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

Eric Bettinger
Stanford University School of Education

September 19, 2008

Over the last 40 years, the supply of US-born scientists and engineers has dropped dramatically. In 1970, 3,547 U. S. citizens received doctoral degrees in the physical sciences. By 2005, this number had fallen to 1,986. Over the same period, the number of doctorates in math fell from 1,088 to 541, and the number of doctorates in engineering fell from 2,957 to 2,284.

The decline of the number of doctorates in science and engineering is not the only indicator of decreased supply. The number of students intending to major in a science or engineering field has either been constant (through 1995) or falling (since 2001) (ACT 2006) over the last 40 years while the the overall number of students attending college has increased by 84 percent over that period. And 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 TIMSS, fourth graders scored twelfth out of twenty-four countries and sixth among the 10 participating OECD countries. Eighth graders performed similarly ranking 19th of the 44 participating countries and 10th of the 12 participating OECD countries.

These trends in science and math have led to great consternation among policymakers and industry analysts. The National Academy of Science, 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 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. The Hart-Rudman Commission on National Security (2001) 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."

Economists and policy analysts have long been interested in the supply of scientists and engineers. Early articles by Arrow (1958), Arrow and Capron (1959), and Blank and Stigler (1957) tried to understand the labor market and the responsiveness of labor supply to shocks in labor demand. Economists quickly identified that a key difference between the labor market for scientists and engineers was the degree of inelasticity in the 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 post-doctoral 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. Over the last 20 years, however, there has been a prolonged period in which many academics and policymakers have argued that there is a shortage of scientists and engineers (e.g. Bowen and Sosa 1989, NSF 1989, Atkinson 1990) although Ryoo and Rosen (2004) have suggested that the engineering labor market continues to function as one might expect.

This article 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. For others, it is a dynamic process throughout their undergraduate studies. Regardless of when the decision is made to enter the major, the probability that students pursue careers in science and engineering is quite small if students do not major in a relevant field during their undergraduate careers.

This article seeks to do four things. First, we review how the trends in STEM (i.e. science, technology, engineering and mathematics)[1] attainment and achievement throughout the age spectrum, specifically focusing on how students' major choice plays a role in the development of scientists and engineers. Second, we present a number of frameworks which may shed light on students' major choices and the perceived shortage of STEM professionals. Third, we present new data showing that many of the brightest undergraduate students who are arguably the most prepared to pursue graduate studies in

[1] 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 paper, 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.

STEM fields are systematically moving away from the hard sciences into more lucrative fields of study such as business. 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 the extent to which minorities and women are under-represented among STEM majors and that among top students, they have divergent paths in college. Top performing African-Americans are more likely than other top performers to persist in STEM majors while top performing women are less likely to do so.

I. Background on STEM Major Choices

To help shed light on why students choose STEM majors, we start by quickly reviewing two sets of literature. First, we review trends in STEM major decisions. We try to place STEM major choice in the context of the overall production of doctorates in STEM fields. Second, we review the literature in education and economics on why students choose the majors that they do.

A. 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 created 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 post-secondary 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.[2]

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 post-secondary school, students in the STEM pipeline may continue to prepare for graduate school admission in a STEM post-graduate 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.

Alarm over the state of the pipeline largely focuses on the fact that the supply of U.S.-born scientists and engineers with doctoral degrees is extremely low relative to the levels from the early 1970's. Figures 1 and 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. In all subjects, there was a systematic and constant decline in the number of doctorates throughout the 1970's. In the physical sciences, the downward trends begin to level off in the late 1970's. Since 1980, the trend has been relatively constant reflecting a 50 percent decline from the 1970 peak.

In engineering, the downward trend in the number of earned doctorates continued through the early 1980's. In the early 1980's the trend started to reverse itself and more and more students began entering doctoral studies in engineering. This upward trend

[2] 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.

continued through the mid-1990's 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 1970's and most of the 1980's. 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 have increased by 86 percent, and the total number of college students has increased by 104 percent (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 (NSF 2004). The number of engineering degrees awarded between 1979 and 2000 increased by 11 percent. While the number of STEM majors increased by 31 percent between 1977 and 2002, the increase masks substantial heterogeneity. The number of bachelor degrees awarded in the physical sciences and in math decreased over this period. The increase is largely stemming from computer science which saw a 482 percent increase in the number of students pursuing this major (NSF 2004).

The proportion of students stating that they wanted to major in science and engineering increased from the mid-1970's to the mid-1990's; however, most of the growth can be explained by an increase in the numbers of women who are now pursuing careers in science and engineering. As Figure 3 shows, the number of males who were awarded degrees in STEM fields decreased between 1977 and 2000 by about one 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 4 shows, the number of minority students receiving Bachelor degrees in STEM fields increased dramatically.

While we have good data on degree completion through IPEDS, we have less data on the dynamics of major choice when students arise at college. The Beginning Post-Secondary Student Survey 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. Of only the students who indicated a major, 28 percent indicated a desire to major in a STEM field. In 2001, only about 48 percent of students in the biological sciences had persisted in the major while 71 percent of students in physical sciences, engineering, and math had stayed in the major.

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

The belief in this pipeline is part of the motivation for policy decisions throughout primary, secondary, undergraduate, and post-graduate education levels. For example, according to ACC (2007), the federal government invested $574 million across 24 programs focused on elementary and secondary school students. The federal government allocated $2.4 billion dollars across 70 undergraduate, graduate, and post-graduate programs. The federal government funded an additional 11 informal projects with an overall budget around $137 million. Additionally, the United States introduced the National SMART Grant in the 2006-2007 school year. This grant augments a Pell grant by up to $4,000 per year if students are US citizens, have a GPA over 3.0, and are enrolled in a key STEM field.

While these statistics certainly suggest a level of unpreparedness for many students, they also shed little light on the choices and decisions that the most prepared students make. In the next section of the paper, 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 theories of how students aim to choose majors.

B. Selecting a Major

We focus on two conceptual frameworks which researchers have used to characterize students' choice of majors. 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 economic model of human capital development. We discuss these in turn.

