalised for family formation behaviour, both marriage and children under the age of 6, by reducing the likelihood to obtain a tenure-track job, but the factors did not explain the lower female probability of attaining tenure. Female researchers within the social sciences have been found to be less likely than men to enter tenure-track jobs in the case they had children, while no difference if they did not, implying distinct preferences of men and women. Moreover, the results indicated the existence of a gender difference in the effect of parenthood on the likelihood of receiving tenure award and becoming full professor (Ginther and Kahn, 2014). In Japan, the gender promotion gap observed within the field of economics was attributed to marriage and children having an adverse effect on female researchers (Takahashi and Takahashi, 2015). Furthermore, the authors called for policies alleviating gender differences in household responsibility.

A policy that has been implemented for the purpose of mitigating the effects of potential productivity shocks connected to entering parenthood is the tenure clock stopping for researchers, adopted at most universities in the United States for having children (but not dependent on parental leave). Despite the intentions of the policy, Antecol et al. (2016) showed that through the gender-neutrality of these policies, the male tenure rates increased between 1985 and 2004 at the expense of the female tenure rates. The driving force behind the results was that male researchers published more in top-journals, suggesting an increase in the within-university tenure standards. The female researchers, however, did not. According to the authors, the implication is that gender-neutral policies have been aimed toward a gender-specific productivity loss, adversely affecting the female tenure rates.

An important point is that the direction of causality in the relationship between parental factors and productivity is unclear: there is data supporting the hypothesis that children affects the researcher productivity negatively, and women more so than men (Hunter and Leahey, 2010). Other studies find the reverse case and suggest that only more productive researchers can 'afford' to have children (Ginther and Kahn, 2004), in which case the implied direction of causality would be from productivity to parenthood and

not the other way around. This notwithstanding, by aiming at capturing a causal effect of parenthood on productivity, Krapf et al. (2017) provide novel evidence for the labour market of academic economists. Their results suggest that parenthood does not affect the research productivity for men, while the picture is somewhat more complex for women. Here, the authors highlight the following results: the unconditional effect of motherhood is negative but not significant, but being unmarried and below 30 at the birth of the first child appears to reduce the research productivity to a great extent. Moreover, productivity losses increase with the number of children for women.

While children may have a direct impact on both promotion and productivity, the effects of the career interruption in form of parental leave reasonably have larger impact on women, considering that they—as a group, and on average—are on parental leave to a higher extent than men are. Unlike the United States—where the Family and Medical Care Act of 1993 only extends to 12 weeks of unpaid parental leave—most European countries have statutory paid parental leave. The importance of parental leave as a determinant of gender differences in labour market outcomes may reasonably hinge on the design of the system. Paid and job-protected parental leave entitlements have been shown to lead to higher female labour force participation (Ruhm, 1998; Thévenon and Solaz, 2013). While this implies an increase along the extensive margin, these entitlements also result in decreases along the intensive margin. To this end, Ruhm (1998) found that extensive periods of parental leaves reduced the relative wage for females whereas short periods of parental leaves did not appear to have this effect. In an extension of the study by Ruhm (1998), Thévenon and Solaz (2013) found that parental leave—both long and short time periods—can explain gender wage gaps. Moreover, this study showed that parental leaves longer than two years had a detrimental effect on the female labour participation. Lalive and Zweimüller (2009) used two policy reforms in Austria—an extension of the parental leave in 1990 and a partial-reversion of it in 1996—as natural experiments to evaluate the effect of parental leave on fertility and the propensity to return to work after having children. The findings indicated that the extension led to reductions in the labour supply in the short run, but not in the long run, whereas the reduction led to increases in the female labour supply along both the extensive and intensive margins.

Swedish data has provided evidence on career interruptions negatively affecting the wages of both men and women, particularly so for occupations with high wages (Albrecht et al., 1999, 2015). On the one hand, the results showed that male wages are more negatively affected by parental leave. On the other hand, women account for the most of the parental leave. Albrecht et al. (2015) argued that these patterns are important in understanding the glass ceiling effect. Moreover, their results implied that the wage loss was less severe for women who concentrated their maternity leave. The effect of entering parenthood on the gender wage and earnings gaps have been estimated to increases 10% and 32% respectively, 15 years after the birth of the first child (Angelov et al., 2016). Here, the within-couple wage gap was investigated, focusing on the wage trajectory of the female in relation to its partner's. Analysing the results, the authors argued that parental leave does not seem to be the sole culprit for the increased gender differences in wages and earnings, but rather that the 'long-term continuing responsibilities for child rearing' fall disproportionately on women, causing the main share of the gender differences implied through a gradually increasing wage gap.

To the best of our knowledge, few studies have focused on parental leave in an academic context. In a study on the role of career interruptions at an Australian university, parental leave did not seem to have an effect on promotion (Kahn, 2012). Mayer and Tikka (2008) studied female representation within academia in Finland and Sweden, arguing that the Nordic family policies should result in higher shares of women in comparison to the United States, but could not find any differences. The authors pointed out, however, there was no available data on parental leave used by Finnish and Swedish academics.

3.3 Co-authorship: proration and gender patterns

The expression 'publish or perish' captures the importance of publications on career advancement within the academic labour market. The field of economics is by no means an exception—it is rather characterised by the phenomenon. A number of studies have shown that research output in top-ranked journals is increasingly important in the promotion decision; a trend which has coincided with a trend of a higher number of co-authors on each paper (Hudson, 2001; Card and Della Vigna, 2013; Hamermesh, 2013; Björklund, 2014). Research collaborations are generally encouraged within academia as a means of increasing both the quantity and the quality of research output, considering that co-authorship may allow for an efficient division of labour and reduce the cost of scientific production for the individual researcher (Becker and Murphy, 1992; Ductor, 2015). This need not be the case, however, which has induced a vivid discussion on co-authorship and proration: the extent to which publications and publication scores should be discounted in regard to the number of co-authors (Hollis, 2001; Ellison, 2013; Liebowitz, 2014).

Two alternative methods of allocation of author credits are either *no proration* (each of the co-authors is attributed the publication score in full) or *strict proration* (each co-author is contributed the publication score divided by the number of authors).[5] Liebowitz (2014) argued that the efficiency of research collaborations is contingent on the reward structure, and moreover, that only strict proration will 'induce efficient team formation and maximise the number of papers written by a given sized research community'. Conversely, no or partial proration of publication scores may lead to inefficient research collaborations and favour co-authorship over solo-authorship. There is evidence showing a positive correlation between co-authorship and high quality as well as length and frequency of the publications for a given researcher, while at the same time, a negative net relationship between co-authorship and output attributable to that given researcher in the light of strict proration. Consequently, the implication is that no proration may undermine the goal of maximizing research output (Hollis, 2001).

Studies on survey data have reported the partial, but not strict, proration of publication scores in the evaluation of jointly produced research at the departments of economics in the United States (Liebowitz and Palmer, 1984; Liebowitz, 2014). Empirical studies on these departments, however, have found mixed evidence: the results vary from no proration of publications for appointments to associate and full professor (McDowell and Smith, 1992) to strict proration in a study of citations and earnings (Sauer, 1988). Ellison (2013) found evidence on partial proration in a study on citations and academic ranks, while Hilmer et al. (2015) showed that researchers received full credit for co-authored

[5] There are also intermediate approaches, but we will not delve deeper into distinct proration methods for the purpose of this study. One of the most common alternative approaches is to divide the publication score with n^c, where $0 < c < 1$ (Ellison, 2013; Hilmer et al., 2015).

work in salary decisions. In sum, there is no consensus in the literature regarding which proration that is used. Yet, the treatment of co-authored work is important in an assessment of the effect of publications on promotion, as well as in understanding how research collaborations form, given that these incentive schemes are likely to affect co-authorship patterns.

Standard economic theory predicts that research collaborations will occur if the expected utility of team formation is higher than the alternative, for instance working alone or take part in another constellation (Becker and Murphy, 1992). Gender may affect the net benefit of a research collaboration through preferences (researchers might prefer to form teams with people of the same gender as ourselves), which in turn may be explained by coordination costs (heterogeneity in the form of gender among research partners may increase the costs of research collaborations). It may also be the case that male and female researchers have different preferences for working alone or in teams in general. Studies on publications in top economics journals have shown that researchers tend to collaborate to a higher extent with other researchers of the same gender (Ferber and Teiman, 1980; McDowell and Smith, 1992; Boschini and Sjögren, 2007). Given the low share of women at the departments of economics, a reduction of co-authorship opportunities or difficulties in finding optimal research collaboration are plausible consequences of gender sorting. This may in turn lead to female researchers solo-authoring, or participating in sub-optimal research teams, to a higher extent (McDowell and Smith, 1992). Moreover, the low share of women at the departments of economics—and particularly at the higher ranks—could make it more difficult for women to connect to mentors and become a part of research networks (McDowell et al., 2006; Blau et al., 2010). In light of the importance of publications and evidence suggesting no or partial proration of publication scores in the promotion decision, the existence of gender patterns in research collaborations may have an important role in explaining gender differences in promotion through its effects on scientific output.

While differences in research collaborations between men and women may have an indirect effect on promotion, there is also evidence suggesting there is a direct effect of co-authorship patterns as well. Information asymmetry between employer and researchers has been shown to play an important role when allocating author credits to co-authored work in promotion decisions (Sarsons, 2017). In an optimal setting, workers are promoted based on their level of productivity. A requirement for this, however, is that the ability of a worker is perfectly observed by its employer. Applied to an academic context, the worker is a researcher whose productivity is reflected in research output in the form of publications. Unlike many other academic fields, researchers in economics are listed in alphabetical order instead of being listed according to level of contribution. Hence, solo-authored papers sends a clear signal about ability to the employer, whereas co-authored papers do not. Instead, there is an information asymmetry, leading the employer to allocate credit to the members of a research collaboration by *estimating* their ability and their respective contributions. By testing whether the uncertainty of the respective researchers' contributions led to gender differences in attribution of credit, Sarsons (2017) found that women were discredited for co-authoring with male researchers, resulting in a lower likelihood of receiving tenure. As follows, information asymmetry may account for a part of the gender promotion gap.

4 Research questions

The purpose of this paper is to study the determinants of gender differences in labour market outcomes. The market for Swedish academic economists has been outlined (Persson, 2002; Jonung and Ståhlberg, 2003, 2008) but, to the best of our knowledge, there have been no empirical studies attempting to find the determinants of the low representation of women except Boström and Sundberg (2016). In the literature review, we presented evidence suggesting that publications, co-authorship and parenthood are important in explaining promotion gaps within academia. Hence, we proceed by further exploring the role of these factors in labour market outcomes for the academic economists in Sweden.

Initially, the existence of a gender promotion gap within the Swedish field of economics needs to be established. Subsequently, the roles of publications, co-authorship and parenthood will be investigated in relation to the likelihood of promotion for men and women. Research output in the form of publications is the most important factor for academic advancement. Hence, it is also the natural starting point for investigating gender differences in promotion.

Research collaborations are deemed important in explaining the gender promotion gap given the increasing trend towards more co-authorship (Hamermesh, 2013; Card and Della Vigna, 2013) and the increasing importance of publications in top journals (Björklund, 2014). Our approach to study co-authorship is two-fold: first of all, by following the work of Sarsons (2017), we study of the allocation of credit for co-authored work on the likelihood of promotion. Secondly, we begin to investigate the existence of gender patterns in co-authorship, which may reflect gender differences in preferences. By establishing gender differences in the propensity to collaborate in different kinds of teams, we hope to find the possible determinants to any publication differentials between men and women. In contrast to the sample of publications in the three top journals in economics used by Boschini and Sjögren (2007) in their study on co-authorship patterns, we aim to include all peer-reviewed papers authored by the Swedish academic economists in our sample, in order to pin down whether the co-authorship patterns observed in top journals apply to the entire field of economics.

Entering parenthood has been shown to negatively affect female researchers (Wolfinger et al., 2008), and studies on the Swedish labour market have found parental leave to decrease the wages of both men and women (Albrecht et al., 2015). To the best of our knowledge, there are no studies which covers the role of parental leave on the Swedish academic labour market. To the extent that parenthood have been shown to have an impact on the career, the role of institutions relating to parenthood is crucial in an analysis of the Swedish labour market. The aim of the study is to account also for parenthood in determining the gender promotion gap.

Finally, the other aspect of a lower likelihood of academic promotion is a higher likelihood of leaving academia. Consequently, we will investigate whether the existence of gender promotion gap also leads to a higher drop-out rate for female researchers. As follows, we have formulated the following research questions:

1. **Gender promotion gap**

    a) Is there a gender promotion gap, measured as 'there is a higher likelihood of promotion for a man than for a woman'?

    b) Does publication differentials account for a part of the gender promotion gap?

    c) Does gender differences in the allocation of credit for co-authored publications account for a part of the gender promotion gap?

    d) Does parenthood account for a part of the gender promotion gap through:

        i) the number of years with young children?

        ii) the number of children?

        iii) parental leave?

2. **Gender differences in the propensity to leave academia**

    a) Is there a gender difference in the propensity to leave Swedish academia?

    b) Is there a gender difference in the propensity to leave Swedish academia, conditional on publications?

3. **Gender patterns in co-authorship**

    a) Are women more likely to solo-author than men are?

    b) Are women more likely to co-author with women than men are?

    c) Are women less likely to co-author with senior co-authors than men are?

5 Data

In this section, we first outline the procedure for our data collection and present an overview of the data, highlighting the gender differences in the descriptive statistics. This overview is followed by closer descriptions of the data structure and the variables.

5.1 Data collection

We have assembled a unique data set of 1,041 doctoral graduates within the field of economics, out of which 572 have pursued an academic career after receiving their doctoral degree. Buiilding upon the dataset of Boström and Sundberg (2016),[6] the main analysis is based on these 572 researchers within the labour market for academic economists. An academic economist is defined as a person who fulfills at least one of the following two criteria: (i) a doctoral degree in economics from a Swedish university and (ii) has held a position as a post-doctoral researcher at a department of economics in Sweden.[7]

[6] In Boström and Sundberg (2016) we assembled a data set in which 245 out of these 572 academic economists were included.

[7] By this definition, an academic economist may have a doctoral degree in a subject that is *not* economics, as long as they are employed as a researcher at a department of economics. There are also as researchers with doctoral degree in economics that are not employed at a department of economics. For instance, a health economist employed at Karolinska Institutet or a labour economist employed at the Swedish Institute for Social Research at Stockholm University (SOFI) would be included in the data. Furthermore, a number of universities do not have a department of economics but rather an interdisciplinary department where doctoral graduates in economics are employed, which are included.

The foundation of the data set is anonymised data provided by Statistics Sweden, containing the number of doctoral graduates in economics in Sweden between 1990 and 2016, categorised annually by gender and university. The total number of doctoral graduates was 1,121. We have identified the names of the doctoral graduates through the doctoral theses presented on the webpages of the universities. This list was cross-checked against records sent to us by administrators at the Exam offices at the universities in August and September 2017. Our total sample coverage of PhD graduates amounts to 83% and is further outlined in Appendix B. In order to include the researchers that have held a position as a researcher in Sweden, but received their doctoral degree elsewhere, we have tried to get hold of employment records from the universities. In addition, the researchers currently employed (as of September 2017) have been located through the webpages of the universities. Next, we continued by collecting CVs, using the websites of the universities or the researchers themselves (including profiles on LinkedIn) in order to gather information on employment history. Through these methods, we compiled a list of 1,041 doctoral graduates, out of which 469 left Swedish academia immediately after receiving their doctoral degree. The remaining 572 doctoral researchers became academic economists within Sweden.

Proceeding with the data collection for these 572 academic economists, we compiled information from their CVs on academic background, employment and publications. In the case of a missing, incomplete or old CV, we have contacted the researchers by e-mail asking them for an updated CV. If the CVs did not contain updated information on publications, we have updated them using databases such as Google Scholar, Web of Science and Scopus. We have cross-checked these databases in order to make sure that all publications are included. Using the publication records of each researcher, we have assembled the following information on all publications (amounting to 5,827): publication year, journal, type of co-authorship and number of co-authors. Furthermore, we have collected characteristics on all co-authors, including gender, field and academic rank at the year of publication. Finally, we conducted a survey, contacting the 572 academic economists for the purpose of collecting data on children and parental leave, leading to a subsample of 359 (63%) researchers containing information on parental factors.

The data was collected between August and October 2017 and stretches from 1 January 1990 to 31 December 2016. Hence, all events (such as publications and promotions) after this date have been excluded from the data. All data have been anonymised through the removal of names and publication titles as soon as feasible.

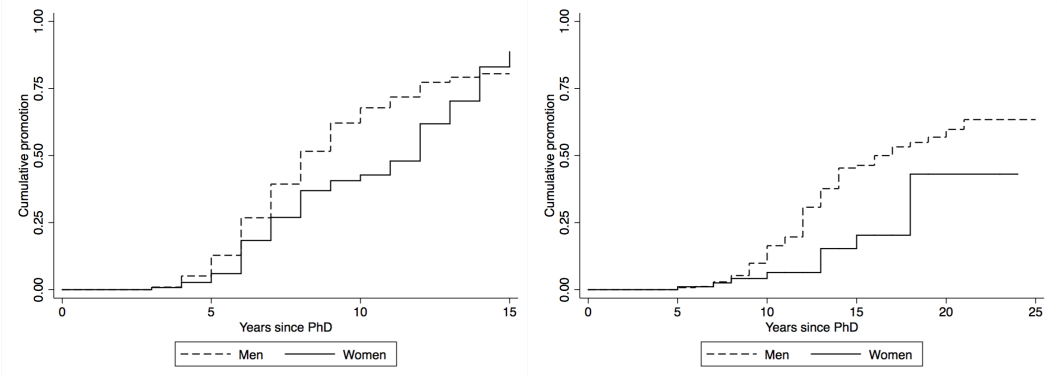
5.2 Data overview

In order to investigate the existence of gender differences in the academic labour market, we use data on 572 researchers, out of which 168 (29%) are female. 123 (22%) researchers leave their employment at some point during the observation period 1990 to 2016. There are no gender differences in the mean share of researchers leaving Swedish academia before promotion to either associate or full professor, as displayed in Table 8. 215 (38%) researchers are promoted to associate professor in the sample. On average, the duration at the level of assistant professor is 6.7 years. 90 (16%) researchers in the sample are promoted to professors within the observation period, with a mean duration of 10.7 years between earning the doctoral degree and the full professor title. Categorised by gender, the average duration for women to the respective categories are longer than for men, but the differences in average duration are not statistically significant, see Table 7.

Although there is no evidence of any gender differences in the average duration to promotion among the *promoted* researchers, a somewhat different picture is presented in the Kaplan and Meier estimations in Figure 2. These estimates display the relationship between the number of years after earning the doctoral degree and the cumulative hazard: the likelihood of promotion. Figure 2 suggests that there are gender promotion gaps at both promotion steps, captured by the area between the male and female curves. A closer examination of Table 7 also shows that there is a statistically significant gender difference in the average share of researchers that were promoted to associate professor within 7 and 10 years after receiving the doctoral degree. Moreover, the share of female researchers that were promoted to full professor within 10 and 15 years is lower than the share of male researchers. In sum, an interpretation of the promotion data presented in this overview suggests that men is promoted to a higher extent than women, but there is no statistically significant difference in the average duration among the promoted researchers.

Figure 2: Gender promotion gap

(a) Associate professor **(b) Full professor**

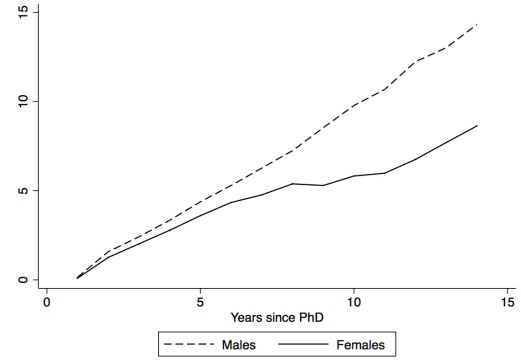


Notes: The Kaplan and Meier (1958) estimates display the cumulative hazard rates of promotion from assistant to associate professor (Figure 2a) and from associate to full professor (Figure 2b). The Kaplan and Meier estimate is equivalent to the Cox regression without covariates (Cleves et al., 2016)—see Section 9.2.

