Volume Title: American Universities in a Global Market

Volume Author/Editor: Charles T. Clotfelter, editor

Volume Publisher: University of Chicago Press

Volume ISBN: 0-226-11044-3; 978-0-226-11044-8

Volume URL: http://www.nber.org/books/clot08-1

Conference Date: October 2-4, 2008

Publication Date: May 2010

Chapter Title: To Be or Not to Be: Major Choices in Budding Scientists

Chapter Author: Eric Bettinger

Chapter URL: http://www.nber.org/chapters/c11593

Chapter pages in book: (69 - 98)

2

To Be or Not to Be
Major Choices in Budding Scientists

Eric Bettinger

2.1 Introduction

Over the last forty years, the supply of US-born scientists and engineers has dropped dramatically. In 1970, 3,547 US citizens received doctoral degrees in the physical sciences. By 2005, this number had fallen to 1,986. Over the same period, the number of Americans earnings doctorates in math fell from 1,088 to 541, and the number in engineering fell from 2,957 to 2,284.[1] From 1966 to 2000 the proportion of US-trained doctorates born in the United States declined from 77 percent to 61 (Freeman, Jin, and Shen 2004).

These trends in science and math, coupled with the increase in foreign-born, US-trained doctorates in science, technology, engineering, and math (STEM) fields have led to great consternation among policymakers and industry analysts. The National Academy of Science (2007, 3), for example, stated,

> "Having reviewed trends in the United States and abroad, the committee is deeply concerned that the scientific and technological building blocks critical to our economic leadership are eroding at a time when many other nations are gathering strength. . . . [W]e are worried about the future prosperity of the United States. Although many people assume that the United States will always be a world leader in science and technology, this may not continue to be the case inasmuch as great minds and ideas exist throughout the world. We fear the abruptness with which a lead in science and

Eric Bettinger is associate professor of education at Stanford University School of Education and a faculty research fellow of the National Bureau of Economic Research.

1. Figures 2.1 and 2.2 show the relative change in the number of math, physical science, and engineering doctorates awarded each year relative to 1970 for US citizens and permanent residents.

technology can be lost—and the difficulty of recovering a lead once lost, if indeed it can be regained at all."

Similar pronouncements have come from the American Council on Competitiveness, the American Association of Universities, and other government agencies. Many of the statements bring up the concern that the increased reliance on foreign-born scientists may have ramifications for national security. For example, the Hart-Rudman Commission on National Security (2001, ix) claimed that the "U.S. government has seriously underfunded basic scientific research in recent years" and that the "inadequacies of our systems of research and education pose a greater threat to U.S. national security over the next quarter century than any potential conventional war that we might imagine."

There are several possible reasons for the decrease in US-born students pursuing advanced studies in STEM[2] fields. One possibility is that US schools have become worse in either fostering interest in the sciences or in actually teaching the material. For example, over the last forty years, a period in which the overall number of students attending college increased by 84 percent, the number of US-born students intending to major in a science or engineering field has either been constant (through 1995) or falling (since 2001) (ACT 2006). Additionally, indicators of students' aptitude in science and math in primary and secondary school provide similar hints that the United States is lagging behind other countries. In the 2003 math scores on the Trends in International Mathematics and Science Study (TIMSS), fourth graders scored twelfth out of twenty-four countries and sixth among the ten participating Organization for Economic Cooperation and Development (OECD) countries. Eighth graders performed similarly, ranking nineteenth of the forty-four participating countries and tenth of the twelve participating OECD countries.[3]

Another potential explanation for the decline in US-born students pursuing advanced studies in STEM fields is that students have become more attuned to labor market outcomes and the rewards for pursuing STEM careers. Indeed, the annual survey of college freshmen conducted since 1966 by the Higher Education Research Institute at UCLA suggests a high and growing attention to pecuniary rewards as a life goal. In 1966, 54 percent of freshmen claimed that it was important to them to be "very well-off financially" and by 2006 this figure had climbed to 73 percent (Pryor, et al. 2007).

2. The definition of STEM is somewhat amorphous. Many early studies on the shortage of STEM workers focused on "scientists and engineers." Modern definitions focus on science, technology, engineering, and mathematics although the range of included fields can also include economics. For the purpose of this chapter, our definition of STEM includes computer science, mathematics, engineering, engineering technologies, and the physical and biological sciences. When we refer to "scientists and engineers," we include all workers included in our definition of STEM workers.

3. The TIMSS results are accessible at http://nces.ed.gov/timss/.

Over that same period, salaries in many non-STEM fields have increased more rapidly than salaries in STEM fields.

Some have argued that, despite the falling numbers, there is no "shortage" of US-born scientists. Addressing Sputnik-era concerns over STEM pipelines, articles by Alchian, Arrow, and Capron (1958), Arrow and Capron (1959), and Blank and Stigler (1957) argued that a key distinction of the labor market for scientists and engineers was the high degree of inelasticity in the short run supply of engineers. The training of new engineers and scientists can take years as students progress through four to five years of undergraduate training, eight to ten years of graduate training, and then postdoctoral work. As a result, the supply of scientists may take years to respond to shifts in demand, and the labor market conditions may change between the time that students enter the labor market and the time that they finish their training (Freeman 1976).

Because supply may take years to respond, the labor market can go through periods of surplus and shortage—called "cobwebs" in the labor market literature. Indeed, the market for scientists and engineers has fluctuated between shortage and surplus throughout the last half century. While many academics and policymakers have argued that there is a shortage of scientists and engineers (e.g., NSF 1989; Atkinson 1990), others (e.g., Teitelbaum 2007; Ryoo and Rosen 2004) have suggested that the STEM labor market continues to function as one might expect.

This chapter focuses on an earlier point in the pipeline of scientists and engineers—specifically, the development of scientists and engineers in undergraduate studies. As the labor market models underscore, the decision to become a scientist or engineer largely starts when students enter their undergraduate study and choose their major. For many students, this may even start in high school as they develop skills and interest in science and engineering and start to choose a major. As students progress through college, they have the opportunity to stay in their major or change. Once they graduate, the probability that students will pursue careers in science and engineering is quite small if they do not major in a relevant field during their undergraduate careers.

This chapter seeks to do four things. First, we review what is meant by the "STEM pipeline," specifically focusing on how students' major choice plays a role in the development of scientists and engineers. Second, we present a number of frameworks that may shed light on students' major choices and the perceived shortage of STEM professionals. We focus extensively on how relative earnings have changed in different professions. Third, we present new data showing that many of the brightest undergraduate students who are arguably the most prepared to pursue graduate studies in STEM fields are systematically moving away from the hard sciences into fields where earnings might be 5 to 15 percent higher (e.g., finance and accounting). While we make few statements about the state of science and math instruction in primary and secondary education, we show that there is a significant pipeline of students who are prepared to enter careers in the sciences. Finally, we examine how women and minorities choose STEM fields. Over the last forty years, the number of women and minorities majoring in STEM fields has dramatically increased (see figures 2.3 and 2.4). The trends for women and minorities seem to be opposite that of the overall profession. Yet among the top performing students in our sample, we find that African Americans are more likely than other top performers to persist in STEM majors while top performing women are less likely to do so.

2.2 The STEM Pipeline

Our focus is on a particular part of the STEM pipeline—students' major choices. To help motivate why major choices are central to the STEM pipeline, we first review what we mean by the STEM pipeline and the role that major choice plays in that pipeline. Then to help shed light on why students choose STEM majors, we discuss the three key phases of career selection. We discuss when and how students make initial indications as to what major they want to pursue, how major choices evolve in college, and how career choices change after college.

2.2.1 STEM Major Choices and the STEM Pipeline

The STEM pipeline is the phrase used to describe STEM education throughout schooling levels and eventually culminating in the labor force. The development of a new scientist begins quite early and can only be effectuated through a series of steps. It starts with primary and secondary school, where students have to acquire both the skills and the interest in STEM fields to be successful in postsecondary studies. It continues grade by grade as students continue to acquire the skills and interests that might shape their decision as to whether or not to study STEM fields after secondary school.[4]

At any level, students must acquire the skills and the interest in STEM fields which will enable them to continue progressing in the field and help qualify them for the next level. Once students enter a postsecondary school, students in the STEM pipeline may continue to prepare for graduate school admission in a STEM postgraduate program. Similarly, a student's performance in their graduate program helps them attain productive employment related to their STEM training. As the STEM pipeline has been popularized, the failure at any level of schooling to spawn interest or to prepare students academically leads to decreased supply of STEM workers.

4. The STEM pipeline as it has been popularized is similar to a model of sequential production in economics (e.g., Kremer 1993). In a model of sequential production, each step in production depends on the previous. The final product can only be produced if the sequential steps leading to have been completed successfully.

Alarm over the state of the pipeline largely focuses on the fact that the supply of US-born scientists and engineers with doctoral degrees is extremely low relative to the levels from the early 1970s, as shown in figures 2.1 and 2.2. In the various STEM fields, there was a systematic and constant decline in the number of doctorates throughout the 1970s. In the physical sciences, the downward trends begin to level off in the late 1970s. Since 1980, the trend has been relatively constant, reflecting a 50 percent decline from the 1970 peak.