Holland's model has its foundations in psychology and sociology.[3] 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 which 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.[4] Specific environmental characteristics are similarly linked to specific "environment types" using the same six personality descriptors. Batteries and surveys which attempt to help students choose majors and occupations try to identify specific majors and specific occupations/settings which bring together both students' internal personality and an appropriate environment.

According to the theory, students persist in 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 to not succeed. Much of the applications of Holland's theory to major choice has focused on the degree to

[3] Holland's theories are reviewed extensively by Smart, Feldman, and Ethington (2006) and Pascarella and Terenzini (2005). Holland's early work is among the most cited papers in psychology on occupational choice.

[4] There are a number of resources which map job titles to college majors including Rosen, Holmberg, and Holland (1989), Gottfredson and Holland (1996), and Rosen, Holmberg and Holland (1997).

which an institution creates an environment which fosters students' personality development (e.g. Feldman, Smart, 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 (2007) find that college remediation affects students' major choice. Feldman et al (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:

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

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.

In the 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, 8.1 years in the biological sciences, to 9.5 years in computer science (NSF 2004).

Students' choice of careers could also 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 than to continue searching. Or alternatively they may overvalue information from their peers and allow peer effects (or "herd" behavior) to influence their choices of careers.

A variation off 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 where 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 discourage 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.

Generally speaking, economists have largely used earnings to measure the overall lifetime utility of careers, and economists likely examine major choice by comparing the returns to earnings. For example, Del Rossi and Hersch (2008) examine the returns to double-majoring to examine how students choose their primary and secondary major, and Donald and Hammermesh (2004) examined how earnings vary by major.

What is unique about the decision to enter STEM fields versus other fields is the duration of the training needed to enter a career. Students have to project into the future what the potential earnings might be in their 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 launched and at a time when the United States was heavily encouraging the development of more U.S.-born scientists. They claimed that a model of "dynamic shortage" could explain the labor market for scientists. Others have called the types of labor market adjustments described by Arrow and Capron as "cobwebs."

Consider the shift in labor demand illustrated in Figure 5. In Arrow and Capron's model, the shift in demand leads to a shortage of engineers and an increase in real wages. This makes a career as a scientist or engineer more attractive to potential students. Students observe the wages in the system when they commit to their career paths, and as Equation 1 suggests, students' expected earnings in STEM fields increases relative to others making it more attractive. College students 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 key difference in the labor market for scientists and engineers is that workers only observe the labor market conditions when they enter their training and these may differ from those at the end of their training, and while workers are getting their training, demand can change further leading to changes in the labor market equilibrium. 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 leftover 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 characterize the market for engineers.

II. 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 STEM pipelines entering college. Instead, we focus on how students make decisions about major choice 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 1998-99 school year. For each student, we observe the students' ACT exam scores and self-reported high school transcript data from the ACT survey. From these data, we know the majors that students intend to pursue while in college. Once students enter college, we observe all of the classes which they take in college, and ultimately we observe their major choices. Our sample consists of students who first enrolled in the 1998-99 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.[5]

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

---

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

students who leave the state although previous work has suggested that any bias from this is small (Bettinger 2004).

Table 1 shows the pre-college major choices for students in our data. We show this for a variety of samples. For example, only about two 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 major 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 1 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 1 include respectively students with science ACT exam scores 25 and over, with math ACT exam scores 25 and over, and with high school GPA's 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 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 as a whole 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 shows some descriptive statistics for these samples. We have restricted our sample to full-time, traditional age (i.e. 18-20), first-time students, so students age at the start of college is around 18. 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.

In the subsamples of students, generally speaking the samples have fewer minority students, less women, higher ACT scores, higher likelihoods of attending four-year colleges, and lower likelihoods of attending math remediation than the overall sample. The one point which Table 2 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 standards, 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 STEM fields or not.[6] In Table 3, 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.

---

[6] We include math, sciences, computer science, engineering and engineering technology as the key 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. STEM majors retain between 50 and 54 percent of students interested in STEM fields. The retention rate is highest among the sample of students with high math scores. 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 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 to which they succeed.

In Figure 6, 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. STEM majors take, on average, 52 percent of their first semester courses in STEM fields. Non-stem majors take about 28 percent of their first semester courses in STEM fields.

Figure 7 repeats the previous exercise yet 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. Among students who stayed in STEM majors, they took about 63 percent of their credit hours in STEM fields in their first semester. The students who abandoned STEM majors only averaged 42 percent. Figure 8 plots the difference between STEM "stayers" and "defectors."

This difference in the content of students' first semester schedules takes place not just in the overall sample, but if we focus on subsamples of high-achieving students, we see similar differences. If we refine our sample and focus on students with the highest ACT scores, the highest ACT math scores, the highest ACT science scores, or high school math GPA's greater than 3.5 (Figures 9-12), we find similar differences between eventual STEM majors and those who abandon STEM fields. Even from the first semester, differences emerge in the types of schedules that students take. Students who more fully immerse themselves in STEM classes are more likely to persist in the major. While we do not present the figures here, the differences between those who stay in STEM majors and those who defect increases each 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. In their first semester of college, students who switched into STEM majors took about 46 percent of their classes in STEM fields. This was 4 percentage points higher than students who were switching out of STEM majors. The difference is statistically significant. We plot the distributions in Figure 13. They look quite similar across these two groups. The distributions also look similar when we focus on the more selective students although at the mean, they remain statistically different in every case.

Another way to view the same results is to figure out the probability that students eventually major in STEM according to the proportion of their 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 is plotted in Figure 14. 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 a lower retention rates? One theory is that students formulate their interest prior to college and only deviate slightly. For example, one review of the STEM literature found that students had decided by age 14 whether or not to pursue a STEM field (IET 2008). Other studies (e.g. NRC 2006) report that students in STEM majors decide to pursue this major prior to college. This is supported in Figures 6-14 by the fact that the differences between individuals commitment to STEM already appear 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. For students who are moving either away from STEM fields or toward them, they 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 theory is the rigidity of STEM majors. STEM majors typically have high credit requirements. For example, The Ohio State University is the largest campus in our sample enrolling about 17 percent of our sample. Engineering fields require between 150 and 165 quarter hours for the core major requirements and technical electives.[7] Students have an additional requirement to complete roughly 40 hours of general education requirements. A majority of students' first couple of years at the university are spent

[7] Electrical engineering is an exception only requiring 92 hours.

taking pre-requisites for upper-division classes. 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 has substantial flexibility. The major requirements range from 45-50 credit hours, and the majors require 90 credit hours. 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 of a student's career, a student in the sciences takes only required classes. If after the first year they choose to pursue a program outside the sciences, they can still graduate in a timely fashion. On the other hand, a student who explores a major in one of these popular social studies majors has not completed the prerequisites necessary to change majors to the sciences. Changing to a STEM-related major would extend the time students must wait for their degree.

