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On Time To the Doctorate

A Study of the Increased Time to Complete Doctorates in Science and Engineering

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PREFACE

A need exists for better models of what contributes to changes in the time that students take to complete the doctorate. Although time to the doctorate has been studied by Abedi and Benkin (1987), Berelson (1960), Prior (1962), and Wilson (1965), none of these studies are based on a causal model of student decisionmaking, and none consider the role of market forces in student decisions. The data presented in Chapter 1 suggest that time to the doctorate in science and engineering fields has been lengthening since 1967—in some fields, by as much as two years. Furthermore, it is anticipated that the lengthening trend will persist, at least into the near future, and have unfortunate consequences because of the decline in the college-age population and the dramatic increase expected in the number of job openings in the academic sector in the 1990s. In response, public policy makers are likely to become increasingly concerned with identifying and understanding ways to augment the supply of new doctorates. While shortages of this type are not expected for a few years, it is useful now to determine whether policies can be adopted that can limit or reverse the trend toward longer completion times in the science and engineering fields. Existing studies do not provide the information needed by policy makers to determine whether public policy could, or should, alter completion times sufficiently to slow or reverse the trends discussed in Chapter 1, or whether any policies can have a major impact on supply in the impacted fields.

The purposes of the present study are to render an in-depth analysis of what has happened to completion times since 1967, to provide a time-series data base for the period 1967-1986, and to develop a model that explains some of the factors that have caused an elongation to occur. This study looks at the effects of changes in five types of variables: family background characteristics, student attributes, financial aid, institutional environment, and market forces. Using data from the Doctorate Records File and the Survey of Doctorate Recipients maintained by the Office of Scientific and Engineering Personnel (OSEP) of the National Research Council and from other data sources,* the study develops a model to explain changes in both total time to the doctorate (TTD) and in the

* A more detailed description of the data from these sources is available on request from the National Research Council, Office of Scientific and Engineering Personnel.

several components of time to the doctorate. The model is then applied to 11 scientific and engineering fields: chemistry; physics and astronomy; earth, atmospheric, and marine sciences; mathematical sciences (including computer and information sciences); engineering; agricultural sciences; biological sciences; health sciences; psychology; economics; and all other social sciences.

This report is organized as follows. Chapter 1 begins with an examination of how and when time to the doctorate has been lengthening, illustrated by the rise in mean TTD from 1967 to 1986 in each of the 11 fields. Three components of TTD are introduced, and the mean values for each are presented and discussed. In addition, time coefficients allow one to contrast the way in which time to the doctorate has changed during the period, and two patterns of change are identified. Finally, quantitative estimates are provided of the person-year losses that society has incurred from the lengthening of completion time during this period. Chapter 2 reviews five avenues of inquiry in the literature as they relate to time to the doctorate and models of student decisionmaking. Chapter 3 introduces a causal model of the determinants of TTD based on an opportunity-cost framework of student decisionmaking. The role of financial aid and of market forces is explored in this context. Chapter 4 presents selected data on the zero-order correlations between the independent variables in the model and TTD (and its components). The correlations among the salary variables and unemployment/employment plans variables are discussed, and the contribution of each major vector (e.g., family background and student attributes) is examined. Chapter 5 introduces the statistical model and presents a summary of which regression coefficients are significant (and of their signs) for alternative specifications of the model. Several variants of the model are introduced to explore the effects of alternative measures of the key variables. Chapter 6 presents the regression coefficients for the basic model and several variants using registered time to the doctorate (RTD) as the dependent variable. Finally, Chapter 7 discusses the findings in this study, their implications, and research questions that warrant further study.

In addition, an extensive bibliography of readings on the determinants of student decisionmaking is provided (pp. 107-111). Appendix A (pp. 113-173) provides additional tables about (1) the components of TTD, (2) the person-year losses resulting from a lengthening of TTD, (3) variables in the model, (4) zero-order correlations among the independent variables, (5) several equations for estimating TTD, and (6) median total time to doctorate for the population as a whole and for selected demographic groups. Finally, acronyms used throughout this report are listed in Appendix B (pp. 175-177).

