Double Majors: One For Me, One For Mom and Dad?*

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Abstract

At least a quarter of college students in the U.S. graduate with more than one undergraduate major. This paper investigates how students choose the composition of their majors conditional on pursuing more than one major. Since students use both their preferences and expectations about the realizations of future major-specific outcomes when choosing their college majors, I collect innovative data on subjective expectations from a sample of Northwestern University sophomores to estimate a choice model of double majors. Though there is substantial heterogeneity in beliefs across students, they seem to have accurate beliefs about the outcomes conditional on major. Students believe that their parents are more likely to approve majors associated with high social status and high returns in the labor market. I find that enjoying the coursework, gaining approval of parents, and finding a job upon graduation are the most important determinants in the choice of majors. The model estimates reject the hypothesis that students major in one field to pursue their own interests and in another for parents' approval. Instead I find that gaining parents' approval and enjoying studying and working in a field of study are outcomes that are important for *both* majors in a student's major pair. However, I do find that students act strategically in their choice of majors by choosing majors that differ in their chances of completion and in finding a job upon graduation, and that entail different hours per week on coursework and on the available jobs.

JEL Codes: D8, I2, J1

Keywords: College majors, uncertainty, subjective expectations, preferences.

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*I am indebted to Charles Manski, Christopher Taber, and Paola Sapienza for extremely helpful discussions and comments. I also thank Raquel Bernal, Adeline Delavande, Marianne Hinds, Luojia Hu, Ben Jones, Hilarie Lieb, Joan Linsenmeier, Carlos Madeira, Ofer Malamud, Ija Trapeznikova, Sergio Urzua, and seminar participants at NBER Higher Education Working Group and Northwestern University for feedback and suggestions. Financial support from a Northwestern University Graduate Research Grant, and Ronald Braeutigam, is gratefully acknowledged. I thank all those involved in providing the datasets used in this paper. The views expressed in this paper do not necessarily reflect those of the Federal Reserve Bank of New York or the Federal Reserve System as a whole. All errors that remain are mine.

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> Occasionally, combinations represent a compromise: where the mother is pushing for law school, for example, and the son wants to pursue ethnomusicology, a "one for me, one for Mom" double major in political science and music can keep the whole family happy.
>
> From "For Students Seeking Edge, One Major Just Isn't Enough"
>
> *New York Times*, November 17, 2002

1 Introduction

At least a quarter of college students have more than one undergraduate major (2003 National Survey of College Graduates), and the share of college students choosing more than one major is increasing at a very fast rate (Lewin, 2002). It has been postulated that parents inadvertently drive their children to have more than one major, i.e., students major in one field to satisfy their own interests, and in another field that meets parents' approval. Other explanations for double majors include students majoring in one field associated with their professional specialty and another that reflects a very different interest (like an Engineering major who's also majoring in French), or students hedging their chances in the labor market by preparing to work in more than field. However, evidence for all these explanations remains anecdotal (Lewin, 2002; Gomstyn, 2003), and there is little systematic evidence on how students choose the composition of their double majors. This paper provides, to the best of my knowledge, the first direct evidence on how students choose their majors conditional on having a double major.[1]

Students choose a college major (or pair of majors) in order to influence the occurrence

[1] There is a small literature on college majors which primarily focuses on the choice of a single field of study: Altonji (1993), Arcidiacono (2004), and Zafar (2009).

of choice-specific outcomes that enter their utility function. These outcomes include, for example, being able to successfully complete a field of study, gaining parents' approval, finding a job upon graduation, enjoying coursework or earnings at the job. Since these outcomes are uncertain at the time the student makes his choice, he has a belief distribution of the probability for the occurrence of these outcomes conditional on each major in his choice set. Therefore, a student uses both his preferences and subjective beliefs in choosing his college major(s). The researcher usually only observes the major(s) that the student chooses, and has to make non-verifiable assumptions on expectations/ beliefs to infer the parameters of the utility function (preferences). The basic difficulty is that observed choices may be consistent with several combinations of expectations and preferences, and the list of underlying assumptions on expectations may not be valid (see Manski, 1993, for a discussion of this inference problem in the context of how students infer returns to schooling). A solution to this identification problem is to use additional data on expectations (Manski, 2004), and that is precisely what I do. I survey a group of 78 Northwestern University students pursuing double majors and elicit their subjective beliefs about major-specific outcomes.

In my relatively homogenous sample, there is substantial heterogeneity in beliefs for outcomes within a major as well as across majors, indicative that there exists tremendous heterogeneity in beliefs in the population of college students. Analysis of beliefs for the same outcome across majors suggests that students have accurate beliefs about the occurrence of outcomes conditional on major. For example, the belief distribution of reconciling work and family at jobs available in Literature and Fine Arts first order stochastically dominates the corresponding distribution in Natural Sciences (in which most pre-med students major). Comparison of beliefs of being able to graduate with a GPA of at least 3.5 and expected income at the age of 30 with objective measures reveals that students are aware of differences across majors. I find that students believe that their parents are more likely to approve majors associated with high social status and returns in the labor market. For example, the mean belief of gaining parents' approval for majoring in Engineering is 0.84 (on a scale of 0-1) compared with 0.58 for Literature and Fine Arts.

The subjective data elicited from the students is employed directly in a structural model of double major choice.[2] The heterogeneity in beliefs allows me to identify the preferences for each outcome considered in the model. Since students may choose more than one major to either expand the set of options they have or hedge along a certain outcome (i.e., they may choose majors that differ in the likelihood of that outcome), the model specification captures both these motivations. I find that enjoying the coursework, gaining approval of parents, and finding a job upon graduation are the most important determinants in the choice of double majors in my sample. However, contrary to existing anecdotal evidence (Lewin, 2002; Gomstyn, 2003), I do not find that students major in one field to gain the approval of their parents and in another to satisfy their interests. Instead, gaining parents' approval and enjoying studying and working in a field of study are outcomes that are important for *both* majors in an individual's major pair. I do, however, find that students act strategically by choosing majors that differ in their chances of completion and in finding a job upon graduation, and that entail different hours per week on coursework and at jobs. This is consistent with anecdotal evidence that students choose double majors to hedge their prospects in the labor market.

It should be pointed out that this paper investigates how students choose the composition

[2]This approach adds to the recent literature which employs expectations data in econometric models to conduct inference on behavior: Lochner (2007); Bellemare, Kroger, and van Soest (2008); Delavande (2008); and Zafar (2009). van der Klaauw (2000) and van der Klaauw and Wolpin (2008) employ expectations data to improve the precision of estimates in their structural dynamic models while maintaining the assumption of rational expectations to identify the model.

of their majors *conditional* on deciding to pursue a double major. I do not attempt to explain why some students choose single majors while others choose double majors. Though I find that, compared to single major respondents (interviewed for a separate study), the double major respondents in my sample arrive in college with more AP credits (suggesting that they need to satisfy fewer requirements for completing a major) and have higher GPAs at the time of the survey (indicative of selection along ability), the limited available data prevent me from answering the question of what drives students to choose more than one major. This paper also does not have anything to say about the costs and benefits to double majors. There is concern that studying more than one major in college may result in too little depth within one's main field of study and a decrease in the breadth of general knowledge. On the other hand, students with double majors have been found to have higher earnings (Del Rossi and Hersch, 2008). In the absence of data on student outcomes and addressing the issue of selection into double majors, it is not possible to evaluate the net benefits of pursuing more than one major.

This paper is organized as follows. Section 2 outlines the choice model and the identification strategy. Section 3 describes the data collection methodology, the institutional setup at Northwestern University, and the subjective data in detail. Section 4 presents the estimation results for the choice model and some robustness checks. Finally, Section 5 concludes.

2 Choice Model

Student i derives utility $U_{ik}(\mathbf{a}, \mathbf{c})$ from choosing a major k (if the student chooses a dual major, p denotes a pair of majors consisting of majors k_1 and k_2). Students are assumed to be forward-looking, so their choice of major(s) depends not only on the current state of the world but also on what they expect will happen in the future. Utility is a function of a vector of major-specific outcomes $\mathbf{a}$ that are realized in college and a vector of outcomes $\mathbf{c}$ that are realized after graduating from college. The vector $\mathbf{a}$ includes the outcomes:

a_1 successfully complete (graduate in) a field of study in four years

a_2 graduate with a GPA of at least 3.5 in the field of study

a_3 enjoy the coursework

a_4 hours per week spent on the coursework

a_5 gain parents' approval of the major

while the vector $\mathbf{c}$ consists of:

c_1 get an acceptable job immediately upon graduation

c_2 enjoy working at the jobs available after graduation

c_3 able to reconcile work and family at the available jobs

c_4 hours per week spent working at the available jobs

c_5 social status of the available jobs

c_6 income at the available jobs

The outcomes $\{a_r\}_{r=\{1,2,3,5\}}$ and $\{c_q\}_{q=\{1,2,3\}}$ are binary (for example, in the case of a_1, you either graduate in four years or not), while outcomes a_4 and $\{c_q\}_{q=\{4,5,6\}}$ are continuous. I change the notation slightly and define $\mathbf{b}$ to be a 7×1 vector of all binary outcomes, i.e., $\mathbf{b} = \{a_1, a_2, a_3, a_5, c_1, c_2, c_3\}$, and $\mathbf{d}$ to be a 4×1 vector of all continuous outcomes, i.e., $\mathbf{d} = \{a_4, c_4, c_5, c_6\}$. The vectors $\mathbf{b}$ and $\mathbf{d}$ are uncertain at the time of the choice, and individual i possesses subjective beliefs $P_{ik}(\mathbf{b}, \mathbf{d})$ about the outcomes associated with major k for all $k \in C_i$, where C_i is i's choice set.[3]