If hours were the sole criteria for shifting major choices, then the largest shifts of students would likely be toward the social sciences and humanities. Indeed, as Table 4 shows, 21 percent of students who started as STEM majors and then eventually switched majors changed to the social sciences and 8 percent to the humanities. Yet almost, 60 percent of students choose business or education. Almost half of students (48.7 percent) who defect from STEM to other fields pursue business. Another 11 percent pursue education. Business and education are much more demanding in terms of hours than the social sciences. For example, an accounting major at Ohio State must complete 88 hours within the major and 95 general education hours, and an education major needs at least 101 hours within the major and 95 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 decided to change their major from a STEM field to another. Half of these students choose business. Twenty to 24 percent of them choose social studies. As before, most of the transitions are going to hour intensive majors.

Additionally, 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 able to switch to STEM majors. Students who switch out of STEM do not have to switch out of STEM fields because they took too many non-STEM classes in their first semester. 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 14, 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.

Another possible explanation for students' switching majors is their potential earnings from these respective majors attract them. Over time, college students have become increasingly focused on college as a means to prepare for the job market. For example, one study (Sax, Astin, Korn, Mahoney 2004) found that 74 percent of incoming students claimed that an important part of college was being "very well off financially" in their future. More ideological reasons (e.g. "develop a meaningful philosophy of life") lagged behind the students' financial motivations.

Others have noted that the shift away from STEM majors has often gone toward more "market-based utilitarianism" (Smart et al 2006). For example, 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.

Going back to Equation 1, the human capital model suggests that lifetime expected earnings in a specific major is a predictor of student major choice. Ryoo and Rosen (2004) perform a systematic evaluation of 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.

Similarly, work by Montmarquette, Cannings, and Mahseredjian (2002) find that expected earnings is the major determinant of students' college choice. Del Rossi and Hersch (2008) find that double majors which 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 defect from the major.

Additionally, in terms of contemporaneous earnings, there is very little difference between the earnings of business majors and majors in the sciences. For example, women in business and accounting earn more money than students in chemistry, biology, or mathematics (Hecker 1995). They earn less than students in architecture or engineering. Women in economics earn more than any of the STEM fields. Men in accounting and business have similar earnings to the highest paid science fields STEM fields – engineering, math, physics, and computer science. They have higher earnings than students in biology and chemistry. Business majors have similar earnings to students in biology and chemistry. For both males and females, majors in the business and economics have higher earnings than students in the other social sciences, humanities, and education.

Finally in terms of changes in the real wage distribution, engineering wages increased by 19 percent from 1991-2001 while business increased by 27 percent. Math and computer science wages increased by 21 percent over the same period. These wage increases are not only indicative of demand shocks, but they may also help students project future earnings in a given profession making business even more attractive relative to the other STEM fields..

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 eroding. 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, talented students are prepared for and in a position to major in STEM fields, and they make a rational decision 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.

III. Changing Patterns for Women and Minorities

As we have already shown, much of the growth in STEM majors over the last 30 years has taken place among women and minorities. 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. 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 5. We report robust standard errors.

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. Women are about 11 percentage points less likely to stay in STEM majors. The results are statistically significant. The coefficient on being African-American is positive but no longer statistically significant. ACT Math scores remain the strongest indicator among the achievement variables. Remediation also seems to matter. Math remediation is marginally significant suggesting that math remediation decreases the likelihood that students persist in STEM fields. English remediation seems to have the reverse relationship and is not significant. It is hard to decipher the causal relationship of these remediation estimates although work by Bettinger and Long (2008) shows that math remediation causes a decrease in the probability that students major in math fields.

The results in the other columns of Table 5 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. 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 robust results across all of the specifications are the results for gender and ACT math scores. ACT math scores is a fairly obvious result. STEM fields require higher math skills and students' retention in these fields is tied to their abilities. On the hand, the gender result is less obvious. The fact that women are underrepresented has long been discussed in academic literature. What is different is that we have focused on the highest ability students, and among them, women who have previously expressed interest in STEM fields are nine to 14 percentage points less likely to stay in STEM majors than other students.

IV. Conclusion

This paper presents new descriptive evidence on the STEM pipeline. Using data from Ohio's four-year colleges, the paper shows that STEM fields retain about half of their students, and the 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 majors and went to business. Out-migration from STEM fields is particularly acute among high performing women.

We also show how students' investigation 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. Students who are committed to be STEM majors and eventually do major in STEM fields take, on average, over 60 percent of their first semester schedules in STEM topics. There are a set of students who take over 40 percent of their schedule in STEM fields who still may major in STEM fields; however, their probability of doing so is much less so.

What are the implications for the STEM pipeline? The first observation is that even strongly prepared students who are interested in STEM fields depart from STEM majors. They move to other fields which are just as lucrative if not more so. These are 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) 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 depart STEM majors early in their careers. As early as students' first semesters, there is already a separation between the STEM course-taking intensity of eventual majors and 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, it suggests that public policy or institutional efforts aimed at improving retention in STEM majors must happen early in students' careers, or in 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. While many are switching to more lucrative majors, they remain under-represented in STEM fields. Other research by Bettinger and Long (2004) 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 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 (Inside Higher Education, September 17, 2008) and others that the shortage of scientists and engineers is overstated.

References

(To be Added)

U.S. Department of Education, National Center for Education Statistics. (2008). *Digest of Education Statistics, 2007* (NCES 2008-022).