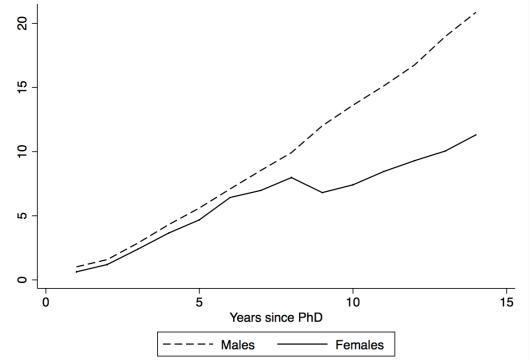
An important part of the data is the publications of the 572 researchers, used as a proxy for productivity and for studying gender patterns in research collaborations. There is a total number of 5,827 observations, which are given publication scores based on the quality of the journal they are published in. On a researcher level, the publication scores are accumulated on a yearly basis. Overall, the statistics presented in Table 11 suggests that male researchers—as a group and on average—have higher accumulated publication scores than female researchers. This notwithstanding, these gender difference are often not significant. Figure 3 shows the publication patterns for the male and female researchers in our sample. The publication scores are accumulated on a yearly basis, starting from the year the researchers received their doctoral degree.

Figure 3: Accumulated number of publications—PhD 1990–2016

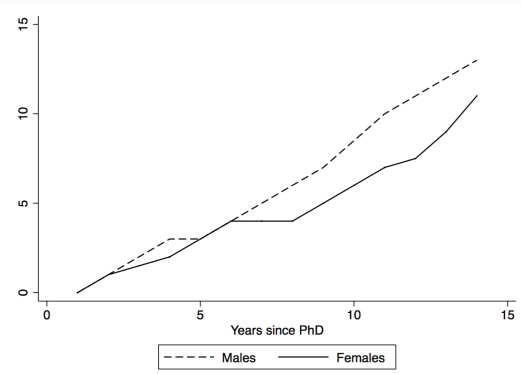
(a) Mean number of publications



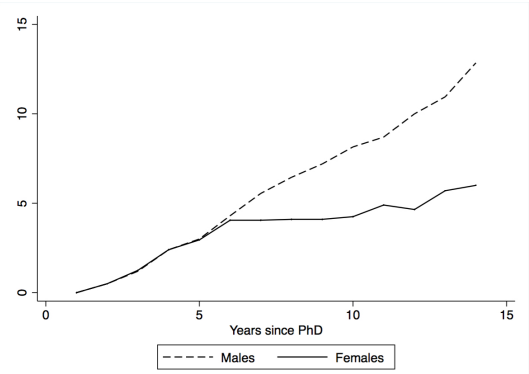
(b) Mean weighted publications*



(c) Median number of publications



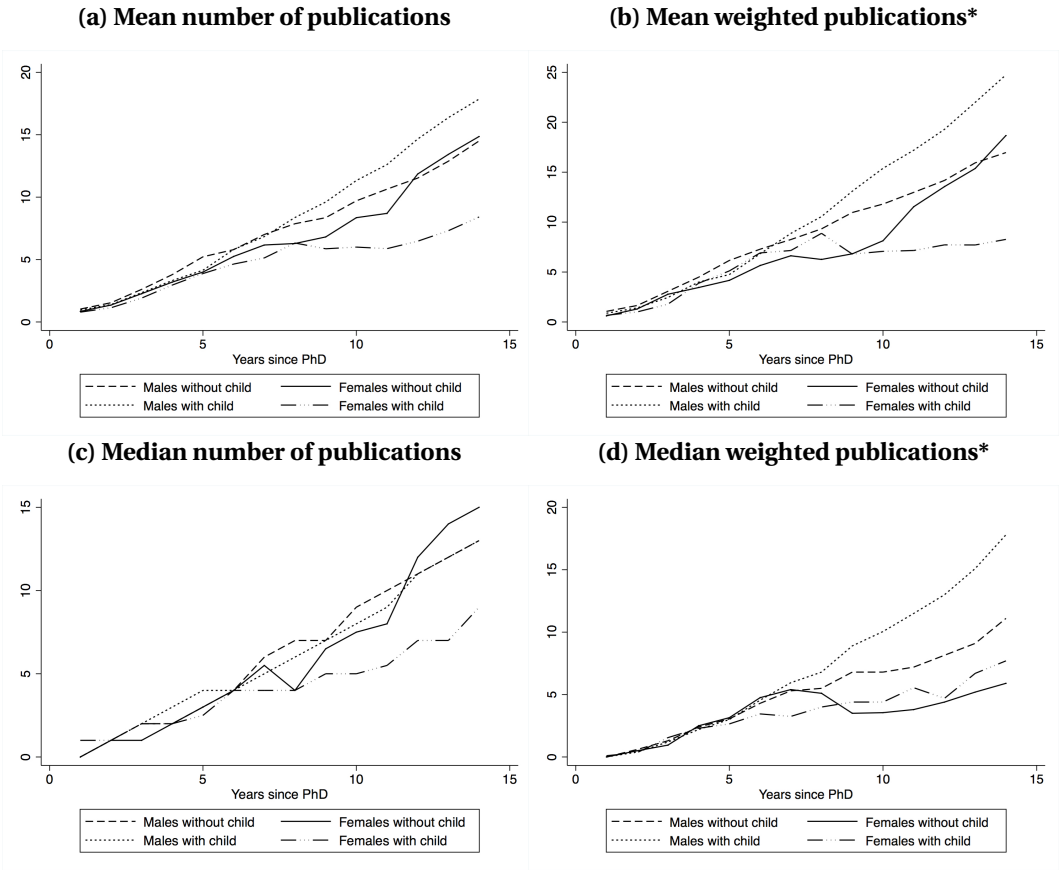
(d) Median weighted publications*



**Each publication is given the Article Influence Score for the journal in which it is published—see Table 9*

Finally, we present unique survey data on parenthood for 359 out of the 572 researchers. If a researcher has children, data has been collected on the number of children and their year of birth, and whether the researcher was on parental leave or not for each child respectively. We define parental leave as a full-time leave for at least six months, given the annual structure of the data set. As displayed in Table 3, the data suggests that there is no significant gender difference in having children or the number of children, but that more female than male researchers have been on parental leave. Furthermore, the average number of parental leaves for a researcher is significantly higher for women than men. In Figure 4, we separate the publication scores for researchers with and without children. Male researchers with children have the highest mean publication scores and women with children has the lowest (Figures 4a–b). This trend is less clear by looking at median number of publications (Figure 4c). The median weighted publication scores show the same patterns as the median impact (Figure 4d).

Figure 4: Accumulated number of publications—children



**Each publication is given the Article Influence Score for the journal in which it is published—see Table 9*

5.3 Data description

This section is divided into two subsections, outlining data on a researcher level and on a publication level, presenting sample statistics alongside definitions and explanations of the data structure.

5.3.1 Researcher data

The sample statistics presented in Table 1 contains a total of 1,041 academic economists. All researchers received their doctoral degree between 1990 and 2016. Out of the 926 Swedish doctoral graduates in the sample statistics, 469 (51%) either left academia or transferred to a foreign university immediately after receiving their doctoral degree and did not return to a Swedish university during the observed period. The focus of this study is the careers of the remaining 572 academic economists between 1990 and 2016, which includes both Swedish doctoral graduates and doctoral graduates from foreign universities. We have information on family factors for 359 out of these 572 researchers (63%). The share of female researcher is approximately 30% in each category.

Table 1: Sample statistics on researchers

	Full sample		Male		Female		Female share
Total sample							
Swedish PhD graduates	926	(89%)	652	(89%)	274	(88%)	30%
PhD at foreign university	115	(11%)	78	(11%)	37	(12%)	32%
Observations	1041		730		311		30%
Swedish PhD graduates							
Employed at Swedish university	457	(49%)	326	(50%)	131	(48%)	29%
Employed at foreign university	140	(15%)	99	(15%)	41	(15%)	30%
Left academia	329	(36%)	227	(35%)	102	(37%)	32%
Observations	926		652		274	30%	
Researcher dataset							
Swedish PhD graduates	457	(80%)	326	(81%)	131	(78%)	29%
PhD at foreign university	115	(20%)	78	(19%)	37	(22%)	32%
Observations	572		404		168		29%
Subsample with parental factors							
Parental factors	359	(63%)	246	(61%)	113	(67%)	32%
No parental factors	213	(37%)	158	(39%)	55	(33%)	26%
Observations	572		404		168		29%

Notes: Number of researchers; percentage of total (sub)sample with respect to each category in parenthesis

The sample distribution of the number of researchers at each academic rank in 2016 is displayed in Table 2, including researchers with doctoral degrees from both Swedish and non-Swedish universities. Out of the 572 researchers in the data set, 449 researchers remains within Swedish academia in 2016, implying that 123 researchers have left their employment at some point before 2016. While the total share of female researchers remaining in academia in 2016 is 30%—in line with the female shares in Table 1—the distribution of women is skewed across the academic ranks. This skewness may follow from the distribution of female doctoral graduates in Sweden between 1990 and 2016, as displayed in Figure 1, but the historical supply of doctoral graduates does not necessarily account for the entire promotion gap. Only 12% of the full professors in the sample are female. Note here that only academic economists who received their doctoral degree between 1990 and 2016 are included in the sample.[8]

[8] 12% of the professors in our sample are female, but there are professors within academia with a doctoral degree before 1990. Given that the share of female doctoral graduates was very low before 1990—a total of 17 women received their doctoral degree between 1970 and 1990, in comparison to 179 men (Jonung and Ståhlberg, 2003)—the female share of professors in our sample is likely overestimated in relation to the entire population of full professors. This implies that we cannot interpret the share of female professors in our sample as an increase in comparison to the descriptive statistics outlined in Jonung and Ståhlberg (2003) and Jonung and Ståhlberg (2008), where all researchers at the departments of economics—including those with a PhD before 1990—were presented.

Table 2: Distribution of employment in 2016

Academic rank	**Full sample**		**Male**		**Female**		**Female share**
Assistant professor	252	(56%)	160	(51%)	92	(69%)	37%
Associate professor	113	(25%)	81	(26%)	32	(24%)	28%
Full professor	84	(19%)	75	(24%)	9	(7%)	11%
Observations	449		316		133		30%

Notes: Number of researchers; percentage of total (sub)sample with respect to each category in parenthesis

Table 3 outlines information on the subsample including parental factors. The information collected includes the number of children and their year of birth, as well as year for parental leave for each child, if applicable. 72% of the respondents have children, and out of them, roughly half have been on parental leave. Out of the 258 researchers with children, 167 (65%) have at least one child born during their employment as assistant professor. Roughly 30% of the men, and 90% of the women, were on parental leave for six months or longer. In Table 4, the variables for researcher characteristics are outlined. The construction of the variables is further described in Section 5.4.

Table 3: Sample statistics on parental factors

	Full sample		**Male**		**Female**		**Female share**
Total subsample							
No children	101	(28%)	72	(29%)	29	(26%)	29%
Children	258	(72%)	174	(71%)	84	(74%)	32%
Observations	359		246		113		31%
No parental leave	126	(49%)	117	(67%)	9	(11%)	7%
Parental leave	132	(51%)	57	(33%)	75	(89%)	56%
Observations	258		174		84		32%
Assistant professors with children born during employment							
No parental leave	84	(50%)	78	(71%)	6	(11%)	7%
Parental leave	83	(50%)	32	(29%)	51	(89%)	61%
Observations	167		110		57		34%

Notes: Number of researchers; percentage of total (sub)sample with respect to each category in parenthesis. Parental leave is defined as a leave corresponding to full-time leave for six months or longer for each child.

Table 4: Definition of variables

Dependent variables	
Promotion	Indicator variable taking value 1 if the researcher is promoted in a given year and zero otherwise. Takes either the form of promotion from assistant to associate professor, or from associate to full professor.
Leave	Indicator variable taking value 1 if the researcher leaves Swedish academia in a given year and zero otherwise. Takes either the form of leaving academia, leaving for a university outside Sweden, or leaving in general.
Independent variables	
Female	Indicator variable taking value 1 if the researcher is female and zero otherwise
Publications	Accumulated publication score in each year, following the procedure outlined in Section 5.4.3
Cohort	Indicator variable for PhD-year binned into years: 1990–1994, 1995–1999, 2000–2004, 2005–2009 and 2010–2016
Field	Indicator variable for primary field divided into categories: theory, macro, finance, agricultural and applied
Years since PhD	Number of years since receiving the doctoral degree—included both in original and quadratic form
Academic affiliation	Indicator variable taking value 1 if the researcher is employed at a top 6 university in a given year and zero otherwise
Child years	Accumulated number of years during employment in Swedish academia with at least one child below the age of 10
Child number	Number of children below the age of 10
Parental leave	Accumulated number of parental leaves during employment in Swedish academia

5.3.2 Publication data

The publication data contains details on papers published in peer-reviewed journals, where each publication is linked to a main author from the researcher data set. If a paper is co-authored, and more than one of the authors appear in the data set, a publication will appear multiple times in the publication data. Note that only published papers are included, i.e. not working papers, MIMEOs or papers categorised as 'forthcoming' or 'in press'. The data set is not limited to papers within the field of economics, i.e. interdisciplinary papers published in journals such as *Science* and *PNAS* are included.

Table 5: Variables for co-authorship characteristics

Solo-authored	Indicator variable taking value 1 if the publication has one author, and zero otherwise
Co-authored	Indicator variable taking value 1 if the publication has at least two authors, and zero otherwise
Co-authored single	Indicator variable taking value 1 if the publication has at least two authors and all authors have the same gender, and zero otherwise
Co-authored mixed	Indicator variable taking value 1 if the publication has at least two authors and all authors do not have the same gender, and zero otherwise
Co-authored female	Indicator variable taking value 1 if at least one of the co-authors is female, and zero otherwise
Co-authored senior	Indicator variable taking value 1 if at least one of the co-authors has a higher academic rank than the main author, and zero otherwise

Table 5 summarises the categorical variables for different types of co-authorship and sample statistics on the publications are presented in Table 6 below. The division by gender indicates whether the main author of a publication is male or female. A woman is registered as the main author in 1,046 (18%) of the 5,827 publications. Each paper is categorised based on solo-authorship (no co-authors) or co-authorship (one or more co-authors). A co-authored paper is either single-gendered (all authors to the paper have the same gender) or mixed-gendered (at least one of the co-authors have a different gender than the main author). The variable *co-authored female* indicates the presence of at least one female co-author. As displayed in Table 6, the female share is roughly equal between solo-authored and co-authored papers (19% and 18% respectively), but only 6% of the papers have female authors only (*co-authored single*). Among the co-authored papers with a female main author, 21% are single-gendered (only female authors) and 79% are mixed-gendered. The corresponding numbers for male main authors are 72% and 28%. Moreover, the share of co-authored papers with at least one female co-author is 28% for the papers with a male co-author and 45% for the papers with a female co-author.

Each paper has also been categorised by the presence of at least one senior co-author—associate professor or full professor—where the papers reported only include papers where the main author has a lower level of seniority.[9] Here, the observations refer to the number of publications of researchers at the level of assistant professor (1,975 publications) and the level of associate professor (1,335 publications).

[9] Note that only researchers within the field of economics count as senior co-authors. This distinction is made based on information asymmetry: the contribution is more likely to be credited to the most senior co-author if their expertise in within the same field. In contrast, senior non-economics researchers are reasonably not credited for the elements related to economics in an interdisciplinary paper.

Table 6: Sample statistics on publications

Publications	**Full sample**		**Male**		**Female**		**Female share**
Total							
Solo-authored	1,246	(21%)	1,010	(21%)	236	(23%)	19%
Co-authored	4,581	(79%)	3,771	(79%)	810	(77%)	18%
Total	5,827		4,781		1,046		18%
Co-authored single	2,870	(63%)	2,703	(72%)	167	(21%)	6%
Co-authored mixed	1,711	(37%)	1,068	(28%)	643	(79%)	38%
Co-authored	4,581		3,771		810		18%
Co-authored female	1,423	(31%)	1,057	(28%)	366	(45%)	26%
Co-authored no female	3,158	(69%)	2,714	(72%)	444	(55%)	14%
Co-authored	4,581		3,771		810		18%
Papers by assistant professors							
Co-authored senior	837	(42%)	616	(42%)	221	(44%)	26%
Total	1,975		1,467		508		26%
Papers by associate professors							
Co-authored senior	526	(39%)	429	(38%)	97	(46%)	18%
Total	1,335		1,124		211		16%

Notes: This table presents sample statistics of the publication data. Number of publications are reported alongside percentage of total (sub)sample with respect to each category in parenthesis.

5.4 Variable description

The purpose of this section is to explain and motivate the construction of the variables. Moreover, summary statistics of the main variables are provided.

5.4.1 Promotion

The employment history of each researcher is tracked through employment location on a yearly basis, starting from the year and the university the researcher received its doctoral degree. We divide the academic ladder into three steps: assistant professor, associate professor and full professor. Given that all researchers in the data set have a doctoral degree, the first step considered is assistant professor, which besides the academic title of assistant professor covers titles such as post-doctoral researcher, lecturer, associate senior lecturer and equivalent positions. A researcher is promoted to the second step in the academic career ladder through an appointment to either *docent* or associate professor.

We argue that associate professor is the most suitable first promotion step, given that the title is used by all universities in our sample—either as the academic qualification *docent* or as the American professional title. In contrast to other titles used by the universities, these titles are standardised both across departments and over time. The final promotion step is the appointment to full professor. A researcher that has been promoted outside of Sweden is not included in the data set for the promotion step in question, given that the promotion did not occur at a Swedish university. A researcher that has received its doctoral degree outside of Sweden and been promoted to either associate professor or full professor at a Swedish university is included in the data. Table 7 below presents summary statistics on promotion to associate and full professor.

Table 7: Summary statistics on promotion variables

	Full sample		Male		Female		p-value
	Mean	*Std error*	*Mean*	*Std error*	*Mean*	*Std error*	
Associate Professor							
Years to Associate Professor	6.702	0.1978	6.552	0.2151	7.302	0.4828	0.1297
Observations	215		172		43		
Associate Professor in 7 years	0.392	0.0257	0.424	0.0297	0.289	0.0501	0.0268
Observations	362		278		83		
Associate Professor in 10 years	0.522	0.0306	0.577	0.0339	0.315	0.0638	0.0005
Observations	267		213		54		
Full Professor							
Years to Full Professor	10.63	0.3542	10.60	0.3543	10.89	1.5674	0.8102
Observations	90		81		9		
Full Professor in 10 years	0.213	0.0311	0.245	0.0361	0.067	0.0463	0.0306
Observations	173		143		30		
Full Professor in 15 years	0.508	0.0447	0.542	0.0484	0.333	0.1143	0.1028
Observations	125		107		18		

Notes: This table presents the mean number of duration in years to promotion together with the mean shares of researchers promoted to associate and full professor within a certain number of years. Categorisation by gender and academic rank.

5.4.2 Leaving Swedish academia

A researcher may leave Swedish academia, either temporarily or permanently, for a non-academic employment or a foreign university. A researcher working at a research institute is not considered to have left academia, but any other employment is not considered as a position within academia.[10] The number of years a researcher is included in the data set corresponds to the number of years employed within Swedish academia. In Table 8 below, summary statistics on the leaving variables are presented. There are no statistically significant gender differences in the average share of researchers leaving Swedish academia.

[10] We do not include researcher positions at authorities such as the Riksbank or the Competition Authority.

Table 8: Summary statistics on leaving variables

	Full sample		Male		Female		p-value
	Mean	*Std error*	*Mean*	*Std error*	*Mean*	*Std error*	
Immediately after PhD							
Leave	0.508	0.0164	0.502	0.0196	0.522	0.0302	0.5861
Observations	926		652		274		
Before Associate Professor							
Leave academia	0.110	0.0131	0.124	0.0164	0.077	0.0207	0.1069
Leave Sweden	0.054	0.0095	0.045	0.0103	0.077	0.0207	0.1146
Leave	0.164	0.0155	0.168	0.0186	0.155	0.0280	0.6909
Before Full Professor							
Leave academia	0.122	0.0137	0.131	0.0168	0.101	0.0233	0.3196
Leave Sweden	0.084	0.0116	0.079	0.0135	0.095	0.0227	0.5297
Leave	0.201	0.0169	0.210	0.0203	0.196	0.0307	0.7075
Observations	572		404		168		

Notes: Mean shares of researchers leaving Swedish academia categorised by gender and time point of leaving. Note that the mean share of leaving immediately after PhD refers to the sample of 926 Swedish doctoral graduates, whereas leaving before promotion to associate professor and full professor refers to the sample of 572 academic economists.