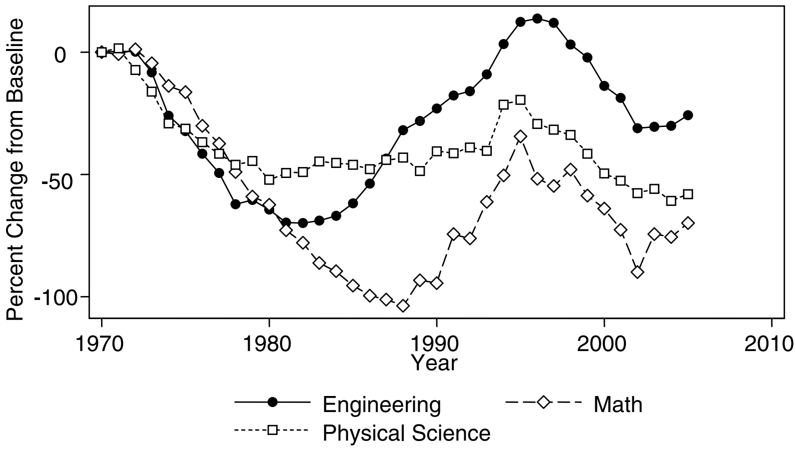

Fig. 2.1 Growth of total doctorates among US citizens and permanent residents relative to 1970

Source: Data from NSF Survey of Earned Doctorates.

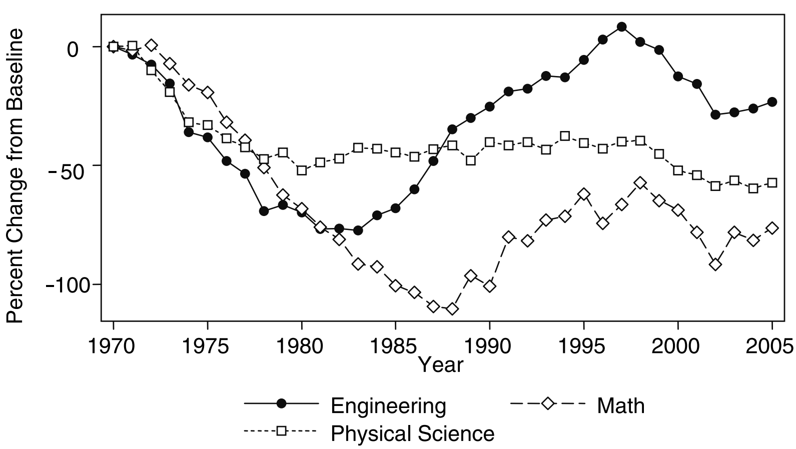

Fig. 2.2 Growth of total doctorates among US citizens relative to 1970

Source: Data from NSF Survey of Earned Doctorates.

In engineering, the downward trend in the number of earned doctorates continued through the early 1980s. In the early 1980s, the trend started to reverse itself and more and more students began entering doctoral studies in engineering. This upward trend continued through the mid-1990s, where it actually surpassed the level from 1970. Thereafter, the number of students earning doctorates declined again.

In math, the drop in the number of earned doctorates continued throughout the 1970s and most of the 1980s. In its lowest years, the decline in math doctorates among US citizens had gone from 1,030 awarded in 1970 to 342 in 1988. While the number of math doctorates awarded each year has failed to reach its 1970 level it has also increased to around 500 per year from its low in 1988.

The decline in earned doctorates contrasts dramatically with the college enrollment patterns from 1970 to 2005. Over that time, undergraduate full-time enrollments increased by 86 percent, and the total number of college students increased by 104 percent (National Center for Education Statistics [NCES] 2008). Yet enrollments in STEM fields have had more modest growth. The number of undergraduate engineering students increased by 14 percent from 1979 to 2002 (National Science Foundation [NSF] 2004), and the number of engineering degrees awarded between 1979 and 2000 increased by 11 percent. Although the number of STEM majors increased by 31 percent between 1977 and 2002, this increase masks substantial heterogeneity: while the number of bachelor degrees awarded in the physical sciences and in math decreased over this period, the number of students majoring in computer science increased by 482 percent (NSF 2004).

The proportion of students stating that they wanted to major in science and engineering increased from the mid-1970s to the mid-1990s; however, most of this growth can be explained by an increase in the numbers of women who are now pursuing careers in science and engineering. As figure 2.3 shows, the number of males who were awarded degrees in STEM fields decreased between 1977 and 2000 by about 1 percent. By contrast, the number of women who were awarded degrees in STEM fields increased by 91 percent (NSF 2004). The number of white students receiving bachelor degrees in STEM fields decreased over this same period from 292,800 in 1979 to 270,420 in 2000. By contrast, as figure 2.4 shows, the number of minority students receiving bachelor degrees in STEM fields increased dramatically.

While we have good data on degree completion through the Integrated Postsecondary Education Data System (IPEDS), we have less data on the dynamics of major choice when students arrive at college. The Beginning Postsecondary Student Survey (BPSS) tracked beginning freshmen over six years. At the start of students' careers in 1995, about 20 percent of all students indicated a desire to major in a STEM field. Among students who indicated a major, 28 percent indicated a desire to major in a STEM field. By 2001, only about 48 percent of those who had started out in the biologi-

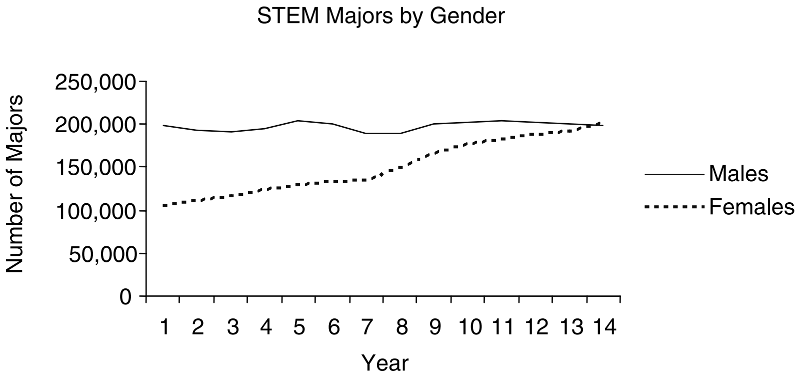

Fig. 2.3 STEM majors by gender, 1977 to 2000
Source: NSF (2004).

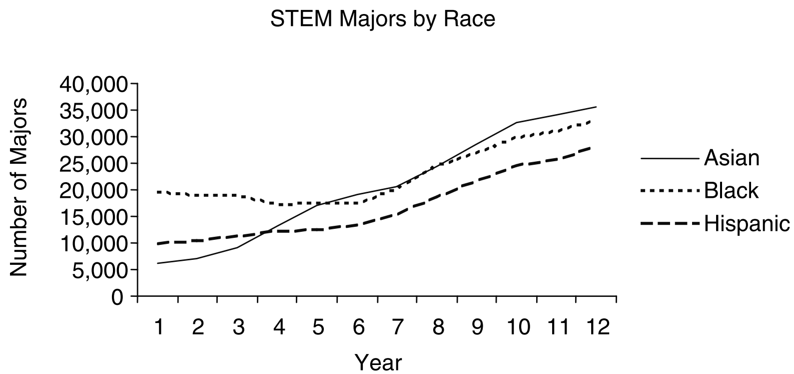

Fig. 2.4 STEM majors by race, 1977 to 2000
Source: NSF (2004).

cal sciences had persisted in the major and only 71 percent of students in physical sciences, engineering, and math had stayed in the major.

Additionally, upon entering college, students lack significant coursework in math and science (ACT 2006). The ACT estimates that only 26 percent of students met the necessary benchmarks in terms of the science curriculum that they took in high school in preparation for college. Only 41 percent of students took the ACT's recommended classes in math. Given that these percentages of students focus only on students who actually took the ACT exam, they likely overestimate the preparedness of students in math and science in the overall population.

Worries about the STEM pipeline have been the motivation for policy decisions affecting education at all levels—primary, secondary, undergraduate, and postgraduate. For example, according to the Academic Competitive Council (ACC 2007), the federal government invested $574 million across twenty-four programs focused on elementary and secondary school students. The federal government allocated \$2.4 billion across seventy undergraduate, graduate, and postgraduate programs. The federal government funded an additional eleven informal projects with an overall budget around \$137 million. Additionally, the United States introduced the National Science and Mathematics Access to Retain Talent (SMART) Grant in the 2006 and 2007 school year. This grant augments a Pell Grant by up to \$4,000 per year if students are US citizens, have a grade point average (GPA) over 3.0, and are enrolled in a key STEM field.[5]

While these statistics certainly suggest a level of unpreparedness for many students, they shed little light on the choices and decisions made by the most prepared students. In section 2.4 of the chapter, we present some data on students who are seemingly prepared to enter STEM fields upon entry into college. Before moving on to those results, we first outline how students choose careers and theories of how students aim to choose majors.

2.2.3 Major and Career Choice

Frameworks for Major Choices

We focus on two conceptual frameworks that researchers have used to characterize students' choice of majors and careers. The first framework is attributed to Holland (1966, 1973) and is widely used by colleges to help students choose between majors. The second framework comes from the economic model of human capital development. We discuss these in turn.