Table 1. Major Intentions of Incoming 1st Year College Students

Intended Major	Sample				
	All Students	Students w/ Overall ACT>24	Students w/ Science ACT>24	Students w/ Math ACT>24	Students w/ 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 18-20) 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.

Table 2. Major Intentions of Incoming 1st Year College Students

Student Characteristic	Sample				
	All Students	Students w/ Overall ACT>24	Students w/ Science ACT>24	Students w/ Math ACT>24	Students w/ HS Math GPA>=3.5
Age	18.4 (0.5)	18.3 (0.5)	18.4 (0.5)	18.4 (0.5)	18.4 (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 (4.3)	27.4 (2.2)	26.9 (2.8)	26.2 (3.1)	24.4 (4.0)
Math ACT	21.9 (4.8)	27.1 (3.4)	26.6 (3.8)	27.7 (2.4)	25.0 (4.5)
Science ACT	22.0 (4.3)	26.7 (3.2)	27.5 (2.6)	25.6 (3.7)	24.0 (4.2)
Attending 4-yr 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 18-20) 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. STEM includes computer science, mathematics, engineering, engineering technologies, and the physical and biological sciences.

Table 3. STEM Major Choices by Pre-College STEM Decisions

Sample	Pre-College STEM Major		Pre-College Non-STEM Major	
	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 18-20) 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. STEM includes computer science, mathematics, engineering, engineering technologies, and the physical and biological sciences.

Table 4. Major Choices Among STEM Defectors

Major	Sample				
	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 18-20) 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. STEM includes computer science, mathematics, engineering, engineering technologies, and the physical and biological sciences.

Table 5. Predictors of Leaving STEM Majors

	Sample Dependent Variable = Probability of Persisting in STEM Major					
	All		ACT>24	ACT Math >24	ACT Science >24	HS GPA >=3.5
Age	-.027 (.013)	-.029 (.019)	-.019 (.022)	-.000 (.020)	-.011 (.021)	-.010 (.019)
White	-.014 (.027)	-.016 (.027)	.033 (.044)	.004 (.039)	.037 (.043)	-.006 (.040)
Black	.087 (.037)	.063 (.037)	.056 (.094)	.080 (.081)	.186 (.096)	.161 (.064)
Female	-.141 (.015)	-.101 (.016)	-.114 (.027)	-.140 (.026)	-.090 (.028)	-.129 (.024)
Overall ACT	-.013 (.005)	-.011 (.004)	.006 (.008)	-.003 (.007)	-.006 (.007)	-.004 (.007)
Math ACT	.029 (.003)	.027 (.003)	.027 (.004)	.028 (.005)	.027 (.004)	.027 (.004)
Science ACT	.009 (.003)	.009 (.003)	.002 (.005)	.005 (.005)	.013 (.006)	.007 (.005)
Attending 4-yr College	.021 (.019)	.016 (.019)	.032 (.043)	.062 (.039)	-.056 (.040)	.045 (.034)
Attended Math Remediation	.000 (.023)	.001 (.023)	-.139 (.076)	-.053 (.088)	-.081 (.069)	.005 (.056)
Attended Eng. Remediation	.036 (.024)	.035 (.024)	.178 (.117)	.085 (.069)	.097 (.083)	.076 (.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: Data are from the Ohio Board of Regents and include traditional-aged (age 18-20) 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. STEM includes computer science, mathematics, engineering, engineering technologies, and the physical and biological sciences.

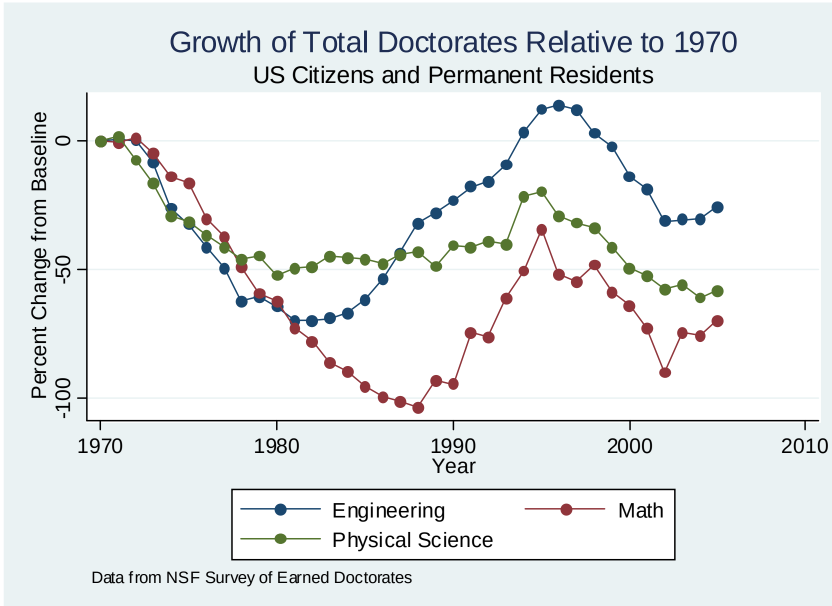

Figure 1. Growth of Total Doctorates Among US Citizens and Permanent Residents Relative to 1970.