Before specifying the structural form of the utility function describing choice of majors for

[3]The vectors $\mathbf{b}$ and $\mathbf{d}$ are the set of outcomes common to all majors. It is the joint probability distribution of these outcomes $P_{ik}(\mathbf{b}, \mathbf{d})$ which is indexed by major k.

double major students, it is useful to outline the objective function of a student with a single major. Students are assumed to maximize their current expected utility. If an individual chooses a major m, then standard revealed preference argument (assuming that indifference between alternatives occurs with zero probability) implies that:

$$m \equiv \arg\max_{k \in C_i} \int U_{ik}(\mathbf{b}, \mathbf{d}) dP_{ik}(\mathbf{b}, \mathbf{d}). \quad (1)$$

The goal is to infer the preference parameters from observed choices. However, the expectations of the individual about the choice-specific outcomes, $P_{ik}(\mathbf{a}, \mathbf{c})$, are also unknown. The most one can do is infer the decision rule conditional on the assumptions imposed on expectations. This would not be an issue if there were reasons to think that prevailing expectations assumptions are correct. However, not only has the information-processing rule varied considerably among studies of schooling behavior, but most assume that individuals form their expectations in the same way.[4] First, there is little reason to think that individuals form their expectations in the same way. Second, different combinations of preferences and expectations may lead to the same choice (Manski, 2002). To cope with the problem of joint inference on preferences and expectations, I elicit subjective probabilities directly from individuals. An additional advantage of this approach is that it allows me to account for the non-pecuniary determinants of the choice (data that do not exist otherwise). Since it would be difficult to elicit the joint probability distribution $P_{ik}(\mathbf{a}, \mathbf{c})$, I assume that utility is linear

[4]Consider, for example, income expectations conditional on schooling choices. Freeman (1971) assumes that students have myopic expectations, Willis and Rosen (1979) hypothesize that expectations are rational, while Arcidiacono (2004) assumes that students condition their expectations on ability, GPA, average ability of other students enrolled in the college and some demographic controls. It's not clear which of these rules is the correct one.

and separable in outcomes, so that:

$$U_{ik}(\mathbf{b},\mathbf{d}) = \sum_{r=1}^{7} u_r(b_r) + \sum_{q=1}^{4} \gamma_q d_q + \varepsilon_{ik},$$

where $u_r(b_r)$ is the utility associated with the binary outcome b_r, γ_q is a constant for the continuous outcome d_q, and ε_{ik} is a random term. Equation (1) can now be written as:

$$m \equiv \arg\max_{k\in C_i}(\sum_{r=1}^{7}\int u_r(b_r)dP_{ik}(b_r) + \sum_{q=1}^{4}\gamma_q \int d_q dP_{ik}(d_q) + \varepsilon_{ik}).$$

The additive separability of the utility function implies that only the marginal distribution of beliefs about the outcomes enter the expected utility. For the binary outcomes ($\{b_r\}_{r=1}^{7}$):

$$\begin{aligned}\int u_r(b_r)dP_{ik}(b_r) &= P_{ik}(b_r=1)u_r(b_r=1) + [1-P_{ik}(b_r=1)]u_r(b_r=0)\\ &= P_{ik}(b_r=1)\triangle u_r + u_r(b_r=0),\end{aligned}$$

where $\triangle u_r \equiv u_r(b_r=1) - u_r(b_r=0)$, i.e., it is the difference in utility between outcome b_r happening and not happening. The linearity assumption of the utility function implies that only the expected value of the continuous outcomes matters since $\int U_i(\mathbf{b},\mathbf{d})dP_{ik}(\mathbf{b},\mathbf{d}) = U_i(\int \mathbf{b},\mathbf{d}\ dP_{ikt}(\mathbf{b},\mathbf{d}))$. Thus, for the continuous outcomes ($\{d_q\}_{q=1}^{4}$), $\int d_q dP_{ik}(d_q)$ equals $E_{ik}(d_q)$, the expected value of the outcome. The expected utility that individual i derives from choosing major m is:

$$\begin{aligned}&U_{im}(\mathbf{b},\mathbf{d},\{P_{im}(b_r=1)\}_{r=1}^{7},\{E_{im}(d_q)\}_{q=1}^{4}) =\\ &\textstyle\sum_{r=1}^{7} P_{im}(b_r=1)\triangle u_r + \sum_{r=1}^{7} u_r(b_r=0) + \sum_{q=1}^{4}\gamma_q E_{im}(d_q) + \varepsilon_{im}.\end{aligned} \tag{2}$$

In equation (2), $\{\triangle u_r\}_{r=1}^{7}$, and $\{\gamma_q\}_{q=1}^{4}$ are the parameters of the utility function that need to be estimated; $\triangle u_r$ is the change in utility from the occurrence of outcome b_r, while

γ_q is the parameter in the utility function for the continuous outcome d_q. $\{P_{ik}(b_r = 1)\}_{r=1}^{7}$ and $\{E_{ik}(d_q)\}_{q=1}^{4}$ are elicited directly from the respondent $\forall k \in C_i$.

Now consider the case of double majors. The relevant set of major-specific outcomes, vectors $\mathbf{b}$ and $\mathbf{d}$, remain the same as in the case of a single major. However, the utility function now becomes more complex. It may be useful to think about why an individual may decide to choose two majors. Respondents pursuing more than one major were asked to explain their reasons; selected responses are shown in Section A.2 of the Appendix. Two main reasons emerge. First, two majors appropriately differentiated can provide a broader mix of options than a single major. Second, it might be the case that no single major meets the needs of the individual. For example, an individual might be interested in both maximizing his income prospects and enjoying the coursework. It could very well be the case that no single major meets his needs, but a combination of two majors does. To capture the enhanced options and specialization of function that two majors provide, I assume that the utility of a pair of majors depends on the attributes of each major separately, as well as on the attributes of a composite major combining the best of both majors. The expected utility function of a pair of majors p consisting of majors p_1 and p_2 takes the form:[5]

$$U_{ip} = U_{ip_1}(\mathbf{b}, \mathbf{d}, \{P_{ip_1}(b_r = 1)\}_{r=1}^{7}, \{E_{ip_1}(d_q)\}_{q=1}^{4})$$

$$+U_{ip_2}(\mathbf{b}, \mathbf{d}, \{P_{ip_2}(b_r = 1)\}_{r=1}^{7}, \{E_{ip_2}(d_q)\}_{q=1}^{4})$$

$$+U_{i\widetilde{p}}(\mathbf{b}, \mathbf{d}, \{\max[P_{ip_1}(b_r = 1), P_{ip_2t}(b_r = 1)]\}_{r=1}^{7},\ \{\max[E_{ip_1}(d_q), E_{ip_2}(d_q)]\}_{q=1}^{4}), \tag{3}$$

where $\widetilde{p}$ refers to the composite major, and $U_{ip_1}(.)$ is as defined in equation (2). Because there

[5]Manski and Sherman (1980) use a similar approach to model the composition of motor vehicles in two-vehicle households.

is no way of specifying a "primary" and a "secondary" major, I use the same functional form for the utility of each major in one's major pairing, i.e., $U_{ip_1} = U_{ip_2}$. Since $U_{ip_1}(.)$ is linear-in-parameters, the average characteristics of the two majors appear in the utility function. Thus, equation (3) can be written as:[6]

$$U_{ip}(\mathbf{b}, \mathbf{d}, \{P_{ip_1}(b_r), E_{ip_1}(d_q), P_{ip_2}(b_r), E_{ip_2}(d_q)\}_{r\in\{1,..,7\},q\in\{1,..,4\}})$$

$$= \sum_{r=1}^{7}\{\tfrac{P_{ip_1}(b_r=1)+P_{ip_2}(b_r=1)}{2}\}\triangle u_{r1} + \sum_{q=1}^{4}\gamma_{q1}\{\tfrac{E_{ip_1}(d_q)+E_{ip_2}(d_q)}{2}\}$$
$$+\sum_{r=\{1,3,4,5,6,7\}} \max[P_{ip_1}(b_r = 1), P_{ip_2}(b_r = 1)]\triangle u_{r2}$$
$$+\sum_{q=\{1,2\}} \gamma_{q2} \min[E_{ip_1}(d_q), E_{ip_2}(d_q)] + \sum_{q=\{3,4\}} \gamma_{q2} \max[E_{ip_1}(d_q), E_{ip_2}(d_q)] + \varepsilon_{ip}$$

$$= U_{ip} + \varepsilon_{ip}, \qquad (4)$$

where $\{\triangle u_{r1},\triangle u_{r2}\}_{r=\{1,3,4,5,6,7\}}$, $\triangle u_{21}$, $\{\gamma_{q1}, \gamma_{q2}\}_{q=1}^{4}$ are the parameters of the utility function that need be estimated. As can be seen in equation (4), I do not consider the composite-major representation for b_2, i.e., graduating with a GPA of more than 3.5 because GPA is a composite of all coursework an individual does, and it is not possible to hedge along this dimension. The probability that an individual i with a choice set C_i and subjective beliefs $\{P_{ik}(b_r)\}_{r\in\{1,..,7\}}, P_{ik}(d_q)_{q\in\{1,..,4\}}\}$ for $\forall k \in C_i$ chooses a major pair p is then:

$$\Pr(p|\{P_{ik}(b_r), P_{ik}(d_q)\}_{r\in\{1,..,7\},q\in\{1,..,4\};\, k\in C_i}) = \Pr\left(U_{ip} + \varepsilon_{ip} > U_{is} + \varepsilon_{is}\right) \qquad \forall s \in C_i,\ p \neq s, \qquad (5)$$

where U_{ip} is defined in equation (4), and s is the set of all possible major pairs and single

[6]The vector $\mathbf{b}$ consists of b_1= graduating in 4 years, b_2= graduating with a GPA of at least 3.5, b_3= enjoying the coursework, b_4= parents approving of the major, b_5= getting a job on graduation, b_6= enjoying work at the jobs, and b_7= being able to reconcile work and family at the jobs. The vector $\mathbf{d}$ consists of d_1= average hours per week spent on coursework, d_2= average hours per week spent at the job, d_3= social status of the job, and d_4= expected income at the age of 30.

majors from the choice set.

