Fast track or failure

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Fast track or failure: A study of the graduation and dropout rates of Ph.D. students in economics

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Abstract

We analyze the production process of Ph.Ds in economics in the Netherlands. Our empirical results are consistent with the incentives that the actors in this process face. Universities succeed in making students who are unlikely to graduate or will need a long time to graduate quit the program. We …nd that supervisors who are active researchers have higher graduation and lower dropout rates. However, this e¤ect is due to the fact that supervisors with a good research record have better students. There is no evidence of an independent e¤ect of having a supervisor who is an active researcher.

Keywords: Educational economics, productivity

1 Introduction

This paper is a contribution to the small empirical literature on the Ph.D. production process. As is common in that literature, we relate the input of students to the output of graduates. This relationship is determined by the attrition of students from the graduate program and the time that students who stay in the program need to complete their doctoral thesis. Attrition and completion are affected by choices made by the students. However, the thesis supervisor, the department, and even the university are also actors in the Ph.D. production process. Breneman (1976) proposed a model for the decisions of the actors, given their preferences and the restrictions that they face. We adapt his model that was formulated for the US, to the conditions in a small European country, c.q. the Netherlands.

Most of the empirical literature has focused on differences in attrition and completion rates between fields and on the effect of financial support on these rates. Because we concentrate on a particular discipline, and all doctoral students essentially have the same generous financial support, we consider other factors. We show that in the Netherlands students who are supervised by active researchers have a lower attrition rate and a higher completion rate. However, this is not due to the quality of the supervision provided by active researchers, but to the higher quality of the students that they attract and select. This result is consistent with the incentives (or the lack thereof) faced by supervisors. Hence, our results are in line with those of Breneman (1976) who concludes that the actors in the Ph.D. production process are sensitive to incentives.

Our study provides an interesting contrast to studies of Ph.D. programs in Anglosaxon countries which are the only programs that have been the subject of empirical research. We give a brief survey of that research. Bowen and Rudenstine (1992) study graduate students in six fields at ten major research universities in the US over a 25-year period. They show that completion rates depend on the type of financial support that the students receive. Booth and Satchell (1995) analyze retrospective information, collected in 1986, on 500 students who entered (in 1980) a British Ph.D. program in the social sciences, arts and languages, or science and engineering. They …nd that neither …nancial support from the research council, nor student quality, as measured by undergraduate scores, have a signi…cant e¤ect on the completion rate. A variable that does in‡uence thesis completion is the subject area, with arts and languages having lower and science and engineering having higher completion rates than the social sciences[1]. Ehrenberg and Mavros (1995) use data on entrants during 1962-1986 in Cornell University's doctoral programs in economics, English, physics and mathematics. Following Breneman (1976) they consider the e¤ect of labor market conditions on the attrition and completion rates. Ehrenberg and Mavros …nd that completion rates decrease with time spent as a teaching assistant. Dropout rates are lower, if, at the start of the program, a Ph.D. student had a master's degree or was not a US citizen or permanent resident. Student quality and labor market conditions do not have a signi…cant e¤ect on the completion and dropout rates. The authors note that this may be due to the inadequacy of the student ability measures and the labor market indicators.

We use data on Ph.D. students in economics at three Dutch universities who have a joint doctoral program. The data are obtained from administrative …les, so that we only have a small number of student and supervisor characteristics.

Beside the substantial contributions to the understanding of the Ph.D. production process, this paper makes two econometric contributions. First, we show how to estimate the risk of an outcome, even if that outcome is never observed. Second, we test for endogeneity of a regressor in a rather complex competing risks model.

The paper is organized as follows. In section 2 we discuss the Ph.D. program in economics in the Netherlands and the incentives that students, supervisors and departments face in this program. The data that we use in our analysis are described in section 3. Section 4 discusses the statistical model and section 5 presents the estimation results. Section 6 discusses some implications of our results.

[1] Again this is consistent with the Breneman (1976) model.

2 The Ph.D. production process

The graduate program in the Netherlands has undergone a major overhaul in the late 1980s. Before the overhaul universities recruited junior faculty from the ranks of the MA graduates. Undergraduate education in the Netherlands is highly specialized, and at the time an undergraduate degree was about equivalent to an MA degree in the US. In addition to teaching, the junior faculty worked on their dissertation which they eventually did or did not complete. The supervision of this dissertation research was rather loosely organized. Full professors had an obligation to provide guidance, but the lack of a deadline did not ensure a timely completion of the thesis. Non-completion was not a reason for denial of tenure, although it precluded promotion to senior faculty positions.

In the 1980s higher education was restructured. First, the duration of (still specialized) undergraduate programs was limited to 4 years. As a consequence, the undergraduate degree was no longer a su¢ cient preparation for independent research. For that reason, a graduate program was established that in addition to the opportunity of research under the supervision of a (full) professor, provided for additional education and training. In the new system, the Ph.D. student or AIO (Assistent In Opleiding) has a four year contract. In these four years he/she attends classes that are a preparation for independent research. The education component of the program lasts about one year[2]. Unlike the US there is no qualifying exam after this year. For the rest of the four years the AIO works under supervision on a Ph.D. thesis. The topic of the thesis is provided by the supervising professor. Indeed, the order is that a professor proposes a project, and if he or she obtains funding, then the search for a student who will work on this project starts.