5.4.3 Publications

In this study, the impact of each publication is measured through scores based on the Article Influence Score (AIS) and the journal ranking on IDEAS/RePEc.[11] These scores are denoted 'publication scores'. Journal-based scores are widely used in the economics profession to measure the impact of publications, for instance in order to evaluate publication merits in promotion and salary decisions (Stern, 2013; West et al., 2013).

The AIS is a journal-based metric, derived from Clarivate Analytics' (previously Thomson Reuters') *Journal Citations Report* (JCR), constructed to capture the average influence of the articles in a journal.[12] The score is normalised, which implies that the mean article in the JCR has a score of 1.0. Moreover, the AIS reflects citations which are weighted in a fashion such that citations in heavily cited journals are worth more than citations in less cited journals. The main benefits of the measure are that it captures a journal's importance to the scientific community and that it is estimated in a way that enables comparisons across distinct academic disciplines (Bergstrom et al., 2008; Chang and McAleer, 2014). Additionally, the AIS is used for measuring research output in promotion decisions by several of the departments of economics in Sweden through the *Tinbergen Institute Journal List*.[13] IDEAS/RePEc journal ranking is a ranking of economics journals only, chosen because it is one of the most popular and well-known journal rankings within the economics profession today (Stern, 2013; Zimmermann, 2013).[14] For reference, the economics journal ranked at place 1 in the IDEAS/RePEc list is the *Quarterly Journal of*

[11] `https://ideas.repec.org/top/top.journals.all.html` [Accessed on 10 December 2017].

[12] `https://clarivate.com/products/journal-citation-reports/` [Accessed on 10 December 2017] Subscription needed.

[13] `http://www.tinbergen.nl/wp-content/uploads/2016/12/TI_jrn_list_update-november-2016.pdf` [Accessed on 10 December 2017].

[14] There have been a number of other influential journal rankings list as well, including Liebowitz and Palmer (1984), Laband and Piette (1994) and Kalaitzidakis et al. (2003, 2010).

Economics with an AIS of 16.5. The journal ranked at place 100 in the IDEAS/RePEc list, the *Oxford Review of Economic Policy*, has a score of 1.0. In turn, this means that an article in the *Quarterly Journal of Economics* is valued 16.5 times higher than an article in the *Oxford Review of Economic Policy*.

There is a total of three measures, which we call AIS, AIS(econ) and RePEc. The difference between AIS and AIS(econ) is that the former includes all journals in the *Journal Citations Report*, while the latter only includes journals from the top 100 economics journals according to IDEAS/RePEc. The RePEc measure is constructed by allocating points of 1 to 100 to the top 100 papers in the IDEAS/RePEc journal rank, following the method of Sarsons (2017). The highest ranked paper is given 100 points, and the lowest is given 1 point. All journals not included in the top 100 are also given 1 point. The correlations between the respective productivity measures are presented in Table 10. We use AIS and AIS(econ) in the main analysis, whereas the other measures are used in the sensitivity analysis in Section 9.3.

Table 9: Productivity measures

AIS	The publication is given the value of the Article Influence Score of the journal in which it is published. Publications in journals with an Article Influence Score below 0.1 are given the score 0.1.
AIS/n	The AIS divided by the number of authors (n).
AIS(econ)	All publications in journals in the top 100 economics journals ranking list by IDEAS/RePEc are given the value of the Article Influence Score for the journal. All other publications are given the value of zero.
AIS(econ)/n	The AIS(econ) divided by the number of authors (n).
RePEc	All publications in journals in the top-100 economics journals ranking list by IDEAS/RePEc are given the values 1–100. The highest ranked journal gives score 100 and the lowest score 1. All publications in journals not included in the top 100 gives the score of 1.
RePEc/n	The RePEc divided by the number of authors (n).

Table 10: Correlation of productivity measures

	AIS	**AIS/n**	**AIS(econ)**	**AIS(econ)/n**	**RePEc**	**RePEc/n**
AIS	1.0000					
AIS/n	0.8285	1.0000				
AIS(econ)	0.7974	0.7951	1.0000			
AIS(econ)/n	0.6992	0.9196	0.8817	1.0000		
RePEc	0.5529	0.5794	0.7702	0.7014	1.0000	
RePEc/n	0.4456	0.6525	0.6330	0.7593	0.8722	1.0000

In Table 11, summary statistics on the average publication scores are displayed on a publication level, categorised based on the co-authorship type and gender. In Table 12, summary statistics on the average accumulated publication scores after 5 and 10 years in academia are displayed on a researcher level, categorised based on the co-authorship type and gender.

Table 11: Summary statistics on publication scores

	Full sample		**Male**		**Female**		**p-value**
Main variables	***Mean***	***Std error***	***Mean***	***Std error***	***Mean***	***Std error***	
Total							
AIS	1.363	0.0298	1.394	0.0334	1.225	0.0651	0.0296
AIS(econ)	0.843	0.0266	0.879	0.0302	0.681	0.0531	0.0043
RePEc	18.498	0.3874	19.098	0.4330	15.754	0.8560	0.0009
Observations	5,827		4,781		1,046		
Solo-authored							
AIS	0.988	0.0458	1.013	0.0533	0.881	0.0801	0.2601
AIS(econ)	0.646	0.0479	0.668	0.0555	0.553	0.0863	0.3499
RePEc	16.239	0.7827	16.670	0.8728	14.394	1.7658	0.2546
Observations	1,246		1,010		236		
Co-authored							
AIS	1.465	0.0356	1.495	0.0397	1.325	0.0804	0.0676
AIS(econ)	0.897	0.0311	0.935	0.0352	0.718	0.0638	0.0078
RePEc	19.112	0.4441	19.749	0.4963	16.151	0.9785	0.0020
Observations	4,581		3,771		810		
Co-authored: single							
AIS	1.455	0.0418	1.481	0.0435	1.034	0.1427	0.0123
AIS(econ)	1.026	0.0421	1.049	0.0437	0.644	0.1448	0.0243
RePEc	21.499	0.5882	21.849	0.6099	15.826	2.1397	0.0165
Observations	2,870		2,703		167		
Co-authored: mixed							
AIS	1.483	0.0647	1.533	0.0868	1.400	0.0941	0.3202
AIS(econ)	0.681	0.0439	0.648	0.0558	0.737	0.0711	0.3218
RePEc	15.110	0.6522	14.433	0.8074	16.235	1.1010	0.1809
Observations	1,711		1,068		643		
Co-authored: female							
AIS	1.449	0.0700	1.524	0.0871	1.230	0.1027	0.0665
AIS(econ)	0.635	0.0477	0.632	0.0554	0.644	0.0942	0.9130
RePEc	14.188	0.6965	14.228	0.8081	14.071	1.3751	0.9216
Observations	1,423		1,057		366		

Notes: This table presents the mean publication scores categorised by type of co-authorship and gender. Note that the table presents the full sample including publications by researchers with senior academic ranks.

Table 12: Summary statistics on accumulated publication scores

	Full sample		Male		Female		p-value
	Mean	*Std error*	*Mean*	*Std error*	*Mean*	*Std error*	
Publications after 5 years							
Publications	2.964	0.2687	3.266	0.3394	2.108	0.3564	0.0585
Solo-authored	0.924	0.1108	1.015	0.1409	0.666	0.1428	0.1672
Co-authored	2.039	0.2296	2.250	0.2891	1.441	0.3160	0.1222
Co-authored single sex	1.722	0.2305	2.191	0.3045	0.390	0.1025	0.0006
Co-authored mixed sex	0.512	0.0991	0.265	0.0807	1.214	0.2926	0.0000
Fraction of solo-authored	0.395	0.0190	0.402	0.0222	0.373	0.0365	0.5077
Number of researchers	353		261		92		
Publications after 10 years							
Publications	7.863	0.7939	8.707	0.9592	4.682	1.0020	0.0388
Solo-authored	1.806	0.3011	2.000	0.3714	1.073	0.3021	0.2109
Co-authored	6.058	0.6362	6.707	0.7655	3.609	0.8549	0.0473
Co-authored single sex	5.087	0.6299	6.212	0.7706	0.841	0.2799	0.0004
Co-authored mixed sex	1.234	0.2482	0.730	0.2103	3.136	0.8260	0.0001
Fraction of solo-authored	0.339	0.0180	0.329	0.0194	0.376	0.0461	0.3054
Number of researchers	210		166		44		

Notes: Publications are weighted according to the procedure AIS(econ) measure as outlined in Table 9 and Section 5.4.3. The variables are defined as outlined in Table 5.

5.4.4 Cohort

All researchers in the sample received their doctoral degree between 1990–2016. Given that this is a relatively long time span, there may be differences in promotion and publication practices over time. Therefore, we control for which cohort the researcher belongs to by using indicator variables for the cohorts 1990–1994, 1995–1999, 2000–2004, 2005–2009 and 2010–2016. As displayed in the summary statistics in Table 13 below, the distribution of researchers is skewed to the later cohorts, and more so for the female subsample.

5.4.5 Field

We have categorised each researcher by primary field of the research, using indicator variables for the following fields: theoretical economics, macroeconomics, financial economics, agricultural economics or applied economics. The primary field of research for the majority of both male and female researchers is applied economics, as shown below in Table 13.

5.4.6 Academic affiliation

The promotion decision is based on criteria defined at a university (or department) level within Swedish academia. In order to control for differences across universities we use an indicator variable if a researcher is employed at one of the following six universities: Lund University, Stockholm School of Economics, Stockholm University, Umeå University, University of Gothenburg and Uppsala University. We denote them the top 6-universities, based on two arguments: firstly, 89% of the doctoral graduates in economics in Sweden

between 1990 and 2016 received their degree from one of these universities. Secondly, these universities are the most prominent in terms of publishing research in economics (Lindqvist, 2003). Hence, we argue that the importance of publications in the promotion decision may differ between smaller and larger universities. Summary statistics on academic affiliation is shown in Table 13.

Table 13: Summary statistics on covariates

	Full sample		**Male**		**Female**		**p-value**
Main variables	***Mean***	***Std error***	***Mean***	***Std error***	***Mean***	***Std error***	
Cohort							
PhD 1990–1994	0.089	0.0119	0.116	0.0160	0.024	0.0118	0.0004
PhD 1995–2000	0.122	0.0137	0.139	0.0172	0.083	0.0214	0.0663
PhD 2000–2004	0.183	0.0162	0.205	0.0201	0.131	0.0261	0.0361
PhD 2005–2009	0.236	0.0177	0.228	0.0209	0.256	0.0338	0.4698
PhD 2010–2016	0.368	0.0202	0.312	0.0231	0.506	0.0387	0.0000
Year for PhD	2006	0.2979	2005	0.3642	2008	0.4591	0.0000
Field							
Applied	0.663	0.0198	0.631	0.0240	0.744	0.0338	0.0092
Theory	0.075	0.0110	0.087	0.0140	0.048	0.0165	0.1074
Macroeconomics	0.114	0.0133	0.124	0.0164	0.089	0.0221	0.2374
Financial economics	0.122	0.0137	0.144	0.0175	0.071	0.0199	0.0165
Agricultural economics	0.040	0.0082	0.035	0.0091	0.054	0.0174	0.2950
Academic affiliation							
First employment at a top 6	0.685	0.0194	0.691	0.0230	0.673	0.0363	0.6739
Number of researchers	572		404		168		

Notes: The variables are defined as outlined in Sections 5.4.4, 5.4.5 and 5.4.6.

5.4.7 Parental factors

The information collected on family factors includes the number of children and their year of birth, as well as parental leave divided into two categories: 0–6 months or 6< months (corresponding to full-time leave for each of the categories). The intervals were chosen because of the yearly structure of the data. Hence, we wanted to make a distinction between the individuals being away from work for a larger or lesser part of the year. Table 14 presents summary statistics on parental factors.

Table 14: Summary statistics on parental factors

	Full sample		Male		Female		p-value
	Mean	*Std error*	*Mean*	*Std error*	*Mean*	*Std error*	
Full sample							
Children (yes/no)	0.719	0.0238	0.707	0.0291	0.743	0.0413	0.4819
Number of children	1.454	0.0575	1.463	0.0719	1.434	0.0948	0.8103
Parental leave (yes/no)	0.331	0.0249	0.179	0.0245	0.664	0.0446	0.0000
Number of parental leaves	0.599	0.0491	0.293	0.0437	1.265	0.0982	0.0000
Number of researchers	359		246		113		
Subsample (researchers with children)							
Number of children	2.023	0.0439	2.069	0.0556	1.929	0.0694	0.1344
Parental leave (yes/no)	0.461	0.0311	0.253	0.0330	0.893	0.0339	0.0000
Number of parental leaves	0.833	0.0626	0.414	0.0594	1.702	0.0924	0.0000
Number of researchers	258		174		84		

5.5 Potential issues

We continue by outlining the potential issues with our data, beginning with a discussion of attrition. Next, we explain some of the trade-offs in the construction of our main variables of interest: promotion, productivity and parental factors.

5.5.1 Attrition

In this study, we have focused on academic economists who received their doctoral degree from 1990 to 2016. The choice of time-frame was based on the trade-off between sample size and accuracy; the extent to which we can measure the impact of variables in a relatively stable environment. The chosen time frame is also a matter of feasibility: the further back in time we go, the harder the researchers are to locate. We have been able to identify 83% of the population of Swedish doctoral graduates between 1990 and 2016 (further outlined in Table 30 in Appendix B). Moreover, we have aimed to include researchers that have been employed at the departments of economics within this period. We have gathered these researchers by collecting employment records from the universities.

There are at least two concerns regarding attrition which are worth discussing. To begin with, we expect a more severe attrition for earlier years. This may be problematic if there is a gender difference in propensity to leave academia which has attenuated over time. In this case, we may not pick up the true propensity to leave academia. Relating to this, even if we do have a sample reflecting the population, there may be two opposing effects which cancel out by studying the average propensity. Secondly, we have not received complete employment records from all universities in the sample. Consequently, we cannot estimate the attrition of researchers with a doctoral degree from a university outside of Sweden. We argue however, that the representation of researchers should be sufficiently good to make inference representative for the population of academic economists in Sweden between 1990 and 2016.

5.5.2 Promotion

We categorise the Swedish academic career ladder into three levels, with two promotion steps. In regard to the first promotion step, we consider a researcher promoted if he or she is appointed either to associate professor or to *docent*. Whereas the first title is used at the universities that apply the Swedish tenure track, the latter appointment is a proxy. This notwithstanding, we argue that this definition is reasonable given that the titles are often used interchangeably in practice when translating them to English.

A potential issue with this definition is that we assume that all researchers will apply for promotion. This is reasonable to assume for the professional title associate professor, but it is not completely evident for the academic qualification *docent*. Consequently, in light of the fact that a researcher has to apply for *docentkompetens*, we may have an issue of *self-selection* into promotion. As discussed in the literature review (Section 3.1), there is evidence suggesting that there is a gender difference in the propensity to apply for promotion in other countries, which would imply that the likelihood of promotion could differ for two equally qualified researchers of different genders. Despite this drawback, we argue that the promotion proxy of *docent* is sufficiently good in order to capture promotion within Swedish academia.

5.5.3 Productivity

Journal-based publication scores, accumulated on a yearly basis, are used for measuring productivity in this study. Several aspects of this choice of proxy ought to be discussed.

First of all, the impact of publications may be measured through alternative methods besides journal-based metrics. Instead of proxying the quality of a paper by the quality of the journal it is published in, an alternative approach is to focus on citation-based metrics: either for each publication or the overall number of citations for a specific researcher. The main advantage of using citation-based metrics is that an overlap has been shown between the citational impact of less cited articles in top-tier journals and the most cited articles in second-tier journals (Stern, 2013). If the objective is to measure the impact of an article—rather than the average impact of an article in the journal it is published in—the use of article or author specific citation-based metrics would be a better procedure than journal quality. This procedure has also been growing in popularity among economists since the invention of the h-index and the development of extensive data bases such as Google Scholar, Scopus and World of Science (WoS) (Hirsch, 2005; Ellison, 2013). There are, however, some drawbacks with citation-based metrics as well. The timing is a major problem for our application of citational counts since our sample stretches from 1990 to 2016. Data gathering in the form of citational counts for every article and researcher in every year would be immense. More importantly, many Swedish universities have formal requirements for promotion primarily focusing on journal-based metrics, rather than the specific number of citations that the article or author receives. This provides a clear incentive scheme for all researchers to publish in the top journals. Consequently, we argue that this journal-based measure of impact is more appropriate in capturing a researcher's publication merits.

Secondly, the descriptive statistics present a picture that women—as a group and on average—have lower publication scores than comparable men. These statistics imply the existence of a 'productivity puzzle' phenomenon described in previous studies, yet this expression should be used with caution. For instance, there may be a gender bias

in the publication measures: by comparing our three measures of journal quality we find that women on average have higher publication scores through the inclusion of non-economics journals compared to by only including economics journals—see Table 11. This may indicate that women in general publish in more interdisciplinary fields. In the promotion criteria that we have received from some of the departments of economics, publications in non-economics journals receive less or no credit in the promotion decision. This is an indication that promotion criteria that are gender neutral on paper may still have implications on gender differences in labour market outcomes. For our application, we argue that the use of three different measures of publication scores—alongside measures adjusted for number of co-authors—is a sufficiently good way of capturing the impact of the publications.

Finally, besides the discussion on how to measure publication scores, publications as a proxy for productivity may in itself be problematic. Publications are one type of scientific output and we do not account for other types of output, such as book chapters or reports, in this study. Moreover, we do not account for the amount of, or proficiency in, teaching and administrative tasks. Most academic positions include both research and teaching obligations and studies have shown that female researchers spend more time on teaching than their male peers—see Section 3.1. Given that a researcher has a limited amount of time, time spent on other obligations results in less time available for producing scientific output. As follows, if there is a gender difference in the time allocation, this may explain the 'productivity puzzle' if the concept of productivity only captures one part of these obligations. This notwithstanding, we argue that publications are a sufficiently good proxy for productivity in this study, considering that research is the far most important factor in the criteria for promotion.

5.5.4 Survey data on parental factors

In order to gather data on parenthood we used a survey approach, where we contacted the researchers in our sample. In order to increase the response rate, we use a relatively coarse measure of parental leave: if the researcher have been on parental leave corresponding to more than 6 months or not in the given year. The main drawback from using this dichotomisation of parental leave is that we do not capture nuances of different spells of parental leave. Given that we are interested in if parental leave has an effect or not on promotion, we argue that the measure is sufficiently detailed in order to test our hypothesis.

6 Duration analysis

This section provides a description of duration analysis, followed by a motivation for using this method. We define the difference between continuous-time and discrete-time duration models and continue by providing the key concepts in duration analysis. The section ends with the model framework for the main analysis.

6.1 Description of duration analysis

Duration analysis can generally be seen as a class of statistical methods for studying the occurrence and the timing of specific events, where individuals are followed over time.[15] The method allows for including the effects of both time-constant explanatory variables (such as gender) and time-varying explanatory variables (such as publication scores, parental leave and academic affiliation). Duration analysis can also handle *censoring*, which otherwise is difficult to incorporate in standard statistical procedure without loss of information or biased estimates (Allison, 2014). Censoring can be divided into *left-censoring* and *right-censoring*. The former occurs if an individual cannot be observed at the origin time, which in our case would imply that we lack information of a researcher at the time they received their doctoral degree. The latter occurs if the event has not taken place; in our case if a researcher has not been promoted.

There is no issue of left-censorship in our model, given that the observation of all researchers starts at the year of receiving the doctoral degree, which arguably is the natural starting point for a researcher's career. A researcher that previously has been employed at a foreign university and takes an employment at a Swedish university should be compared with a researcher that has been employed for the same number of years after receiving their doctoral degree, given that they have had the same opportunity to accumulate publication scores. This researcher therefore enters the data set in some year after $t = 1$. If a researcher is associate professor at the year of employment at a Swedish university, the researcher is included in the model for promotion to full professor, but not for promotion to associate professor given that the appointment to associate professor did not occur at a Swedish university.