The composite-major representation captures the notion of functional specialization as follows. Say an individual with a pair of majors chooses one major with a low-completion probability (i.e., $P(b_1)$ is low) because of some of its other attributes and a second major where the completion probability is the most important consideration. Given the specification above, one would expect $\triangle u_{11} \approx 0$ and $\triangle u_{12} > 0$ in this case of extreme specialization. On the other hand, for an individual who equally values the completion probabilities associated with both his majors, one would expect $\triangle u_{12} \approx 0$ and $\triangle u_{11} > 0$. Thus the ratio $\triangle u_{12}/\triangle u_{11}$ (and similarly $\{\triangle u_{r2}/\triangle u_{r1}\}_{r=\{1,3,4,5,6,7\}}$, $\{\gamma_{q2}/\gamma_{q1}\}_{q=1}^{4}$) is a measure of the extent to which an individual desires to functionally specialize his majors along the given outcome.

The exact parametric restrictions on the random terms required for identifying the model parameters are outlined in section 4, which discusses the estimation.

3 Data

To estimate a choice model of double majors, the subjective beliefs about the outcomes associated with a major, $P_{ik}(\mathbf{b}, \mathbf{d})$, need to be elicited for each major ($\forall k \in C_i$) in individual i's choice set. Since the range of majors available to students and institutional details vary considerably across institutions, one standard survey cannot be used to collect data in different settings. As a first step towards understanding how college students choose the composition of double majors, I focus on Northwestern University and use data on 78 Northwestern University students who were pursuing more than one major at the time of the survey. This section describes the institutional details at Northwestern University, the data collection method, and the subjective data.

3.1 Institutional Details

For the purposes of this study, I focus on students who are in the process of choosing their majors but have not necessarily chosen one. There are several reasons for this criteria: Students who are in the process of choosing a major are actively thinking about the occurrence of outcomes associated with the majors, and hence their responses to subjective questions related to majors are more likely to be meaningful. Second, interviewing students who have already chosen their majors raises the issue of cognitive dissonance (Festinger, 1957), i.e., students who have already chosen their major could rationalize their choice of major by devaluing their beliefs for outcomes associated with the majors they considered but rejected, and upgrading their beliefs for outcomes associated with the major that they chose. This systematic measurement error in elicited subjective beliefs would be problematic, and would result in biased estimates of preference parameters. Northwestern University requires students to declare their major by the end of their sophomore year. Surveying juniors and seniors would exacerbate issues arising from cognitive dissonance. On the other hand, freshmen may have little idea of what majors they want to pursue when they first arrive in college, and may not have thought about the likelihood of the various outcomes conditional on choice of major. Therefore, I restrict my sample to Northwestern University sophomores.

The study is further restricted to schools at Northwestern University that accord students flexibility in choosing a major. For example, a student in the School of Engineering has to declare his major at the time of admission and can change his major only by a special request to the school. For such a student, the choice of college and majors is jointly determined. Since, I model the choice of majors conditional on deciding to attend Northwestern University, such students are not eligible for the study. I further assume that the choice set for an individual is exogenous. This eliminates students in smaller schools at Northwestern since this assumption would have to be relaxed for them. Therefore, I restrict the study to students with at least one major in the Weinberg College of Arts & Sciences (WCAS) at Northwestern.

The data used in this study come from a survey administered to a sample of Northwestern University students. Sophomore students with at least one intend major in WCAS were recruited by e-mail and flyers posted around campus. Prospective participants were told that the survey was about the choice of college majors and that they would receive $10 for completing a 45-minute electronic survey. It was emphasized that students need not have declared their majors to participate in the study. The survey was conducted from November 2006 to February 2007, which corresponds to the first half of the students' sophomore year. Respondents were required to come to the Kellogg Experimental Laboratory to take the electronic survey. A total of 161 sophomores were surveyed, of whom 78 stated that they were pursuing more than one major. Since this study investigates the composition of double majors conditional on having a double major, the analysis in this paper is restricted to the 78 respondents with more than one major.[7]

3.1.1 Choice Set

WCAS offers a total of 41 majors. To estimate the choice model, one needs to elicit the subjective probabilities of the outcomes for each major in one's choice set (i.e., for the majors that the individual is pursuing, as well as for the other majors in the individual's choice set). In order to limit the size of the choice set, similar majors are pooled together. Table 1 shows the majors divided into various categories. Categories *a* through *g* span the majors offered

[7]Interested readers are referred to Zafar (2009) which uses data on all 161 respondents to investigate how students choose college majors.

in WCAS. Categories *h* through *l* span undergraduate majors offered by other schools at Northwestern University. There is a trade-off between the number of categories and the length of the survey. This categorization is fairly fine and also seems reasonable.

The choice set of an individual is conditional on whether both his majors are in WCAS and the School of Engineering, or not. Conditional on the student's majors being in WCAS and the School of Engineering, the choice set includes all the categories that span WCAS majors (*a*-*g*) and category *k*, the majors offered in the School of Engineering. Conditional on one of the majors being in a school other than WCAS or the School of Engineering, the choice set includes all major categories that span WCAS, category *k,* and the category which includes the student's non-WCAS major. For example, the choice set for a student with a major in WCAS and the School of Education would be categories *a*-*g*, *i*, and *k*.

Table 2 presents the distribution of double majors in the sample. For the purposes of the table, I simply label one of the majors as "Major 1" and the other as "Major 2"; this labelling should not signify any hierarchy. The table shows that, with the exception of five instances, all major pairs consist of majors from different categories. The most common major pair in the sample consists of Social Sciences I and Social Sciences II (eleven instances), followed by Area Studies and Social Sciences II (ten instances). These major pairs consist of majors that differ particularly in their labor market returns. As will be discussed later, these examples are consistent with specialization along certain dimensions. There is also some suggestive evidence that students stick to related fields when choosing double majors. For example, students with a major in Literature and Fine Arts or Social Sciences I are very likely to have Area Studies as their second major.

3.2 Subjective Data

For each major k in the individual's choice set, the survey elicited the probability of the occurrence of the binary outcomes, i.e., $P_{ik}(b_r = 1)$ for $r = \{1, .., 7\}$, and the expected value for the continuous outcomes, i.e., $E_{ik}(d_q)$ for $q = \{1, .., 4\}$.

Questions eliciting the subjective probabilities of major-specific outcomes are based on the use of percentages. An advantage of asking probabilistic questions relative to approaches that employ a Likert-scale or a simple binary response (yes/no or true/false) is that responses are interpersonally comparable, more informative, and allow the respondent to express uncertainty (Juster, 1966; Manski, 2004).[8] As is standard in studies that collect subjective data, a short introduction (similar to the one in Delavande, 2008), was read and handed to the respondents at the start of the survey. Respondents had to answer two practice questions before starting the survey to make sure they understood how to answer questions based on the use of percentages. Here, I present some of the questions that elicited the subjective expectations. For example, the belief for the binary outcome a_2 was elicited as follows:

> *If you were majoring in [X], what do you think is the percent chance that you will graduate with a GPA of at least 3.5 (on a scale of 4)?*

The question eliciting the expected number of hours per week spent on coursework (a_4) was:

> *If you were majoring in [X], how many hours per week do you think you will need to spend on the coursework?*

[8]Existing studies that have examined the role of non-pecuniary influences in the choice of schooling: Fiorito and Dauffenbach (1982), Daymont and Andrisani, (1984), Easterlin (1995), and Weinberger (2004) use questions that employ a Likert-scale.

Social status of the available jobs (c_5) was elicited as follows:[9]

Look ahead to when you will be 30 years old. Rank the following fields of study according to your perception of the social status of the jobs that would be available to you and that you would accept if you graduated from that field of study.

Wording for the question that elicited expected income (c_6) was similar to that in Dominitz and Manski (1996):

Look ahead to when you will be 30 years old. Think about the kinds of jobs that will be available to you and that you will accept if you graduate in [X]. What is the average amount of money that you think you will earn per year by the time you are 30 YEARS OLD?

The short introduction, practice questions, and questions eliciting beliefs about major-specific outcomes can be viewed in Section A.1 of the Appendix. The 15 questions that elicit beliefs about major-specific outcomes were asked for *each* major category in the student's choice set. The full questionnaire (which also collected data on demographic information, formation of beliefs etc.) is available from the author on request.

3.3 The Data

This section provides a brief description of the subjective data elicited from the students. There are two main reasons for doing this: 1) to get a sense of the precision and accuracy of such data, and 2) to highlight the heterogeneity in responses across students.

[9]This question elicits an ordinal ranking of the social status of the jobs. However, I treat these ordinal responses as cardinal in the choice model. In hindsight, this question should have been asked in terms of subjective expectations of getting a high-status job, since the ordinal ranking does not reveal the respondent's uncertainty about the outcome.