Holland's model has its foundations in psychology and sociology.[6] Holland's theory is that there are six personality types (Realistic, Investigative, Artistic, Social, Enterprising, and Conventional). People with each personality type have competencies and values that draw them to specific activities and give them a certain self-perception. When a student is trying to decide on a major, college career centers usually offer a battery of questions aimed at deriving competencies, activities, self-perceptions, and values that interest or characterize a specific student. These competencies, activities, self-perceptions, and values are then mapped into specific careers.[7] Specific environmental characteristics are similarly linked to specific "environment types" using the same six personality descriptors. Batteries and surveys that attempt to help students choose majors and occupations try to identify specific majors and specific occupations/settings that bring together both students' internal personality and an appropriate environment.

5. As of June 2009, Congress was strongly considering eliminating this program.

6. Holland's theories are reviewed extensively by Smart, Feldman, and Ethington (2000) and Pascarella and Terenzini (2005). Holland's early work is among the most cited papers in psychology on occupational choice.

7. There are a number of resources that map job titles to college majors including Rosen, Holmberg, and Holland (1989) and Gottfredson and Holland (1996).

According to the theory, students persist or initially adopt majors if their personality characteristics and their environment are compatible. For example, an investigative student in an investigative environment will be able to pursue a major compatible with their interests (e.g., engineering). By contrast, a student who is not in a "compatible" environment will likely switch majors multiple times and is at risk of not succeeding. Much of the application of Holland's theory to choice of major has focused on the degree to which an institution creates an environment that fosters students' personality development (e.g., Feldman, Smart, and Ethington 2004).

Because Holland's theory focuses heavily on the institution and its compatibility, it has led policymakers and scholars in psychology and sociology to focus extensively on institutional characteristics in the retention of students in specific majors and their development within majors. Research in both education and economics has shown that institutional characteristics matter for major choice. For example, Bettinger and Long (2009) find that college remediation affects students' major choice. Feldman, Smart, and Ethington (2004) shows that institutions can affect competencies, values, and self-perceptions, which in turn can alter students' dominant personality traits. Other research in economics finds that peer effects influence students' study habits and perceptions (e.g., Sacerdote 2001; Kremer and Levy 2003).

Another theory of major choice comes from models of human capital formation (e.g., Manski 1993). The standard idea is that students will choose a specific major (or course/degree in education) if the expected, present-value of lifetime utility for choosing that major is higher than the expected value of any other. Equation (1) demonstrates this relationship in more mathematical terms:

$$(1) \qquad E\left[\sum_{t=K_j}^{T} R^{t-1}(y_{jt}) - \sum_{t=1}^{K_j} R^{t-1}(c_{jt})\right] > E\left[\sum_{t=K_i}^{T} R^{t-1}(y_{it}) - \sum_{t=1}^{K_i} R^{t-1}(c_{it})\right],$$

where R is the discount rate, T represents the working lifetime of an adult, K_i is the length of training in the field of study i, $E[.]$ is the expectation operator, and y_i and c_i refer to the earnings and cost of training in the field of study i. The equation shows that a student will choose field j so long as the expected earnings in that field net of the cost of training exceed that of another field i. The length of training, the earnings, and costs can differ by field.

Supporting the relevance of the human capital model to decision making of students is the fact that American students have become more focused on vocational offerings. Many have noted that the students' shifts away from STEM majors have often gone toward more "market-based utilitarianism" (Smart, Feldman, and Ethington 2006). Several authors have noted that over the last two decades students are increasingly pursuing more vocational course offerings (e.g., Adelman 1995; Brint 2002; Grubb and Lazerson

2005). Students are moving toward majors related to specific professions, a trend that is consistent with the rise, noted previously, in the percentage of American college freshmen who highly value being "very well off financially" in their future and the decline in the percentage who count as an important goal to "develop a meaningful philosophy of life" (Pryor et al. 2007, ?).

Similarly, work by Montmarquette, Cannings, and Mahseredjian (2002) find that expected earnings is the major determinant of students' college choices. Del Rossi and Hersch (2008) find that double majors that include business are even more lucrative to students than double majors not involving business. This may also explain why business accounts for half of students who eventually move away from STEM majors.

In the human capital model, students' discount rates play a vital role in helping balance the trade-offs between current costs and future rewards. The more impatient that students are, the more they will eschew long periods of training before entering the labor force. Additionally, the years of training and the earnings profile within careers can also discourage investment in specific careers. In science and engineering, especially in the case of students pursuing doctoral careers, the median completion time for students to complete their doctorate following their bachelor degree work is high, ranging from 8.5 in engineering, 8.0 years in mathematics, and 8.1 years in the biological sciences, to 9.5 years in computer science (NSF 2004).

A student's choice of careers can be costly. It takes time to search through several possible fields of study, and the costliness of the search may encourage students to reduce the amount of search that they do (e.g., Oi 1974) or to trust other students. In the standard model, students incur search costs as they try to identify the optimal career. They may be content to take a "lesser" career rather than to continue searching. Alternatively, they may overvalue information from their peers and allow peer effects (or "herd" behavior) to influence their choices of careers.

A variation of the search cost model is one of limited information. Students may not have full access to information about careers when they make their decisions to study. A student who pursues business and commits early on may not explore other fields in which the student may have experienced similar success. Students, especially those who wish to study in high credit degree areas like in the sciences, must commit to their field of study early in order to complete the degree requirements and to graduate in a timely fashion. The rigidity of the degree requirements in science and engineering fields often discourages exploration of other disciplines.

Holland's model and the human capital model are not mutually exclusive. For example, suppose that students compute the expected value of a profession given their current information about their skills. As students acquire new information about their abilities or as institutions improve students' capabilities in a specific dimension, students will have new information about their skills and potential returns in a given field. If students are

Bayesian updaters, then they will reevaluate equation (1) continuously. If the expected value of an alternative major (given students' current beliefs about their abilities) exceeds that of their current major, students will change majors.

Both of these frameworks provide conceptualization about both the process of initially choosing a major and about persistence within that major. We now turn our attention to the timing of initial major choices and subsequent persistence in the major.

Timing of Major Choice

Students initially decide on a major at the end of high school or the beginning of college. College admissions tests and application forms ask students to indicate a potential field of study when they enter college. When UCLA began surveying incoming students in 1966, only 2 percent of students were undecided as to what major they wanted to pursue when they entered college. Over time, this has increased to over 8 percent of students entering without majors chosen (Astin et al. 1997).

Although an overwhelming majority of students have indicated a potential major, there is much less certainty about whether they will persist in the major. According to UCLA's survey of first-year students, 49 percent of students entered college saying that there was "some chance" or "a very good chance" that they would change their major at some point in college (Saenz and Barrera 2007). Similarly, 55 percent of students thought that they would change their choice of careers. The large number of students who think that they may change fields suggests that students are consciously and actively considering multiple major and career options as they enter college.

Students' movements across majors begin in their first semesters. Within the first year of college, 30 percent of students change their major (Saenz and Barrera 2007). What has changed in that first year? According to the UCLA student survey, there have been increases in students' reported computer skills, public speaking ability, and writing. Students also report higher levels of cooperation and "self-understanding." By contrast, students report less mathematical ability, less "drive to achieve," and less academic ability than they thought they had when they first arrived. Holland's model would predict that these changes should push students toward majors requiring less mathematical ability and where the competitive environment is less intense.

Once students formally choose a major (typically by the start of the second year), they still frequently switch majors. One institution, for example, found that 51 percent of students changed their majors at least once after formally indicating a major, and 19 percent of students changed their major two or more times after formally declaring a major (Sethi and Shi 2008). Given that the formal declaration of a major need not be the same major as indicated on a student's application or college entrance exam, it is clear that there is substantial mobility across majors once students arrive at school.

Even if a student enters a specific STEM major, there is no guarantee that their eventual career will be in a STEM field. To illustrate, about 50 percent of engineering majors aim to pursue an advanced degree in business or law. Similarly, 50 percent of students in biology and physics pursue advanced degrees in fields other than biology or physics. Medical degrees are the most common training among these students, although many also pursue advanced degrees in business or law. Depending on the field of study, only 30 to 40 percent of engineering, physical or computer science, or math students go on to study these same fields in graduate school.

2.3 The Role of Relative Wages

The heart of the human capital model is the idea that individuals make educational decisions by comparing their lifetime utilities in alternative prospective careers. This calculation applies to major choice as well. Generally speaking, economists have largely used earnings as the measure of the overall lifetime utility of careers, and so economics typically examines major choice by comparing the returns to earnings across many disciplines. Identifying the economic returns to a particular major is difficult since students' choices of majors may be correlated with students' underlying abilities. Perhaps the best measures of returns to various disciplines come from Donald and Hammermesh (2004). Using data from a single, large university, they tracked earnings profiles across majors. They control for students' ability to separate the financial rewards from a specific major and those from students' abilities. Their estimates appear in table 2.1. The estimates represent the percent differences in wages across majors relative to majoring in education.

The highest earning field was "hard" business. This category included the more quantitative fields in business, including accounting, finance, and

Table 2.1 Returns to major by discipline

Major choice	Percent difference in wages relative to education
Humanities	.097
Social science	.314
Communications	.366
Natural sciences	.293
Business—soft	.413
Business—hard	.522
Engineering	.372
Architecture	.165
Education	.000
Social work	.212

Notes: Estimates come from Donald and Hamermesh (2004 table 5, column 2).

business engineering. Hard business majors earned about 52 percent more than students in education. Students in the "soft" business majors, which include management and marketing, made 41 percent more than students in education. Social science majors earned 31 percent more than education. The STEM fields fared far better than education, with engineers making 37 percent more and natural science majors making 29 percent more, but in both cases students make less money than they do in the business fields.