The AIO receives a salary that increases during the contract. The salary in the fourth year is about 10% below the starting salary of an assistant professor.

[2] The three universities that provided the data, have a joint training program. The organization of the education component di¤ers between …elds and universities.

Although the AIO would make more if he or she found a non-research job, in particular in the …rst year, the foregone income during the four year contract is not very large[3]. The teaching load for an AIO is very small[4]. Equipment and even travel expenses to visit conferences are paid for by the department. The AIO is an employee with full bene…ts which include medical insurance.

A Ph.D. degree is required for academic jobs. Usually a new Ph.D. applies for a post-doc position. If he or she does well, and remains interested in an academic job, he or she may …nd a position as assistant or associate professor (depending on experience and research output). The supervisor is usually important during the …rst years of the academic career. Not all graduates are interested in or are able to …nd an academic job. There is a strong demand for Ph.D. economists in the government sector and in research institutes and consulting …rms. Of the students that completed their thesis 55% found a …rst job in academia and the rest found a job elsewhere. There is no unemployment among new Ph.Ds. The non-academic jobs that are taken by new Ph.Ds usually have a research component, and employers now require a doctoral degree for such jobs. Non-academic employers value the research skills of the new Ph.Ds and not so much the specialized knowledge on the topic of the thesis. Although we do not have much information on the dropouts, we have the impression that they …nd jobs that are similar to those found by students with only an undergraduate degree.

If the AIO does not complete the thesis in the four years of the contract, then he or she is entitled to unemployment bene…ts for a maximum period of 18 months[5] If the Ph.D. student does not succeed in defending his/her thesis within four years, he/she has to …nish the thesis while being unemployed or while working in a regular job. Most students do not submit their thesis during

[3] We estimate that the AIO could make 30% more if he/she chose not to write a doctoral thesis.

[4] There is some variation, but in general it amounts to one course during the four year contract.

[5] This is true for the students considered in this paper. Recently, the students only receive public assistance which is much less. The students have to search for a job.

the four years of the contract (see figure 1).

In this study we restrict attention to three Dutch universities that have a joint Ph.D. program in economics. Economics should be interpreted in a broad sense, as econometrics, operations research, and business economics are also covered by this program.

The allocation of AIOs over professors is done at the departmental level. If a number of AIO positions is vacant, there is a competition between potential supervisors who write research proposals. After an internal selection procedure some potential supervisors receive permission to hire a graduate student for a period of four years. The quality of the proposal and the track record of the supervisor are important criteria, but an equal distribution over professors is also considered desirable. Only in exceptional cases does any supervisor have more than two AIOs. If the students of a supervisor drop out of the program, the committee may decide not to allocate any AIOs to that professor. Some additional AIO positions are financed by the Netherlands Science Foundation (NWO). These positions are awarded in a national competition in which researchers propose projects. The quality of the proposal and the research record of the prospective supervisor are the main criteria in the selection of proposals that will be funded. The funding is only for the Ph.D. student and does not include direct support for the supervisor. Because AIOs have a regular job, the recruitment of new graduate students follows roughly the same procedure as the recruitment of new faculty. To attract candidates usually an advertisement is placed in a national newspaper or magazine. Often candidates are suggested by colleagues, or recent graduates of the recruiting university are approached. Candidates are screened by a committee and if they meet minimum requirements, the supervisor chooses among the candidates. The supervisor both selects and guides the student during the thesis research. The selection process of the externally funded AIO is the same as that of a university funded Ph.D. student.

For each doctorate the university receives 150,000 guilders (about $ 60,000). Part of that amount is given to the department where the doctorate is awarded[6].

[6] The fraction differs between universities

In most universities, none of it reaches the supervisor. The university is responsible for the unemployment benefits that the student receives if he or she does not submit a thesis in the contract period and he/she has not found a job (yet). Salaries of professors are independent of the number of graduate students that they supervise (or have supervised). There is no clear ranking between Dutch economics departments and the potential of a salary increase by moving is limited by a payscale that applies to professors. The lack of a ranking means that there are no more and less prestigious placements of new Ph.Ds.

It should be obvious that the incentives for professors to provide quality supervision are not very large. If the student works on a project that has the interest of the supervisor, the student may expect that the supervisor will be involved. Given the lack of reward, the supervisor prefers that the student will do the work on his/her own. Good students need less guidance and for that reason the supervisor wants to select the best student for the project. Good students have an incentive to apply for a position with a well-known professor who can help in the early stages of the career. As we shall see the selection of students and the amount of supervision are consistent with these incentives.