In contrast to left-censorship, the case of right-censorship is more of an issue in this study. Right-censorship may occur for three reasons: (i) the researcher leaves for a university outside Sweden, (ii) the researcher leaves for an employment outside academia or (iii) the last year of observation is in year 2016. The two first kinds of right-censoring are called *random* and the third is called *fixed*. The important distinction between the random and fixed right-censoring is that the latter can be controlled for in the study, while the former cannot. The notation of random right-censoring stems from the fact that researchers may leave the data set at different time periods for reasons which are unknown. If a researcher leaves Swedish academia because he or she has not been promoted, and does not expect to be promoted in the future, this random censoring is *informative*. Informative random censoring is problematic since the model assumes that all censoring is *non-informative*, meaning that there should be no systematic differences in researchers remaining or dropping out of the data set over the studied years. The likelihood of leaving Swedish academia may be correlated with the estimated likelihood of being promoted, which would imply that random censoring is informative. There is no way of testing whether the assumption of non-informative censoring is violated and the assumption of non-informative censoring cannot be relaxed (Allison, 2014). The issue of random censoring is further analysed in Section 9.1.

The *fixed* censoring is on the other hand essentially non-informative, given that it is the result of the construction of the data set. We cannot observe any outcomes after the year 2016 and there is no systematic bias in this censoring since it is an arbitrary cut-off

[15] Duration analysis is also known as survival analysis (medicine), event history analysis (sociology) and reliability analysis (engineering). While the econometric approach is the same, we use the term duration analysis given that it is the expression used most frequently in the economics literature.

in time that is uncorrelated with the characteristics of the researchers. We know that later cohorts of researchers are more likely to be fixed right-censored than earlier cohorts, and we can control for this difference by including their year for PhD. Censoring is only an issue if there is information in the residuals, and not if there is information that we can control for in the covariates. An important note here is that an alternative statistical procedure, including the procedures discussed in Section 6.2, would not solve the issue of random right-censoring either. The issue of random-right censoring is consequently not an argument against duration analysis, but rather something that needs to be taken into consideration.

6.2 Motivation of duration analysis

The use of a standard procedure in estimating the likelihood of promotion would demand a cut-off in time for promotion: a specific number of years after receiving the doctoral degree. There are cases where this may be an appropriate estimation, for instance if Sweden had a tenure track system with a precise tenure window. The majority of the universities in Sweden do not use the tenure-track system. Moreover, as shown in Table 35 and 36 in Appendix C, the appointments to associate and full professor occur after a varying number of years. Consequently, a cut-off would be arbitrary and problematic for a number of reasons. The first issue with a cut-off regards the treatment of researchers that either leaves academia before the cut-off period, or that has not been employed for that number of years at the end of the observation period (31 December 2016). These researchers would be censored, given that it is impossible to know whether these researchers would have been promoted or not after the cut-off. Consequently, all the censored observations would have to be discarded, leading to an unnecessary loss of information (Allison, 2014). Another issue stemming from an arbitrary cut-off in time regards the treatment of individuals that have been promoted before or after the cut-off. This model would not account for the information in the duration to promotion: all promotions occurring before the cut-off would be treated as occurring *at* the cut-off, while all promotions occurring after the cut-off would be treated as if they had not occurred at all. This dichotomisation of the dependent variable would also lead to an unnecessary loss of information (Allison, 2014).

An alternative approach to estimating the likelihood of promotion would be to focus on the mean duration to promotion. In this procedure, all researchers that have not been promoted would be censored. As follows, they would have to be excluded. This procedure would lead to a loss of information and, more importantly, there is a risk of serious bias as well given that only promoted researchers are included. Through the use of duration analysis, it is not necessary to specify a specific cut-off in time or to exclude researchers that have not been promoted (Allison, 2014), which makes it a more suitable model for our purpose.

6.3 Discrete-time versus continuous-time

There are two ways of treating the data in a duration analysis: discretely or continuously. We have intrinsically continuous data recorded in discrete intervals, which makes both a continuous-time and a discrete-time model possible to use. Promotions occur continuously in real life, but are grouped into discrete intervals of one year; a more correct term for our data is therefore grouped data. This is also the case for most duration analyses because even though the concept of time is intrinsically continuous, some form of discretisation

of time is necessary in the estimation of an event. As the increments of the discrete-time periods become smaller, the discrete-time model converges to a continuous-time model and the results of the two types of models are often very similar (Allison, 2014).

In this study, all time-varying variables are reported on an annual basis. The implication of this yearly discretisation is that a full year is *interval censored*. In turn, interval censoring means that the timing of distinct events occurring in the same year cannot be separated, for instance establishing whether a paper was published preceding a promotion in a given year, or vice versa. The interval censoring is inevitable given the annual construction of the data: the time-varying variables in the analysis—promotion, publications, parenthood, parental leave and employment—are in general reported on yearly basis in the CVs of the researchers. This one-year discretisation needs to be considered in light of how important a precise timing of the events is. In this study, we argue that the issue of interval censoring to some extent is mitigated by the fact that all the relevant variables inhibit rather long duration spells.

The one-year interval censoring also leads to that the timing of the promotions for two or more researchers cannot be distinguished—a case that is denoted *tied events*. In a continuous-time model, events can theoretically not occur in the same time period, and the model will be a bad approximation if there are many tied events (Allison, 2014). Chalita et al. (2002) ran Monte Carlo simulations on data with a varying number of tied events and recommended—as a rule of thumb—to use a discrete-time model with a complementary log-log estimation, rather than the Cox proportional hazards model, if the proportion of tied events is above 0.25. In our case, we have a proportion of tied events equal to 0.35 for the appointments to associate professor.[16] In line with the arguments provided by Allison (2014), and the recommendation of Chalita et al. (2002), we therefore use a discrete-time model in our primary analysis. The continuous-time model in the form of the Cox proportional hazards models is used as a robustness check in Section 9.2.

6.4 Important concepts in duration analysis

6.4.1 The risk set

Applied to this study, all the researchers that are at risk for promotion in each time period after receiving the doctoral degree constitutes the *risk set*. The risk set is consequently the group of researchers that can be promoted in each given time period. In the first year of employment after doctoral degree (in year $t = 1$), all researchers in our data set are at risk for promotion. The risk set then gradually decrease over the years as an increasing number of researchers are either censored or promoted.

[16] Proportion of tied events (pt) is defined as: $pt = (nf - r)/n$ where nf is total number of 'failures' (promotions), r is number of distinct 'failures' (periods where a promotion occur) and n is number of individuals. In our case we have 215 appointments to associate professor, 15 number of distinct failures and 572 individuals, which gives us a proportion of tied events equal to: $pt = (215 - 15)/572 \approx 0.35 > 0.25$.

6.4.2 The hazard rate

The hazard rate is crucial in understanding duration analysis. In a discrete-time model, the hazard rate $\lambda_i(t)$ is the conditional probability of researcher i being promoted in year t, conditional on not being promoted in a year prior t and still being in the risk set:

$$\lambda_i(t) = P(T = t | T \geq t)$$

where T is the year that promotion occur (Mills, 2011). The hazard rate controls both the occurrence of an event and the duration to the event, and is the dependent variable in the duration model. Moreover, the hazard rate depends on the number of promotions occurring in specific year but also the number of researcher included in the risk set in that year. If a constant fraction of identical researchers were promoted in each year, the hazard rate would be constant over time. Note that the empirical hazard rate in this study is increasing over time, which is likely an effect of two factors in combination: first, it takes some years to accumulate enough publications to be promoted; few researchers are promoted within the first years as assistant professor. Secondly, researchers that are not promoted in later periods are inclined to leave their employment, which reduces the risk set and consequently increases the hazard rate.

6.4.3 The specification of time

The time variable is constructed as the number of years after receiving the doctoral degree (years since PhD). There are different alternatives for the inclusion of time in a discrete-time model. One alternative is to include time as indicator variables for each year. Other alternatives are to include time as a covariate ('Gombertz' model), or as a covariate in a logarithmic scale ('Weibull' model). If we include time through indicator variables, a time trend can be observed: the likelihood of promotion increases for each time period, but the relative increase deteriorates over time. We therefore argue that we should allow for a time dependence that is non-linear in our time specification. For all models we include time and a quadratic effect of time as covariates to account for this curve-linearity (Allison, 2010, 2014).

6.5 Estimation of the discrete-time duration model

We estimate our discrete-time duration model using maximum likelihood estimation. A non-linear model in the form of the complementary log-log specification is used in order to transform the hazard rate to a continuous scale. The complementary log-log model can be seen as the discrete-time representation of the Cox proportional hazards model. The complementary log-log model specification is relatively common in discrete-time duration analysis, as it includes a proportional hazards assumption instead of the proportional odds assumption included in the logit model. This makes the complementary log-log function more analytically similar to the Cox proportional hazards model. The underlying feature of a proportional hazards model is that absolute differences in the independent variables implies proportionate differences in the hazard rates. This means that the hazard ratio—which is the quotient of the two hazard functions—should remain constant over time. Consequently, we assume that the effect of gender on promotion should have the same effect over time (measured in terms of years since PhD). The hazard

rate for the complementary log-log function is defined as:

$$\lambda_i(t) = 1 - \exp\Big\{ - \exp\big[\theta(t) + \beta' \boldsymbol{X}_{it}\big]\Big\} \Longleftrightarrow \log\big[-\log[1-\lambda_i(t)]\big] = \theta(t) + \beta' \boldsymbol{X}_{it}$$

where $\lambda_i(t)$ is the hazard rate (Jenkins, 1995). As can be derived from the equation, the complementary log-log model is asymmetric:

$$\log\big[-\log[1-\lambda_i(t)]\big] \neq -\log\big[-\log[\lambda_i(t)]\big]$$

in contrast to the symmetric logit model. The results from the complementary log-log model are however often very similar to the ones of the logit model, as the latter converges to a proportional hazards model when the hazard rates become increasingly small:

$$\text{logit}\,[\lambda_i(t)] \approx \log\big[-\log[1-\lambda_i(t)]\big]$$

For larger hazard rates, the complementary log-log model approaches infinity slower than the logit. As the hazard rates are sufficiently small in most duration analysis applications, the use of the proportional complementary log-log or the non-proportional logit has few practical implications. We have used the complementary log-log model in our primary analysis because it is the standard procedure for intrinsically continuous data that is grouped into intervals (Jenkins, 1995; Allison, 2014). Additionally, the model estimates the same underlying parameters as the Cox proportional hazards model, allowing for continuity and better comparison in regard to coefficients. More specifically, the exponentiation of the coefficients gives us the hazard rates (Allison, 2010). In order to evaluate the effects of our covariates we therefore transform the coefficients β_{it} so that their interpretation is the percent change in the hazard of promotion for a one unit increase in x_{it} holding all other variables fixed:

$$100\big[\exp(\beta_{it}) - 1\big]$$

Both the coefficients and the hazard rates are directly comparable to those from a Cox proportional hazards model.

7 Empirical strategy

The empirical strategy of the study is outlined through presenting the model specifications relating to each research question. We begin by outlining the models of promotion, with the purpose of establishing the existence of a promotion gap. The promotion models are divided into two categories: controlling for publications and controlling for other factors. By including publications in a separate model, we can establish the existence of a promotion gap, and in turn, if the promotion gap is caused by publication differentials. Moreover, we investigate the effects of co-authorship and parenthood on promotion. Next subsection outlines the model specifications of the propensity to leave Swedish academia, which are identical to the promotion model specifications, with the exception of the dependent variable. Finally, co-authorship is closer studied by examining the propensity to solo-author, co-author with female researchers and co-author with senior researchers. This is an initial step in exploring gender patterns in co-authorship within the Swedish field of economics.

7.1 Promotion models

The purpose of the promotion models is to study the existence of a gender promotion gap and three possible determinants which may explain the under-representation of female researchers within the field of economics: publications, gender differences in credit allocation of co-authored papers and parental factors. We begin by estimating the gender promotion gap to associate and full professor, both with and without controlling for the role of publications. Next, the effects of credit allocation in co-authorship and parenthood are added respectively into the analysis on promotion to associate professor. The models are aligned with the model of discrimination as outlined by Cain (1986), where we assume that the characteristics of a researcher are exogenous to the model. The interpretation of the assumption is that workers are 'naive' and do not anticipate discrimination. Hence, they do not alter their decisions, for instance whether to solo-author or co-author, by the threat of discrimination. We use the discrete-time duration method as outlined by Allison (1982), and cluster the standard errors ϵ_{it} by individual i.

7.1.1 Model specification

The first model estimates the likelihood of promotion to associate professor and full professor, holding researcher characteristics fixed. The model is specified as:

$$promotion_{it} = \beta_1 fem_i + Z'\delta + \epsilon_{it} \tag{1}$$

where $promotion_{it}$ is equal to 1 if promotion occurs for researcher i in year t, fem_i is 1 if researcher i is female and Z' is a vector including researcher characteristics such as gender, field, cohort and academic affiliation for researcher i in year t. We study promotion to associate professor and full professor respectively. In the latter case, the likelihood of promotion to full professor is conditional on the researcher being an associate professor. The coefficient of interest is β_1. If we can reject that $\beta_1 = 0$, one of the genders is more likely to be promoted than the other, which implies that there is a gender promotion gap.

7.1.2 Model specification including publications

In order to account for publication differentials we proceed by including the accumulated publication score of each researcher to our promotion model, yielding the following model specification:

$$promotion_{it} = \beta_1 fem_i + \beta_2 publ_{it} + Z'\delta + \epsilon_{it} \tag{2}$$

where $publ_{it}$ is the accumulated publication score for researcher i in year t. Again, the coefficient of interest is β_1. A rejection of $\beta_1 = 0$ implies that one gender is more likely to be promoted than the other, conditional on their publication score. Following the definition of discrimination by Cain (1986), a gender coefficient significantly different from zero would indicate that there is discrimination in the labour market, conditional on that all relevant variables are captured by the model.

7.1.3 Model specification including co-authorship patterns

In this section, the likelihood of promotion given certain co-authorship patterns is estimated. In contrast to model (2), the publication scores are now accumulated separately

along three dimensions: (i) solo-authored or co-authored, (ii) if co-authored: single gender or mixed gender, (iii) if co-authored single gender: male or female. The model specifications include interaction effects between the publication scores and gender, in order to capture potential gender differences. We are interested in the interaction of co-authored papers and the variable for female. If there are gender differences in the allocation of credits, the interaction on female will be significantly different from zero. The third model is specified as:

$$\begin{aligned} promotion_{it} = \beta_1 fem_i + \beta_2 solo_{it} + \beta_3 ca_{it} + \beta_4 (fem_i \times solo_{it}) \\ + \beta_5 (fem_i \times ca_{it}) + Z'\delta + \epsilon_{it} \end{aligned} \tag{3}$$

where $solo_{it}$ is accumulated publication score for solo-authored papers for researcher i in year t, ca_{it} is accumulated publication score for co-authored papers for researcher i in year t and Z' is a vector including author characteristics such as gender, field, cohort and academic affiliation for researcher i in year t. The variable of interest is the coefficient for the interaction term of gender and co-authored publications β_5. A gender difference in this interaction term implies that the marginal effect of an additional paper on promotion differs depending on the gender of the main author. If we can reject that $\beta_5 = 0$, one gender suffers a penalty from co-authoring. Finally, we separate co-authored papers into single-gendered and mixed-gendered research teams:

$$\begin{aligned} promotion_{it} = \beta_1 fem_i + \beta_2 solo_{it} + \beta_3 ca_{it}^{single} + \beta_4 ca_{it}^{mix} \\ + \beta_5 (fem_i \times solo_{it}) + \beta_6 (fem_i \times ca_{it}^{single}) \\ + \beta_7 (fem_i \times ca_{it}^{mix}) + Z'\delta + \epsilon_{it} \end{aligned} \tag{4}$$

where the coefficients of interest are β_6 and β_7. If we can reject that one of these coefficients is equal to zero, but not the other, we have found evidence suggesting that the gender of the main author together with the gender of the co-authors have implications for the allocation of author credits to the main author.

7.1.4 Model specification including parental factors

Parenthood is a choice and the causal direction of any effects cannot be established in these models; any captured effect reflects a correlation between parenthood and the likelihood of promotion. The fifth model is specified as:

$$promotion_{it} = \beta_1 fem_i + \beta_2 child_{it} + \beta_3 parl_{it} + Z'\delta + \epsilon_{it} \tag{5}$$

where $child_{it}$ is taken the following two forms respectively: (i) the accumulated number of years t that researcher i has had a child below the age of 10 and (ii) the number of children below the age of 10. $Parl_{it}$ is the accumulated number of times that researcher i has been on parental leave for more than 6 months in year t and Z' is a vector including author characteristics such as gender, field, cohort and academic affiliation for researcher i in year t. We estimate the model both with and without controlling for children and parental leave, in order to establish whether any correlation between parenthood and the likelihood of promotion stems from having children or parental leave. The coefficients of interest are β_2 and β_3. A rejection of $\beta_2 = 0$ or $\beta_3 = 0$ implies that there is a correlation

between the likelihood of promotion and having young children or parental leave take-up respectively. A rejection of both coefficients implies that both parental factors are correlated with the likelihood of promotion.

In model (6), a gender interaction term is included for the purpose of detecting any gender differences in the effect of parenthood on promotion. Hence, the sixth model specification considers gender differences in the effects of parenthood through the inclusion of a gender interaction term on the variables for children:

$$promotion_{it} = \beta_1 fem_i + \beta_2 child_{it} + \beta_3 (fem_i \times child_i) + Z'\delta + \epsilon_{it} \tag{6}$$

where the coefficient of interest is β_3. If we can reject that $\beta_3 = 0$ we have found that there is a gender difference in the correlation between having children and the likelihood of promotion.

7.1.5 Publications and parental factors on promotion

Finally, we estimate the correlation between parenthood and promotion conditional on publication scores, in order to investigate if parenthood per se is correlated with promotion or if the effect works through publications. The model is specified as:

$$promotion_{it} = \beta_1 fem_i + \beta_2 child_{it} + \beta_3 parl_{it} + \beta_4 publ_{it} + Z'\delta + \epsilon_i \tag{7}$$

where the coefficient of interest is β_2 and β_3. If we can reject that $\beta_2 = 0$ or $\beta_3 = 0$ we have found that there is a gender difference in the correlation between parenthood and the likelihood of promotion, conditional on publication scores. If we can reject that $\beta_2 = 0$ or $\beta_3 = 0$ in model (5) but not in model (7) however, that is an indication that parenthood is correlated with promotion through publications.

7.2 Models of the propensity to leave Swedish academia

The gender promotion gap may also be studied in terms of gender differences in the propensity to leave academia. Hence, the model specifications (1) and (2) outlined in Sections 7.1 will be re-estimated using the event of *leaving* as the dependent variable. Three cases will be investigated: first, we look at propensity to leave for a non-academic institution such as an authority or the corporate sector. Secondly, we look at propensity to leave for a university outside Sweden. Finally, we study the overall propensity to leave Swedish academia.

7.2.1 Model specification

We begin by investigating the existence of any gender differences in the propensity to leave with the following model:

$$leave_{it} = \beta_1 fem_i + Z'\delta + \epsilon_{it} \tag{8}$$

where $leave_{it}$ is an indicator variable taking value 1 if researcher i leaves in year t. For all models, we study the propensity to leave before an appointment to associate professor and full professor respectively. Apart from the dependent variable, the model specification is identical to model (1) in Section 7.1.1. The coefficient of interest is still β_1. A rejection of $\beta_1 = 0$ implies that one gender is more likely to leave Swedish academia than the other.

7.2.2 Model specification including publications

In the ninth model, we also include publication scores to model (8) in order to investigate if there are any gender differences in the propensity to leave Swedish academia conditional on publication scores:

$$leave_{it} = \beta_1 fem_i + \beta_2 publ_{it} + Z'\delta + \epsilon_{it} \tag{9}$$

Apart from the dependent variable, the model specification is identical to model (2) in Section 7.1.2. The rejection of $\beta_1 = 0$ would imply that one gender has higher propensity to leave, regardless of their publication scores.