Similarly, older data from the Bureau of Labor Statistics seem to support Donald and Hamermesh's evidence. Hecker (1995) reports that there was very little difference between the earnings of business majors and STEM majors. In fact, women in business and accounting earned more money than women whose degrees were in chemistry, biology, or mathematics. They earned less than those with degrees in architecture or engineering. Women in economics earned more than women in any of the STEM fields. Men in accounting and business had similar earnings to those in the highest-paid STEM fields—engineering, math, physics, and computer science—and they had higher earnings than men who had majored in biology and chemistry. Business majors had similar earnings to those in biology and chemistry. For both males and females, majors in business and economics had higher earnings than majors in the other social sciences, humanities, and education.

Not only are the absolute wages of non-STEM fields often higher than those in STEM fields, the wage growth has also been higher. From 1991 to 2001, business wages increased by 27 percent, compared to only 19 percent for engineering and 21 percent for math and computer science. These divergent wage increases are not only indicative of demand shocks, but they may also provide one key input to students' decision making. They help students project future earnings in a given profession, making business even more attractive relative to STEM fields. As we show following, at least half of students who started as STEM majors and eventually moved to other majors ended up pursuing business as a major.

There are still other job-related differences that could contribute to the attractiveness of non-STEM majors over STEM majors. For example, one factor that influences major decision and labor market participation is the duration of the training needed to enter a career. Each additional year that a student needs to pursue training means another year of foregone earnings. Since the returns to majors may be dynamic, students have to project into the future their potential earnings in a given career. Arrow and Capron (1959) were among the first to explore how labor supply responded given the fact that training took time. They published their paper shortly after Sputnik had been launched and at a time when the United States was heavily encouraging the development of more US-born scientists. They claimed that a model of "dynamic shortage" could explain the labor market for scientists. As noted before, the type of labor market adjustments described by Arrow and Capron is an example of a cobweb model.

In Arrow and Capron's model, an increase in labor demand leads to a shortage of engineers and an increase in real wages. This wage increase makes a career as a scientist or engineer more attractive to potential students. As students' expected earnings in STEM fields increase relative to other majors, college students should respond accordingly by switching their majors. As more workers respond to the higher wages by changing careers, the labor supply curve shifts out leading real wages to decline. As each person finishes their training, they lead the supply curve to shift out, but there is no guarantee that the supply curve will not shift "too far" out.

The duration of training in STEM fields is longer than that of other fields. For example, the eight to ten years that students typically spend earning a doctorate in a STEM field is quite a bit longer than the two years needed for a business degree or the three years needed for a law degree. Not only do students forego more years in the labor market, but the labor market conditions may have changed dramatically from when they entered their training to the end of their training, and while workers are getting their training. If the labor supply curve shifts too far, it could actually lead to declining real wages among scientists and engineers. It could also lead to periods of surplus and shortage in the market for scientists and engineers—cobwebs left over from the previous shift in supply. The key factor in the adjustment is the elasticity of the supply of scientists and engineers.

The cobweb model has been tested over and over again. Freeman (1971, 1975, 1976) and Breneman and Freeman (1974) provided early tests examining the market for engineers. It has also been applied to the market for lawyers (Freeman 1975, Pashigian 1977). More recent work by Ryoo and Rosen (2004) extends these models with advances made in economic theory. As in the earlier studies, Ryoo and Rosen (2004) find that the cobweb model of supply and demand accurately characterizes the market for engineers. They note that there have been several periods of surplus in the market over the last four decades. They also pay special attention to identifying the lifetime earnings that an engineer can reasonably expect at the time that they commit to a specific area of study. They find that the supply of engineers closely corresponds with variations in the lifetime earning cycle of engineers at the time that engineers commit to their career. Periods of shortage and surplus correspond to unexpected demand shocks in the labor market for engineers. One important consequence of the resulting gyrations in wages has been to make engineering a riskier, and thus less attractive, career option for American students.

2.4 Major Choices and Transitions

To shed some light on the STEM pipeline during college, we present some evidence based on students' transcripts in college. We do not present any new evidence on the STEM pipeline leading to college. Instead, we focus on how college students make decisions about major choice once enrolled in college.

The data that we use come from the Ohio Board of Regents and represent students who entered college for the first time during the 1998 and 1999 school year. Beginning in the 1998 and 1999 school year, the Ohio Board of Regents began tracking students' transcripts at all of Ohio's fifty-two public colleges and universities. Additionally, the Ohio Board of Regents collaborates with the College Board to match students' collegiate records to the students' ACT exam scores and survey. Hence, for each student, we observe the students' ACT exam scores and self-reported high school transcript data from the ACT survey. During the ACT survey, students indicate which majors they intend to pursue while in college. With the transcript data from the Ohio Board of Regents, we observe all of the classes that they take in college, and ultimately we observe their major choices.

Our sample consists of students who first enrolled in the 1998 and 1999 school year at one of Ohio's four-year campuses. We further restrict our sample to those students who took the ACT exam when they entered college and who designated a major at that time.[8] We need this last restriction to identify students who have interests in STEM fields.

The Ohio data are advantageous in that we can track students across schools within the Ohio public higher education system (four-year and two-year institutions). If a student transfers and changes majors, we can observe the outcome. We cannot track students who leave the state, although previous work has suggested that any bias from this is small (Bettinger 2004).

Table 2.2 shows the pre-college major choices for students in our data. We show this for a variety of samples. For example, only about 2 percent of the sample claims that they want to major in the humanities at the start of college. The social sciences attract 13.3 percent while the sciences attract 8.0 percent of students. Business and education are the most attractive pre-college majors, with 23.4 and 17.5 percent of students choosing these topics, respectively. Engineering also attracts a significant number of students, with nearly 11.7 percent of students choosing this major before college.

The other columns of table 2.2 refine the sample somewhat. The second column focuses on students scoring 25 or over on their ACT exams. This represents the top 28 percent of all students taking the ACT exam. This is likely a subsample that is more likely to pursue the sciences or engineering in college. Similarly, the other columns of table 2.2 include, respectively, students with science ACT exam scores 25 and over, with math ACT exam scores 25 and over, and with high school GPAs 3.5 and over in math.

Of these subsamples, each of them is more likely to major in science and engineering than the overall sample. For example, of the students scoring

8. The ACT survey allows students to declare a specific discipline (e.g., economics) or a more general distinction (e.g., social studies).

Table 2.2 **Major intentions of incoming first-year college students, Ohio public colleges and universities, fall 1998**

	Sample				
Intended major	All students	Students with overall ACT > 24	Students with science ACT > 24	Students with math ACT > 24	Students with HS math GPA ≥ 3.5
Humanities	2.1	3.2	2.7	2.2	1.6
Foreign language	0.5	0.8	0.6	0.8	0.8
Social science	13.3	14.6	13.3	11.6	12.3
Communications	8.1	8.0	6.7	5.9	6.4
Science (biological or physical)	8.0	11.7	12.6	10.7	10.5
Math	0.6	1.0	1.1	1.3	1.3
Business	23.4	19.1	18.4	22.4	22.9
Computers	4.7	6.3	6.9	6.4	5.2
Engineering	11.7	18.0	19.9	20.9	17.5
Engineering technology	2.4	2.5	3.0	2.8	2.5
Architecture	3.8	3.0	3.5	3.8	3.7
Education	17.5	10.2	9.7	9.6	13.3
Social work	4.0	1.5	1.7	1.6	2.1
N	17,969	5,031	4,702	5,676	6,265

Notes: Data are from the Ohio Board of Regents and include traditional-aged (age eighteen to twenty) students who entered a four-year Ohio public college in the fall 1998. The sample is further restricted to students who declared a major on their ACT survey.

over 24 on the ACT science exam, 12.6 percent hope to major in science and 19.9 percent hope to major in engineering. As a whole, science and engineering are more attractive than education and business combined. In thinking about the STEM pipeline, these subsamples of students are likely the ones who may eventually pursue careers in science and engineering and go on for study in those fields.

Table 2.3 shows some descriptive statistics for these samples. We have restricted our sample to full-time, traditional age (i.e., eighteen to twenty), first-time students, so students' age at the start of college is around eighteen. About 86 percent of students are white. This is slightly higher than the Ohio's overall system, but given that we are focused on students who took the ACT exam, this is not surprising.

About 7 percent of students are African American and 52 percent of students are female. The average ACT score is 22 and this is true for the math and science tests as well. About 78 percent of the sample currently or last attended a four-year college. Twenty-two percent of this sample took math remediation during their college careers.