It is interesting to compare the incentives in the US and Dutch Ph.D. programs. Breneman (1976) notes that in the US the structure of the labor market has a strong effect on the completion rates. In disciplines with a strong demand for Ph.Ds outside the academic sector, students have no incentive to delay the submission of their thesis. In disciplines where many candidates compete for few academic positions and there is no demand outside academia, the relative quality of the thesis is very important and students may want to work on it for a longer period. Moreover, in disciplines with a strong demand salaries will be higher, and so are the costs of being in the program. Because we have data on just one field, we can not use the differences between disciplines to investigate the relevance of this effect in the Netherlands. As noted, the demand for Ph.D. economists was strong in the period covered by our data, and the labor market conditions do not provide an incentive to delay the submission of the thesis. Because the compensation of AIOs increases over the contract period, the cost of being in the program decreases. Hence, we expect that projects that are …nished on time will lead to graduation in the …fth year after entrance[7]. Because students can complete their thesis while receiving UI bene…ts[8] for up to 1.5 years or in their spare time while working, there is a strong incentive to graduate within 6 years.

In the US professors derive prestige from the placement of their graduate students at highly ranked universities. Moreover, the return to prestige is high, both for the individual professor and for the department that may be able to secure additional resources from the university administration. In the Dutch system in which there is no clear ranking of departments and in which the return to prestige is much lower, placement of graduate students is less important. Hence supervisors have no incentive to set high standards that will force out students who cannot be placed in a high ranking department. Note also that contrary to the US the university and department are rewarded for the output of Ph.Ds and not on the basis of the number of students in the program. Moreover, the enrollment is …xed and departments cannot expand their graduate program to attract additional resources. The individual incentives in the Dutch system should minimize the attrition from the program. The department has an incentive to force out students who will not be able to meet the minimum standards for a thesis or will require UI bene…ts to do so. Dropouts do essentially quit from the program and this may happen at any time. Hence we do not expect variation in the attrition rate during the time in the program.

3 Data

From the administrative …les of three Dutch universities we derived information concerning characteristics of the Ph.D. students and their supervisors. In our

[7] Due to administrative delays, the graduation date is about 6 months after the date of submission. Approval is obtained within 6 weeks after the date of submission.

[8] The bene…ts are about the same as the salary received in the third year.

analysis we use information on 250 Ph.D. students who started before January 1, 1993. The closing date of our administrative …les is January 1, 1998. After removing Ph.D. students who had a foreign[9] undergraduate education or for whom not all relevant information could be extracted from the …les, we have a sample of 200 Ph.D. students, who all have been exposed to the 'risks' of completion or dropout for more than 5 years.

Figure 1 presents the cumulative completion and dropout probabilities in the program as a function of time in the program[10]. No Ph.D. student defends his or her thesis within three years, while a few students graduate in three to four years. Most students …nish in …ve to seven years after the start, and after seven years the fraction remains almost constant, i.e. there are few graduations after seven years. Figure 1 also shows that already after a few months some Ph.D. students drop out. The attrition continues until the fourth year, and after that all students seem to stay on. This is due to the fact that dropout after the end of the contract is not registered, and students have little incentive to report that they will not …nish their thesis.

For each Ph.D. student in the sample the administrative …les contain information on gender, time to undergraduate degree, undergraduate degree at the university that employs the supervisor (or not), …eld of undergraduate degree, supervisor is a research fellow (or not). Although all undergraduate programs have a duration of four years, students may receive …nancial support up to 5.5 years. Because in The Netherlands it is possible to fail (even repeatedly), only students that pass (most of the) exams on the …rst occasion succeed in ful…lling the degree requirements in four years. Hence an indicator of the event that the degree was obtained in less than …ve years is an indicator of the ability and motivation of the student. If the undergraduate degree was granted by the

[9] We excluded students with a foreign undergraduate degree, because foreign (and Dutch) Ph.D. applicants are not subjected to a standardized entrance test as in the US. Dutch undergraduate programs in a particular …eld are of comparable quality. At the time this was a small fraction of the starting graduate students. The number has grown substantially after 1998.

[10] Note that the dropout probabilities are on the right axis and read top-down.

same university that employs the supervisor, the supervisor may have inside information on the quality of the student. Moreover, the student may have started on the research project as an undergraduate. Both the better assessment and a possible headstart can have a positive effect on the thesis completion rate. Although undergraduate programs in a particular field are comparable between universities, students with an undergraduate degree in econometrics or mathematics are considered to be better prepared for the graduate program in economics. Although we have no detailed information on the track record of supervisors, we know whether they are a research fellow or not. Research fellows are chosen on the basis of their track record. Periodically, a joint committee of the three universities collects a list of publications of the faculty. If the quantity and quality of the publications meets a standard, the faculty member becomes a research fellow. Being a research fellow is mainly a honorary distinction. Research fellows may be better supervisors, but as we noted, they may also select/attract better students. Appendix A gives the definition of all the variables.

For a first impression of the effects of the explanatory variables we calculated the probability of completion or dropout after 5 years, shown in Table 1. The last column summarizes the composition of our sample. One in five students is female, one in three has finished the undergraduate study in less than 5 years, one in three has a mathematics or econometrics undergraduate degree, one in four has a degree from the university that employs their supervisor, two in five have a supervisor who is a research fellow.

The bottom row shows that 43% of the students finished their Ph.D. within 5 years, 20% dropped out and 37% had not completed their dissertation yet. The columns of Table 1 show the 5 year completion, dropout, and censored fractions for subgroups. Men, students who received their undergraduate degree in less than five years, students with an econometrics/mathematics degree, students who graduated from the supervisor's university, and students who have a research fellow as supervisor, have a higher completion probability. Note that the apparent negative correlation between the completion and dropout probabilities is a statistical artifact. Only when we consider the underlying hazards, can we study the relation between the completion and dropout processes.