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EXECUTIVE SUMMARY

This study provides an in-depth analysis of what has happened to doctorate completion times from 1967 to 1986, an aggregate time-series data base, and a model that explores some of the factors that cause an elongation of total time to the doctorate (TTD). The model looks at the effects of five types of variables: family background characteristics, student attributes, financial aid, institutional environment, and market forces. Using data from the Doctorate Records File and the Survey of Doctorate Recipients maintained by the Office of Scientific and Engineering Personnel of the National Research Council, a model is developed and tested to explain changes in TTD and in the several component parts of the TTD measure. The model is applied to 11 scientific and engineering fields: chemistry; physics and astronomy (P&A); earth, atmospheric, and marine sciences (EAM); mathematical sciences (including computer and information sciences); engineering; agricultural sciences; biological sciences; health sciences; psychology; economics; and all other social sciences.

Findings

Trends in TTD

The analysis finds that TTD, defined as the time lapse from the year that a student receives an undergraduate degree to the year that the doctorate is completed, initially decreased in the 1960s and then rose swiftly in the 1970s and 1980s. As a consequence, it now takes longer to complete a doctoral degree than at any previous time in this century. Mean TTD increased in each of the 11 fields in this study, ranging from a low of 0.3 years in economics to a high of 2.8 years in the health sciences. Increases in excess of two years were experienced in mathematics, psychology, and social sciences. Moreover, a double-digit percentage increase in TTD was experienced in all but biosciences and agricultural sciences. TTD increased even in fields where the time lapse to the doctorate was already quite long. For example, the average TTD in the health sciences was 10.5 years in 1967 and 13.3 years in 1986; in the social sciences it was 10.6 years in 1967 and 12.9 years in 1986. The evidence also

suggests that student completion times are becoming more concentrated around the mean.

The rise in TTD is occurring at a nonlinear rather than a linear rate. In chemistry, physics and astronomy, and engineering, TTD has been rising at a decreasing rate. However, in the eight other fields examined, TTD has been rising at an increasing rate and is thus cause for greater concern.

Trends in Components of TTD

TTD can increase because students spend more time registered as students or because interruptions on the path from a bachelor's to a doctorate cause them not to be enrolled in school. Analysis of components of TTD indicates that most of the increase is attributable to the increase in registered time to degree (RTD)—that is, TTD less the time prior to graduate school entry (TPGE) and time not enrolled in graduate school (TNEU). In all of the 11 fields examined, RTD has increased substantially since 1967, accounting for most of the change in TTD in every case. Where RTD did not account for the total increase in TTD, interruptions in studies were the most frequent cause for lengthening of TTD. Delays in starting graduate school were an important additional explanation in only one field, health sciences.

Modeling TTD

Careful review of the relevant literature reveals five distinct but related lines of inquiry that bear on the development of a model of the causes of the rise in TTD. These lines of inquiry include the determinants of persistence and attrition, students' educational aspirations, the factors affecting enrollment in college, the role of expected returns and their effect on the decision to enter graduate school, and the literature on TTD. Several variables are consistently identified as affecting student choice: financial aid, whether the student is self-supporting, immediate background characteristics (rather than past background), quality of the undergraduate and graduate college, and differences in expected earnings and changes in market conditions.

The model used in the present study consists of five vectors of variables: family background characteristics, student attributes, tuition and financial aid, institutional environment and policies, and market forces. The model is estimated in both linear and nonlinear form and with two variants. Variant 1, the "common variables" model, includes the same variables for each field and is designed to determine whether a consistent set of variables is important in each field. Variant 2, the "unique variables" model, allows the number of variables in the explanatory equation to vary so that only those that are statistically significant are included in each final regression equation. For each field, regression equations are estimated using the 1967-1986 years as the units of analysis. Separate analyses made for the TTD and RTD variables produce the following results:

Results For TTD: Student characteristics and market forces are the key variables that affect TTD. However, the explanatory variables differ by field and by equation specification. The variable that most consistently explains rises in TTD is age at time of entry to graduate school. This is statistically significant in 9 of the 11 fields studied. Unfortunately, the model does not enable one to determine whether this variable relates to physical or intellectual effects of age (e.g., it takes older persons longer to learn) or whether its effects on TTD operate primarily because students who start later have a longer TPGE.

Among the market force variables, the salary ratio of doctorates 10 years after the doctorate to the salary of recent doctorates is significant in chemistry and EAM (using the common variables linear model) and in agricultural sciences and psychology (using the unique variables model). The salary level of doctorates 10 years after the degree is statistically significant in economics and social sciences. Among the family background variables, female gender is statistically significant in EAM and marine sciences. Type of institution attended affects TTD in some fields and quality of undergraduate institution (but not quality of graduate institution) is usually statistically significant. In psychology, a 1 percent increase in the percentage of a doctoral cohort with a bachelor's degree from a top 70 institution is associated with a 0.1 year decrease in TTD.