The subsamples of students, generally speaking, have fewer minority students, fewer women, higher ACT scores, higher likelihoods of attending four-year colleges, and lower likelihoods of attending math remediation

Table 2.3 Student characteristics, Ohio public colleges and universities, fall 1998

	Sample				
Student characteristic	All students	Students with overall ACT > 24	Students with science ACT > 24	Students with math ACT > 24	Students with HS math GPA ≥ 3.5
Age	18.4	18.3	18.4	18.4	18.4
	(0.5)	(0.5)	(0.5)	(0.5)	(0.5)
White	0.86	0.92	0.93	0.92	0.90
Black	0.07	0.02	0.01	0.02	0.04
Female	0.52	0.47	0.40	0.40	0.52
Overall ACT	22.0	27.4	26.9	26.2	24.4
	(4.3)	(2.2)	(2.8)	(3.1)	(4.0)
Math ACT	21.9	27.1	26.6	27.7	25.0
	(4.8)	(3.4)	(3.8)	(2.4)	(4.5)
Science ACT	22.0	26.7	27.5	25.6	24.0
	(4.3)	(3.2)	(2.6)	(3.7)	(4.2)
Attending 4-year college	0.78	0.92	0.90	0.92	0.87
Attended math remediation	0.22	0.02	0.04	0.01	0.06
N	17,969	5,031	4,702	5,676	6,265

Notes: Data are from the Ohio Board of Regents and include traditional-aged (age eighteen to twenty) students who entered a four-year Ohio public college in the fall 1998. The sample is further restricted to students who declared a major on their ACT survey. The STEM includes computer science, mathematics, engineering, engineering technologies, and the physical and biological sciences.

than the overall sample. The one point that table 2.3 accentuates is that women and minorities continue to be underrepresented among students who enter college highly prepared to study in science and technology. Similar to national patterns, at least at this point in the pipeline, these groups are continuing to be underrepresented.

Our focus is to see what majors students eventually choose. To do that, we focus simply on whether students intended to major in a STEM field or not.[9] In table 2.4, we compare students' pre-college choices of major to their college decisions. For students originally desiring to major in STEM fields, only about 43 percent of them actually go on to major in STEM fields. The rest transfer to non-STEM majors. For students who originally desired to major in non-STEM fields, most (95 percent) stay in non-STEM fields. Only 5 percent of them ever transfer into STEM fields.

As we focus on a more science- and/or math-oriented population, there is some improvement, but STEM majors have a poorer retention rate than non-STEM majors. The STEM majors retain only between 50 and 54 percent of students interested in STEM fields. The retention rate is highest

9. We include math, sciences, computer science, engineering, and engineering technology as the key STEM fields.

Table 2.4 STEM major choices by pre-college STEM decisions

	Pre-college STEM major		Pre-college non-STEM major	
Sample	STEM major	Non-STEM major	STEM major	Non-STEM major
All students	42.9	57.1	5.5	94.6
ACT > 24	52.2	47.8	7.7	92.3
ACT science > 24	51.6	48.4	8.7	91.3
ACT math > 24	54.2	45.8	8.5	91.5
HS math GPA ≥ 3.5	50.4	49.6	7.0	93.0

Notes: Data are from the Ohio Board of Regents and include traditional-aged (age eighteen to twenty) students who entered a four-year Ohio public college in the fall 1998. The sample is further restricted to students who declared a major on their ACT survey. The STEM includes computer science, mathematics, engineering, engineering technologies, and the physical and biological sciences.

among the sample of students with high math scores. The STEM majors attract away 7 to 9 percent of students who originally wanted to major in non-STEM fields.

One way to examine major choice and STEM retention is to look at the timing of students' defections from STEM majors. When we observe students at the end of high school, we know their major intentions. The nature of our data allows us to then track their course schedules as they start college. We focus on the first semester schedules, as these are likely the most exogenous to institutional efforts to increase STEM participation. Students commit to these schedules when they arrive at college, and we focus on the classes that they attempt rather than those that they complete successfully.

In figure 2.5, we plot the proportion of STEM courses that students take during the first semester. Students who are interested in STEM fields clearly take more STEM classes than students who expressed interest in another major. The STEM majors take, on average, 52 percent of their first semester courses in STEM fields, compared to 28 percent for non-STEM majors.

Figure 2.6 repeats the previous exercise, but it divides the pre-college students who were interested in STEM into two categories: those who eventually majored in STEM and those who did not. Students who would stay in STEM majors took about 63 percent of their credit hours in STEM fields in their first semester, whereas those who would eventually abandon STEM majors averaged only 42 percent. Figure 2.7 plots the difference between STEM "stayers" and "defectors."

This difference in the content of students' first semester schedules can be seen not just in the overall sample, but also within subsamples of high-achieving students. For example, if we restrict our sample to students with the highest ACT scores, the highest ACT math scores, the highest ACT science scores, or high school math GPAs greater than 3.5, we find similar differences between eventual STEM majors and those who abandon STEM

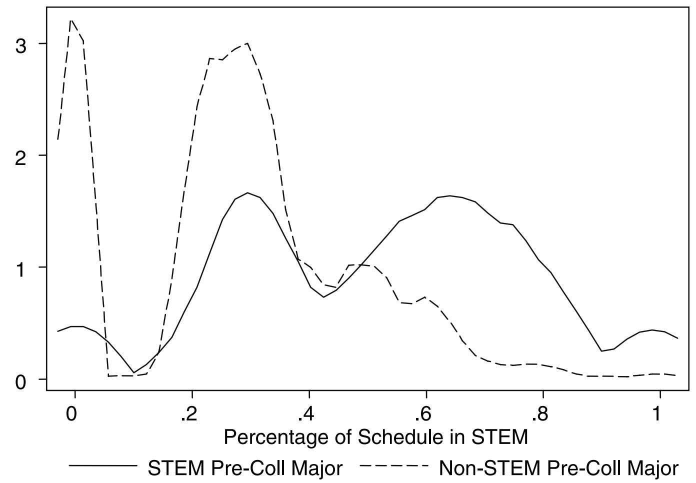

Fig. 2.5 Proportion of first-semester courses in STEM fields for pre-college majors in STEM and non-STEM fields

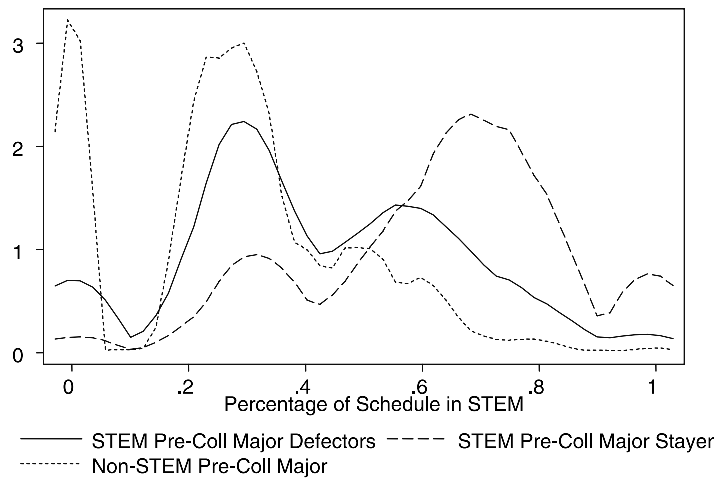

Fig. 2.6 Proportion of first-semester courses in STEM fields for pre-college majors in STEM and non-STEM fields, by students' eventual major

fields (figures 2.8 through 2.11). Even from the first semester, differences emerge in the types of schedules that students take.

It is not clear which way the causality runs in these cases. On the one hand, students who take fewer STEM courses may be identifying themselves as students who want to defect. On the other hand, taking more courses may generate more interest and consequently more commitment to the STEM major. Regardless, we see that students who more fully immerse themselves in STEM classes at the start are more likely to persist in the major. Although

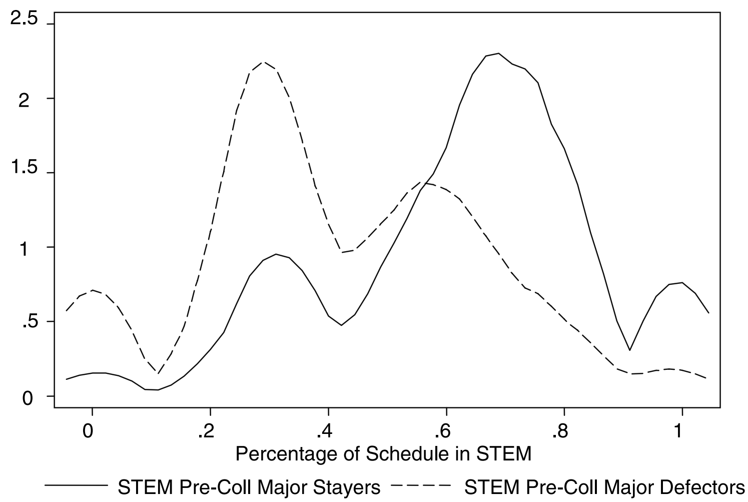

Fig. 2.7 Proportion of first-semester courses in STEM fields for pre-college majors in STEM fields, by eventual major

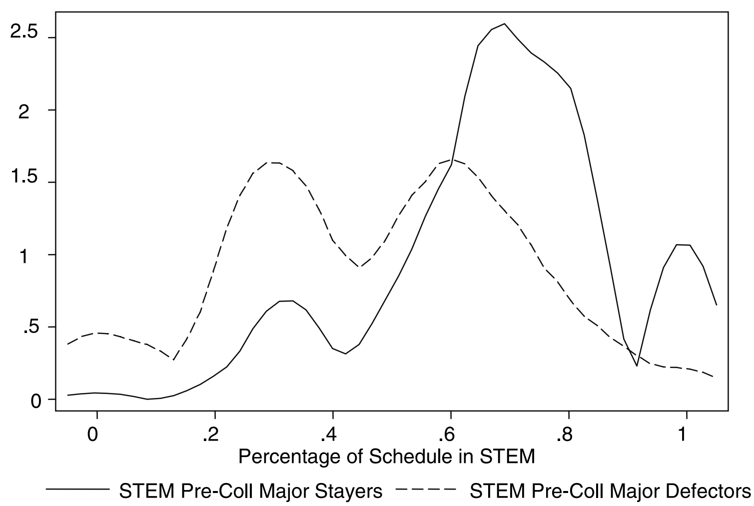

Fig. 2.8 Proportion of first-semester courses in STEM fields for pre-college majors in STEM fields, by eventual major for students with ACT scores over 24

we do not present the figures here, the differences between those who stay in STEM majors and those who defect increases with each successive semester, as one might expect.