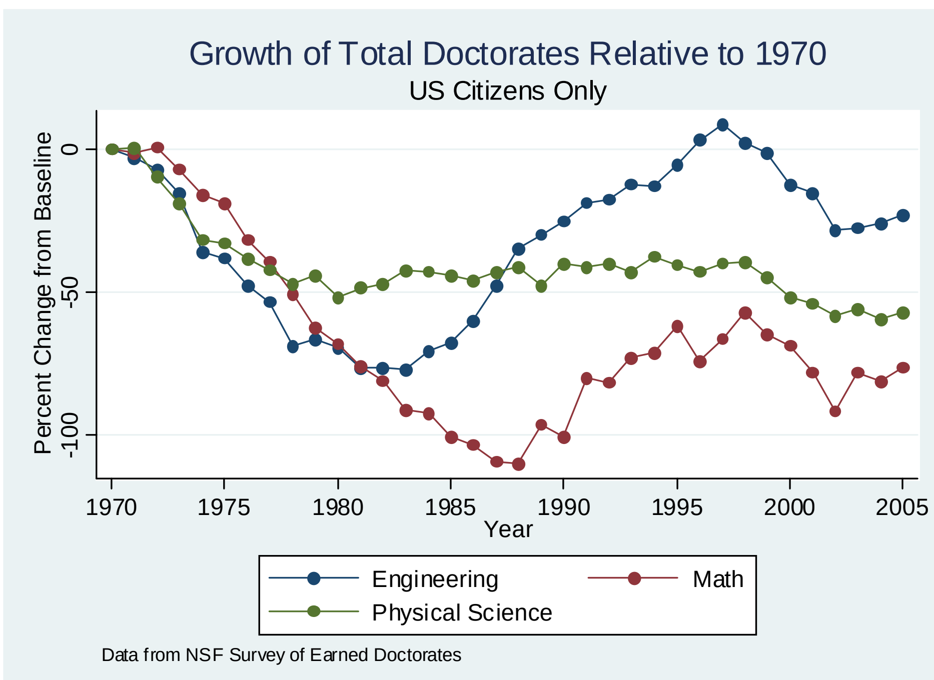

Figure 2. Growth of Total Doctorates Among US Citizens Relative to 1970.

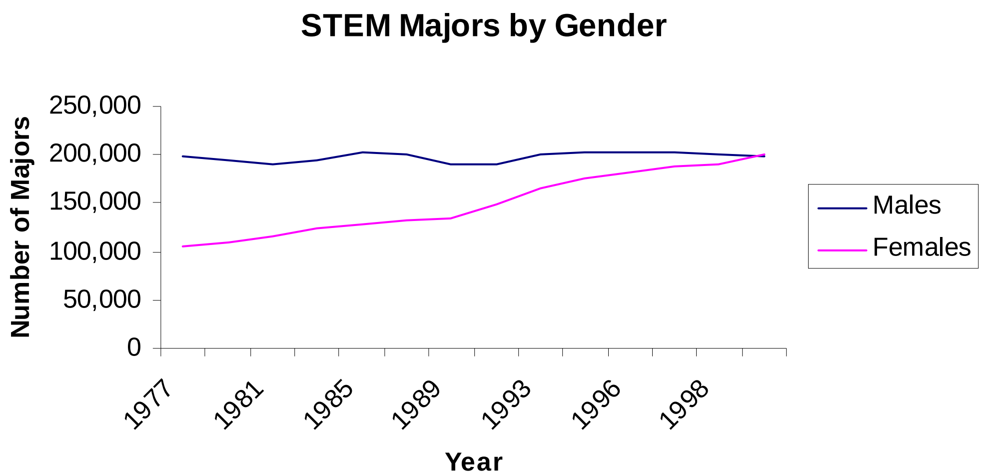

Figure 3. STEM Majors by Gender, 1977-2000
Source: NSF 2004

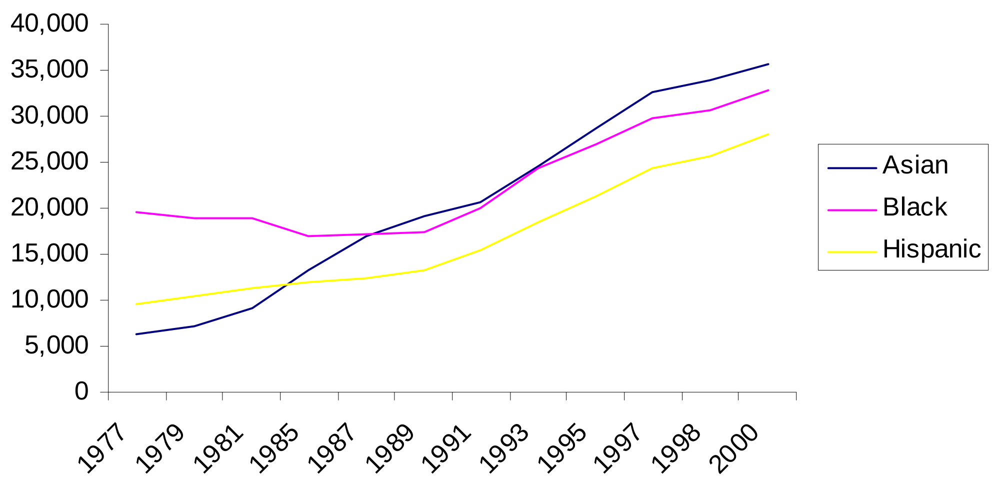

Figure 4. STEM Majors by Race, 1977-2000
Source: NSF (2004)