Figure 2 gives the cumulative completion and dropout probabilities for the subsamples of students who are supervised by a research fellow or not. After 6 years the cumulative completion probability for students with a research fellow as supervisor is 81%, while it is 43% for the other students. After 9 years the cumulative completion probabilities are 85% and 50%, respectively. The di¤erence in dropout probability is also substantial. After two years the students with a research fellow as supervisor have a dropout probability of 1%, while this is 14% for the other students. After four years the probabilities are 3% and 22%.

In Table 2 we contrast the characteristics of students who are and who are not supervised by a research fellow. The main di¤erences are that research fellows prefer students who have a quantitative background and that they are more successful in attracting external (NWO) funding. In the sequel we will use the latter distinction to test whether supervision by a research fellow speeds up completion and prevents dropout.

4 Statistical model

Our statistical model is similar to the competing risks model used by Ehrenberg and Mavros (1995). We assume that a Ph.D.-student faces two 'risks': one of completing the Ph.D., the other of dropping out. We investigate several alternative speci…cations. We start with a competing risks model in which, conditionally on the observed regressors, both transition rates are independent. Next, we allow for dependence between the risks by introducing unobserved di¤erences between the students. We consider only the simplest form of unobserved heterogeneity that allows us to check whether there is a negative relation between the unobservables in the dropout and completion rates.

The completion rate at elapsed duration t conditional on observed characteristics x[11], $\theta_c(t|x)$ has a proportional hazard specification:

$$\theta_c(t|x) = \exp(v_c + x'\beta_c + I'_{ct}\gamma_c) \qquad (1)$$

where β_c is a vector of regression coefficients. The coefficient v_c is a constant term. Duration dependence is specified as a step function: I_{ct} is a vector of indicator variables for the duration intervals that take value 1 on specified annual duration intervals and value 0 otherwise, and γ_c is a corresponding vector of coefficients. These coefficients give the relative change in the hazard in comparison to a reference interval (the interval 3-4 years). The last duration interval is the open interval 6+ years. Since there is no completion in the first three years, we set $\gamma_{c1} = \gamma_{c2} = \gamma_{c3} = -1$, so that the completion hazard is 0 during the period $0 - 3$ years. Note that these would also be the Maximum Likelihood Estimates (MLE) of these parameters.

The dropout rate at elapsed duration t conditional on observed characteristics x, $\theta_d(t|x)$ also has a proportional hazard specification:

$$\theta_d(t|x) = \exp(v_d + x'\beta_d + I'_{dt}\gamma_d) \qquad (2)$$

where β_d is a vector of regression coefficients and v_d is a constant term.

Again, duration dependence is specified as a step function: I_{dt} is a vector of indicator variables for the duration intervals. We assume that the hazard rate is constant during the period $0 - 4$ years, and again, be it at a different level, after 4 years.

The observations can be divided into three groups (remember that all students are followed for at least five years): dropouts during $[0; 3)$ (in that interval

[11] In addition to the variables presented in the Appendix we also use two university dummy variables to account for possible differences between the three universities. We are not allowed to report the coefficients of these two dummy variables.

the completion hazard is 0), dropouts or completions in $[3;4)$ (both outcomes are possible), and completions and right-censored observations during $[4;\infty)$. After four years dropout is not registered. By censoring all observations after 4 years, we conclude that the regression coefficients in the completion and dropout hazard and also the baseline hazard for both intensities during these years are identified. The identification of the baseline hazards for the completion and dropout rates after 4 years is more problematic, because we do not observe dropouts. The baseline hazard of the graduation intensity is identified, if we assume that the baseline hazard of dropout is constant after 4 years[12], at a level that may be different from that during $[0;4)$.

To allow for (conditional) dependence of the completion and dropout rates, we introduce unobserved differences between the students. In particular, we want to allow for the fact that students who have a low completion rate (for reasons not known to us), have a high dropout rate, and the other way around. The simplest specification that allows for this, distinguishes between two types of students with constants in the dropout and completion rates equal to $v_{d1}; v_{c1}$ and $v_{d2}; v_{c2}$ and with the fraction of type 1 students equal to p. Efficient dropout, as defined above, corresponds to (without loss of generality we assume $v_{d1} > v_{d2}$) $v_{c1} < v_{c2}$. The identification of the parameters is as before.

The parameters are estimated by maximum likelihood. The likelihood functions are given in Appendix B.

5 Estimation results

The estimation results are given in table 3. The first column shows the results for the competing risks model without unobserved heterogeneity. Students who have a degree from their supervisor's university have a significantly higher graduation rate. The same is true for students who obtained their undergraduate degree in less than five years. There is significant duration dependence in the completion rate with the rate being lowest in the fourth year, higher from 4 to 6

[12] Proof available upon request

years, and decreasing again after 6 years. In the dropout hazard the coefficient of research fellow is significantly different from zero at the 5% level. The effect is large. Students with a research fellow as supervisor have a dropout rate that is only 12% of the dropout rate of the other students. Female students also have a higher attrition rate (significant at the 10% level).