What about the other students who switch to STEM fields from other fields? At least in the first semester, they look quite similar to the students who originally declared a STEM major and then left. We plot their distribu-

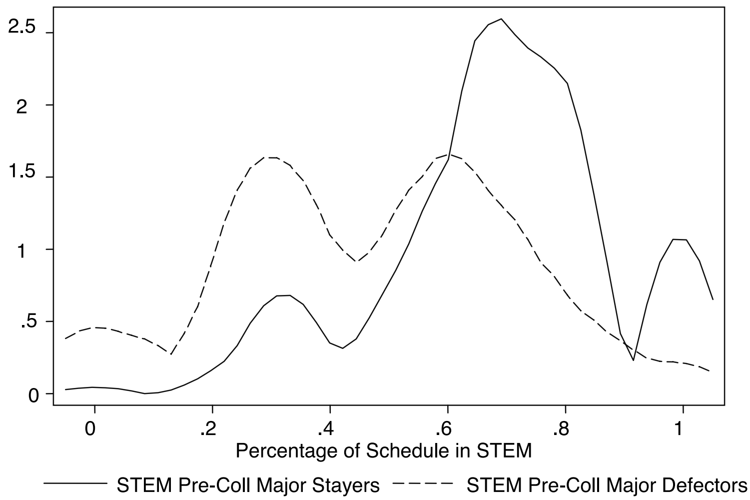

Fig. 2.9 Proportion of first-semester courses in STEM fields for pre-college majors in STEM fields, by eventual major for students with ACT science scores over 24

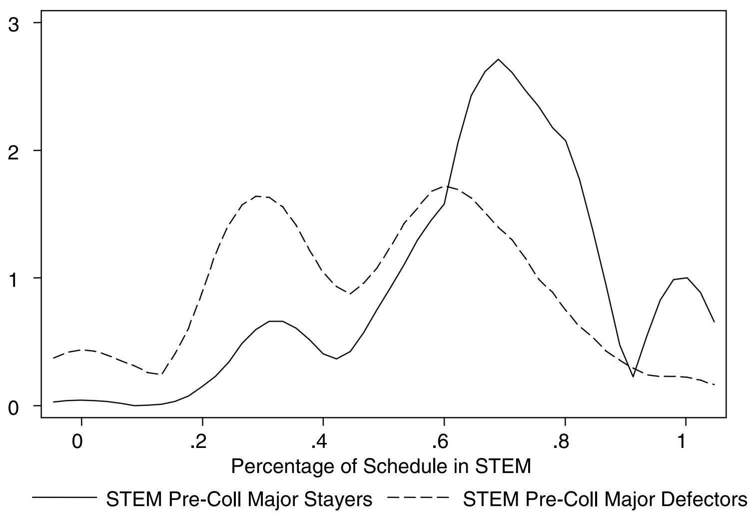

Fig. 2.10 Proportion of first-semester courses in STEM fields for pre-college majors in STEM fields, by eventual major for students with ACT math scores over 24

tions in figure 2.12. The distributions also look similar when we focus on students with higher ACT scores.

Another way to view the same results is to figure out the probability that students eventually major in STEM according to the proportion of the courses they took in STEM fields during their first semester and according to whether they indicated before college a desire to major in STEM fields. This

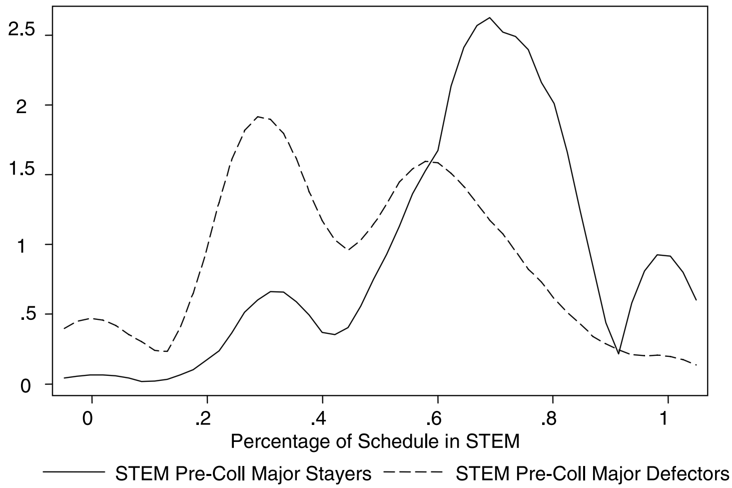

Fig. 2.11 Proportion of first-semester courses in STEM fields for pre-college majors in STEM fields, by eventual major for students with high school math GPA's 3.5 and over

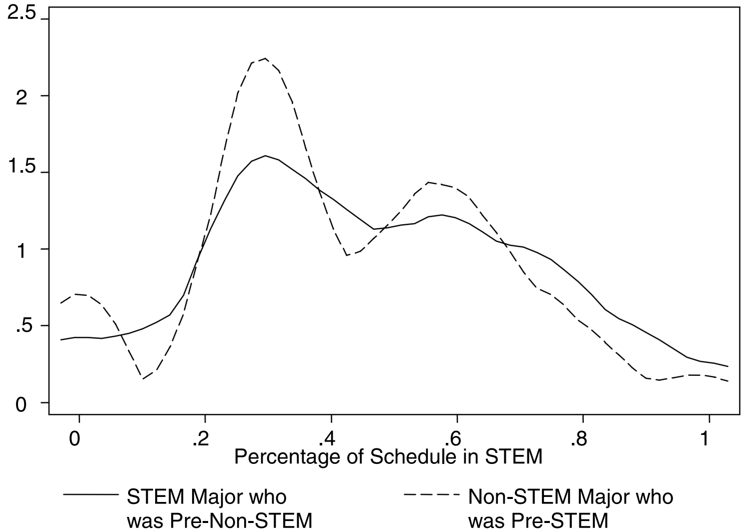

Fig. 2.12 Proportion of first-semester courses in STEM fields for students who later switch to STEM fields and those who switch out

is plotted in figure 2.13. Declaring a major in STEM fields before college automatically increases the probability that a student eventually majors in STEM fields. There is also a positive association of the proportion of STEM courses in the first semester and eventual major choice for both groups.

So what do we make of these results, and why do STEM fields have such

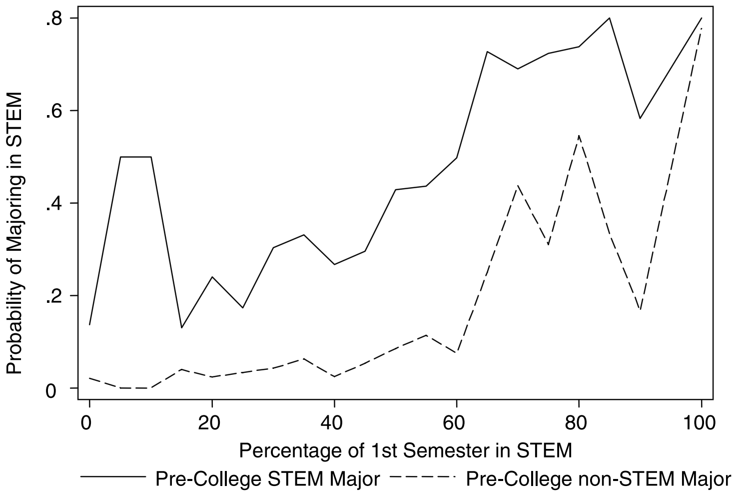

Fig. 2.13 Probability of majoring in STEM field by the percentage of first-semester courses in STEM fields, by pre-college major

lower retention rates? One possible explanation is that students formulate their interest prior to college and only deviate slightly thereafter. For example, many studies (e.g., NAC 2007) report that students in STEM majors decided to pursue this major prior to college. These findings are supported in figures 2.5 through 2.13 in that the differences between individuals' commitment to STEM already appears in students' first semesters. Students who originally declared that they wanted to be a STEM major take a more STEM-filled schedule in their first semester than other students. Students who are moving either away from STEM fields or toward them seem to take a lighter STEM load, but one that is still significantly larger than students who have never expressed interest in STEM and eventually major in non-STEM fields.

Another possible explanation is based on the rigidity of STEM majors. The STEM majors typically have high credit requirements. For example, engineering fields at the Ohio State University, the largest campus in our sample, require between 150 and 165 quarter hours for the core major requirements and technical electives.[10] Students have an additional requirement to complete roughly forty hours of general education requirements. A majority of students' first couple of years at the university are spent taking prerequisites for upper-division classes, so a student majoring in one of these fields would have little space to explore other majors in their early careers.