Results for RTD: No one variable is consistently large enough or consistently statistically significant enough across fields to explain the observed increase in RTD in all fields. Instead, different combinations of variables explain the rise in RTD in each of the 11 fields. In those equations where age is statistically significant, it tends to have a large impact on RTD. In the common variables log model, for example, the coefficients of the models range from 0.9 years (health sciences) to 6.4 years (social sciences). Since RTD is purged of TPGE, age does not act as a measure of late arrival at graduate school and, hence, its meaning is somewhat clearer in these regressions. Perhaps in part as a consequence, the age variable is not statistically significant in as many fields in the RTD equations (4) as it is in the TTD equations (9).

Financial aid that reduces student reliance on outside employment can make a difference in terms of RTD, and the type of aid is important in determining RTD as to which type of aid is most likely to reduce RTD, the models do not permit a single statement that applies to all fields. Instead, the effects of financial aid are highly field-specific. For example, a 1 percentage point change in federal support reduces RTD by 0.06 percent in EAM, 0.11 year in biological sciences, 0.23 in health sciences, and 0.09 in economics. Teaching assistantship (TA) support reduces RTD in EAM but increases it in biological sciences; and research assistantship (RA) support reduces RTD in math but raises it in biological sciences. The effects of particular forms of aid warrant further exploration.

In the fields of chemistry, mathematics, and economics, increases in the percentage of students with baccalaureates increase RTD in the common

variables log model. Changes in market variables, particularly in the unemployment rate and the salary ratio, also affect RTD. Specifically, in the common variables log model, increases in the unemployment rate of 4-year college graduates tend to reduce RTD. A 1 percentage point change in the variable causes a 0.07 decline in TTD in EAM and a 0.02 decline in biological sciences. In the unique variables model, an increase in the percentage of new graduates seeking (but not yet finding) a position prior to graduation raises RTD in the biological sciences. Finally, increases in salaries for those who already hold doctorates, relative to increases in the salaries of new doctorates, have the effect of reducing RTD. This phenomenon is found primarily in the unique variables model and primarily in chemistry, mathematics, biological sciences, health sciences, psychology, and economics (Note: Several ratios are constructed with different years in the denominator, and which ratio is statistically significant is field specific).

Additional research on the sources of the rise in TTD is warranted. The process of acquiring a doctorate is a complex one that involves a variety of decisionmakers. No one set of unique factors adequately explains the rise in TTD and RTD. Moreover, our findings lack robustness with respect to the determinants of TTD and RTD. This may, in part, be attributable to lack of sufficient independent variation in the doctoral cohort's average annual time-series data for the period 1967-1986. For example, although time-series analysis did not indicate large and uniformly statistically significant effects for the student aid variables, simple cross-tabulations for 1986 and 1987 show that students reporting primary support from "own" earnings take, on average, over five more years to complete the doctorate than those with external financial aid. While this difference may be attributable to differences in the abilities and knowledge of recipients and non-recipients, we cannot rule out the possibility that a study of individuals would produce a stronger role for the financial variables. It may well be that alternative units of analysis will produce different and/or more consistent results than those presented here.

Conclusions

The data in this report indicate that students in general now take longer to complete their doctorates than at any previous time in this century. This exploratory analysis of the factors underlying these trends revealed a complex process that is affected by a variety of factors including availability of student support, labor-market conditions, sociodemographic characteristics of the degree recipients, and characteristics of both undergraduate and graduate degree-granting institutions. As noted earlier, no one of these factors consistently explained the pervasive upward trend that was found. Thus, more effort will be required to enhance understanding of this process.

Moreover, the authors did not explore the consequences of these trends, although the rising trend in TTD found in this study might lead to unacceptably

high levels in some fields. First, increases in TTD lengthen the amount of time required for the supply to respond to any shifts in market demand. Such lags in supply responsiveness are costly to society. Second, increases in TTD may raise the costs and lower the returns to investment in doctoral training with possible consequences for career choice decisions of potential doctoral students. Other things equal, higher costs and lower returns can discourage students from pursuing training at the doctoral level. In addition, given the decision to pursue such training, increasing TTD may encourage some students to drop out before completing their degrees. Finally, lengthening TTD may, other things equal, reduce productivity by reducing the number of years spent by cohorts of newly produced degree-holders working as doctorates. Little is currently known about these possible consequences, but they are potentially serious enough to merit further attention.