7.3 Models of co-authorship patterns

The purpose of this section is to investigate the existence of gender patterns in co-authorship by studying the propensity for men and women to solo-author, co-author with female researchers and co-author with senior researchers respectively. An article may appear more than once if more than one of the authors to a paper is included in our data set. Consequently, the observations are not independent. In order to solve for this bias, the standard errors are clustered by publications. Gender differences in co-authorship patterns are studied through logit estimation.[17]

7.3.1 Model of propensity to solo-author

The model specifies the propensity to solo-author:

$$solo_{it} = \alpha_1 fem_i + X'\gamma + \varepsilon_{it} \tag{10}$$

where $solo_{it}$ is an indicator variable taking value 1 if an article is solo-authored, fem_i is an indicator variable taking value 1 if researcher i is female and X' is a vector including cohort, field, academic affiliation and academic rank for researcher i as well as publication year and quality of journal for the article. The coefficient of interest is α_1. A rejection of $\alpha_1 = 0$ would imply that there is a gender difference in the propensity to solo-author.

7.3.2 Model of propensity to co-author with female researchers

The model specifies the propensity to co-author with female researchers:

$$fca_{it} = \alpha_2 fem_i + X'\gamma + \varepsilon_{it} \tag{11}$$

where fca_{it} is an indicator variable taking value 1 if an article is co-authored with a female researcher, fem_i is an indicator variable taking value 1 if researcher i is female and X' is a vector including cohort, field, academic affiliation and academic rank for researcher i as well as publication year and quality of journal for the article. The coefficient of interest is α_2. A rejection of $\alpha_2 = 0$ would imply that there is a gender difference in the propensity to co-author with female researchers.

[17] We estimated the models using a probit model as well and the results were qualitatively the same for all estimations.

7.3.3 Model of propensity to co-author with senior researchers

The model specifies the propensity to co-author with senior researchers:

$$senior_{it} = \alpha_3 fem_i + X'\gamma + \varepsilon_{it} \tag{12}$$

where $senior_{it}$ is an indicator variable taking value 1 if one of the co-authors to an article has a higher academic rank than researcher i, fem_i is an indicator variable taking value 1 if researcher i is female and X' is a vector including cohort, field, academic affiliation and academic rank for researcher i as well as publication year and quality of journal for the article. The coefficient of interest is α_3. A rejection of $\alpha_3 = 0$ would imply that there is a gender difference in the propensity to co-author with senior researchers.

8 Results

8.1 Promotion models

In this section we outline the results from our promotion models in Section 7. The existence of a gender promotion gap is established, followed by the estimated effects of co-authorship and parental factors on promotion.

8.1.1 Gender promotion gap and publications

We hypothesise that there is a gender difference in the likelihood of promotion to associate and full professor respectively, and that a part of this gap can be explained by gender differences in publications. The coefficient of interest is *female*.

Table 15: Gender promotion gap

	(1) Associate professor	(2) Associate professor	(3) Full professor	(4) Full professor
Female	-0.384**	-0.252	-0.701**	-0.473
	(0.181)	(0.179)	(0.356)	(0.354)
Publications		0.0535***		0.0362***
		(0.0101)		(0.00739)
Cohort	Yes	Yes	Yes	Yes
Field	Yes	Yes	Yes	Yes
Years since PhD	Yes	Yes	Yes	Yes
Academic affiliation	Yes	Yes	Yes	Yes
Observations	3,266	3,266	2,489	2,489

*Notes: This table presents the estimations of models (1) and (2) in Section 7.1 using discrete-time duration analysis with a proportional hazards assumption—using complementary log-log estimation. The first regression includes the promotion step from assistant to associate professor, while the second includes the promotion step from associate to full professor. For definitions of covariates—see Table 4. Publications are weighted according to the AIS(econ) measure—see Table 9. The number of observations is the number of researcher-years. Standard errors are clustered by researcher and reported in parentheses. Significance levels are reported as *** p<0.01, ** p<0.05 and * p<0.1.*

In Table 15, models (1) and (3) estimate the gender promotion gap, measured as 'there is a higher likelihood of promotion for a man than for a woman'. The coefficients for *female* are negative and significant at a 5% level, implying that there is a gender promotion gap at the promotion levels to both associate and full professor. These results are aligned with the literature (see Section 3.1) and the pattern presented in the descriptive and summary statistics (see Figure 2 and Table 7). Interpreting the coefficients in terms of hazard rates, the estimates in model (1) suggests that being female is correlated with having a $100(1-\exp(-0.384)) \approx 32\%$ lower likelihood of appointment to associate professor, conditional on being assistant professor. Equivalently in model (3), being female is correlated with a $100(1-\exp(-0.701)) \approx 50\%$ lower likelihood of appointment to full professor, conditional on being associate professor. By including a 95% confidence interval to these estimates, the implied gender difference in the likelihood of promotion to associate professor is at least $100(1-\exp(-0.030)) \approx 3\%$ and at most $100(1-\exp(-0.738)) \approx 52\%$. The gender difference in the likelihood of promotion to full professor lies between $100(1-\exp(-0.020)) \approx 2\%$ and $100(1-\exp(-1.399)) \approx 75\%$ for the 95% confidence interval.

By controlling for publications in models (2) and (4) in Table 15, the coefficients for *female* are insignificant. The estimations indicate that we can no longer reject the null hypothesis of gender equality in the likelihood of promotion. As follows, the gender promotion gap found in models (1) and (3) becomes non-significant by controlling for publications, in turn implying that gender differentials in publications account for some of the promotion gap at both promotion levels. Even though the estimated coefficients are mitigated in models (2) and (4) the confidence intervals remain large, and we cannot make any inference on to what extent the publication differentials account for the gap.

8.1.2 Co-authorship on promotion

By turning to the effects of co-authorship on promotion to associate professor, we hypothesise that the results are in line with the results found in Sarsons (2017): there is a gender difference in the allocation of credit for co-authored publications. We are interested in the interaction terms of female and co-authorship: *female* × *co-authored*, *female* × *co-authored single gender* and *female* × *co-authored mixed gender*.

Table 16: Co-authorship on promotion to associate professor

	(1) Associate professor	(2) Associate professor	(3) Associate professor	(4) Associate professor
Female	-0.254	-0.340*	-0.489**	-0.460**
	(0.180)	(0.187)	(0.227)	(0.222)
Solo-authored	0.0412*	0.0397*	0.0386	0.0361
	(0.0247)	(0.0240)	(0.0244)	(0.0236)
Co-authored	0.0601***		0.0575***	
	(0.00938)		(0.00950)	
Co-authored single		0.0525***		0.0536***
		(0.00874)		(0.00874)
Co-authored mixed		0.0886***		0.0792*
		(0.0285)		(0.0439)
Female × Solo-authored			0.192*	0.181*
			(0.101)	(0.107)
Female × Co-authored			0.0238	
			(0.0366)	
Female × Co-authored single				-0.0436
				(0.0960)
Female × Co-authored mixed				0.00801
				(0.0586)
Cohort	Yes	Yes	Yes	Yes
Field	Yes	Yes	Yes	Yes
Years since PhD	Yes	Yes	Yes	Yes
Academic affiliation	Yes	Yes	Yes	Yes
Observations	3,266	3,266	3,266	3,266

*Notes: This table presents the estimations of models (3) and (4) in Section 7.1 using discrete-time duration analysis with a proportional hazards assumption—using complementary log-log estimation. For definitions of covariates—see Table 4. Publications are weighted according to the AIS(econ) measure—see Table 9. The number of observations is the number of researcher-years. Standard errors are clustered by researcher and reported in parentheses. Significance levels are reported as *** p<0.01, ** p<0.05 and * p<0.1.*

In Table 16, the coefficient for female is not significant at a 5% level, neither by separating publications into solo-authored and co-authored in model (1) nor by separating co-authored papers into co-authored single gender and co-authored mixed gender in model (2). This reinforces the result that publication differentials can explain a part of the gender promotion gap, as found in Table 15. By turning to the coefficients of interest, the interaction between *female* and *co-authored*, in model (3) we cannot reject the hypothesis that there is no gender difference in the allocation of credit for co-authored papers. The interpretation is that there is no evidence suggesting that the gender of the main author has an impact on the credit allocated for a co-authored paper. Turning to model (4), we cannot reject the hypothesis that there is no gender difference in the allocation of credit either. The interpretation is that there is no evidence suggesting that the gender of the main author *in combination* with the gender of the co-authors, has an impact on the allocation of credit to the main author. These findings imply that we cannot reject

the hypothesis that men and women are equally credited for co-authored work in the appointment to associate professor.

8.1.3 Parental factors on promotion

We proceed by turning to the effects of parenthood on promotion to associate professor, hypothesising that there is a gender difference in the effect of having children, measured as the accumulated number of years with young children and the accumulated number of children. We estimate the effects of parenthood on promotion, both with and without accounting for parental leave and for any gender differences in the effects of parenthood. The coefficients of interest are *child years*, *child number* and *parental leave*. Moreover, we investigate whether a part of the effect of having children can be explained by the career interruption in the form of parental leave. Hence, the coefficients of interest are also *child years* and *child number* when controlling for *parental leave*. Proceeding, we hypothesise that there are gender differences in the effect of parenthood on promotion, turning to the interaction of *female* and *child years* as well as *child number*. Finally, we hypothesise that the effect of parenthood works through publications. As follows, we investigate if a potential correlation between parenthood and promotion is contingent on the role of publications or not.

Table 17: Parenthood on promotion to associate professor

	(1) Associate professor	(2) Associate professor	(3) Associate professor	(4) Associate professor	(5) Associate professor
Female	-0.257	-0.236	-0.324	-0.352	-0.350
	(0.236)	(0.235)	(0.266)	(0.284)	(0.277)
Child years	-0.0652**			-0.0713**	
	(0.0302)			(0.0306)	
Child number		-0.176*			-0.215**
		(0.100)			(0.107)
Parental leave			0.0324	0.130	0.170
			(0.145)	(0.152)	(0.159)
Cohort	Yes	Yes	Yes	Yes	Yes
Field	Yes	Yes	Yes	Yes	Yes
Years since PhD	Yes	Yes	Yes	Yes	Yes
Academic affiliation	Yes	Yes	Yes	Yes	Yes
Observations	2,169	2,169	2,169	2,169	2,169

*Notes: This table presents the estimations of model (5) in Section 7.1 using discrete-time duration analysis with a proportional hazards assumption—using complementary log-log estimation. For definitions of covariates—see Table 4. The number of observations is the number of researcher-years. Standard errors are clustered by researcher and reported in parentheses. Significance levels are reported as *** p<0.01, ** p<0.05 and * p<0.1.*

In model (1) in Table 17, the coefficient for *child years* is negative and statistically significant at a 5% level, showing that there is negative correlation between accumulated number of years with young children and the likelihood of promotion. The estimated results in model (2) shows that the coefficient for the *child number* is not significant at

a 5% level. As suggested by the insignificant coefficient of parental leave in model (3), there is no correlation between *parental leave* and promotion. In models (4) and (5), the correlation between having children and promotion is investigated while simultaneously controlling for parental leave. The estimated negative correlation between having children and promotion is accentuated through the inclusion of the control for parental leave, and moreover, the coefficient for *child number* is statistically significant at a 5% level, indicating that the effect of parenthood on promotion is not driven by parental leave take-up.

Table 18: Children on promotion to associate professor

	(1) Associate professor	(2) Associate professor
Female	-0.708*	-0.381
	(0.420)	(0.472)
Child years	-0.0922***	
	(0.0316)	
Child number		-0.201*
		(0.109)
Female × Child years	0.0969	
	(0.0593)	
Female × Child number		0.0984
		(0.238)
Cohort	Yes	Yes
Field	Yes	Yes
Years since PhD	Yes	Yes
Academic affiliation	Yes	Yes
Observations	2,169	2,169

*Notes: This table presents the estimations of model (6) in Section 7.1 using discrete-time duration analysis with a proportional hazards assumption—using complementary log-log estimation. For definitions of covariates—see Table 4. The number of observations is the number of researcher-years. Standard errors are clustered by researcher and reported in parentheses. Significance levels are reported as *** p<0.01, ** p<0.05 and * p<0.1.*

In models (1) and (2) in Table 18, the coefficient for the interaction of *female* and *child years* and the interaction of *female* and *child number* are both insignificant, which means that we cannot reject the null hypothesis of gender equality in the effect of children on the likelihood of promotion. The implication is that we find no evidence of any gender differences in the effect of having young children on promotion.

Table 19: Parenthood and publications on promotion to associate professor

	(1) Associate professor	(2) Associate professor	(3) Associate professor	(4) Associate professor	(5) Associate professor
Female	-0.147	-0.116	-0.107	-0.142	-0.138
	(0.231)	(0.234)	(0.265)	(0.279)	(0.276)
Child years	-0.0553*			-0.0549*	
	(0.0307)			(0.0311)	
Child number		-0.179*			-0.186*
		(0.0995)			(0.106)
Parental leave			-0.0889	-0.00705	0.0327
			(0.150)	(0.154)	(0.164)
Publications	0.0424***	0.0448***	0.0463***	0.0425***	0.0444***
	(0.0115)	(0.0114)	(0.0112)	(0.0116)	(0.0114)
Cohort	Yes	Yes	Yes	Yes	Yes
Field	Yes	Yes	Yes	Yes	Yes
Years since PhD	Yes	Yes	Yes	Yes	Yes
Academic affiliation	Yes	Yes	Yes	Yes	Yes
Observations	2,169	2,169	2,169	2,169	2,169

*Notes: This table presents the estimations of model (7) in Section 7.1 using discrete-time duration analysis with a proportional hazards assumption—using complementary log-log estimation. For definitions of covariates—see Table 4. Publications are weighted according to the AIS(econ) measure—see Table 9. The number of observations is the number of researcher-years. Standard errors are clustered by researcher and reported in parentheses. Significance levels are reported as *** p<0.01, ** p<0.05 and * p<0.1.*

Finally, we turn to the effects of parenthood on promotion conditional on publications, for the purpose of investigating whether the results are driven by parenthood per se, or if the true correlation is due to publication differentials between researchers with and without children. In models (1) and (2) in Table 19, none of the coefficients for *child years* or *child number* are significant at a 5% level. The same results hold for models (4) and (5), implying that, conditional on publication scores, we cannot reject that parenthood is uncorrelated with the likelihood of promotion. In model (3) the effect of parental leave on promotion is non-significant with controls for publications. In sum, these results indicate that the correlation between parenthood and promotion is, at least in partial, driven by publication differentials between researchers with and without children.

8.2 Models of the propensity to leave Swedish academia

In this section, we turn to the results from the model estimations on the propensity to leave Swedish academia (outlined in Section 7.2). We estimate the effects of leaving before associate and full professor respectively, with and without controlling for publication differentials, for the purpose of capturing any gender differences in overall propensity to leave Swedish academia as well as conditional on publication scores. Similar to Section 8.1.1, the coefficients of interest are *female*.

Table 20: Propensity to leave Swedish academia as an assistant professor

	(1) Leave academia	(2) Leave Sweden	(3) Leave	(4) Leave academia	(5) Leave Sweden	(6) Leave
Female	-0.128	0.164	-0.0148	-0.225	0.253	-0.0448
	(0.305)	(0.362)	(0.233)	(0.309)	(0.371)	(0.236)
Publications				-0.265***	0.0421*	-0.0279
				(0.101)	(0.0215)	(0.0305)
Cohort	Yes	Yes	Yes	Yes	Yes	Yes
Field	Yes	Yes	Yes	Yes	Yes	Yes
Years since PhD	Yes	Yes	Yes	Yes	Yes	Yes
Academic affiliation	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,892	2,833	2,936	2,892	2,833	2,936

*Notes: This table presents the estimations of models (8) and (9) in Section 7.2 using discrete-time duration analysis with a proportional hazards assumption—using complementary log-log estimation. All covariates—except years since PhD—are defined as in Table 4. Since there is no time trend in when researchers tend to leave (see Table 37 in Appendix C), we have included years since PhD as an indicator variable, which assumes no function on the hazards rate. When including time as an indicator variable, all years where no researchers left needs to be removed and hence the number of observations —researcher-years—varies across the models. Additionally, the hazard rates need not to converge. For definitions of covariates—see Table 4. The number of observations is the number of researcher-years. Standard errors are clustered by researcher and reported in parentheses. Significance levels are reported as *** p<0.01, ** p<0.05 and * p<0.1.*

Table 21: Propensity to leave Swedish academia as an assistant or associate professor

	(1) Leave academia	(2) Leave Sweden	(3) Leave	(4) Leave academia	(5) Leave Sweden	(6) Leave
Female	-0.0716	0.0423	-0.0248	-0.156	0.0994	-0.0456
	(0.305)	(0.349)	(0.231)	(0.306)	(0.355)	(0.232)
Publications				-0.192***	0.0293*	-0.0185
				(0.0731)	(0.0175)	(0.0208)
Cohort	Yes	Yes	Yes	Yes	Yes	Yes
Field	Yes	Yes	Yes	Yes	Yes	Yes
Years since PhD	Yes	Yes	Yes	Yes	Yes	Yes
Academic affiliation	Yes	Yes	Yes	Yes	Yes	Yes
Academic rank	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,587	3,581	3,766	3,587	3,581	3,766

*Notes: This table presents the estimations of models (8) and (9) in Section 7.2 using discrete-time duration analysis with a proportional hazards assumption—using complementary log-log estimation.All covariates—except years since PhD—are defined as in Table 4. Since there is no time trend in when researchers tend to leave (see Table 37 in Appendix C), we have included years since PhD as an indicator variable, which assumes no function on the hazards rate. When including time as an indicator variable, all years where no researchers left needs to be removed and hence the number of observations —researcher-years—varies across the models. Additionally, the hazard rates need not to converge. For definitions of covariates—see Table 4. The number of observations is the number of researcher-years. Standard errors are clustered by researcher and reported in parentheses. Significance levels are reported as *** p<0.01, ** p<0.05 and * p<0.1.*

In Tables 20 and 21, the coefficients for *female* are all insignificant, implying that we cannot reject the null hypothesis that there is no gender difference in the propensity to leave Swedish academia. The results hold regardless of whether the control for publications is included or not. Moreover, we find no gender difference in the propensity to leave Swedish academia contingent on academic rank.

8.3 Models of co-authorship patterns

In this section we outline the results from the models on co-authorship patterns in Section 7.3. The coefficient of interest is *female*.

Table 22: Co-authorship patterns

	(1)	(2)
	Solo-authored	Female co-author
Female	-0.0120	0.547***
	(0.0900)	(0.0918)
Journal	-0.150***	0.0231
	(0.0302)	(0.0145)
Year	-0.00386***	0.130***
	(0.000703)	(0.00886)
Cohort	Yes	Yes
Field	Yes	Yes
Academic affiliation	Yes	Yes
Academic rank	Yes	Yes
Observations	5,827	5,827

*Notes: This table presents the estimations of models (10) and (11) in Section 7.3 using a logit estimation. For definitions of covariates—see Table 4. Journal is included as its Article Influence Score—see Table 9. The number of observations is the number of publications. Standard errors are clustered by unique publication and reported in parentheses. Significance levels are reported as *** p<0.01, ** p<0.05 and * p<0.1.*

In model (1) in Table 22, the coefficient for *female* is insignificant for the model on solo-authoring, which means that we find no evidence of any gender difference in the propensity to solo-author. In model (2) we can, however, reject the null hypothesis of no gender difference in the propensity to co-author with female researchers. Consequently, we find evidence on female researchers having a higher propensity to co-author with other women than comparable male researchers.[18]

Moreover, by interpreting the other point estimates in Table 22, the results suggest that the prominence of the journal is negatively correlated with solo-authoring in model (1) on the one hand, and not correlated with having a female co-author in model (2) on the other. There is a negative correlation between the publication year of a paper and solo-authoring—indicating that there is a general trend towards increasing co-authorship. The publication year is also positively correlated with a higher likelihood of having a

[18] In model (2) in Table 22 we include both solo-authored and co-authored papers, which means that there are three categories of authoring: (i) solo-author, (ii) co-author with female co-author(s) and (iii) co-author with only male co-author(s). The results are qualitatively equal by excluding solo-authored papers, only considering the likelihood of a co-authored paper to be co-authored with a female researcher.

female co-author in general, which is likely due to an increased female presence in the field of economics (see Figure 1).