Table 3 shows the mean belief for each of the eleven outcomes for the eight main major categories. This table shows substantial variation in mean belief for the same outcome across the various major categories, indicating that students do perceive differences in the occurrence for these outcomes across majors. For example, the mean belief of being able to graduate in 4 years varies from 0.83 (on a 0-1 scale) for Engineering and Math & Computer Studies to 0.95 for Social Sciences I. Similarly, the mean belief about gaining parents' approval varies from a low of 0.58 for Literature and Fine Arts to a high of 0.87 for Natural Sciences. Since students associate Natural Sciences with a higher social status (mean value of 0.73 on a 0-0.9 scale versus 0.37 for Literature & Fine Arts) and higher returns in the labor market (mean earnings of $87,300 at the age of 30 versus $49,500 for Literature & Fine Arts), this suggests that students believe that parents are more likely to approve of majors associated with higher status and returns in the labor market.

Assessing the *accuracy* of these beliefs is not an easy task since that requires some objective measures to which the beliefs can be compared. Such an exercise is not possible for non-pecuniary outcomes such as approval of parents or enjoying coursework since no objective measures exist for these outcomes. Even in instances where objective measures exist such as for expected income or GPA, they correspond to outcomes for students who choose to pursue that major. In this study, since beliefs are elicited from an individual about the occurrence of the various outcomes in his current major as well as for other majors in his choice set which he considered but did not choose, using data on realizations of students who choose that major may not be the *correct* objective measure. However, since that is the only data available, in Table 4, I compare the mean belief about graduating with a GPA of at least 3.5 and about expected income at the age of 30 in the various majors with realizations of bachelor graduates from institutions that are similar to Northwestern University.

Column (1a) of Table 4 shows the mean GPA by major category of bachelor graduates in the 2001 Baccalaureate & Beyond Longitudinal Study (B&B 2001), and column (1b) ranks the majors according to their GPA. Columns (2a) and (2b) provide the survey respondents' mean belief of being able to graduate with a GPA of at least 3.5 and the ranking of the majors in this dimension, respectively. The relative ranks of majors according to their GPA are similar in my sample and the B&B 2001, suggesting that students are aware of the relative difficulty of the various majors. For comparison purposes, columns (3a) and (3b) report the responses about graduating with a GPA of at least 3.5 for the single major respondents in the sample. Based on mean responses, it seems that double major respondents, relative to their single major counterparts, report a higher probability of being able to graduate with a GPA of at least 3.5 in most categories (though the difference is only statistically significant in three of the cases). This result could possibly be explained by the selection into who chooses to double major: Average GPA of double major respondents is 3.49 opposed to 3.39 for single major respondents. Columns (4)-(6) of the table report the corresponding statistics for expected income at the age of 30. The objective measure in this case is the 2003 average annual salary of 1993 college graduates of selective colleges (Carnegie code 4) from the B&B 1993/2003 Study. The relative ranking of majors by income reported by the double major respondents are similar to that computed using the B&B sample, indicating that students correctly perceive income differences across majors. In the case of expected income, the responses of single major and double major respondents are not statistically different.

The mean beliefs reported in Table 4 mask the heterogeneity in responses across respondents for the *same* outcome. Figures 1 through 4 present the histogram of the beliefs for some of the outcomes. The figures show that there is substantial heterogeneity in beliefs in my relatively homogenous sample. Respondents seem to be willing to use the entire scale from zero to 100. There has been some concern that respondents might answer 50% when they want to respond to the interviewer, but are unable to make any reasonable probability assessment of the relevant question (Bruine de Bruin et al., 2000). However, the 50% response is not the most frequent one in the majority of the cases. Moreover, there doesn't seem to be any evidence of anchoring, since numbers that were presented in the introductory text do not occur more often than others.

The figures show that there is substantial heterogeneity in beliefs for the outcomes *across* majors as well. Figure 1 presents the cumulative distribution of the belief of being able to graduate with a GPA of at least 3.5 in Engineering and Literature & Fine Arts. The belief distribution for Literature & Fine Arts first order stochastically dominates the Engineering belief distribution. While less than 40% of the respondents believe that there is a greater than 60% chance of graduating with a GPA of at least 3.5 in Engineering, nearly 90% of the respondents believe that to be case in Literature & Fine Arts. This is consistent with the evidence in Table 4 that the graduation GPAs are higher is Literature & Fine Arts relative to Engineering. Moreover, according to the Northwestern 2006 Graduate Survey, average GPA of Northwestern Engineering graduates of 2006 was 3.43, while that of Literature & Fine Arts was 3.56.

Figure 2 presents the distribution of parents' approval in Area Studies and Natural Sciences. The belief distribution in the case of Natural Sciences is first order stochastically dominated by that of Area Studies, which is consistent with the hypothesis that (students believe that) parents are more likely to approve majors that are associated with higher social status and better prospects in the labor market. Figure 3 shows that students perceive better chances of getting an acceptable job in the case of Social Sciences II relative to Social Sciences I; this is consistent with anecdotal evidence of better job prospects in Social Sciences II which includes Economics. Finally, Figure 4 shows that the belief distribution of being able to reconcile family and work at the jobs in Natural Sciences is first order stochastically dominated by the corresponding distribution in Literature and Fine Arts. This is consistent with the general perception of hectic work schedules in the pure sciences and medical profession in which most Northwestern University Natural Sciences bachelors' graduates get jobs.

On the whole, analysis of the subjective data indicates that students are aware of differences across majors along the various dimensions, and that they answer meaningfully. At the same time, as shown in Figures 1 through 4, there is substantial heterogeneity in beliefs about outcomes *across* majors as well as *within* majors. This questions the accuracy of restrictions imposed on expectations in the literature. Moreover, this section also highlights the advantage of eliciting beliefs as probabilistic expectations since simple binary responses would be unable to unmask this heterogeneity entirely.

4 Estimation

4.1 Baseline Model

In order to estimate the choice model of double majors described in Section 2, I assume that the random terms $\{\varepsilon_{ip}\}$ are independent for every individual i and every alternative p, and have a Type I extreme value distribution, implying that $\{\varepsilon_{ip} - \varepsilon_{is}\}$ has a standard logistic distribution. Then equation (5), i.e., the probability that individual i chooses major pair p is:

$$\Pr(p|\{P_{ik}(b_r), E_{ik}(d_q)\}_{r\in\{1,..,7\},q\in\{1,..,4\};\, k\in C_i}) = \frac{\exp(U_{ip})}{\sum_{s\in C_i}\exp(U_{is})},$$

where U_{ip} is as defined in equation (4), and s is the set of all possible single and double major alternatives from the individual's choice set C_i. Depending on the exact composition of the individual's major pair, the choice set of the individual consists of either 8 or 9 categories.[10] For estimation, I assume that the individual may choose a single major or a pair of majors. The set of alternatives, s, includes all subsets of two majors in WCAS and the School of Engineering (${}^8C_2 = 28$), all possible single majors in WCAS (7), and all *possible* pairings of WCAS majors with non-WCAS and non-Engineering majors. Therefore, s consists of either 35 alternatives in the case that C_i has 8 categories, or 42 alternatives in the case that C_i has 9 categories.

The elicited subjective probabilities, $\{P_{ik}(b_r = 1)\}_{r=1}^{7}$, and elicited expected values, $\{E_{ik}(d_q)\}_{q=1}^{4}$, described in Section 3.3 are used in estimation. The heterogeneity in these beliefs is crucial for identification of the model parameters. The parameters of interest are $\{\triangle u_{r1}, \triangle u_{r2}\}_{r=\{1,3,4,5,6,7\}}$, $\triangle u_{21}$ and $\{\gamma_{q1}, \gamma_{q2}\}_{q=1}^{4}$, and they are identified under these parametric assumptions.

The maximum-likelihood estimates are shown in column (1) of Table 5. All of the outcomes associated with college are significant, while in the workplace, outcomes that are statistically significant are finding a job upon graduation, hours per week spent at work and enjoying work at the jobs. The estimates indicate specialization in the case of graduating in

[10]It would be the former if both majors are in WCAS and/or the School of Engineering. In the event that one of the majors is in neither of the two schools, the choice set will be the latter, with the extra category including the majors offered in that school.

4 years ($\triangle u_{12} > 0$, $\triangle u_{11} \approx 0$) and finding a job upon graduation ($\triangle u_{52} > 0$, $\triangle u_{51} \approx 0$). This implies that students concentrate their chances of graduating in four years and getting a job upon graduation in one of their two majors.[11] On the other hand, gaining approval of parents, enjoying coursework and enjoying work at the jobs are outcomes that are important in the choice of both majors (i.e., $\triangle u_{41} > 0$, $\triangle u_{42} \approx 0$; $\triangle u_{31} > 0$, $\triangle u_{32} \approx 0$; $\triangle u_{61} > 0$, $\triangle u_{62} \approx 0$, respectively). This suggests that the hypothesis that students major in one field to satisfy their own interests and in another to meet parents' approval does not hold in my data. The coefficients on hours per week spent on coursework, γ_{12}, and on hours per week spent at the job, γ_{22}, are negative which supports the specialization hypothesis, i.e., individuals prefer pairs of majors that entail different hours per week in college and in the workplace. Column (1) of Table 6 shows the absolute ratio of $\{\triangle u_{r2}/\triangle u_{r1}\}_{r=\{1,3,4,5,6,7\}}$and $\{\gamma_{q2}/\gamma_{q1}\}_{q=1}^{4}$ using the model estimates from column (1) of Table 5. This ratio is a measure of the extent to which an individual specializes his majors along the given outcome: A ratio greater than one indicates that the student desires to choose majors that differ in the likelihood of that outcome (i.e., he prefers specialization), while a ratio of less than one indicates that the student values that outcome in the choice of both majors. The table shows that there is strong evidence of specialization for graduating in 4 years, i.e., students prefer to choose majors that differ in their chances of completion. On the other hand, there is strong evidence that enjoying coursework, parents' approval, and enjoying work at the jobs are important determinants in the choice of both majors in one's major pair. There is weak evidence of specialization along the dimension of finding a job upon graduation and reconciling work and family at available jobs (but ratios are greater than 2 but not statistically different from one).