1
WHAT HAS BEEN HAPPENING TO TIME TO THE DOCTORATE?

While factors leading to attainment of the doctoral degree have attracted research attention over the last 30 years, only recently has interest focused on the length of time it takes to earn the degree. Surprisingly, most current studies seem to overlook the phenomenon of increasing time to the doctorate occurring over the last two decades. Aggregate data on doctoral degrees show that while median time to the doctorate decreased in the 1960s, the decline was followed by a rather swift and steep increase through the 1970s and 1980s (Figure 1). Although lengthening degree time might simply reflect a distributional shift from doctorates in fields in which time to the doctorate is short (such as physical sciences and engineering) to those in which it is longer (such as humanities and education), other studies have found the increase is occurring in all fields (Coyle, 1987).

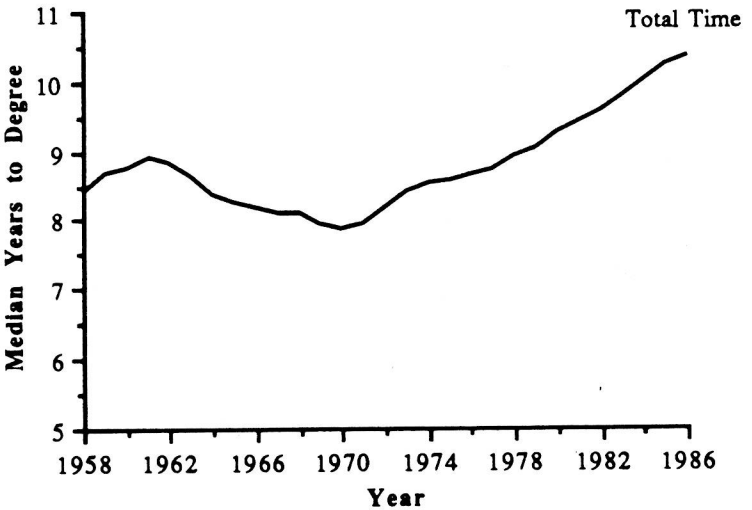

Figure 1 Median years to the doctorate, all fields combined including humanities and education fields, 1958-1986.

Components of Time to the Doctorate and How They Have Changed Through Time

The Several Kinds of Time

The time required to complete the doctorate can be measured in a number of ways, and the type of measurement used affects the degree of observed change as well as conclusions about which factors led to that change. The most comprehensive measure of time is total time to the doctorate (TTD), defined as the time from receipt of an undergraduate degree to completion of the doctorate. TTD is particularly useful for "pipeline" studies that examine the availability of new doctorates to enter the labor force. Similarly, TTD is useful for determining how quickly the supply of doctorate-level personnel will respond to changes in the demand for people with doctorates. Other things being equal, for example, a 10-year TTD would mean a delayed response of new doctorates to an increase in demand and a long wait for employers wanting to hire them.

Time to the doctorate also can be measured by the length of time that a student is actually registered in graduate school. Registered time to doctorate (RTD) is defined as TTD less the length of time prior to graduate entrance (TPGE) and any other time not enrolled in the university (TNEU)—that is, RTD = TTD - (TPGE + TNEU). TPGE may consist of service in the armed forces, time spent in travel, leisure or home-related activity, and/or postbaccalaureate work experience. There are two additional elements of RTD for which we have no measure: time spent in actual study/work toward the degree and time spent at the university in other pursuits. RTD is not a measure of the minimum time needed to complete the doctorate, since time spent in nondoctorate-related activity is also included. RTD, like TTD, is a measure of how quickly supply can respond to demand. In addition, it can be used as an indicator of the need for faculty and other resources in a graduate program. The relationship among these four time measures is summarized in Table 1.1.

Mean TTD for each of 11 science and engineering fields—chemistry; physics and astronomy ("P&A"); earth, atmospheric, and marine sciences ("EAM"); mathematical sciences, including computer and information sciences ("math"); engineering; agricultural sciences; biological sciences ("biosciences"); health sciences; psychology; economics; and all other social sciences ("social sciences")—is taken from the Doctorate Records File (DRF), the data base of the Survey of Earned Doctorates conducted annually by the National Academy of Sciences' Office of Scientific and Engineering Personnel (see, for example, Coyle, 1987: Table 2). Mean TTD, rather than median TTD, is used because it is more sensitive to small yearly changes in the data and easier to compare