Note that the coefficients that are significantly different from 0 (10% level) in either hazard, except the study duration indicator, have opposite signs. Hence, students with characteristics that make them unlikely to finish their thesis on time leave the program.

The second column of table 3 shows the estimation results when we allow for two types of students. These types are not observed, but inferred from the data. While the difference in the completion rates of both groups is small, their dropout rates differ substantially. The group with the lower completion rate has the higher dropout rate and the group with the higher completion rate has a dropout rate that is not distinguishable from zero. Again the students who belong to the type that takes a long time to graduate leave the program. There are about as many lower and higher quality students. Note that all regression coefficients are somewhat larger if we allow for unobserved differences. In particular, the effect of having a research fellow as supervisor is now significant at the 10% level in the graduation hazard.

In the third and fourth column we consider the question whether research fellows are better at supervising Ph.D. students than non-fellows, or whether they are better at attracting able students. In other words, we decompose the large negative and highly significant effect of supervision by a research fellow on the attrition hazard and the smaller positive and marginally significant effect on the graduation hazard into a selection effect and a supervision effect. We use two estimation methods to decompose the effect: a test using an instrumental variable and selection on unobservable type.

We already noted (see table 2) that research fellows are more successful in obtaining external (NWO) funding for Ph.D. positions. The indicator of NWO funding is a potential instrumental variable that affects the probability that an

AIO is supervised by a research fellow, but this indicator should have no direct effect on the completion or dropout rate. The first condition can be verified by estimating a linear probability model for the research fellow indicator on the included explanatory variables in the model and the external funding indicator. The regression coefficient of the latter indicator is 0.40 (with robust standard error 0.13). The second condition can not be verified from the data, but it is likely to be satisfied given the similar nature of the national and university competition for projects and the fact that the selection of AIOs is independent of the type of funding. It may be that the national competition favors researchers with a strong track record, and one might suspect that the quality of the proposals in the national competition is higher. If a better proposal increases the completion and decreases the dropout rate, we would expect that the indicator of external funding has significantly positive and negative coefficients in the corresponding hazards. Because the potentially biased coefficients in column 2 are positive and negative, respectively, using the predicted value of the regression of the research fellow indicator on the explanatory variables and the NWO funding indicator as an instrumental variable would result in a positive and negative coefficient of the instrument in the completion and dropout hazards. The results reported in the third column of Table 3 show that the coefficient of the instrument is essentially zero in the dropout hazard and even reverses sign (but remains insignificant) in the graduation hazard. Hence, if NWO funded AIOs work on more promising projects, than the only explanation is that supervision by a research fellow has a negative effect on the completion and a positive effect on the dropout rate. From this we conclude with confidence that even if external funding is not a perfect instrument, the conclusion that the research fellow effects in column 2 of table 3 is a selection effect does not change.

Note that we use the instrument only to test for a zero research fellow effect. This corresponds to an Intention to Treat (ITT) test. Estimation of a nonzero effect is complicated, because the IV estimator for competing risks models has not been developed (Bijwaard and Ridder (2002) make a first attempt).

In the second estimation method, we concentrate on selection on unobservable type. In particular, we assume that the fraction p of students with (due to unobserved variables) a low dropout rate and a high completion rate differs between research fellows and non-fellows. Column 4 reports the estimates. Research fellows only supervise low attrition/high graduation rate students, whereas the fraction for non-research fellows is .56. Apparently, research fellows are better in attracting this type of students. This confirms the conclusion that the research fellow effect is a selection effect. Note that the model in column 4 fits even better than the model in column 2 (with the same number of parameters).

To illustrate the differences between the two types of graduate students and to indicate the importance of selection, we use the estimates of column 4 of Table 2 to compare the dropout and completion of the two types of students. For a male Ph.D. student, with an undergraduate degree in economics that was obtained in less than 5 years at the university of his supervisor, we calculate cumulative completion and dropout rates in case this student is a low attrition/high graduation rate type (type 1) and in case he is a high attrition/low graduation rate type (type 2). The results are shown in Table 4. After four years 25% of the type 1 students has graduated, while only 1% has dropped out. After five years the cumulative completion rate is 81%, after six years 97%. Columns three and four of Table 4 show the cumulative completion rates and dropout rates in case the student with the same observable characteristics is of type 2. Now, the completion rates are much lower and the dropout rate is substantially higher. After four years 26% of the type 2 students has dropped out, while only 3% has graduated. Even after eight years only 42% of the type 2 students has graduated. After 15 years 54% of the type 2 students has graduated while the remaining 43% has dropped out. This can be taken as the final outcome.

6 Conclusions

This paper presents an analysis of the production process of Ph.Ds in economics at three universities in the Netherlands. We find that students who are likely to take a long time to graduate, are also more likely to drop out. The university and the department succeed in making these students quit the program. However, this attrition occurs over the full four years of the contract and even after the end of the contract. It would be preferable to introduce a more stringent evaluation e.g. after one year. The current evaluation does not succeed in making the students who will not graduate or who will take a long time to graduate, leave the program.