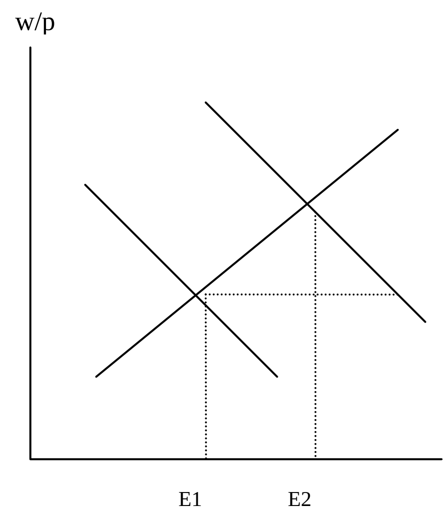

Figure 5. Shifts in Labor Demand for Engineers

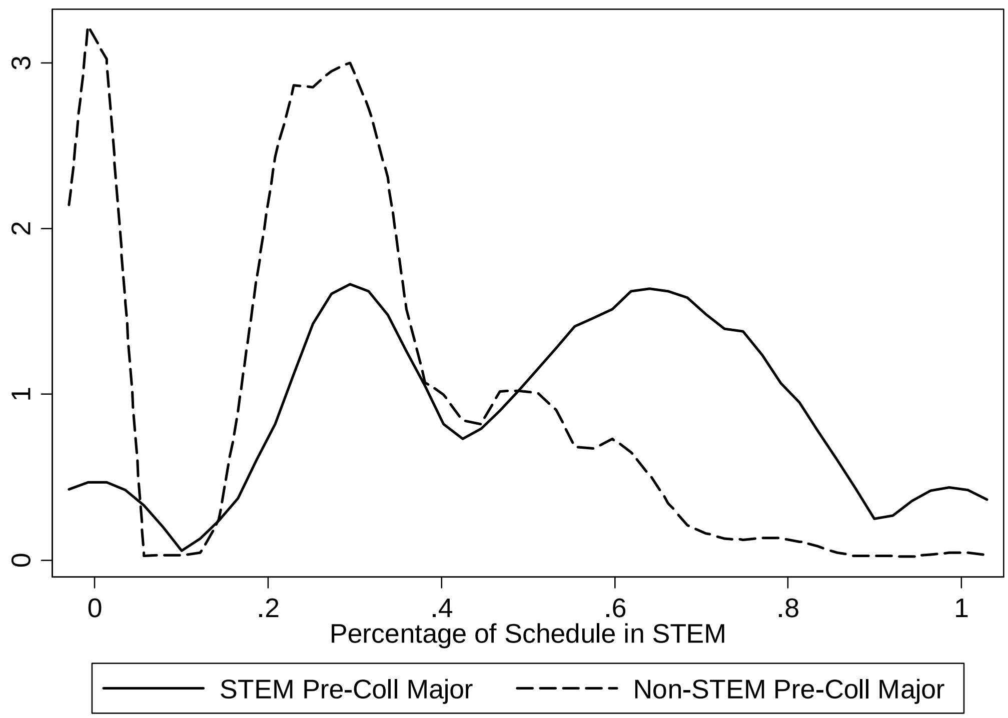

Figure 6. Proportion of 1st Semester Courses in STEM Fields for Pre-College Majors in STEM and non-STEM Fields

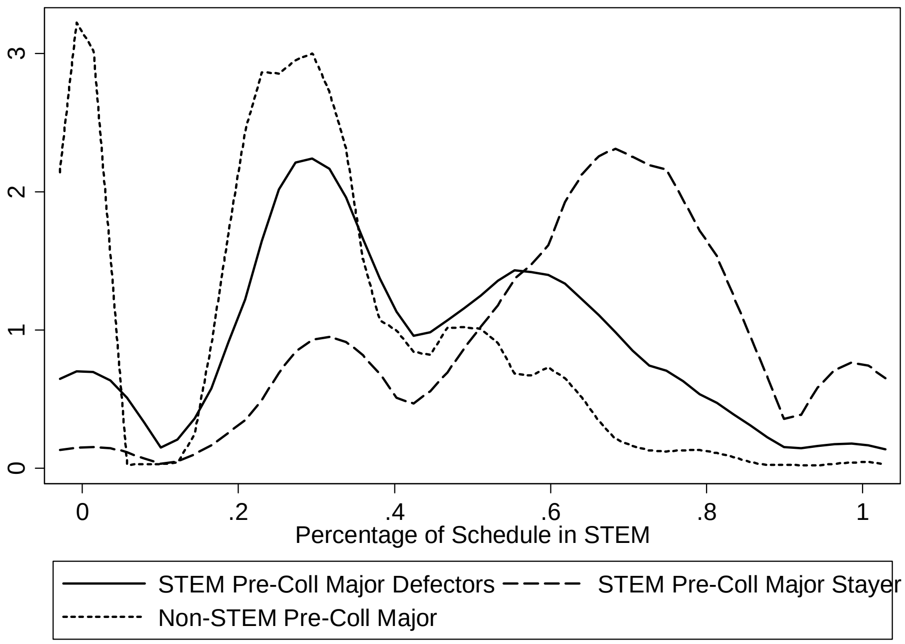

Figure 7. Proportion of 1st Semester Courses in STEM Fields for Pre-College Majors in STEM and non-STEM Fields, by Students Eventual Major

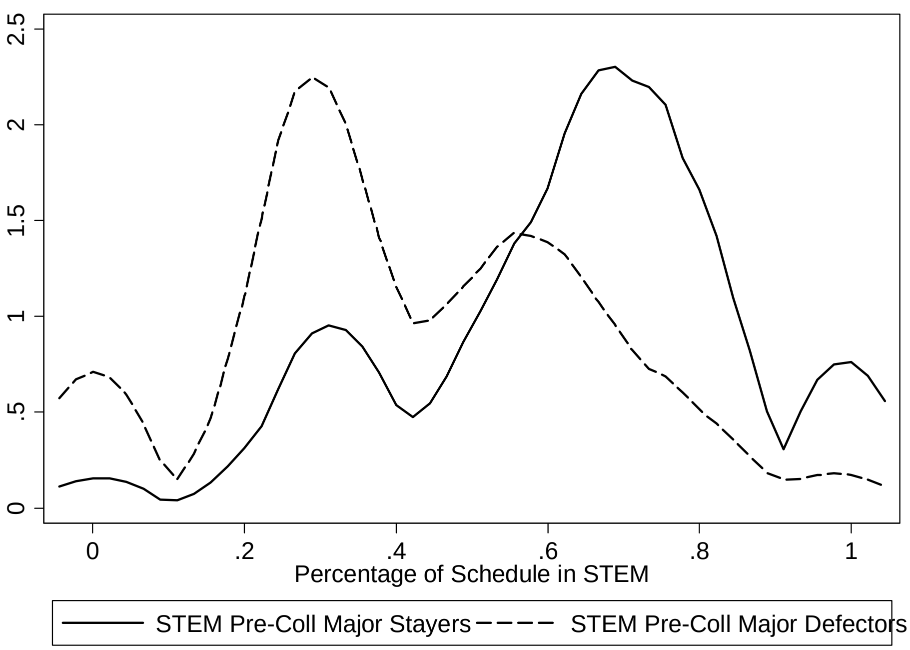

Figure 8. Proportion of 1st Semester Courses in STEM Fields for Pre-College Majors in STEM Fields, by Eventual Major