Table 23: Seniority of co-authors

	Assistant professors		*Assistant and associate professors*
	(1) Co-authored with associate or full professor	(2) Co-authored with full professor	(3) Co-authored with full professor
Female	-0.00321	-0.0919	-0.0290
	(0.0976)	(0.102)	(0.0856)
Journal	0.0900***	0.100***	0.104***
	(0.0202)	(0.0201)	(0.0171)
Year	0.0515***	0.0418***	0.0409***
	(0.0107)	(0.0117)	(0.00909)
Cohort	Yes	Yes	Yes
Field	Yes	Yes	Yes
Academic affiliation	Yes	Yes	Yes
Academic rank	No	No	Yes
Observations	2,798	2,798	4,425

*Notes: This table presents the estimations of models (12) in Section 7.3 using a logit estimation. For definitions of covariates—see Table 4. Journal is included as its Article Influence Score—see Table 9. The number of observations is the number of publications. Standard errors are clustered by unique publication and reported in parentheses. Significance levels are reported as *** p<0.01, ** p<0.05 and * p<0.1.*

In models (1) to (3) in Table 23, the coefficient for *female* is not significant at a 5% level for any of the model estimations. Consequently, we find no evidence on any gender differences in the propensity to co-author with senior co-authors. The estimations show that the quality of the journal is positively and significantly correlated with having a senior co-author, indicating that there is a positive relationship between journal prominence and the seniority of the co-authors. In addition, the propensity to co-author with senior researchers is increasing with the year for publication, indicating that co-authoring with senior researchers is becoming increasingly common.

9 Sensitivity analysis

In this section, the robustness of our results are examined. We test the assumption of non-informative censoring, followed by an alternative model estimation using the Cox proportional hazards model and finally, test the effect of using alternative measures of publication scores.

9.1 The assumption of non-informative random censoring

There are no ways of testing for any violations of the assumption of non-informative censoring, as discussed in Section 6.1, but the sensitivity of the model can be studied through an alternative specification of the model (Allison, 2010). This re-specification alters the outcome of the dependent variable for the purpose of analysing the effects on the results. An important note, however, is that the re-estimation is an extreme case, in that it is a 'worst-case scenario' (Allison, 2010). Applied to this study, there is a risk that the researchers leaving Swedish academia have a systematically lower likelihood of being promoted. As follows, all random right-censored researchers are treated as if they do not leave the sample in the re-specification of the model. Instead, these researchers remain in the sample to the last year of observation (2016) without being promoted. This corresponds to a case where all the researchers leaving the data set have a systematically lower likelihood of promotion.

Table 24: Test of the assumption of non-informative censoring

	(1) Associate professor	(2) Associate professor	(3) Full professor	(4) Full professor
Female	-0.405**	-0.351*	-0.720**	-0.533
	(0.175)	(0.185)	(0.337)	(0.340)
Publications		0.0355***		0.0292***
		(0.00887)		(0.00683)
Cohort	Yes	Yes	Yes	Yes
Field	Yes	Yes	Yes	Yes
Years since PhD	Yes	Yes	Yes	Yes
Academic affiliation	Yes	Yes	Yes	Yes
Observations	4,397	4,397	2,907	2,907

*Notes: This table presents the estimations of models (1) and (2) in Section 7.1 using discrete-time duration analysis with a proportional hazards assumption—using complementary log-log estimation. For definitions of covariates—see Table 4. Publications are weighted according to the AIS(econ) measure—see Table 9. The number of observations is the number of researcher-years. All researchers are included in the sample until the last year of observation (2016). Standard errors are clustered by researcher and reported in parentheses. Significance levels are reported as *** p<0.01, ** p<0.05 and * p<0.1.*

In Table 24, the results of the re-specification are qualitatively the same as in the main results in Table 15. The interpretation is that our results are not sensitive to the assumption that researchers leaving the sample have a systematically lower likelihood of promotion than the researchers remaining.

9.2 The Cox proportional hazards model

We use a discrete-time duration model in the primary analysis. An alternative is the more widely used proportional hazards model of Cox (1972), which is a continuous-time duration model. The main advantages of using the Cox proportional hazards model for this study would be that it is well acknowledged and in some sense the standard procedure for duration analysis. The model uses partial likelihood estimation instead of

maximum likelihood estimation used for the complementary log-log model. In contrast to the maximum likelihood estimation, which takes the exact time for occurrence in consideration, partial likelihood estimation is only concerned with the order in which events occur. Moreover, the Cox proportional hazards model does not make the restrictive assumption on time as we do in our primary analysis. The benefit of not restricting time is that there is no need of making an assumption regarding the functional form of the hazard rates. The drawback is that time-dependence in the hazard rates are not allowed and the estimates may therefore be less precise (Mills, 2011). The hazard rate for the continuous-time data is defined as:

$$\lambda_i(t) = \lim_{\Delta t \to 0} \frac{Pr(t \leq T < t + \Delta t | T \geq t)}{\Delta t} \tag{13}$$

Given that we have a relatively high proportion of tied events, we use the exact partial-likelihood method to handle tied events instead of the 'standard' procedure of using the Breslow-method.[19] The results from the Cox proportional hazards model are shown in Table 25 and Table 26.

Table 25: Gender promotion gap including publications—Cox model

	(1) Associate professor	(2) Associate professor	(3) Associate professor	(4) Full professor	(5) Full professor	(6) Full professor
Female	-0.338*	-0.230	-0.230	-0.688*	-0.449	-0.454
	(0.174)	(0.191)	(0.191)	(0.373)	(0.377)	(0.378)
Publications		0.075***			0.042***	
		(0.011)			(0.008)	
Solo-authored			0.073***			0.050**
			(0.027)			(0.022)
Co-authored			0.076***			0.040***
			(0.013)			(0.011)
Cohort	Yes	Yes	Yes	Yes	Yes	Yes
Field	Yes	Yes	Yes	Yes	Yes	Yes
Years since PhD	Yes	Yes	Yes	Yes	Yes	Yes
Academic affiliation	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,266	3,266	3,266	2,489	2,489	2,489

*Notes: This table presents the estimations of models (1) and (2) in Section 7.1 using the Cox proportional hazards model. Additionally, publications are separated into solo-authored and co-authored. For definitions of covariates—see Table 4. Publications are weighted according to the AIS(econ) measure—see Table 9. The number of observations is the number of researcher-years. Standard errors are reported in parentheses. Significance levels are reported as *** p<0.01, ** p<0.05 and * p<0.1.*

In Table 25, the coefficients for female are not significant at a 5% level by using the Cox proportional hazards model. In comparison to the point estimates in Table 15, the relative magnitude on the coefficients are slightly mitigated: from -0.384 to -0.338 on associate professor and from -0.702 to -0.688 on full professor. Estimating the 95% confidence intervals, the likelihood of promotion to associate professor is between $100(\exp(0.011)-1) \approx 1\%$ higher and a $100(1-\exp(-0.630)) \approx 46\%$ lower for a female researcher. Conversely, the likelihood of appointment to full professor for a woman is estimated between $100(\exp(0.043)-1) \approx 4\%$ higher and $100(1-\exp(-1.419)) \approx 76\%$ lower

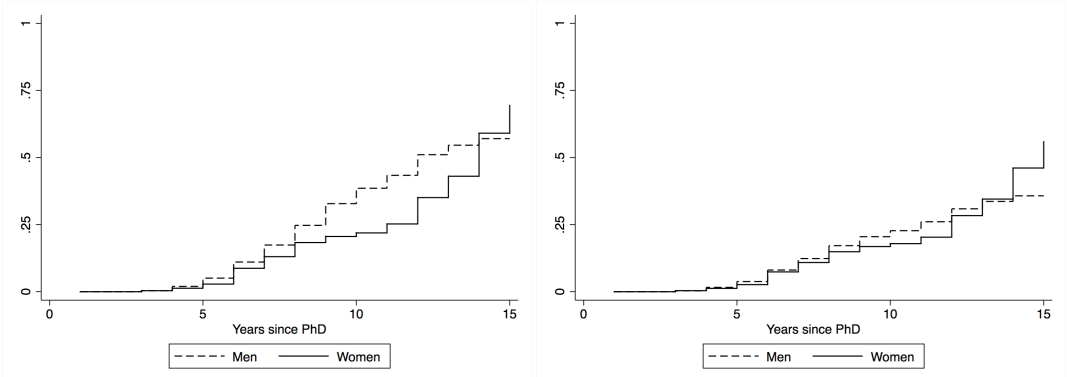
[19] For reference on why to use the exact method—see Cleves et al. (2016).

for the 95% confidence interval, in comparison to a male researcher. Consequently, we cannot reject the hypothesis of equal likelihood of promotion for men and women using a continuous-time duration model. These results are not aligned with the results from the discrete-time duration model in the primary analysis. We argue that given the point estimates, there is still a strong indication that there exists a gender promotion gap when not controlling for publication scores.

Continuing with a re-estimation of model (2) in Section 7.1, we find that the coefficient for female remains insignificant in all regressions when including publications, with a reduced point estimate in comparison to models (2), (3), (5) and (6) in Table 25. These results, aligned with our primary analysis in Tables 15 and 16, indicate that publication differentials can explain a part of the gender differences in likelihood of promotion. Figure 25 illustrates the convergence of the gender promotion gap based on the estimations in Table 25. As shown in the figure, the gap in Figure 5a appears to narrow considerably when including publications to the model in Figure 5b.

Figure 5: Gender promotion gap—Cox model

(a) Model (1)—Table 25 **(b) Model (2)—Table 25**



Notes: Figure 5a displays the gender promotion gap when not controlling for publication scores (model (1) in Table 25). Figure 5b displays the gender promotion gap when controlling for publication scores (model (2) in Table 25).

We proceed by re-estimating model (5) in Section 7.1, examining the correlation between children and the likelihood of promotion in Table 26. We find that the negative correlation between children and appointment to associate professor persists using the Cox proportional hazards model. In contrast to model (2) in Table 17, the coefficient for number of children is now significant at a 5% level—implying that not only the accumulated number of years with young children may be important but also the number of young children. Again, these are only correlations and not a causal effect of children on promotion. We cannot find any correlation between parental leave and promotion, which is also in line with the results in our primary analysis in Table 17.

Table 26: Parenthood on promotion to associate professor—Cox model

	(1) Associate professor	(2) Associate professor	(3) Associate professor	(4) Associate professor	(5) Associate professor
Female	-0.219	-0.198	-0.273	-0.289	-0.306
	(0.220)	(0.221)	(0.250)	(0.250)	(0.250)
Child years	-0.0600**			-0.0639**	
	(0.0276)			(0.0286)	
Child number		-0.184**			-0.221**
		(0.0915)			(0.101)
Parental leave			0.0177	0.0957	0.160
			(0.156)	(0.160)	(0.170)
Cohort	Yes	Yes	Yes	Yes	Yes
Field	Yes	Yes	Yes	Yes	Yes
Years since PhD	Yes	Yes	Yes	Yes	Yes
Academic affiliation	Yes	Yes	Yes	Yes	Yes
Observations	2,169	2,169	2,169	2,169	2,169

*Notes: This table presents the estimations of model (5) in Section 7.1 using the Cox proportional hazards model. For definitions of covariates—see Table 4. Publications are weighted according to the AIS(econ) measure—see Table 9. The number of observations is the number of researcher-years. Standard errors are reported in parentheses. Significance levels are reported as *** p<0.01, ** p<0.05 and * p<0.1.*

9.3 Measures of publication merits

The quantity and quality of scientific publications are relatively easily measured, but there are some difficulties in how they should be weighted in order to properly account for the productivity of a researcher. Stern (2013) found that there are great uncertainties in the rankings of journals and Henrekson and Waldenström (2011) showed that the outcome of a researcher's total output can vary to a substantive amount depending on which measure of output that is used. We conduct robustness checks using alternative measures in order to investigate whether the results of the study are contingent on the choice of publication measure. These robustness checks include the use of another measure of journal quality (Section 9.3.1) and another weighting of publications in non-economics journals (Section 9.3.2). Moreover, we adjust the accumulated publication scores for the number of co-authors (Section 9.3.3). The measures used are defined in Table 9 and the correlation between them is shown in Table 10. The results are shown in Appendix D.

9.3.1 Alternative measures of journal quality

In the primary analysis, we use a productivity measure based on the journal ranking list in IDEAS/RePEc combined with the Article Influence Score. Here, we test the robustness of the results by using the ordering according the IDEAS/RePEc ranking. The top journal according to the list is receiving the score of 100, and the last journal is receiving the score of 1. All journals not included in the top 100 receive the score of 1. In contrast to the Article Influence Score, this measure of journal quality captures the prominence of the journal according to the economics profession and is not merely a metric based on citations. The results are found in Table 38 in Appendix D—the results did not qualitatively change.

9.3.2 Weighting of non-economics journals

In the primary analysis, we use a productivity measure based on the journal ranking list in IDEAS/RePEc combined with the Article Influence Score. Each journal included in the top 100 economics journals according to IDEAS/RePEc is given the value of its Article Influence Score. This measure bias the publication score intentionally in favour of economics journals. Economics journals are explicitly mentioned in promotion criteria by the departments of economics and are in general the only journals included in studies estimating the productivity of academic economists (Ginther and Kahn, 2004; Sarsons, 2017). This notwithstanding, researchers within the field of economics may publish in non-economics journals of equal general scientific prominence as the top economics journals. Arguably, these publications should also be accounted for in the evaluation of the productivity of these researchers and should favour researchers that conduct research in more interdisciplinary fields. The results are found in Table 39 in Appendix D—the results did not qualitatively change.

9.3.3 Weighting of number of co-authors

In the primary analysis, publications are categorised into solo-authored and co-authored papers, but the number of co-authors is not accounted for. There are proponents for discounting publication scores by the number of co-authors, arguing that this procedure would more rightfully capture the contribution of the single author (Hollis, 2001; Liebowitz, 2014). In order to verify that our results do not depend on the weighting of co-authors, we use the same productivity measures as in our primary analysis but linearly adjusted for the number of co-authors (see Table 9). Consequently, we use the two extreme cases of co-authorship discounting: *no proration* in our primary analysis and *strict proration* in our sensitivity analysis. If our results do not depend on which procedure that is used, our results should be robust also for weighting schemes in the form of *partial proration*, which is likely to be the form that is used in practice (Liebowitz, 2014). The results are shown in Table 40 in Appendix D—the results did not qualitatively change.

10 Exploratory analysis

In this section, we explore some of the features of our data beyond our research questions and hypotheses. We examine gender differentials in publications across cohorts and moreover, we investigate gender differences in promotion depending on academic affiliation.

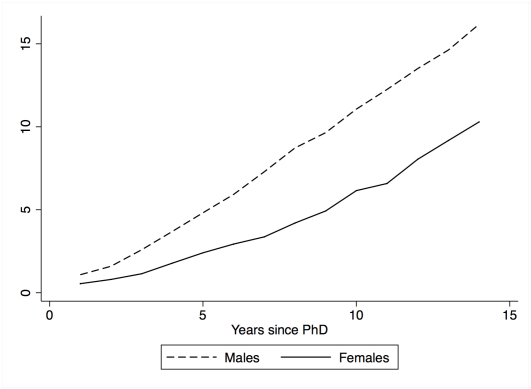
10.1 Cohort

By observing the accumulated publications (numbers and weighted scores) in Figure 3 on page 16, a kink in the female line can be noted after 7–8 years in all graphs. This kink appears to be a shift in the time-trend, but it is not evident what the mechanism behind this gender diversion in publications is. A possible reason is that it is an effect of a career break, for instance due to gender differences in promotion or parental factors; another that it is driven by publication differentials across cohorts. We therefore divide our sample into two cohorts: researchers with a doctoral degree between years 1990–2004 and researchers with a doctoral degree between years 2005–2016.

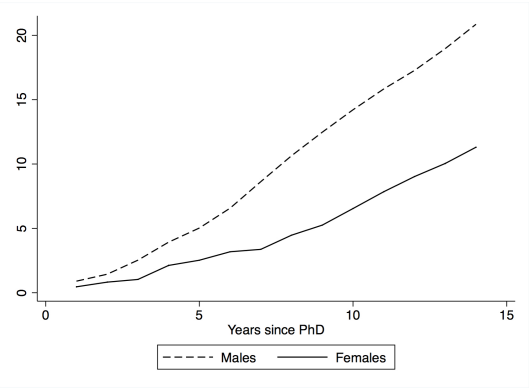
First, we re-estimate the figure with the first cohort (1990–2004) in Figure 6 and then with the second (2005–2016) in Figure 7. The pattern displayed in the figures suggests that there is a diversion in publications appearing during the first years within academia for the first cohort, while it does no appear at all for the latter. A possible interpretation is that the diversion in publications after 7–8 years in Figure 3 is not driven by a career-break after 7–8 years—but rather that the 'publication gap' is closed for the most recent cohort. Following Figures 6 and 7, we re-run models (1) and (2) in Section 7.1 for each cohort separately. The coefficients of interest are *female*.

Figure 6: Accumulated number of publications—PhD 1990–2004

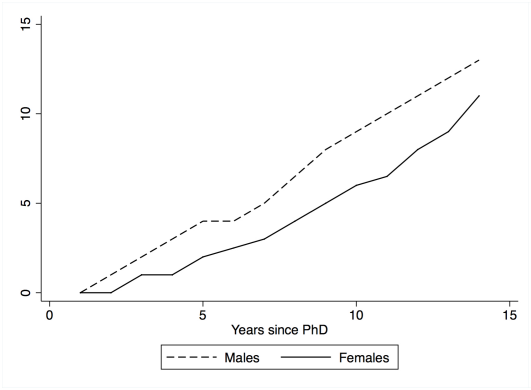
(a) Mean number of publications



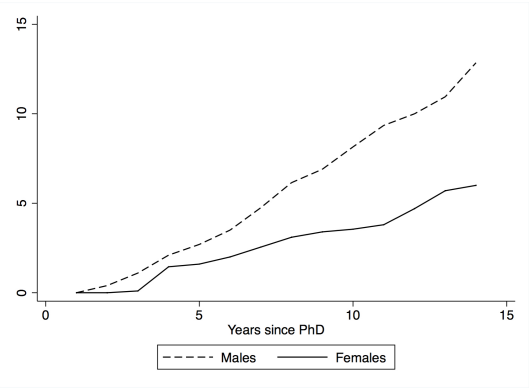
(b) Mean weighted publications*



(c) Median number of publications



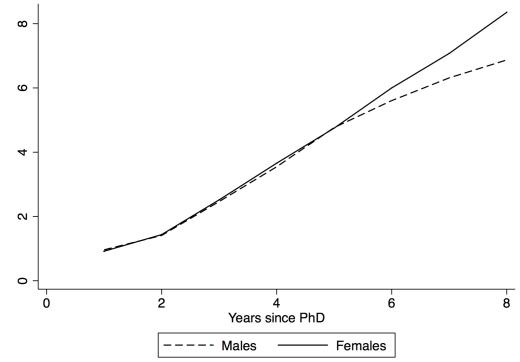
(d) Median weighted publications*



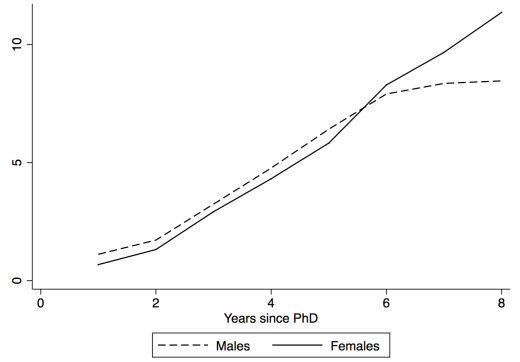
**Each publication is given the Article Influence Score for the journal in which it is published—see Table 9*

Figure 7: Accumulated number of publications—PhD 2005–2016

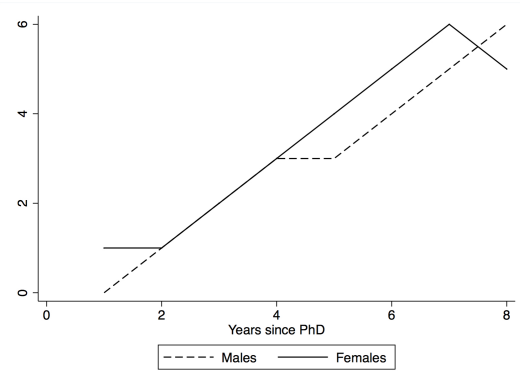
(a) Mean number of publications



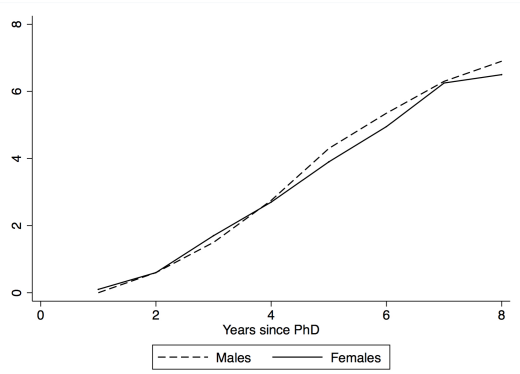
(b) Mean weighted publications*



(c) Median number of publications



(d) Median weighted publications*



**Each publication is given the Article Influence Score for the journal in which it is published—see Table 9*

Table 27: Gender promotion gap—cohorts

	(1) Associate professor *PhD: 1990–2004*	(2) Associate professor *PhD: 1990–2004*	(3) Associate professor *PhD: 2005–2016*	(4) Associate professor *PhD: 2005–2016*
Female	-0.585**	-0.386	-0.084	-0.020
	(0.247)	(0.237)	(0.276)	(0.275)
Publications		0.054***		0.054***
		(0.013)		(0.014)
Cohort	Yes	Yes	Yes	Yes
Field	Yes	Yes	Yes	Yes
Years since PhD	Yes	Yes	Yes	Yes
Academic affiliation	Yes	Yes	Yes	Yes
Observations	1,684	1,684	1,582	1,582

*Notes: This table presents the estimations of models (1) and (2) in Section 7.1 using discrete-time duration analysis with a proportional hazards assumption—using complementary log-log estimation. For definitions of covariates—see Table 4. Publications are weighted according to the AIS(econ) measure—see Table 9. The number of observations is the number of researcher-years. Standard errors are clustered by researcher and reported in parentheses. Significance levels are reported as *** p<0.01, ** p<0.05 and * p<0.1.*

In models (1) and (3) in Table 27, the coefficient for *female* is significantly different from zero at a 5% level for the earlier cohort but not for the latter when not including publication scores. This shows that the gender differences in the likelihood of promotion have converged over time; we find no evidence on any gender promotion gap for the latter cohort at all. Through the inclusion of publications in models (2) and (4), we cannot reject the null hypothesis of gender equality in the likelihood of promotion for any of the cohorts. These findings suggest that the promotion gap has narrowed or even closed for the more recent generation of academic economists in Sweden. Moreover, this narrowing seems to be driven by a convergence in publications.