By contrast, a student majoring in economics or political science at Ohio

10. Electrical engineering is an exception only requiring ninety-two hours.

State has substantial flexibility. They must take forty-five to fifty quarter credits within their major. Students in these majors must complete an additional forty to forty-five credit hours in general education as well. Given that the university requires 180 credit hours for graduation, students have almost two quarters of "free time" to explore other majors.

In the first year, a student in the sciences takes only required classes. If after that first year the student chooses to pursue a program outside the sciences, he or she can still graduate in a timely fashion. On the other hand, a student who begins by exploring a major in one of these popular social studies majors will not complete the prerequisites necessary to change majors to the sciences. Changing to a STEM-related major would necessarily extend the time such students must wait for their degree.

If hours were the sole criterion for shifting major choices, then the largest shifts of students would likely be toward the social sciences and humanities, but that is not the case. As Table 2.5 shows, of students who started as STEM majors and then eventually switched majors, 21 percent changed to the social sciences and 8 percent to the humanities. In comparison, 60 percent of defectors chose either business or education, majors that are much more demanding in terms of hours than the social sciences. For example, an accounting major at Ohio State must complete eighty-eight hours within the major and ninety-five general education hours, and an education major needs at least 101 hours within the major and ninety-five general education hours. While the general education hours may provide more flexibility (and interchangeability with other majors), the hours in the major are almost twice that required in most social science or humanities majors.

The same pattern appears when we look at high performing students who

Table 2.5 **Major choices among STEM defectors**

	Sample				
Major	All students	ACT > 24	ACT science > 24	ACT math > 24	HS math GPA ≥ 3.5
Humanities	8.2	10.7	8.4	7.9	6.4
Foreign language	1.0	1.5	1.4	1.3	0.9
Social science	21.2	24.3	23.9	21.3	20.5
Communications	6.5	5.4	5.9	4.8	5.6
Business	48.7	46.2	47.8	53.2	53.9
Architecture	2.2	1.5	1.3	2.0	2.1
Education	11.1	9.6	10.6	9.3	9.8
Social work	2.0	1.0	0.6	0.3	0.8

Notes: Data are from the Ohio Board of Regents and include traditional-aged (age eighteen to twenty) students who entered a four-year Ohio public college in the fall 1998. The sample is further restricted to students who declared a major on their ACT survey. The STEM includes computer science, mathematics, engineering, engineering technologies, and the physical and biological sciences.

decided to change their major from a STEM field to another. Half of these students choose business, while 20 to 24 percent of them choose social studies. As before, most of the transitions are going to hour-intensive majors.

Part of the criticism of the hour-intensity of STEM majors is that students have little chance to explore other majors. While there may be some validity to this, we find that many students who did not indicate interest in STEM prior to college are in fact able to switch to STEM majors. Students who switch out of STEM are not forced to do so because they took too many non-STEM classes in their first semester. Another fact that undercuts the rigidity argument is that a number of students who are switching into STEM fields take similar schedules and are able to complete the hours needed for a STEM major. However, there are two facts that might still suggest some rigidity. First, when we look at figure 2.13, we see that the probability of majoring in STEM fields is quite low for students who did not indicate interest in STEM prior to college and who take less than about 60 percent of their first semester schedule in non-STEM fields. Second, we have only examined students' first semester schedules. It could be that students have very little flexibility after the first semester.

What are the implications of these patterns in major choice on the STEM pipeline? On the one hand, the defection of many top students suggests that the STEM pipeline is leaky. Only about half of students in the top of the ability distribution who wanted to major in sciences before college continue in those majors through the end of college.

On the other hand, many talented students who are prepared for and in a position to major in STEM fields make seemingly rational decisions to do otherwise. Significant numbers have taken the early courses in STEM majors and switch majors to fields that are almost or perhaps even more lucrative both contemporaneously and in the long run.

2.5 Changing Patterns for Women and Minorities

As we have already shown, much of the growth in STEM majors over the last thirty years has taken place among women and minorities. Over that period, the number of women majoring in STEM fields increased by 91 percent. The number of African Americans and hispanics majoring in STEM fields increased dramatically as well.

To examine how gender and race predict the likelihood that students major in STEM fields, we run linear probability models comparing the likelihood of switching out of a STEM major to the covariates in table 2.3. Our purpose is not to obtain causal estimates of any individual factor but to determine what correlates with the likelihood that students persist in a STEM major. Our sample focuses solely on students who indicated that they intended to major in STEM fields prior to college. The results appear in table 2.6.

Table 2.6 Predictors of persisting in STEM majors

	All		ACT > 24	ACT math > 24	ACT science > 24	HS GPA ≥ 3.5
Age	–.027	–.029	–.019	–.000	–.011	–.010
	(.013)	(.019)	(.022)	(.020)	(.021)	(.019)
White	–.014	–.016	.033	.004	.037	–.006
	(.027)	(.027)	(.044)	(.039)	(.043)	(.040)
Black	.087	.063	.056	.080	.186	.161
	(.037)	(.037)	(.094)	(.081)	(.096)	(.064)
Female	–.141	–.101	–.114	–.140	–.090	–.129
	(.015)	(.016)	(.027)	(.026)	(.028)	(.024)
Overall ACT	–.013	–.011	.006	–.003	–.006	–.004
	(.005)	(.004)	(.008)	(.007)	(.007)	(.007)
Math ACT	.029	.027	.027	.028	.027	.027
	(.003)	(.003)	(.004)	(.005)	(.004)	(.004)
Science ACT	.009	.009	.002	.005	.013	.007
	(.003)	(.003)	(.005)	(.005)	(.006)	(.005)
Attending 4-year	.021	.016	.032	.062	–.056	.045
college	(.019)	(.019)	(.043)	(.039)	(.040)	(.034)
Attended math	.000	.001	–.139	–.053	–.081	.005
remediation	(.023)	(.023)	(.076)	(.088)	(.069)	(.056)
Attended English	.036	.035	.178	.085	.097	.076
remediation	(.024)	(.024)	(.117)	(.069)	(.083)	(.051)
Pre-college major FE	No	Yes	Yes	Yes	Yes	Yes
N	4,914	4,914	1,988	2,387	2,040	2,321

Notes: Sample = students indicating STEM major before college. Dependent variable = Probability of persisting in STEM major. FE = fixed effects. Data are from the Ohio Board of Regents and include traditional-aged (age eighteen to twenty) students who entered a four-year Ohio public college in the fall 1998. The sample is further restricted to students who declared a major on their ACT survey. The STEM includes computer science, mathematics, engineering, engineering technologies, and the physical and biological sciences.

In the first column, we report results for the full sample. In the full sample, females and older students are less likely to stay in STEM majors. African Americans are more likely to persist in STEM majors than other students. Students' overall ACT scores are negatively correlated with the likelihood of staying in a STEM major after controlling for students ACT math and science scores. These other scores are strongly and positively correlated with persistence in STEM fields. In column (2) we add fixed effects for the specific major that students indicated prior to college. The results are very similar to those in column (1).

In the third column, we focus only on students whose ACT scores are high. Within that group, women are about 11 percentage points less likely to stay in STEM majors, a result that is statistically significant. This is similar to the finding by Dickson (2010) that women are less likely to major in STEM fields even after controlling for SAT scores and high school rank.

The coefficient on being African American is positive but not statistically significant. The ACT math scores remain the strongest indicator among the achievement variables. Remediation also seems to matter. Math remediation is marginally significant, suggesting that it decreases the likelihood that students persist in STEM fields. English remediation seems to have the reverse relationship but is not significant. It is hard to decipher the causal relationship of these remediation estimates, although work by Bettinger and Long (2009) shows that math remediation causes a decrease in the probability that students major in math fields.

The results in the other columns of table 2.6 are similar. In every case, females, even among the top students who previously indicated an interest in STEM fields, are less likely to major in STEM fields. The ACT math scores seem to predict greater likelihoods of persistence in STEM fields. The coefficient on African Americans is always positive, suggesting that, among high achievers, African Americans are more likely to persist in STEM majors, but it is not always statistically significant.

The only results that are robust across all of the specifications are those for gender and ACT math scores. Those for ACT math scores seem fairly obvious: STEM fields require higher math skills and students' retention in these fields is tied to their abilities. On the other hand, the gender result is less obvious. The fact that women are underrepresented has long been discussed in academic literature. What is different here is that we have focused on the highest ability students; among them, women who have previously expressed interest in STEM fields are 9 to 14 percentage points less likely to stay in STEM majors than men.

2.6 Conclusion

This chapter presents new descriptive evidence on the STEM pipeline. Using data from Ohio's four-year colleges, the chapter shows that STEM fields retain only about half of their students, and this retention rate does not improve significantly when we restrict the analysis to top performing students. Even among top performing students, almost half of the students who indicated interest in STEM majors did not persist in STEM majors. Almost half of them switched and became business majors. Detection from STEM fields is particularly acute among high performing women.

We also show how students' experimentation of STEM fields varies in the first semester with their early and ultimate interest in STEM fields. During students' first semester in college, the proportion of courses that they take in STEM fields is directly correlated with their eventual major. It is not clear which direction causality runs: students with less commitment to a STEM major may take fewer courses, or taking fewer courses may lead to less commitment.