Our estimates also show that students of supervisors who have been certified as active researchers graduate faster and have a higher probability of staying in the program. However, this is a pure selection effect because active researchers attract better students. Hence, the hypothesis that better researchers are also superior supervisors is rejected in our data. Again this is consistent with incentives that supervisors face: they do not derive much prestige from the placement of their students and even if they need less effort to give good supervision, they do not make this effort due to the lack of a reward. Because any supervisor has no more than two students at any time, the result can not be due to the fact that certified researchers have more students.

The quality of the supervision has been a major concern in the discussion of the Dutch Ph.D. system. Rick van der Ploeg who is a deputy minister and a former professor of economics, has argued that there is no incentive to provide quality supervision in the current system and that the quality of the dissertations is lower because of this (Van der Ploeg (1996)). He blames this on the assignment of students to professors at the start of the program. The students are captives of their supervisors. To improve the quality of the supervision he proposes that students who qualify for the Ph.D. program, select their supervisor. In this system supervisors who are perceived to provide low quality guidance, will not attract graduate students. Our results show that good students already chose supervisors with a better research record. These supervisors do not provide better supervision. However, they may be helpful in the initial stages of the graduate's career.

If the supply of Ph.D. candidates is not affected by the freedom of choice, and supervisors can refuse to supervise more students than they do in the old system, then nothing will change if the students chose their supervisor. The problem is more with the reward structure: supervisors do not benefit from high quality research by graduate students, except if these students perform part of the research agenda of their supervisor. To create a reward for the supervisor, the university could transfer a part of the $ 60,000 that it receives for each graduate to the supervisor, for instance as a research budget. The payment could be related to the quality of the thesis by making it dependent on the number and quality of publications derived from the thesis. This system will be biased towards the better researchers who attract the better students, but that can only be avoided by setting the standard for payment at a higher level for these supervisors.

Although our conclusions are specific to graduate education in the Netherlands, the results are relevant in much of continental Europe that has a similar Ph.D. program. The methodology is relevant in all countries, and in particular, our method to distinguish between the effect of structural features of the programs and the effect of selection into these programs.

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Appendix A: Definition of variables

Female: dummy variable with value 1 if the Ph.D. student is female and 0 if male.

Study < 5 years: dummy variable with value 1 if the undergraduate study took less than 5 years and 0 otherwise.

Home degree: dummy variable with value of 1 if the Ph.D. student has an undergraduate degree of the university of the supervisor and 0 otherwise.

Research fellow: dummy variable with value 1 if the Ph.D. student has a research fellow as supervisor and value 0 otherwise.

Econometrics: dummy variable with value 1 if the Ph.D. student has an undergraduate degree in econometrics or mathematics and 0 otherwise.

Duration until completion: period of time (in years) between entry in the Ph.D. and the date of the thesis defense.

Duration until dropout: period of time (in years) between entry in the Ph.D. program and the date that the Ph.D. student quitted the program.

Appendix B: Likelihood functions

The observations can be divided into three groups: dropouts during $[0;3)$, N_1 observations, dropouts or completions in $[3;4)$, N_2 observations, and completions and right-censored observations during $[4;\infty)$, N_3 observations.

The contributions to the loglikelihood of the observations in the first two groups are easily determined. In the third group we only observe completions. If a student drops out after 4 years, it will appear as if he or she is still in the program at the end of the observation period. Hence, the censored observations comprise of students who are still working on their thesis, at the time of censoring and of students who have dropped out after 4 years in the program, but before the time of censoring. These are non-overlapping groups, and the likelihood contribution is the sum of the probabilities of the corresponding events.

If $d = 1$ if the outcome is completion and $d = 0$ if it is dropout, and $c = 0$ if the duration is censored, then the loglikelihood is

$$
\begin{aligned}
\log L \quad = \quad & \sum_{i=1}^{N_1} \ln \left[\mu_d(t_i \mid x_i) e^{-\int_0^{t_i} \mu_d(s|x_i)ds} \right] + \\
+ \quad & \sum_{i=1}^{N_2} \ln \left[\mu_c(t_i \mid x_i)^{d_i} \mu_d(t_i \mid x_i)^{1-d_i} e^{-\int_0^{t_i} (\mu_c(s|x_i)+\mu_d(s|x_i))ds} \right] + \\
+ \quad & \sum_{i=1}^{N_3} c_i \ln \left[\mu_c(t_i \mid x_i) e^{-\int_0^{t_i} (\mu_c(s|x_i)+\mu_d(s|x_i))ds} \right] + \\
+ \quad & \sum_{i=1}^{N_3} (1-c_i) \ln \left[\int_4^{t_i} \mu_d(t \mid x_i) e^{-\int_0^{t} (\mu_c(s|x_i)+\mu_d(s|x_i))ds} dt \right. \\
+ \quad & \left. e^{-\int_0^{t_i} (\mu_c(s|x_i)+\mu_d(s|x_i))ds} \right]
\end{aligned}
$$