10.2 Academic affiliation

All models in this study include controls for academic affiliation, which separates the top 6 universities from the others. A possible reason for the imprecise estimates in many of the models is data heterogeneity, which in turn may be explained by differences between universities. For instance, the criteria for promotion may differ based on the research intensity of the universities. In order to investigate if there are any differences in the likelihood of promotion for these two groups we re-estimate models (1) and (2) in Section 7.1 for each group separately. The coefficient of interest is *female*.

Table 28: Gender promotion gap—academic affiliations

	(1) Associate professor *Non-top 6*	(2) Associate professor *Non-top 6*	(3) Associate professor *Top 6*	(4) Associate professor *Top 6*
Female	0.0584	-0.183	-0.580***	-0.420*
	(0.326)	(0.357)	(0.224)	(0.226)
Publications		0.155***		0.0473***
		(0.0296)		(0.0104)
Cohort	Yes	Yes	Yes	Yes
Field	Yes	Yes	Yes	Yes
Years since PhD	Yes	Yes	Yes	Yes
Observations	1,017	1,017	2,249	2,249

*Notes: This table presents the estimations of models (1) and (2) in Section 7.1 using discrete-time duration analysis with a proportional hazards assumption—using complementary log-log estimation. For definitions of covariates—see Table 4. Publications are weighted according to the AIS(econ) measure—see Table 9. The number of observations is the number of researcher-years. Standard errors are clustered by researcher and reported in parentheses. Significance levels are reported as *** p<0.01, ** p<0.05 and * p<0.1.*

In Table 28, the coefficient for *female* is non-significant for the non-top 6 universities in models (1) and (2). The interpretation is that we cannot find any evidence of a gender promotion gap at the non-top 6 universities. In contrast, the estimations in model (3) suggests that there is a gender difference in the likelihood of promotion for the top 6 universities, implying a gender promotion gap. By including publications, this gender difference becomes non-significant at a 5% significance level in model (4), suggesting that publication differentials can explain a part of the gender promotion gap to associate professor at the top 6 universities.

11 Discussion

In this section, we interpret our results presented in Section 8 in light of the sensitivity and exploratory analyses in Sections 9 and 10. Moreover, we discuss the implications of these findings in light of the purpose of the study.

11.1 The gender promotion gap and its determinants

We begin this section by answering our first research question, which regards the existence of a gender promotion gap within the field of economics in Sweden between 1990 and 2016. Based on the model estimations in Table 15 in Section 8.1.1, the results suggest that there are gender differences in the likelihood of promotion at the steps to associate and full professor. This implies that there exists a gender promotion gap.[20] This notwithstanding,

[20] Note that we could not reject the null hypotheses of no gender differences in the continuous-time estimations of the Cox model (Table 25 in Section 9.2). We argue, however, that discrete-time duration analysis is more appropriate for the estimation of the gender promotion gap.

the large confidence intervals call for some concern in interpreting the results; we argue that there is a gender promotion gap, but refrain from interpreting the magnitude of it.

There are two possible facts which may explain the imprecise estimates: the low number of female researchers and data heterogeneity. The low share of female researchers follows from investigating a field with documented under-representation of women. There is a total number of 43 female researchers promoted to associate professor between 1990 to 2016. Moreover, there are only 9 women promoted to full professor. Previous studies have mainly focused on American universities, where some studies have oversampled the number of female researchers in order gather a larger number of women (Kahn, 1993; Ginther and Kahn, 2004) but by using Swedish data, this method is not feasible. While we could have added a handful of women by stretching the sample further back in time, the fact is that this would only increase the number of female researchers marginally. A potential solution to this issue is to extend the sample by including other fields of research or other countries close to the Swedish population of academic economists. This is a trade-off: an extension would enable a larger sample, which may result in better estimations, but it may also lead to greater data heterogeneity. Given that another potential reason to the imprecise estimates is data heterogeneity in *our* sample, extending the sample may not be desirable.

In the exploratory analysis, we find evidence suggesting that the results in the main analysis are driven by gender differences in the appointment to associate professor within the top 6 universities. We note that the impact of publication scores on promotion appears to be greater for the subsample of the top 6 universities, than for the sample of the other universities as well as the total sample. A possible interpretation is that more weight is placed on publications at these top universities, while other merits, such as teaching, is given more weight at the other universities.

11.1.1 Publication differentials

The summary statistics in Table 12 and Figure 3 together indicate that there are gender differentials in the mean and median number of publications and publication scores. This picture is confirmed in light of the findings of Table 15: the significance of the coefficient for female disappears in both regressions by controlling for publication differentials, and the estimated magnitude is mitigated. Moreover, by separating solo-authored and co-authored publications for the purpose of allowing for some proration of author credits, the results hold in models (1) and (2) in Table 16. This pattern is consistent across all estimations and is not contingent on the choice of publication measure in the sensitivity analysis in Section 9. Moreover, the insignificant coefficient of female implies that we cannot find any evidence on discrimination, given a certain level of productivity. This notwithstanding, we cannot rule out that discrimination may be a factor in explaining the observed gender difference in promotion, given the large confidence intervals of the coefficient for *female*. Additionally, a more dynamic framework of discrimination, where the labour supply is not exogenously given, would be an appropriate extension of this study.

Our results show that publication differentials explain a part of the gender promotion gap, but to what extent remains to be further studied. In the exploratory analysis, we found evidence suggesting that the gender publication differentials have converged over time. Furthermore, we could not find any evidence of a gender promotion gap for later cohorts of academic economists. These findings are aligned with the results found in

McDowell et al. (1999) and Arensbergen et al. (2012). A suggestion for future research is to further investigate the causes and consequences of the convergence in both publications and promotions. If publication differentials have been an important factor in explaining the gender promotion gap historically, this convergence may imply that the promotion gap is closing as well. Hence, the magnitude of the role of publication differentials on the historic gender promotion gap needs to be further studied, and the convergence needs to be tracked over the coming decades.

11.1.2 Gender differences in the credit allocation of co-authored papers

Continuing with the impact of co-authorship on promotion, we do not find any evidence of gender differences in the allocation of credit for co-authored publications. This finding implies that we cannot replicate the results of Sarsons (2017) on the sample of academic economists in Sweden. The results are robust to different measures of publication scores—including the RePEc measure similar to the measure used in Sarsons (2017)—as shown in Appendix D. In turn, this calls for an explanation on why we cannot replicate the results. One possible explanation is that we have failed to pin down a gender difference that is there. Another explanation is that the results might reflect differences in the American and Swedish university systems. These differences may be institutional or even cultural.

We do, however, note that the estimated coefficient in model (3) in Table 16 suggests that female researchers benefit from solo-authoring to a higher extent than comparable men. The same pattern is shown in Table 39 in Appendix D, where the effect is significant at a 1% level by measuring publication scores with the AIS measure. In line with the theory outlined by Sarsons (2017), we have argued that a solo-authored paper sends a clear signal about ability, and should yield no gender differences. Hence, these results were not predicted theoretically. Using economic theory to understand this pattern, an explanation could be that employers expect female researchers to be less productive than male researchers and, in light of facing information asymmetry, assign more credit to the female researchers showing their ability through a clear signal. In this case, the effect would be the opposite aspect of being punished for co-authoring. We refrain from drawing any conclusions based on these estimates, given that any gender differences in solo-authorship is not a part of our theory in explaining the gender promotion gap—but the topic may be further explored in the future using another data set.

11.1.3 Parenthood

Finally, we have studied the role of parenthood in explaining the gender promotion gap by measuring the correlation between the likelihood of promotion, on the one hand, and the long-term effects of having children and the short-term effects of parental leave on the other. The results implied that parenthood may account for a part of the gender differences in promotion. In particular, we found that the accumulated number of years with young children was negatively correlated with promotion. We did not find any evidence on a correlation between parental leave and promotion. The interpretation is that this kind of career interruption does not seem to affect the likelihood of promotion for academic economists in Sweden. As discussed in the literature review in Section 3, many of the American universites have adopted gender-neutral tenure-clock stopping policies which Antecol et al. (2016) showed have a negative effect on the likelihood of promotion for female researchers but a positive effect for male. In contrast, the Swedish

universities with a tenure-track system stop the clock for parental leave and not for having children, which reasonably explains why parental leave do not affect the likelihood of promotion.

Given that parental leave does not seem to be correlated with the likelihood of promotion, we interpret that the observed negative correlation between parenthood and the likelihood of promotion stems from *having* children. We cannot, however, detect a gender difference in this aspect, which is not in line with the results in Antecol et al. (2016). The negative correlation between parenthood and promotion was further analysed by accounting for the impact of publications on the likelihood of promotion and parenthood jointly, suggesting that the observed negative correlation between children and promotion may work through publication output. The results support the economic intuition that there is a conflict with work and family, but not our hypothesis that women would be affected more negatively by this conflict given their gender identity. Explaining the mechanisms at play is outside the scope of this study, so a suggestion for future research is to pin down the role of parenthood in explaining publication differentials.

11.2 Propensity to leave academia

Our second research question regards gender differences in the propensity to leave Swedish academia. Based on the results found in Tables 20 and 21 in Section 8.2, we do not find any evidence on any gender differences in the propensity to leave academia. These results may reflect an institutional difference between Sweden and the United States, explained through the fact that most of the Swedish universities do not have a tenure-track system. In contrast to the American tenure review forcing researchers 'up or out', Swedish researchers can stay longer at the lower ranks without being forced to find a new employment. In line with the evidence of Takahashi and Takahashi (2015), the results presented in Tables 20 and 21 suggest that female researchers stay longer at the lower ranks without being promoted. This notwithstanding, the results in model (4) in the tables suggest a negative correlation between publication scores and the propensity to leave. In turn, this correlation may be induced by researchers with lower publication scores being less likely to be promoted within academia and consequently having a higher propensity to leave for a non-academic employment. In conclusion, we cannot reject the hypothesis that the propensity to leave Swedish academia is independent of gender.

11.3 Gender patterns in co-authorship

Our third, and last, research question focus on the existence of gender patterns in co-authorship. Our findings imply that female researchers have a higher propensity to co-author with women than male researchers, which is in line with the patterns found by Boschini and Sjögren (2007) and McDowell and Smith (1992). Additionally, we find that the propensity to co-author with female researcher increases over time, which may be explained by the increased female presence within economics. Given the scope of this paper, we have tried to establish gender differences in co-authorship patterns which may explain the gender promotion gap. Assuming that there are preferences in the gender of the co-authors, an increase in the supply of female co-authors may play a role in explaining the observed convergence in the publication differentials between men and women. Furthermore, the decision of entering a labour market may be contingent on the expected supply of co-authors within the research field. As follows, the role of co-

authorship in explaining gender segregation within academic fields and subfields may be further explored.

In contrast to Boschini and Sjögren (2007) and McDowell and Smith (1992), we cannot find any evidence on women being more likely to solo-author than men. This suggests that differences in solo-authorship is not a mechanism explaining the gender publication differentials in our sample. We do, however, find a negative correlation between solo-authored articles and the prominence of the journal. In light of the fact that the universities do not fully prorate author credits in promotion decisions, presented in Appendix A, the choice of solo-authoring may play a role in the likelihood of promotion for both genders through the impact of publication scores.

Moreover, we find that the prominence of the journal is positively correlated with having senior co-authors, implying that senior co-authors may be an important contributing factor to higher publication scores. Considering that we do not find that women co-author with senior researchers to a lower extent than their male peers, an implication is that we have no evidence suggesting that gender differences in access to senior co-authors is a main contributing factor to the publication differentials. This is not aligned with the literature suggesting that research networks and mentor effects can be a main contributing factor to the paucity of female researchers at higher academic ranks (McDowell et al., 2006; Blau et al., 2010).

11.4 External validity

The existence of a gender promotion gap captures the vertical dimension of labour market outcomes and have been portrayed as a glass ceiling preventing women to reach top positions in their careers. To conclude this paper, we wish to interpret the findings discussed in this section in light of the aim of this study: investigating the determinants of gender differences in labour market outcomes. The scope of this paper includes exploring gender differences in the likelihood of promotion from a perspective of discrimination, preferences and gender identity, by empirically studying the roles of publications, credit allocation of co-authored papers and parenthood on the gender promotion gap within the Swedish field of economics.

Our main results suggest that the role of publications is the most important of our studied determinants in pinning down the gender promotion gap. Through the exploratory analysis, we note that the gender differentials in publications appear to have converged for the most recent cohorts. While these findings do not lend evidence to other fields of research on the existence of gender promotion gaps or publication differentials, we argue that the results point toward future studies on gender convergence over the last decades.

While the existence of gender patterns in co-authorship may be applicable across other academic fields in Sweden as well as other countries, the findings of this study imply that there is need for caution in applying evidence of previous studies if the institutional settings differ. First of all, we cannot replicate the results of Sarsons (2017) in a Swedish context, which might imply that the results in Sarsons (2017) are contingent on institutional and cultural factors of the American university system. Secondly, a comparison of the results found by Antecol et al. (2016) to our finding that parental leave within Swedish academia is uncorrelated with the likelihood of promotion suggests that gender-neutral tenure-clock stopping policies do not adversely affect female researchers by default, but rather through their construction in a specific institutional context. The American system, with no statutory parental leave, stops the tenure-clock unconditionally for both genders,

while the Swedish system only stops the tenure-clock conditional on parental leave take-up. Hence, we argue that this implies that conditional tenure-clock stopping policies may alleviate the effects of parenthood on the career for women, who have a higher parental leave take-up on average.

We have aimed to include the population of academic economists in Sweden between 1990 and 2016. By increasing the heterogeneity of the labour force within the labour market under study, we hoped to improve upon the external validity of previous studies. In this respect, we argue that any study on vertical gender differences in labour market outcomes should also take into consideration horizontal aspects. The higher propensity of female researchers to co-author with female colleagues, in comparison to male researchers, may indicate that there are gender preferences in team formation, as suggested by Boschini and Sjögren (2007). Establishing this pattern as well as exploring its effect on publication differentials may be important in understanding the gendered aspect of differences in labour market outcomes. Moreover, in a greater perspective this pattern may have a role in explaining any path dependence of occupational segregation in the Swedish labour market.

12 Conclusion

In this study, we present a unique data set of 1,041 Swedish doctoral graduates, which we have collected in order to investigate the under-representation of women within the field of economics in Sweden between 1990 and 2016. Identifying a research gap in the literature, we set out the purpose of investigating the determinants of gender differences in labour market outcomes. Through the chosen scope of our paper, we focus on the roles of publications, credit allocation of co-authored papers and parenthood on gender differences in the likelihood of promotion.

By performing a duration analysis on 572 academic economists—the doctoral graduates that have pursued a career within Swedish academia—we find gender differences in the likelihood of promotion to both associate and full professor, which can be partially explained by publication differentials between men and women. An exploratory analysis shows that these publication differentials have converged and that the promotion gap has narrowed—or even closed—for the young generation of academic economists. An interpretation is that the gender promotion gap in the main analysis can be explained by historical differences in publications. There is no evidence suggesting any discrimination.

In regard to the role of co-authorship, we do not find any evidence of gender differences in the credit allocation of co-authored papers in promotion decisions, which contrasts to previous findings on the departments of economics in the United States. Furthermore, a closer investigation of gender patterns in co-authorship do not indicate that there is a higher propensity for female researchers to solo-author, or a lower propensity for female researchers to co-author with senior co-authors. We do find, however, that the female propensity to co-author with female colleagues is higher than the male.

Through conducting a survey on parental factors, we find a negative correlation between parenthood and the likelihood of promotion for both men and women. The data suggests that this correlation stems from having young children rather than parental leave take-up. Moreover, while we cannot find any gender differences in the correlation between the likelihood of promotion and parenthood, a part of the negative mechanism of parenthood appears to work through the accumulated publication scores.

In summary, the main finding of the thesis is the existence of a gender promotion gap in the Swedish labour market for academic economists, which can be accounted for in partial by publication differentials between men and women. This notwithstanding, we do not find any evidence of a promotion gap, or publication differentials, for the young generation of academic economists. Hence, a proposal for future research is to investigate the determinants of this convergence, as well as to follow the development of the female representation at top positions within academia in light of it.

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Appendix A Proration of author credits

In the evaluation of publication scores, a co-authored paper must be weighted somewhere between $1/n$ and 1 of a solo-authored paper where n is number of authors. We test the two extreme cases of *strict proration* $(1/n)$ and *no proration* (1) in order to see if any of the hypotheses can be rejected. The importance of which proration of author credits that is used by the departments of economics is that it will affect the incentive scheme for researchers to solo- respectively co-author. An increased proration reduces the net gain from co-authoring, and vice versa. In this section we empirically test for the proration method used at the Swedish universities, by following the method outlined by McDowell and Smith (1992).

A.1 Model of no proration

The first model specifies the probability of appointment to associate professor for researcher i in year t:

$$promotion_{it} = \delta_1 solo_{it} + \delta_2 ca_{it} + \delta_3 (solo_{it} \times ca_{it}) + Z_i'\phi + \varepsilon_i \tag{14}$$

where $promotion_{it}$ is equal to 1 if promotion occurs for researcher i in year t, $solo_{it}$ is accumulated publication score for solo-authored papers for researcher i in a given year t, ca_{it} accumulated publication score for co-authored papers for researcher i in a given year t and Z_i' is a vector including author characteristics such as gender, field, cohort and academic affiliation for researcher i. The coefficient of interest is δ_3. If we can reject that $\delta_3 = 0$, then a solo-authored paper is not equated with a co-authored paper in promotion decisions. If we are able to reject this hypothesis, the departments do not use no proration.