Nonetheless, students who eventually major in STEM fields take, on average, over 60 percent of their first semester courses in STEM topics. To be sure, there are some students who take less than 60 percent of their schedule in STEM fields who still may major in STEM fields; however, students' chances of successfully completing STEM majors decline significantly if they take less than 60 percent of the first semester courses in STEM fields.

What are the implications for the STEM pipeline? The first observation is that some strongly prepared students who are interested in STEM fields nevertheless depart from STEM majors. Often they move to other fields that are more lucrative; as we showed in the previous section, wages in business can often be 5 to 15 percent higher than in STEM fields. These defections appear to be rational decisions. Evidence from other economists suggests that periods of surplus and shortage are endemic to the STEM market because of the prolonged training required. Given the responsiveness of students to wages, it may be that, as Ryoo and Rosen (2004, S110) observe, public policies that "build technical talent ahead of demand are misplaced unless public policy makers have better information on future market conditions than the market participants do."

The second observation is that students who depart STEM majors tend to do so early in their careers. As early as students' first semesters, there is already a separation between the STEM course-taking intensity of eventual majors compared to the STEM intensity of students who previously expressed interest in STEM fields but eventually depart. If indeed the decision to depart from STEM fields occurs early in students' careers, public policy or institutional efforts aimed at improving retention in STEM majors must happen early in students' careers, or in enough time so that students can incorporate their expectations of the effects of such efforts in their career decision making.

Third, women even at the top of the ability distribution are not pursuing STEM majors. In part because many are switching to more lucrative majors, they remain underrepresented in STEM fields. Other research by Bettinger and Long (2005) suggests that women's early experiences in STEM subjects in college affects their likelihood of persisting in these subjects.

Finally, as other chapters in this volume have highlighted, the United States remains a net importer of scientific talent. While fewer US citizens are pursuing doctoral degrees in STEM fields, the US continues to lead the world in the production of doctorates and a significant proportion of these students stay in the United States (NSF 2004). These facts, coupled with the choices that students make in choosing college majors, support the claims of Teitelbaum (2007) and others that the shortage of scientists and engineers is overstated.

References

Academic Competitive Council (ACC). 2007. *Report of the Academic Competitive Council.* Washington, DC: US Department of Education.

ACT. 2006. ACT National high school profile report. Data available at: http://www.act.org/news/data.html.

Adelman, C. 1995. *The new college course map and transcript files: Changes in course-taking and achievement, 1972–1993* (NCES PE 95-800). Washington, DC: US Department of Education, National Center for Education Statistics.

Alchian, A. A., K. J. Arrow, and W. M. Capron. 1958. *An economic analysis of the market for scientists and engineers.* Santa Monica, CA: The RAND Corporation.

Arrow, K. J., and W. M. Capron. 1959. Dynamic shortages and price rises: The engineer-scientist case. *Quarterly Journal of Economics* 73 (May): 292–308.

Astin, A. W., S. A. Parrott, W. S. Korn, and L. J. Sax. 1997. *The American freshman: Thirty-year trends.* Los Angeles: Higher Education Research Institute, UCLA.

Atkinson, R. 1990. Supply and demand for scientists and engineers: A national crisis in the making. *Science* 248 (4954): 425–32.

Bettinger, E. 2004. Is the finish line in sight? Financial Aid's impact on retention and graduation. In *College choices: The economics of where to go, when to go, and how to pay for it,* ed. C. M. Hoxby, 207–83. Chicago: University of Chicago Press.

Bettinger, E., and B. Long. 2009. Addressing the needs of under-prepared students in higher education: Does college remediation work? *Journal of Human Resources* 44 (3): 736–71.

———. 2005. Female role models for female college students. *American Economic Review Papers and Proceedings* 95 (2): 152–57.

Blank, D. M., and G. J. Stigler. 1957. *The demand and supply of scientific personnel.* New York: National Bureau of Economic Research.

Breneman, D., and R. Freeman. 1974. Forecasting the PhD labor market: Pitfalls for policy. Technical Report no. 2. Washington, DC: National Board of Graduate Education.

Brint, S. 2002. The rise of the "Practical Arts." In *The future of the city of intellect,* ed. S. Brint, 231–59. Stanford: Stanford University Press.

Del Rossi, A. F., and J. Hersch. 2008. Double your major, double your return? *Economics of Education Review* 27 (4): 375–86.

Dickson, L. 2010. Race and gender differences in college major choice. *Annals of the American Academy of Political and Social Science* 627:108–24.

Donald, S., and D. Hamermesh. 2004. The effect of college curriculum on earnings: Accounting for non-ignorable non-Response Bias. NBER Working Paper no. 10809. Cambridge, MA: National Bureau of Economic Research, October.

Feldman, K., J. Smart, and C. Ethington. 2004. What do college students have to lose? Exploring the outcomes of differences in person-environment fits. *The Journal of Higher Education* 75 (5): 528–55.

Freeman, R. 1971. *The labor market for college-trained manpower.* Cambridge, MA: Harvard University Press.

———. 1975. Legal "cobwebs": A recursive model of the market for new lawyers. *The Review of Economics and Statistics* 57 (2): 171–79.

———. 1976. A cobweb model of the supply and starting salary of new engineers. *Industrial and Labor Relations Review* 29 (2): 236–48.

Freeman, R., E. Jin, and C.-Y. Shen. 2004. Where do US trained science engineering PhDs come from? NBER Working Paper no. 10554. Cambridge, MA: National Bureau of Economic Research, June.

Gottfredson, G. D., and J. L. Holland. 1996. *Dictionary of Holland occupational codes,* 3rd ed. Odessa, FL: Psychological Assessment Resources.

Grubb, W. N., and M. Lazerson. 2005. Vocationalism in higher education: The triumph of the education gospel. *The Journal of Higher Education* 76 (1): 1–25.

Hart-Rudman Commission on National Security. 2001. Road map for national security: Imperative for change. Available at: http://govinfo.library.unt.edu/nssg/PhaseIIIFR.pdf.

Hecker, D. 1995. Earnings of college graduates, 1993. *Monthly Labor Review* 118 (2): 3–17.

Holland, J. L. 1966. *The psychology of vocational choice.* Waltham, MA: Blaisdell.

———. 1973. *Making vocational choices.* Englewood Cliffs, NJ: Prentice-Hall.

Kremer, M. 1993. The O-ring theory of economic development. *The Quarterly Journal of Economics* 108 (3): 551–75.

Kremer, M., and D. Levy. 2003. Peer effects and alcohol use among college students. NBER Working Paper no. 9876. Cambridge, MA: National Bureau of Economic Research, July.

Manski, C. 1993. Identification of social effects: The reflection problem. *Review of Economic Studies* 60 (3): 531–42.

Montmarquette, C., K. Cannings, and S. Mahseredjian. 2002. How do young people choose college majors? *Economics of Education Review* 21 (6): 543–56.

National Academy of Science (NAC). 2007. Rising above the gathering storm: Energizing and employing America for a brighter economic future. Washington, DC: National Academy Press.

National Center for Education Statistics. 2008. *Digest of education statistics, 2007.* US Department of Education (NCES 2008-022).

National Science Foundation. 1989. *Science and engineering indicators.*

———. 2004. *Science and engineering indicators.* NSB 04-01.

Oi, W. 1974. Scientific manpower forecasts from the viewpoint of a dismal scientist. Princeton University Industrial Relations Section Working Paper 47.

Pascarella, E. T., and P. T. Terenzini. 2005. *How college affects students: A third decade of research.* San Francisco: Jossey-Bass.

Pashigian, B. 1977. The market for lawyers: The determinants of the demand for and supply of lawyers. *Journal of Law and Economics* 20 (1): 53–85.

Pryor, J. H., S. Hurtado, V. B. Saenz, J. L. Santos, and W. S. Korn. 2007. The American freshman: Forty-year trends, 1966–2006. University of California, Los Angeles. Higher Education Research Institute. Available at: http://www.gseis.ucla.edu/heri/40yrtrends.php.

Rosen, D., K. Holmberg, and J. L. Holland. 1989. *The college majors finder.* Odessa, FL: Psychological Assessment Resources.

Ryoo, J., and S. Rosen. 2004. The engineering labor market. *Journal of Political Economy* 112 (1): S110–40.

Sacerdote, B. 2001. Peer effects with random assignment: Results for Dartmouth roommates. *The Quarterly Journal of Economics* 116 (2): 681–704.

Saenz, V. B., and D. S. Barrera. 2007. *Findings from the 2005 College Student Survey (CSS): National aggregates.* Los Angeles: Higher Education Research Institute.

Sethi, S. J., and S. Shi. 2008. Major migration by college at UTPA. Available at: http://www.texis-air.org/conference/2008/presentations/C3_Major_Migration-Feb_2008-Tair.ppt#256.

Smart, J. C., K. A. Feldman, and C. A. Ethington. 2000. *Academic disciplines: Holland's theory and the study of college students and faculty.* Nashville, TN: Vanderbilt University Press.

Teitelbaum, M. 2007. Testimony before the Subcommittee on Technology and Innovation, Committee on Science and Technology, US House of Representatives. Washington, DC. Available at: http://democrats.science.house.gov/Media/File/Commdocs/hearings/2007/tech/06nov/Teitelbaum_testimony.pdf