The loglikelihood with unobserved heterogeneity is (we denote integrals of the hazard rates by capital letters, and we use a subscript i to indicate dependence on x_i)

$$
\begin{aligned}
\log L &= \sum_{i=1}^{N_1} \ln \Big[p v_{d1} \mu_{di}(t_i) e^{-\Lambda_{di}(t_i) v_{d1}} + (1-p) v_{d2} \mu_{di}(t_i) e^{-\Lambda_{di}(t_i) v_{d1}} \Big] \\
&+ \sum_{i=1}^{N_2} \ln \Big[p (v_{d1}\mu_{di}(t_i))^{1-d_i} (v_{c1}\mu_{ci}(t_i))^{d_i} e^{-\Lambda_{di}(t_i) v_{d1} - \Lambda_{ci}(t_i) v_{c1}} + \\
&+ (1-p)(v_{d2}\mu_{di}(t_i))^{1-d_i} (v_{c2}\mu_{ci}(t_i))^{d_i} e^{-\Lambda_{di}(t_i) v_{d2} - \Lambda_{ci}(t_i) v_{c2}} \Big] + \\
&+ \sum_{i=1}^{N_3} c_i \ln \Big[p v_{c1} \mu_{ci}(t_i) e^{-\Lambda_{di}(t_i) v_{d1} - \Lambda_{ci}(t_i) v_{c1}} + \\
&+ (1-p) v_{c2} \mu_{ci}(t_i) e^{-\Lambda_{di}(t_i) v_{d2} - \Lambda_{ci}(t_i) v_{c2}} \Big] + \\
&+ \sum_{i=1}^{N_3} (1-c_i) \ln \Bigg[\int^{t_i} \Big\{ p v_{d1} \mu_{di}(t) e^{-\Lambda_{di}(t) v_{d1} - \Lambda_{ci}(t) v_{c1}} + \\
&+ (1-p) v_{d2} \mu_{di}(t) e^{-\Lambda_{di}(t) v_{d2} - \Lambda_{ci}(t) v_{c2}} \Big\} dt + \\
&+ p e^{-\Lambda_{di}(t_i) v_{d1} - \Lambda_{ci}(t_i) v_{c1}} + (1-p) e^{-\Lambda_{di}(t_i) v_{d2} - \Lambda_{ci}(t_i) v_{c2}} \Bigg]
\end{aligned}
$$

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Figure 1 Cumulative completion and dropout probabilities

Figure 2 Cumulative completion and dropout probabilities; research fellows and non-research fellows

Table 1 Fraction graduate, dropout and censored after 5 years and in sample (% of subgroup)

	After 5 years			Sample			
Variable	Grad.	Out	Cens.	Grad.	Out	Cens.	Total
Female	31	31	38	52	32	16	22
Male	47	17	36	69	18	13	78
Study < 5 years	54	20	26	66	20	14	33
Study ¸ 5 years	38	20	42	65	21	13	67
Econometrics	56	13	32	76	13	11	32
Other …eld	37	23	39	61	25	15	68
Home degree	50	18	32	69	19	12	59
Other university	33	23	44	60	24	16	41
Research fellow	53	5	42	88	5	6	39
Not fellow	37	30	34	51	31	18	61
Total	43	20	37	66	21	14	100

Table 2 Characteristics of students supervised by a research fellow (%)

	Research fellow	Not fellow	All
Female	21	23	22
Study < 5years	37	30	33
Econometrics	53	18	32
Home degree	58	60	59
External funding	13	3	7

Table 3 Maximum Likelihood Estimates (t-values)

Graduation hazard	Obs.	Unobs.	ITT	Unobs. +
Female	-0.07 (0.2)	-0.37 (1.0)	-0.05 (0.2)	-0.28 (0.8)
Study < 5 years	0.45 (2.0)	0.54 (1.9)	0.63 (2.4)	0.35 (1.5)
Econometrics	0.30 (1.3)	0.30 (1.0)	0.51 (2.3)	0.26 (1.0)
Home degree	0.45 (2.0)	0.62 (2.1)	0.44 (2.0)	0.51 (2.2)
Research fellow	0.30 (1.3)	0.58 (1.7)	-1.08 (1.1)	-
Duration dependence				
4-5 years	1.57 (6.3)	1.73 (6.0)	1.58 (6.3)	1.60 (6.4)
5-6 years	2.05 (6.7)	2.40 (5.1)	2.10 (6.5)	2.13 (7.0)
6+ years	1.57 (2.7)	2.01 (2.9)	1.45 (2.4)	1.58 (2.8)
v_{c1}	-2.61 (4.8)	-3.46 (3.8)	-2.19 (3.6)	-4.06 (3.4)
v_{c2}	-2.61 (4.8)	-2.28 (3.7)	-2.19 (3.6)	-2.10 (3.7)
Dropout hazard				
Female	0.58 (1.7)	0.96 (1.8)	0.42 (1.2)	0.90 (1.6)
Study < 5 years	0.54 (1.5)	0.62 (1.3)	0.58 (1.7)	0.65 (1.4)
Econometrics	0.00 (0.1)	0.13 (0.2)	-0.56 (1.3)	0.17 (0.3)
Home degree	-0.30 (0.9)	-0.50 (1.2)	-0.39 (1.2)	-0.49 (1.1)
Research fellow	-2.13 (3.6)	-2.57 (3.6)	-0.40 (0.2)	-
Duration dependence				
4+ years	0.73 (1.5)	0.72 (1.0)	0.52 (0.9)	-0.04 (0.0)
v_{d1}	-3.30 (5.7)	-2.89 (3.6)	-3.28 (3.6)	-2.73 (3.4)
v_{d2}	-3.30 (5.7)	¡ 1	-3.28 (3.6)	-5.93 (4.8)
p	-	0.53 (4.9)	-	-
p(non-fellow)	-	-	-	0.44 (4.7)
p(fellow)	-	-	-	0.00
¡ ln L	335.7	333.7	348.4	332.9