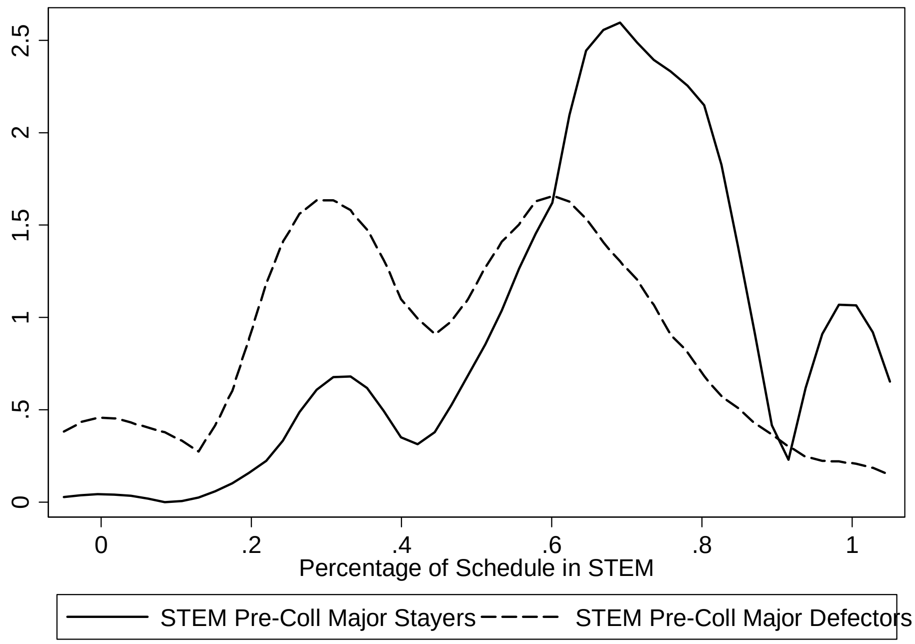

Figure 9. Proportion of 1st Semester Courses in STEM Fields for Pre-College Majors in STEM Fields, by Eventual Major for Students w/ ACT Scores Over 24

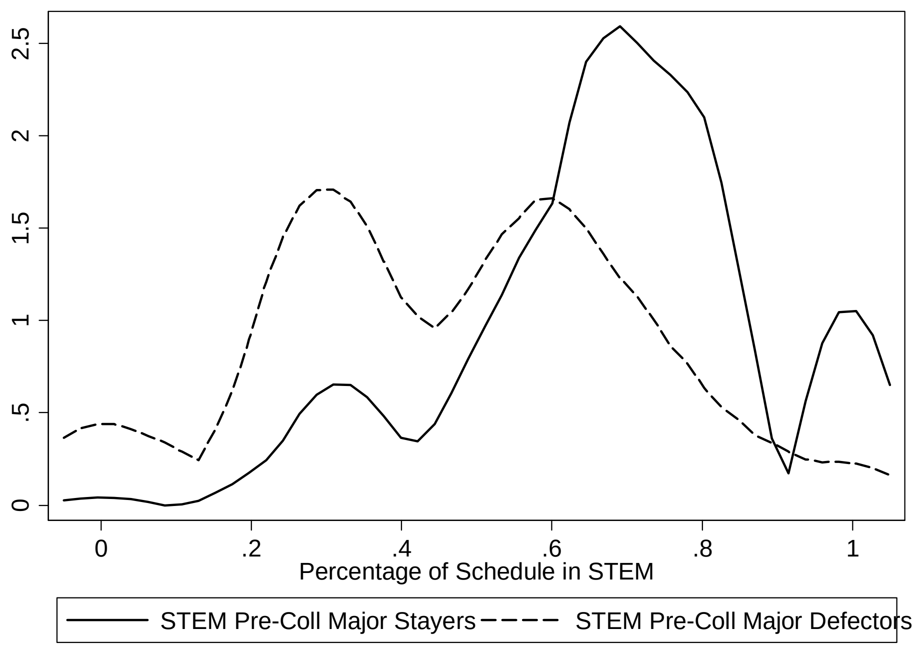

Figure 10. Proportion of 1st Semester Courses in STEM Fields for Pre-College Majors in STEM Fields, by Eventual Major for Students w/ ACT Science Scores Over 24

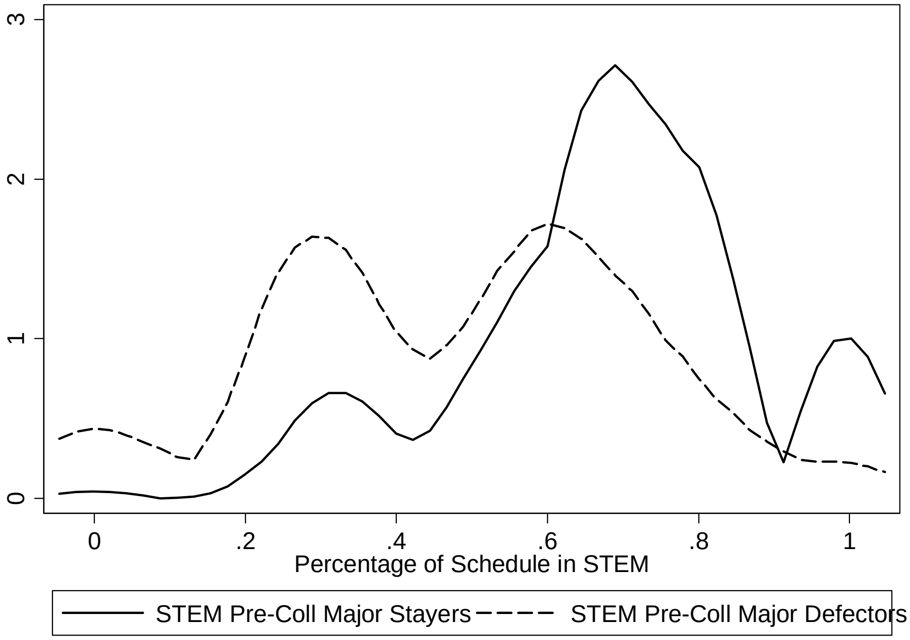

Figure 11. Proportion of 1st Semester Courses in STEM Fields for Pre-College Majors in STEM Fields, by Eventual Major for Students w/ ACT Math Scores Over 24