[11] There is evidence of the latter in the comments submitted by the respondents (see Section A.2).

Because of the non-linear nature of the model, it is hard to interpret the coefficients on the various outcomes. To get a measure of the magnitude of the estimates in column (1) of Table 5, the natural thing would be to do willingness-to-pay calculations, i.e., translate the differences in utility levels into the amount of earnings that an individual would be willing to forgo at the age of 30 in order to experience that outcome.[12] However, since expected income at age 30 is not significant, the standard errors on such calculations are huge, and the results are not very meaningful. Instead of presenting the willingness-to-pay calculations, I use a decomposition method to gain insight into the relative importance of the various outcomes in the choice. For illustration, suppose that $\Pr(choice = j) = F(\mathbf{X}_j\boldsymbol{\beta})$ and that $\mathbf{X}$ includes two variables, X_1 and X_2. Given the parameter estimates, $\widehat{\beta}_1$ and $\widehat{\beta}_2$, the contribution of X_1 to the choice is defined as:

$$M_{X_1} \equiv || \overline{\Pr(choice \ = j| \{\widehat{\beta_1}, \widehat{\beta_2}\}} - \overline{\Pr(choice \ = j| \{\widehat{\beta_1} = 0, \widehat{\beta_2}\}} ||$$

$$= \sqrt{\sum_j \left[\ \sum_{i=1}^N \frac{\Pr(choice = j| \{\widehat{\beta_1}, \widehat{\beta_2}\})}{N} - \ \sum_{i=1}^N \frac{\Pr(choice = j| \{\widehat{\beta_1} = 0, \widehat{\beta_2}\})}{N} \right]^2},$$

where the first term is the average probability of majoring in choice j predicted by the model, and the second term is the average predicted probability of majoring in j if outcome X_1 were not considered. The difference in the two terms is a measure of the importance of X_1 in the choice. The *relative* contribution of X_1 to the choice is then $R_{X_1} = \frac{M_{X_1}}{M_{X_1} + M_{X_2}}$. Column (1) of Table 7 presents the results of this decomposition strategy using the estimates from column (1) of Table 5. Each cell shows the *relative* contribution (R) of the outcome to the choice. The table shows that nearly two-thirds of the choice is explained by outcomes realized in college, with enjoying coursework explaining nearly a quarter of the choice. Gaining approval of

[12]For example, the amount that an individual would be willing to forgo in earnings at the age of 30 for a 2% change in the probability of outcome j is $\frac{0.02 \times \triangle u_j}{\gamma_{41} + \gamma_{42}}$.

parents seems to be the second most important determinant accounting for one-fifth of the choice, followed by hours per week spent at work and finding a job upon graduation, each accounting for about 10% of the choice.

4.2 Robustness Checks

4.2.1 Modified Choice Model

It could be argued that outcomes associated with the workplace come as a package; for example, one does not have the option to choose the income associated with jobs available in one major and the lifestyle associated with jobs in the second major. If that were the case, the model estimated in Section 4.1 may be biased. I modify the choice model described in Section 2, and apply the idea of a composite major only to outcomes associated with college. As before, I do not consider the composite-major representation for graduating with a GPA of more than 3.5 because GPA is a composite of all coursework an individual does. The outcomes for which the composite-major specification is used are graduating in four years, hours per week spent on coursework, enjoying the coursework, gaining approval of parents, and finding a job upon graduation.

The model estimates are shown in column (2) of Table 5. The estimates are qualitatively similar to those of the model which uses the composite-major representation for all outcomes (except GPA). As before, all outcomes associated with college are significant. In the workplace, outcomes that are statistically significant are finding a job upon graduation and enjoying work at the jobs. The estimates indicate specialization in the case of graduating in 4 years and finding a job upon graduation. On the other hand, gaining approval of parents, enjoying coursework and enjoying work at the jobs are outcomes that are important in the choice of both majors. The results of the ratios shown in column (2) of Table 6, and the relative contribution of the various outcomes in the choice shown in column (2) of Table 7 are also qualitatively similar to earlier results indicating that the model with the full composite-major representation is not misspecified.

4.2.2 Flexible Substitution Patterns

The models that have been estimated so far exhibit the restrictive IIA property, which is not a very realistic assumption in this particular situation. For example, one could imagine that an individual majoring in Area Studies and in Literature & Fine Arts is more likely to choose Area Studies and Ethics & Values, rather than Natural Sciences and Ethics & Values. To allow flexible substitution patterns, I allow for a stochastic part for each major that is perhaps correlated over majors and heteroskedastic over individuals and majors (these appear as 12 random effects, one for each of the 7 alternatives in WCAS and the 5 categories outside WCAS) and another stochastic part that is iid over individuals and alternatives.[13] The utility function of a pair of majors p is now:

$$U_{ip}(\mathbf{b}, \mathbf{d}, \{P_{ik}(b_r), E_{ik}(d_q)\}_{r\in\{1,..,7\},q\in\{1,..,4\};\, k\in C_i}) = U_{ip} + \varepsilon_{ip} + c_{p1}\eta_{i,1} + c_{p2}\eta_{i,2} + ... + c_{p12}\eta_{i,12},$$

where, as before, U_{ip} is as defined in equation (4) and ε_{ip} is a random term with zero mean that is iid over alternatives of major pairs and is normalized to set the scale of utility. The $\eta_{i,k}$ for $k = \{1, .., 12\}$ are normally distributed effects with zero mean, and $c_{px} = 1$ if major x appears in the pair of majors p. For example, the utility function of a pair of majors p that

[13] This approach is similar to Brownstone and Train (1998), who use a "mixed logit" choice model without the IIA property and with flexible substitution patterns to forecast demand for new vehicles.

includes Natural Sciences ($k = 1$) and Social Sciences II ($k = 4$) would be:

$$U_{ip}(\mathbf{b}, \mathbf{d}, \{P_{ik}(b_r), E_{ik}(d_q)\}_{r\in\{1,..,7\}, q\in\{1,..,4\};\, k\in C_i}) = U_{ip} + \varepsilon_{ip} + \eta_{i,1} + \eta_{i,4}.$$

This structure allows flexible substitution patterns across alternatives. For example, the correlation between a pair of majors κ consisting of majors $\{1, 2\}$, and a second pair of majors ω consisting of majors $\{2, 3\}$ is $E([U_{i\kappa} + \varepsilon_{i\kappa} + \eta_{i,1} + \eta_{i,2}][U_{i\omega} + \varepsilon_{i\omega} + \eta_{i,2} + \eta_{i,3}]) = Var(\eta_{i,2})$. So utility is now correlated over alternatives. Given the vector $\boldsymbol{\eta}_i$, the *conditional* choice probability is simply logit, since the remaining error term is iid extreme value. The probability of individual i choosing the pair of majors p *conditional* on $\boldsymbol{\eta}_i$ is:

$$\begin{aligned}\Pr(p|\boldsymbol{\eta}_i) &= \Pr(p|\, \{P_{ik}(b_r), E_{ik}(d_q)\}_{r\in\{1,..,7\}, q\in\{1,..,4\};\, k\in C_i}, \boldsymbol{\eta}_i) \\ &= \frac{\exp(U_{ip} + c_{p1}\eta_{i,1} + c_{p2}\eta_{i,2} + ... + c_{p12}\eta_{i,12})}{\sum_{k\in C_i} \exp(U_{ik} + c_{k1}\eta_{i,1} + c_{k2}\eta_{i,2} + ... + c_{k12}\eta_{i,12})}.\end{aligned}$$

The *unconditional* probability of choosing p is the integral of this *conditional* probability over all possible values of $\boldsymbol{\eta}_i$, and depends on the density of $\boldsymbol{\eta}_i$. I denote this density $\mathbf{g}(\boldsymbol{\eta}_i|\Omega)$ where Ω are the parameters of the distribution. The *unconditional* probability for i choosing p is:

$$P_{ip}(\Omega) = \int \Pr(p|\boldsymbol{\eta}_i)\mathbf{g}(\boldsymbol{\eta}_i|\Omega)d\boldsymbol{\eta}_i.$$

Since the integral does not have a closed form in general, it is approximated through simulation. I use 100,000 draws of $\boldsymbol{\eta}_i$ for a given value of the parameters Ω. For each draw, the $\Pr(p|\boldsymbol{\eta}_i)$ is calculated, and the average of these probabilities is taken as the approximate choice probability:

$$\widehat{P_{ip}(\Omega)} = \frac{1}{100,000} \sum_{d=1}^{100,000} \Pr(p|\boldsymbol{\eta}_i^d).$$

The estimated parameters from maximizing the simulated log-likelihood, $\sum_i \ln(\widehat{P_i(\Omega)})$, are shown in Table 8. The first column presents the parameters of a model that allows the composite-major categorization for all outcomes (except GPA), while the second column only allows the composite-major categorization for outcomes in college. The coefficients are similar in relative magnitude, but larger in absolute terms than the corresponding fixed coefficients in Table 5. This is expected because the variance of the error term in the standard logit model (ε) is larger than in a mixed logit since some of the variance is now captured by the η's rather than the ε in the mixed logit model. Since utility is scaled so that ε has the variance of an extreme value, the variance before scaling is larger in the standard logit than in the mixed logit, and hence parameters are scaled down in a standard logit relative to the mixed logit (Revelt and Train, 1998).