Table 4 Cumulative graduation and dropout probabilities (%) by type[a)]

	High grad./low dropout		Low grad./high dropout	
	Graduation	Dropout	Graduation	Dropout
4 years	25	1	3	26
5 years	81	1	16	31
6 years	97	1	31	34
7 years	98	1	37	36
8 years	99	1	41	38
15 years	99	1	43	54

[a)] Male student with undergraduate degree in less than 5 years, degree in economics from supervisor's university.

Figure 1 Cumulative completion and dropout probabilities

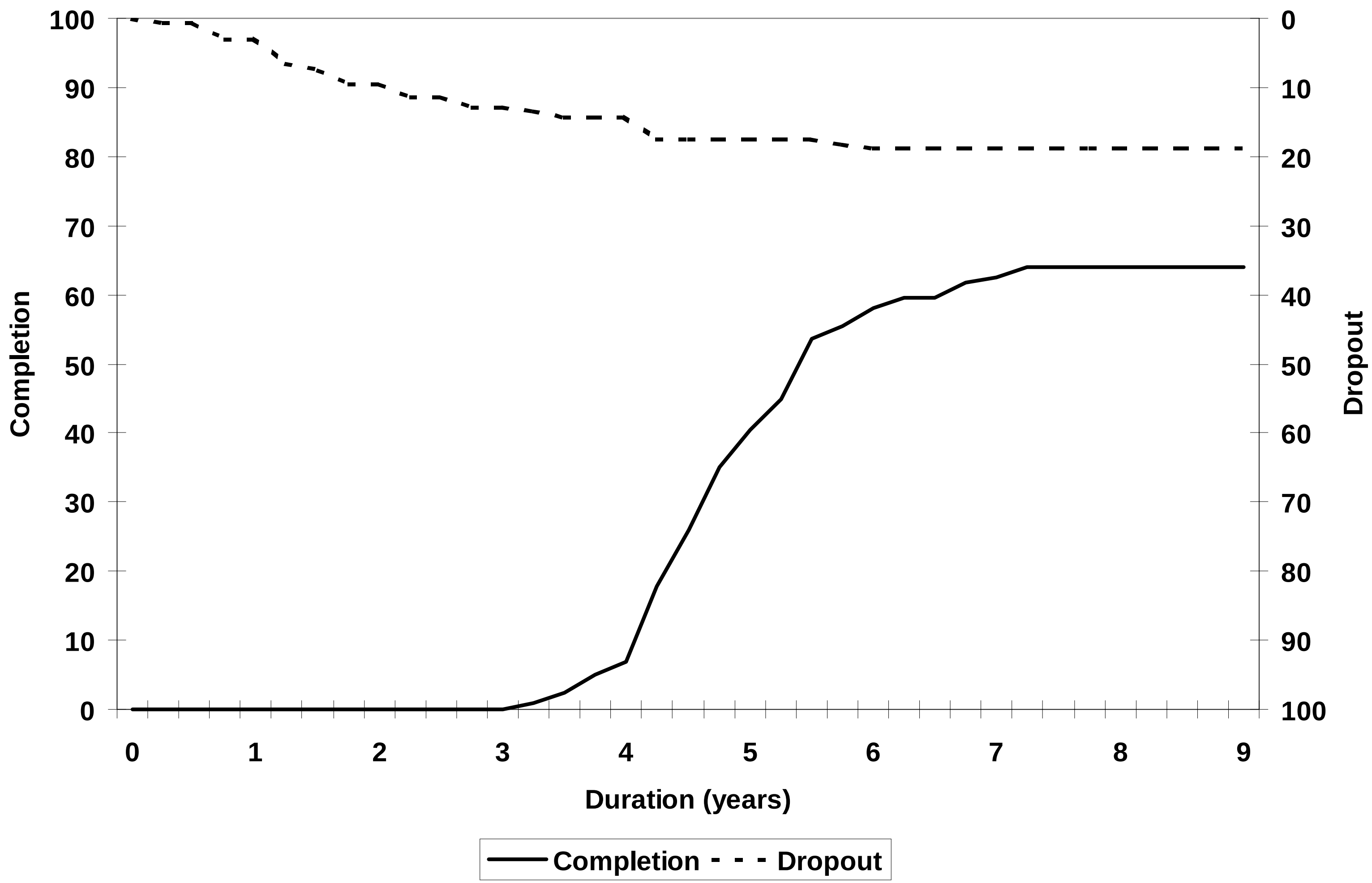

Figure 2 Cumulative Completion and dropout probabilities; research fellows and non-research fellows