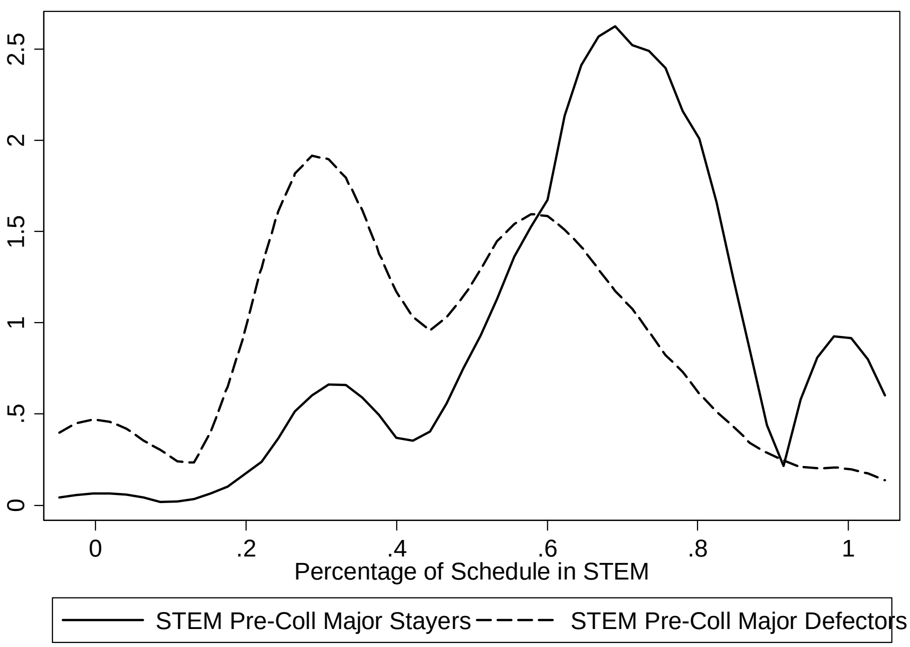

Figure 12. Proportion of 1st Semester Courses in STEM Fields for Pre-College Majors in STEM Fields, by Eventual Major for Students w/ High School Math GPA's 3.5 and Over

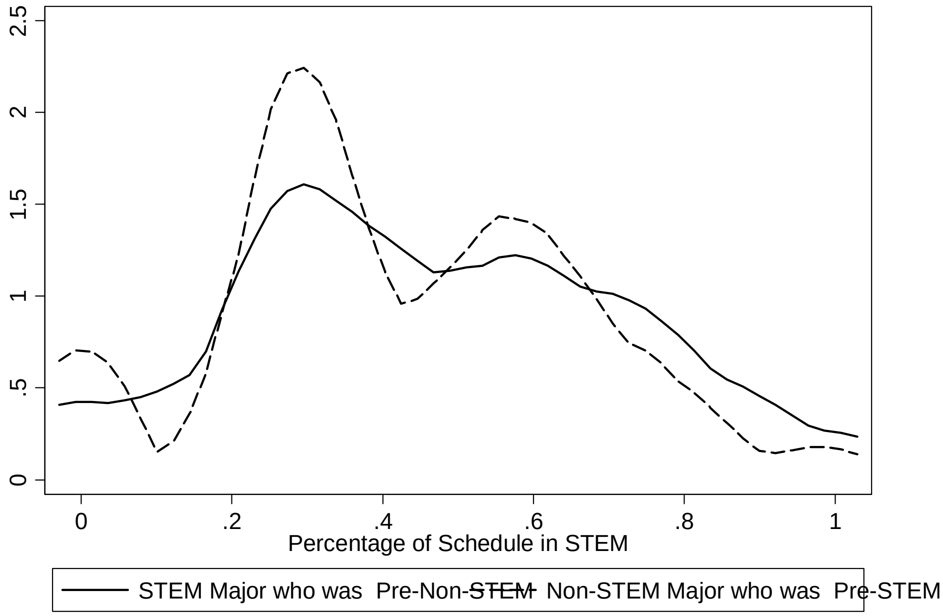

Figure 13. Proportion of 1st Semester Courses in STEM Fields for Students Who Later Switch to STEM Fields and Those Who Switch Out

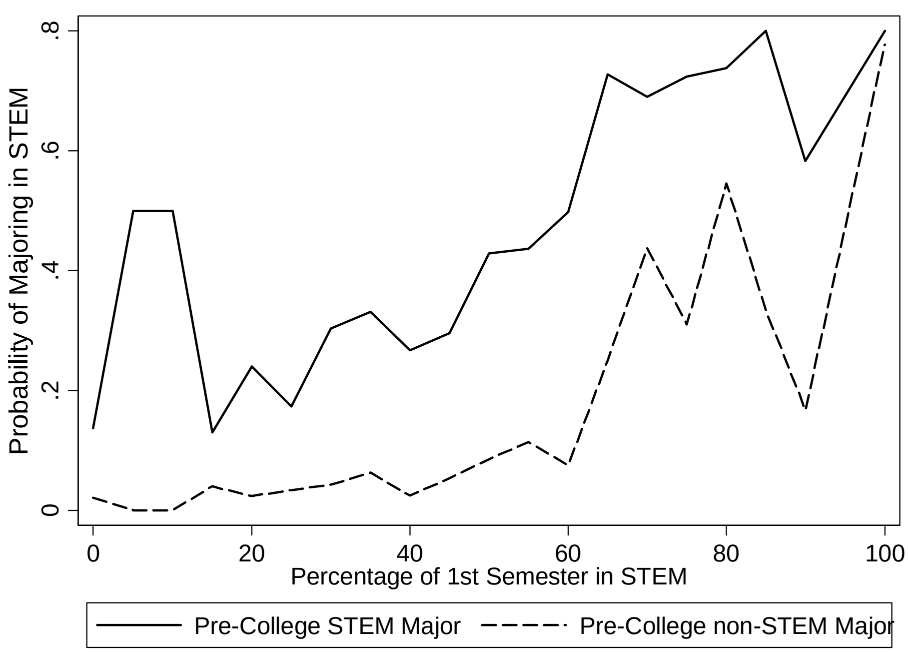

Figure 14. Probability of Majoring in STEM Field by the Percentage of 1st Semester Courses in STEM Fields, by Pre-College Major