In line with the previous estimates, I find that students choose a major pair such that they enjoy the coursework, gain approval of parents, and enjoy working at the jobs in *both* majors ($\triangle u_{31} > 0$, $\triangle u_{32} \approx 0$; $\triangle u_{41} > 0$, $\triangle u_{42} \approx 0$; $\triangle u_{61} > 0$, $\triangle u_{62} \approx 0$, respectively). There is some evidence that individuals prefer majors that differ in their chances of graduating in four years ($\triangle u_{12}/\triangle u_{11} > 1$). The somewhat puzzling results are the positive coefficients on hours per week spent on coursework and at the jobs (the latter is not significant). The coefficient on $\min[E_{ip_1}(d_1), E_{ip_2}(d_1)]$, γ_{12}, is negative, suggesting that individuals prefer pairs of majors with different time commitments at college. However, it is not significantly different from zero. In general, the results are similar to earlier findings in Tables 5 and 6, but the estimates are less precise now. One possible reason for this could be that the sample size is small and the number of parameters to be estimated in the model with error components for the majors is larger.

Columns (3) and (4) of Table 7 show the relative contribution of the various outcomes using the estimates from columns (1) and (2) of Table 8, respectively. As before, I find that majority of the choice is explained by outcomes realized in college. One notable difference from the previous results is that graduating in 4 years is now one of the more important determinants of the choice, followed by enjoying coursework and approval of parents.

On the whole, the results are similar to earlier findings, suggesting that there is no significant bias coming from the IIA assumption made in the model estimation in Section 4.1.

5 Conclusion

This paper investigates how college students choose their majors conditional on pursuing a double major. Since college majors are chosen under uncertainty (about personal tastes, academic ability, and realizations of major-specific outcomes), students use their preferences and expectations about the uncertain aspects of the choice to make their choices. In order to overcome the identification problem of inferring preferences from observed choices when expectations are also unknown, I elicit expectations from a sample of 78 Northwestern students pursuing double majors, and use them directly to estimate a choice model of double majors.

The subjective data reveals that there is substantial heterogeneity in expectations in my relatively homogenous sample, indicating tremendous heterogeneity in beliefs among the population of college students. This also raises concerns about the accuracy of restrictions imposed on expectations in the literature. Analysis of expectations data reveals that students seem to be aware of differences across majors along the various dimensions and, when compared to objective measures, their responses seem to be meaningful and accurate. Moreover, I find that students believe that their parents are more likely to approve majors that are associated with higher social status and higher labor market returns. I use the expectations data to estimate a choice model of double majors. Contrary to stories in the popular press and anecdotal evidence (Lewin, 2002; Gomstyn, 2003), I do not find that students major in one field to satisfy their own interests and another to gain parents' approval. Instead the results show that students take into account parents' approval as well as how much they'll enjoy studying and working in that field when choosing *both* majors in their major pair. However, I do find that students act strategically by choosing majors that differ in their chances of completion and in finding a job upon graduation, and that entail different hours per week on coursework and in the workplace.

The analysis in this paper is based on data from Northwestern University, and it's not clear whether the findings of this study can be generalized to other settings. This paper clearly calls for similar data collection of college major-related expectations at a larger scale. Moreover, this paper investigates *how* students choose double majors (conditional on pursuing a double major) without attempting to explain *why* some students choose double majors. Given that a large fraction of college students have more than one undergraduate major and the share of students pursuing more than one college major is increasing, a natural question to ask is what drives some students to choose a single major and others to pursue more than one major. The available data are insufficient to answer this question. However, the approach used in this paper of eliciting subjective expectations data and using them to understand decision-making under uncertainty could be useful in shedding light on this.

From a policy viewpoint, it is not clear whether pursuing more than one major is good or bad. College administrators have expressed concerns about possible negative impacts of loading on majors such as neglecting extracurricular activities and elective classes essential for a balanced education. On the other hand, studies have shown that double majors are associated with higher returns in the labor market (Del Rossi and Hersch, 2008). The question of whether double majors should be encouraged or not is important, and one that remains unanswered. Richer data on outcomes of students (both in college and after college) are needed to address this.

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Appendix A

A.1 Survey Excerpt

A.1.1 Introduction and Practice Questions

In some of the survey questions, you will be asked about the PERCENT CHANCE of something happening. The percent chance must be a number between zero and 100. Numbers like 2 or 5% indicate "almost no chance," 19% or so may mean "not much chance," a 47 or 55% chance may be a "pretty even chance," 82% or so indicates a "very good chance," and a 95 or 98% mean "almost certain." The percent chance can also be thought of as the NUMBER OF CHANCES OUT OF 100.

We will start with a couple of practice questions.

PRACTICE QUESTION 1: What do you think is the PERCENT CHANCE (or CHANCES OUT OF 100) that you will eat pizza for lunch next week? ________%

PRACTICE QUESTION 2: What do you think is the PERCENT CHANCE (or CHANCES OUT OF 100) that you will eat pizza for lunch on Tuesday next week? _________%

Once students had answered the questions, they were given the following instructions:

Since "pizza for lunch next week" INCLUDES the possibility of "pizza for lunch on Tuesday next week", your answer to PRACTICE QUESTION 2 should be SMALLER or EQUAL than your answer to PRACTICE QUESTION 1.

A.1.2 Questionnaire

The following set of questions was asked for EACH of the relevant major categories. For example, the questions below were asked for the category of Natural Sciences.

Q1. If you were majoring in Natural Sciences, what would be your most likely major?

Q2. If you were majoring in Natural Sciences, what do you think is the percent chance that you will successfully complete this major in 4 years (from the time that you started college)? (Successfully complete means to complete a bachelors)

NOTE: In answering these questions fully place yourself in the (possibly) hypothetical situation. For example, for this question, your answer should be the percent chance that you think you will successfully complete your major in Natural Sciences in 4 years IF you were (FORCED) to major in it.

Q3. If you were majoring in Natural Sciences, what do you think is the percent chance that you will graduate with a GPA of at least 3.5 (on a scale of 4)?

Q4. If you were majoring in Natural Sciences, what do you think is the percent chance that you will enjoy the coursework?

Q5. If you were majoring in Natural Sciences, how many hours per week on average do you think you will need to spend on the coursework?

Q6. If you were majoring in Natural Sciences, what do you think is the percent chance that your parents and other family members would approve of it?

Q7. If you were majoring in Natural Sciences, what do you think is the percent chance that you could find a job (that you would accept) immediately upon graduation?

Q8. If you obtained a bachelors in Natural Sciences, what do you think is the percent chance that you will go to graduate school in Natural Sciences some time in the future?

Q9. What do you think was the average annual starting salary of Northwestern graduates (of 2006) with Bachelor's Degrees in Natural Sciences?

Now look ahead to when you will be 30 YEARS OLD. Think about the kinds of jobs that will be available for you and that you will accept if you successfully graduate in Natural

Sciences.

NOTE that there are some jobs that you can get irrespective of what your Field of Study is. For example, one could be a janitor irrespective of their Field of Study. However, one could not get into Medical School (and hence become a doctor) if they were to major in Journalism.

Your answers SHOULD take into account whether you think you would get some kind of advanced degree after your bachelors if you majored in Natural Sciences.

Q10. What kind of jobs are you thinking of?

Q11. Look ahead to when you will be 30 YEARS OLD. If you majored in Natural Sciences, what do you think is the percent chance that you will enjoy working at the kinds of jobs that will be available to you?

Q12. Look ahead to when you will be 30 YEARS OLD. If you majored in Natural Sciences, what do you think is the percent chance that you will be able to reconcile work and your social life/ family at the kinds of jobs that will be available to you?

Q13. Look ahead to when you will be 30 YEARS OLD. If you majored in Natural Sciences, how many hours per week on average do you think you will need to spend working at the kinds of jobs that will be available to you?

When answering the next two questions, please ignore the effects of price inflation on earnings. That is, assume that one dollar today is worth the same as one dollar when you are 30 years old and when you are 40 years old.

Q14. Look ahead to when you will be 30 years old. Think about the kinds of jobs that will be available to you and that you will accept if you graduate in Natural Sciences. What is the average amount of money that you think you will earn per year by the time you are 30 YEARS OLD?

Q15. Now look ahead to when you will be 40 years old. Think about the kinds of jobs that will be available to you and that you will accept if you graduate in Natural Sciences. What is the average amount of money that you think you will earn per year by the time you are 40 YEARS OLD?

5.1 A.2 Debriefing: Why Choose Two Majors

This section presents some of the responses to the question posed to survey respondents pursuing more than one major: "**Why are you pursuing more than one major?**"

- I am unsure as to what I want to do later in life and would like to open up my options.
- To have more options, since I am not certain as to what career I want to follow.
- There are plenty of econ majors in the country, doubling with Math will help me stand out. Also, they complement each other well and I enjoy them both.
- My first major, MMSS, is an adjunct major. Getting a second major allows me to broaden my horizons and also specialize in a practical field. Also, I feel it looks more impressive if you have completed more than one major.
- I want to have a science major (chemistry) as well as another route (economics) for careers in life.
- One practical (MMSS) One personal interest (Linguistics). Real goal is to go to law school soon after grad. perhaps working a couple years in the consulting/finance industry.
- Because Spanish is for a career and art is for a lifetime hobby.