A.2 Model of strict proration

The second model specifies the probability of appointment to associate professor for researcher i in year t:

$$promotion_{it} = \delta_1 solo_{it} + \delta_2 ca/n_{it} + \delta_3 (solo_{it} \times ca/n_{it}) + Z_i'\phi + \varepsilon_i \tag{15}$$

where $promotion_{it}$ is equal to 1 if promotion occurs for researcher i in year t, $solo/n_{it}$ is accumulated publication score divided by number of authors for solo-authored papers for researcher i in a given year t, ca_{it} accumulated publication score for co-authored papers divided by number of authors for researcher i in a given year t and Z_i' is a vector including author characteristics such as gender, field, cohort and academic affiliation for researcher i. The coefficient of interest is δ_3. If we can reject that $\delta_3 = 0$, then a solo-authored paper is not equated with a co-authored paper that is strictly adjusted for the number of authors (n) in promotion decisions. If we are able to reject this hypothesis, the departments do not use strict proration.

A.3 Results from models of proration of author credits

Table 29: Models of no and strict proration

	(1) Associate professor *no proration*	(2) Associate professor *strict proration*
Solo-authored	0.0692**	0.0747**
	(0.0311)	(0.0311)
Co-authored	0.0574***	0.148***
	(0.0105)	(0.0270)
Solo-authored × Co-authored	-0.00151	-0.00506**
	(0.00104)	(0.00217)
Gender	Yes	Yes
Cohort	Yes	Yes
Field	Yes	Yes
Years since PhD	Yes	Yes
Academic affiliation	Yes	Yes
Observations	3,266	3,266

*Notes: This table presents the estimations of models (14) and (15) in Appendix A using discrete-time duration analysis with a proportional hazards assumption—using complementary log-log estimation. For definitions of covariates—see Table 4. Publications are weighted according to the AIS(econ) measure—see Table 9. The number of observations is the number of researcher-years. Standard errors are clustered by researcher and reported in parentheses. Significance levels are reported as *** p<0.01, ** p<0.05 and * p<0.1.*

As shown in model (1) in Table 29, the hypothesis that the score for a solo-authored paper is equated with the score for a co-authored paper cannot be rejected. The implication is that we cannot reject the notion that the departments use *no proration* in their promotion decision. We can however reject the hypothesis that the score for a solo-authored paper is equated with the score for a co-authored paper linearly adjusted for number of authors as seen in model (2). This means that we can reject the notion that the departments use *strict proration*. The result is aligned with the studies by McDowell and Smith (1992), Ellison (2013) and Liebowitz (2014), and the formal requirements for promotion that we have received from some of the universities in our sample. We therefore use *no proration* in our primary analysis on gender patterns in co-authoring, in order to stay close to the procedure used by the universities since that is most aligned with the incentive schemes that the researchers in our sample have when deciding whether to co-author or not.

Appendix B Data collection

Table 30: Coverage of doctoral graduates from Sweden

Swedish doctoral graduates	**Full sample**	**Male**	**Female**	**Female share**
1990–2016				
Researcher dataset	926	652	274	30%
Data from Statistics Sweden	1121	805	316	28%
Identification ratio	83%	81%	87%	
1990–1994				
Researcher dataset	71	55	16	23%
Data from Statistics Sweden	97	81	16	16%
Identification ratio	73%	68%	100%	
1995–1999				
Researcher dataset	126	101	25	20%
Data from Statistics Sweden	182	155	27	15%
Identification ratio	69%	65%	93%	
2000–2004				
Researcher dataset	192	150	42	22%
Data from Statistics Sweden	238	179	59	25%
Identification ratio	81%	84%	71%	
2005–2009				
Researcher dataset	223	154	69	31%
Data from Statistics Sweden	267	185	82	31%
Identification ratio	84%	83%	84%	
2010–2016				
Researcher dataset	314	192	122	39%
Data from Statistics Sweden	337	205	132	39%
Identification ratio	93%	94%	92%	

Table 30 compares the number of researchers in the researcher dataset with the data on doctoral graduates provided by Statistics Sweden, categorised into five-year periods (with the exception of the last period, which stretches from 2010 to 2016). There are several factors explaining the deviations between our researcher dataset and the data from Statistics Sweden, the most common being that we have not been able to locate the researcher. In some cases, the researchers have wished not to participate and in others, we lack information on crucial variables, e.g. time for promotion.

Appendix C Duration analysis: statistics and tests

Table 31: Sample statistics—associate professor

	Full sample	Male	Female	Female share
Time at risk	3,266	2,355	911	39%
Promotion rate	0.066	0.073	0.047	64%
Number of researchers	565	400	165	41%
Time to promotion				
First quartile	7	6	7	117%
Second quartile	9	8	12	150%
Third quartile	13	12	14	117%

Notes: The time at risk is the number of researcher-years, namely one observation is one researcher in the risk set for promotion for a specific year. The promotion rate is the average likelihood of promotion to occur for all researchers and all years employed in academia. Time to promotion is the number of years until promotion divided into quartiles. The female share is the duration for female researchers divided by the duration for male.

Table 32: Sample statistics—full professor

	Full sample	Male	Female	Female share
Time at risk	2,489	2,003	486	24%
Promotion rate	0.0361	0.040	0.019	48%
Number of researchers	215	173	42	24%
Time to promotion				
First quartile	12	11	15	136%
Second quartile	15	14	18	129%
Third quartile	.	.	.	.

Notes: The time at risk is the number of researcher-years, namely one observation is one researcher in the risk set for promotion for a specific year. The promotion rate is the average likelihood of promotion to occur for all researchers and all years employed in academia. Time to promotion is the number of years from doctoral degree to promotion to full professor divided into quartiles. Only associate professors are included. The female share is the duration for female researchers divided by the duration for male. The last percentile cannot be estimated since the time to promotion can only be estimated for completed 'survival' times.

Table 33: Wilcoxon (Breslow) test for equality of duration functions

	Full sample	Male	Female
Events observed	215	172	43
Events expected	215.00	157.38	57.62
Sum of ranks	0	3,844	–3,844
chi2(1) = 6.89			
Pr>chi2 = 0.0087			

Notes: The Wilcoxon (Breslow) test is a rank test in order to test the equality of the duration curves. It is similar to the log-rank test but puts more weight to earlier years when more researchers are at risk—before they either are promoted or censored. This weighting scheme may however be problematic if there are differences in censoring patterns across gender. For this reason we also use the Peto-Peto-Prentice test, see Table 34. We can reject the hypothesis of equality of duration curves for men and women according to the Wilcoxon (Breslow) test.

Table 34: Peto–Peto–Prentice test for equality of duration functions

	Full sample	Male	Female
Events observed	215	172	43
Events expected	215.00	157.38	57.62
Sum of ranks	0	10.562	–10.562
chi2(1) = 7.14			
Pr>chi2 = 0.0076			

Notes: The Peto-Peto-Prentice test is a rank test in order to test the equality of the duration curves. It is similar to the Wilcoxon (Breslow) test but is not as sensitive to differences in censoring patterns across gender. We can reject the hypothesis of equality of duration curves for men and women according to the Peto–Peto–Prentice test.

Table 35: Summary statistics on promotion to associate professor

	Male							Female						
Year	Number at risk	Number promoted	Net lost	Cumulative promoted	Standard errors	95% Confidence intervals		Number at risk	Number promoted	Net lost	Cumulative promoted	Standard errors	95% Confidence intervals	
1	400	0	25	0.0000	0.0000	.	.	165	0	9	0.0000	0.0000	.	.
2	375	0	24	0.0000	0.0000	.	.	156	0	21	0.0000	0.0000	.	.
3	351	3	30	0.0085	0.0049	0.0028	0.0263	135	1	21	0.0074	0.0074	0.0010	0.0514
4	318	12	33	0.0460	0.0116	0.0280	0.0751	113	2	16	0.0250	0.0143	0.0081	0.0757
5	273	20	21	0.1159	0.0185	0.0845	0.1578	95	3	11	0.0558	0.0223	0.0253	0.1207
6	232	34	14	0.2454	0.0259	0.1989	0.3006	81	10	12	0.1723	0.0397	0.1087	0.2671
7	184	29	21	0.3644	0.0298	0.3093	0.4259	59	6	9	0.2565	0.0483	0.1755	0.3658
8	134	25	12	0.4829	0.0323	0.4218	0.5481	44	6	4	0.3579	0.0567	0.2589	0.4805
9	97	20	11	0.5896	0.0333	0.5252	0.6551	34	2	4	0.3957	0.0593	0.2908	0.5219
10	66	9	5	0.6455	0.0336	0.5798	0.7108	28	1	5	0.4172	0.0610	0.3087	0.5460
11	52	6	7	0.6864	0.0336	0.6200	0.7509	22	2	5	0.4702	0.0660	0.3512	0.6066
12	39	7	6	0.7427	0.0336	0.6750	0.8059	15	4	2	0.6115	0.0775	0.4649	0.7605
13	26	2	6	0.7625	0.0338	0.6939	0.8255	9	2	0	0.6978	0.0808	0.5381	0.8434
14	18	1	4	0.7757	0.0344	0.7054	0.8393	7	3	1	0.8273	0.0730	0.6658	0.9401
15	13	0	2	0.7757	0.0344	0.7054	0.8393	3	1	0	0.8849	0.0676	0.7189	0.9749

Table 36: Summary statistics on promotion to full professor

	Male							Female						
Year	Number at risk	Number promoted	Net lost	Cumulative promoted	Standard errors	95% Confidence intervals		Number at risk	Number promoted	Net lost	Cumulative promoted	Standard errors	95% Confidence intervals	
1	139	0	-9	0.0000	.	.	.	34	0	-2	0.0000	.	.	.
2	148	0	-6	0.0000	.	.	.	36	0	-3	0.0000	.	.	.
4	154	0	-2	0.0000	.	.	.	39	0	-1	0.0000	.	.	.
5	156	2	-4	0.0128	0.0090	0.0032	0.0503	40	1	0	0.0250	0.0247	0.0036	0.1645
6	158	1	-2	0.0191	0.0109	0.0062	0.0579	39	0	-1	0.0250	0.0247	0.0036	0.1645
7	159	4	2	0.0437	0.0162	0.0211	0.0896	40	1	2	0.0494	0.0340	0.0126	0.1833
8	153	5	7	0.0750	0.0208	0.0433	0.1283	37	1	4	0.0751	0.0417	0.0248	0.2151
9	141	9	13	0.1340	0.0273	0.0895	0.1982	32	0	4	0.0751	0.0417	0.0248	0.2151
10	119	11	10	0.2141	0.0338	0.1562	0.2894	28	1	5	0.1081	0.0517	0.0415	0.2655
11	98	5	1	0.2542	0.0365	0.1906	0.3342	22	0	3	0.1081	0.0517	0.0415	0.2655
12	92	16	4	0.3839	0.0422	0.3073	0.4721	19	0	1	0.1081	0.0517	0.0415	0.2655
13	72	9	2	0.4609	0.0440	0.3793	0.5509	18	2	-1	0.2072	0.0805	0.0939	0.4213
14	61	9	6	0.5404	0.0448	0.4556	0.6299	17	0	2	0.2072	0.0805	0.0939	0.4213
15	46	1	8	0.5504	0.0449	0.4651	0.6399	15	1	3	0.2601	0.0908	0.1267	0.4880
16	37	3	7	0.5869	0.0460	0.4988	0.6774	11	0	3	0.2601	0.0908	0.1267	0.4880
17	27	2	1	0.6175	0.0474	0.5260	0.7098	8	0	3	0.2601	0.0908	0.1267	0.4880
18	24	1	4	0.6334	0.0480	0.5403	0.7264	5	2	1	0.5560	0.1710	0.2742	0.8722
19	19	1	7	0.6527	0.0492	0.5567	0.7472	2	0	1	0.5560	0.1710	0.2742	0.8722

Table 37: Summary statistics on leaving Swedish academia before appointment to associate professor

	Male							Female						
Year	Number at risk	Number left	Net lost	Cumulative left	Standard errors	95% Confidence intervals		Number at risk	Number left	Net lost	Cumulative left	Standard errors	95% Confidence intervals	
1	400	1	24	0.0025	0.0025	0.0004	0.0176	165	0	9	0.0000	0.0000	.	.
2	375	12	12	0.0344	0.0094	0.0201	0.0585	156	2	19	0.0128	0.0090	0.0032	0.0503
3	351	11	22	0.0647	0.0128	0.0438	0.0950	135	7	15	0.0640	0.0207	0.0338	0.1195
4	318	14	31	0.1059	0.0163	0.0781	0.1427	113	4	14	0.0971	0.0257	0.0574	0.1619
5	273	10	31	0.1386	0.0187	0.1061	0.1800	95	5	9	0.1447	0.0320	0.0931	0.2210
6	232	6	42	0.1609	0.0203	0.1253	0.2053	81	2	20	0.1658	0.0345	0.1094	0.2468
7	184	7	43	0.1928	0.0228	0.1524	0.2423	59	3	12	0.2082	0.0405	0.1409	0.3014
8	134	5	32	0.2229	0.0256	0.1773	0.2782	44	2	8	0.2442	0.0460	0.1671	0.3486
9	97	7	24	0.2790	0.0314	0.2228	0.3459	34	2	4	0.2886	0.0529	0.1990	0.4071
10	66	2	12	0.3009	0.0340	0.2398	0.3732	28	2	4	0.3395	0.0601	0.2364	0.4715
11	52	3	10	0.3412	0.0392	0.2706	0.4241	22	2	5	0.3995	0.0680	0.2811	0.5453
12	39	1	12	0.3581	0.0417	0.2830	0.4461	15	0	6	0.3995	0.0680	0.2811	0.5453
13	26	1	7	0.3828	0.0468	0.2985	0.4814	9	2	0	0.5330	0.0986	0.3573	0.7305
14	18	0	5	0.3828	0.0468	0.2985	0.4814	7	0	4	0.5330	0.0986	0.3573	0.7305
15	13	0	2	0.3828	0.0468	0.2985	0.4814	3	0	1	0.5330	0.0986	0.3573	0.7305

Appendix D Measures of publication merits

Table 38: Publications and co-authorship on promotion—using RePEc

	(1) Associate professor	(2) Associate professor	(3) Associate professor	(4) Associate professor	(5) Associate professor
Female	-0.216	-0.228	-0.345*	-0.492*	-0.477*
	(0.181)	(0.182)	(0.191)	(0.260)	(0.259)
Publications	0.00553***				
	(0.000552)				
Solo-authored		0.00662***	0.00617***	0.00623***	0.00574***
		(0.00150)	(0.00144)	(0.00149)	(0.00146)
Co-authored				0.00504***	
				(0.000732)	
Co-authored single			0.00438***		0.00476***
			(0.000771)		(0.000806)
Co-authored mixed			0.00701***		0.00568**
			(0.00109)		(0.00222)
Female × Solo-authored				0.00692*	0.00741*
				(0.00383)	(0.00449)
Female × Co-authored				0.00121	
				(0.00136)	
Female × Co-authored single					-0.0106*
					(0.00577)
Female × Co-authored mixed					0.00412
					(0.00271)
Cohort	Yes	Yes	Yes	Yes	Yes
Field	Yes	Yes	Yes	Yes	Yes
Years since PhD	Yes	Yes	Yes	Yes	Yes
Academic affiliation	Yes	Yes	Yes	Yes	Yes
Observations	3,266	3,266	3,266	3,266	3,266

*Notes: This table presents the estimations of models (2), (3) and (4) in Section 7.1 using discrete-time duration analysis with a proportional hazards assumption—using complementary log-log estimation. For definitions of covariates—see Table 4. Publications are weighted according to the RePEc measure—see Table 9. The number of observations is the number of researcher-years. Standard errors are clustered by researcher and reported in parentheses. Significance levels are reported as *** p<0.01, ** p<0.05 and * p<0.1.*

Table 39: Publications and co-authorship on promotion—using AIS

	(1) Associate professor	(2) Associate professor	(3) Associate professor	(4) Associate professor	(5) Associate professor
Female	-0.252	-0.217	-0.154	-0.715***	-0.682***
	(0.184)	(0.180)	(0.181)	(0.233)	(0.228)
Publications	0.0453***				
	(0.00737)				
Solo-authored		0.0758***	0.0706**	0.0705**	0.0605**
		(0.0281)	(0.0281)	(0.0278)	(0.0273)
Co-authored		0.0397***		0.0388***	
		(0.00804)		(0.0119)	
Co-authored single			0.0473***		0.0511***
			(0.0105)		(0.00872)
Co-authored mixed			0.0307***		-0.00256
			(0.00962)		(0.0337)
Female × Solo-authored				0.323***	0.292***
				(0.0777)	(0.0897)
Female × Co-authored				0.00899	
				(0.0139)	
Female × Co-authored single					0.0106
					(0.0930)
Female × Co-authored mixed					0.0478
					(0.0352)
Cohort	Yes	Yes	Yes	Yes	Yes
Field	Yes	Yes	Yes	Yes	Yes
Years since PhD	Yes	Yes	Yes	Yes	Yes
Academic affiliation	Yes	Yes	Yes	Yes	Yes
Observations	3,266	3,266	3,266	3,266	3,266

*Notes: This table presents the estimations of models (2), (3) and (4) in Section 7.1 using discrete-time duration analysis with a proportional hazards assumption—using complementary log-log estimation. For definitions of covariates—see Table 4. Publications are weighted according to the AIS measure—see Table 9. The number of observations is the number of researcher-years. Standard errors are clustered by researcher and reported in parentheses. Significance levels are reported as *** p<0.01, ** p<0.05 and * p<0.1.*

Table 40: Publications and co-authorship on promotion—using AIS(econ)/n

	(1) Associate professor	(2) Associate professor	(3) Associate professor	(4) Associate professor	(5) Associate professor
Female	-0.282	-0.264	-0.366**	-0.431*	-0.419*
	(0.178)	(0.182)	(0.187)	(0.224)	(0.215)
Publications	0.0671***				
	(0.0209)				
Solo-authored		0.0374	0.0315	0.0345	0.0285
		(0.0253)	(0.0232)	(0.0249)	(0.0227)
Co-authored		0.147***		0.146***	
		(0.0243)		(0.0245)	
Co-authored single			0.117***		0.119***
			(0.0204)		(0.0207)
Co-authored mixed			0.199**		0.244**
			(0.0827)		(0.113)
Female × Solo-authored				0.197**	0.194*
				(0.0993)	(0.108)
Female × Co-authored				0.00507	
				(0.0967)	
Female × Co-authored single					-0.120
					(0.129)
Female × Co-authored mixed					-0.0858
					(0.153)
Cohort	Yes	Yes	Yes	Yes	Yes
Field	Yes	Yes	Yes	Yes	Yes
Years since PhD	Yes	Yes	Yes	Yes	Yes
Academic affiliation	Yes	Yes	Yes	Yes	Yes
Observations	3,266	3,266	3,266	3,266	3,266

*Notes: This table presents the estimations of models (2), (3) and (4) in Section 7.1 using discrete-time duration analysis with a proportional hazards assumption—using complementary log-log estimation. For definitions of covariates—see Table 4. Publications are weighted according to the RePEc measure—see Table 9. The number of observations is the number of researcher-years. Standard errors are clustered by researcher and reported in parentheses. Significance levels are reported as *** p<0.01, ** p<0.05 and * p<0.1.*

Table 41: Comparing measures of publication merits

	(1) Associate professor *AIS*	(2) Associate professor *AIS/n*	(3) Associate professor *AIS(econ)*	(4) Associate professor *AIS(econ)/n*	(5) Associate professor *RePEc*	(6) Associate professor *RePEc/n*
Female	-0.252	-0.194	-0.252	-0.282	-0.216	-0.217
	(0.184)	(0.179)	(0.179)	(0.178)	(0.181)	(0.178)
Publications	0.0453***	0.0863***	0.0535***	0.0671***	0.00553***	0.00801***
	(0.00737)	(0.0214)	(0.0101)	(0.0209)	(0.000552)	(0.00114)
Cohort	Yes	Yes	Yes	Yes	Yes	Yes
Field	Yes	Yes	Yes	Yes	Yes	Yes
Years since PhD	Yes	Yes	Yes	Yes	Yes	Yes
Academic affiliation	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,266	3,266	3,266	3,266	3,266	3,266

*Notes: This table presents the estimations of models (2) in Section 7.1 using discrete-time duration analysis with a proportional hazards assumption—using complementary log-log estimation. For definitions of covariates—see Table 4. Publications are weighted according to the measures outlined in Table 9. The number of observations is the number of researcher-years. Standard errors are clustered by researcher and reported in parentheses. Significance levels are reported as *** p<0.01, ** p<0.05 and * p<0.1.*