- Multiple personal interests, having additional options later in life, stand apart from others.
- I have a conflict between what is practical for the job prospect and what I truly would enjoy learning about, so I am pursuing one major which falls into each of the two categories.
- There is no single major at Northwestern which encompasses my interests.
- I want to have more fields open to me.
- To make it more easy to get a job and have a solid career.
- Keep career opportunities open.
- I feel that having both majors will open up a wider range of job opportunities when I graduate. I also feel that I am interested in both subjects and am taking the opportunity to further my knowledge in them.
- Interest in subject, a more applicable major for attaining business jobs.
- The Quarter system at Northwestern makes obtaining a double major very feasible. I have multiple interests so it makes sense for me to pursue multiple majors.
- I want to be a well rounded person after I graduate, and also just in case one of them does not work out.
- Because I enjoy the material, have the time, and feel like it will improve my chances of acquiring a job after I graduate.

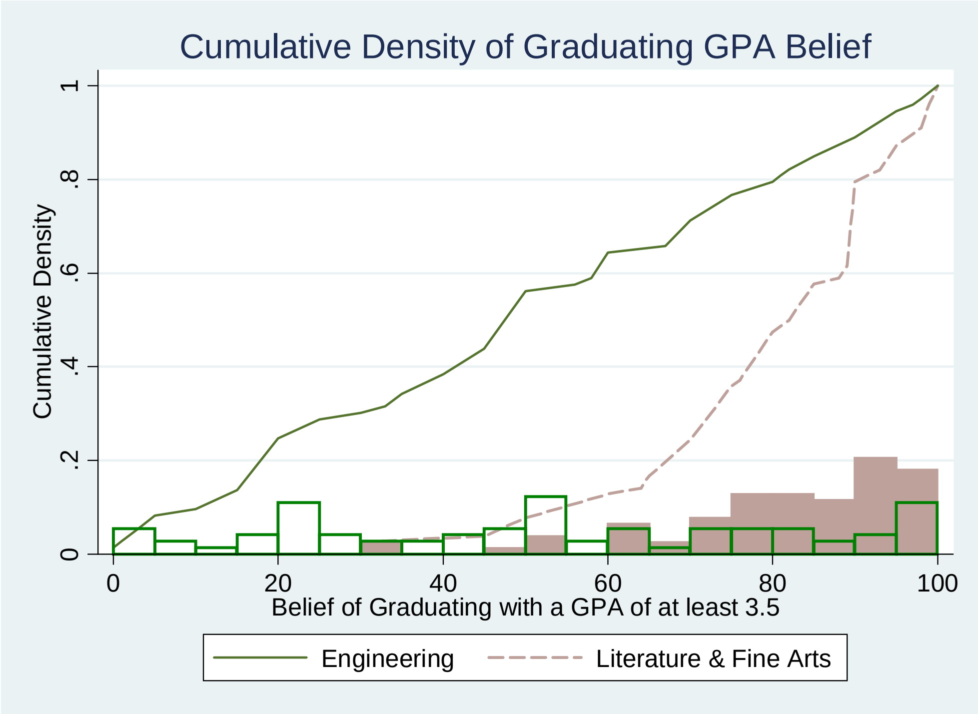

Figure 1: Cumulative density and distribution of the belief of graduating with a GPA ≥ 3.5 in Engineering and Literature & Fine Arts.

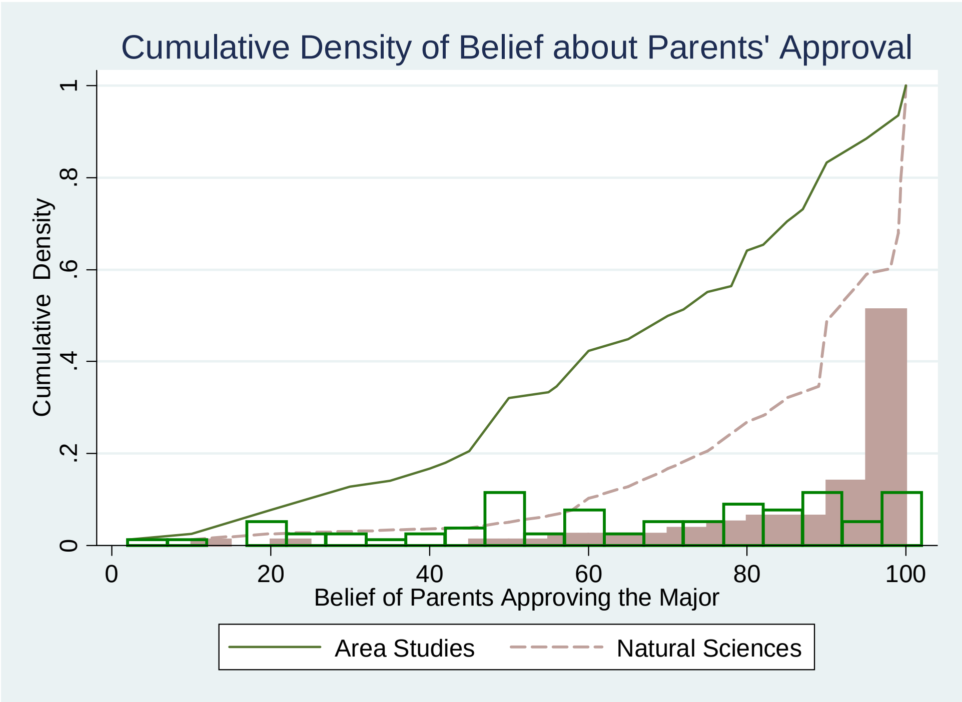

Figure 2: Cumulative density and distribution of the belief of gaining parents' approval for majoring in Area Studies and Natural Sciences.

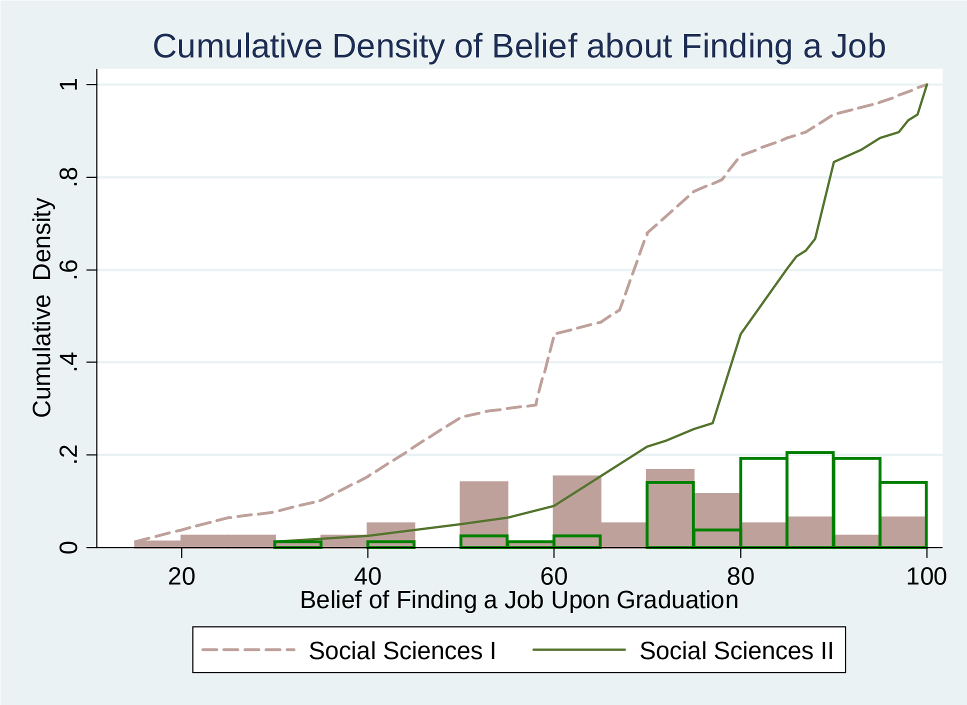

Figure 3: Cumulative density and belief distribution of finding an acceptable job upon graduation in Social Sciences I and Social Sciences II.

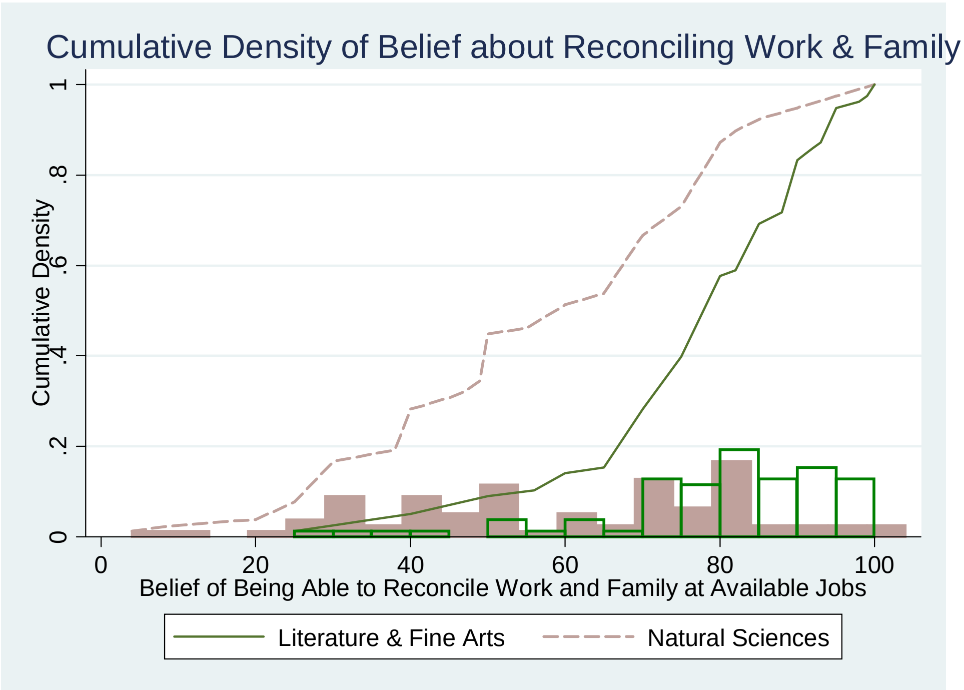

Figure 4: Cumulative density and belief distribution of being able to reconcile work and family at jobs available in Literature & Fine Arts and Natural Sciences.

Table 1: List of Majors

The following is the classification of majors into categories:

a Natural Sciences
- Biological Sciences
- Chemistry
- Environmental Sciences
- Geography*
- Geological Sciences
- Integrated Science
- Materials Science
- Physics

b Mathematical and Computer Sciences
- Cognitive Science
- Computing and Information Systems
- Mathematics
- Statistics

c Social Sciences I
- Anthropology
- Gender Studies*
- History
- Linguistics
- Political Science
- Psychology
- Sociology

d Social Sciences II
- Economics
- Mathematical Methods in Social Sciences*

e Ethics and Values
- Legal Studies*
- Philosophy
- Religion
- Science in Human Culture*

f Area Studies
- African American Studies
- American Studies
- Asian & Middle East Languages & Civilization
- European Studies
- International Studies*
- Slavic Languages and Literatures

g Literature and Fine Arts
- Art History
- Art Theory and Practice
- Classics
- Comparative Literary Studies
- Drama
- English
- French
- German
- Italian
- Spanish

h Music Studies[1]
- Jazz Studies
- Music Cognition
- Music Composition
- Music Education
- Music Technology
- Music Theory
- Musicology
- Piano Performance
- String Performance
- Voice and Opera Performance
- Wind and Percussion Performance

i Education and Social Policy[2]
- Human Development and Psychological Services
- Learning and Organizational Change
- Secondary Teaching
- Social Policy

j Communication Studies[3]
- Communication Studies
- Dance
- Human Communication Science
- Interdepartmental Studies
- Performance Studies
- Radio/Television/ Film
- Theatre

k Engineering[4]
- Applied Mathematics
- Biomedical Engineering
- Chemical Engineering
- Civil Engineering
- Computer Engineering
- Computer Science
- Electrical Engineering
- Environmental Engineering
- Industrial Engineering
- Manufacturing and Design Engineering
- Materials Science& Engineering
- Mechanical Engineering

L Journalism[5]
- Journalism

∗ *Adjunct majors. These do not stand alone*

1 Majors in the School of Music
2 Majors in the School of Education and Social Policy
3 Majors in the School of Communication
4 Majors in the McCormick School of Engineering
5 Majors in the Medill School of Journalism

Table 2: Distribution of Double Majors

	Major 2						
Major 1[a]	Natural Sciences	Math & Comp Sci.	Social Sci. I	Social Sci. II	Ethics & Values	Area Studies	Lit. & Fine Arts
Natural Sciences	1	-	-	-	-	-	-
Math & Computer Sci	2	0	-	-	-	-	-
Social Sciences I	2	0	2	-	-	-	-
Social Sciences II	3	1	11	0	-	-	-
Ethics and Values	2	1	0	1	0	-	-
Area Studies	1	0	9	10	1	0	-
Literature and Fine Arts	1	1	3	2	0	5	2
Music Studies	1	0	1	1	0	0	1
Education	0	0	1	1	0	1	0
Communication Studies	1	0	1	1	0	0	0
Engineering	0	0	0	5	0	0	0
Journalism	0	0	1	0	0	0	1
Total[b]	14	5	31	36	5	27	16

[a]Whether a major in a major pair is denoted to be major 1 or major 2 does not signify any hierarchy.

[b]Number of instances in which the category shows up as one of the majors in a major pair.

Table 3: Summary Statistics: Mean and Standard Deviation of Elicited Beliefs

	Graduate in 4 years	GPA ≥ 3.5	Enjoy Courses	Courses hrs/wk	Parents' Approval	Find Job	Enjoy Work	Reconcile Family	Job hrs/wk	Status of Jobs	Income At 30
Natural Sciences	0.86	0.55	0.54	26.37	0.87	0.73	0.64	0.59	49.79	0.73	87.34
	(0.19)	(0.29)	(0.27)	(10.90)	(0.18)	(0.20)	(0.25)	(0.23)	(11.73)	(0.19)	(93.18)
Math & Computer Sci	0.83	0.56	0.47	25.61	0.77	0.74	0.52	0.66	43.63	0.54	73.03
	(0.23)	(0.29)	(0.28)	(11.37)	(0.22)	(0.20)	(0.25)	(0.21)	(9.77)	(0.20)	(56.75)
Social Sciences I	0.95	0.83	0.82	19.66	0.77	0.64	0.75	0.73	43.63	0.59	66.10
	(0.087)	(0.14)	(0.15)	(8.23)	(0.20)	(0.19)	(0.17)	(0.18)	(8.76)	(0.18)	(40.36)
Social Sciences II	0.90	0.68	0.66	24.19	0.85	0.81	0.64	0.64	50.03	0.69	103.2
	(0.16)	(0.25)	(0.24)	(9.86)	(0.16)	(0.14)	(0.22)	(0.21)	(11.63)	(0.19)	(111.9)
Ethics and Values	0.91	0.80	0.73	20.29	0.65	0.55	0.64	0.71	43.62	0.43	62.47
	(0.13)	(0.16)	(0.19)	(8.70)	(0.27)	(0.21)	(0.21)	(0.19)	(9.09)	(0.19)	(27.47)
Area Studies	0.93	0.84	0.75	19.99	0.67	0.59	0.66	0.70	42.55	0.36	56.60
	(0.09)	(0.15)	(0.20)	(8.09)	(0.26)	(0.20)	(0.20)	(0.17)	(8.57)	(0.17)	(21.71)
Literature & Fine Arts	0.93	0.80	0.68	21.02	0.58	0.50	0.63	0.78	40.20	0.37	49.50
	(0.09)	(0.16)	(0.27)	(8.54)	(0.29)	(0.24)	(0.25)	(0.16)	(7.84)	(0.21)	(48.34)
Engineering	0.83	0.51	0.42	24.49	0.84	0.84	0.84	0.65	46.05	0.67	85.21
	(0.22)	(0.30)	(0.30)	(9.38)	(0.20)	(0.17)	(0.17)	(0.19)	(7.98)	(0.18)	(60.85)

Binary outcomes (all outcomes except coursework hrs/wk, job hrs/wk, social status of jobs; income at 30) are on a 0-100 scale (and then divided by 100); Coursework hrs/wk and job hrs/wk elicited on a scale of 0-70; Social status elicited on a 0-0.9 scale; Income at age 30 is expressed in 1000s.
There are 78 observations for each cell (except for outcomes related to Engineering for which there are 73 observations)

Table 4: Comparing GPA and Income Beliefs with Objective Measures

	Average GPA[a]		Belief GPA $\geq 3.5^b$		Single Major GPA $\geq 3.5^c$		Average Salary[d]		Belief of Income at 30[e]		Single Major Income at 30[f]	
	Mean	**Rank**[g]	**Mean**	**Rank**	**Mean**	**Rank**	**Mean**	**Rank**	**Mean**	**Rank**	**Mean**	**Rank**
	(1a)	(1b)	(2a)	(2b)	(3a)	(3b)	(4a)	(4b)	(5a)	(5b)	(6a)	(6b)
Natural Sciences	3.22	5	0.55	7	0.59	6	75.86	3	87.34	2	80.43	2
			(0.29)		(0.26)				(93.18)		(51.20)	
Math & Computer Sci	3.21	6	0.56	6	0.58	7	73.32	4	73.03	4	65.30	5
			(0.29)		(0.27)				(56.75)		(35.68)	
Social Sciences I	3.29	1	0.83	2	0.78**	1	72.73	5	66.10	5	58.68	6
			(0.14)		(0.19)				(40.36)		(25.88)	
Social Sciences II	3.09	8	0.68	5	0.63	5	78.10	2	103.2	1	118.9	1
			(0.25)		(0.26)				(111.9)		(152.8)	
Ethics and Values	3.29	1	0.80	3	0.76	2	68.23	6	62.47	6	67.40	4
			(0.16)		(0.20)				(27.47)		(49.78)	
Area Studies	3.29	1	0.84	1	0.76**	2	68.23	6	56.60	7	55.48	7
			(0.15)		(0.22)				(21.71)		(26.44)	
Literature & Fine Arts	3.29	1	0.80	3	0.75*	4	62.87	8	49.50	8	53.56	8
			(0.16)		(0.20)				(48.34)		(30.09)	
Engineering	3.11	7	0.51	8	0.48	8	89.26	1	85.21	3	80.03	3
			(0.30)		(0.26)				(60.85)		(46.81)	

Mean response of double and single major respondents is statistically significant at 1% (***), 5% (**), 10% (*) using a 2-tailed T-test.

[a]Mean GPA of bachelor graduates of Doctoral/Research Universities in 2001 (Source: 2001 Baccalaureate and Beyond Longitudinal Study).

[b]Belief of survey respondents with DOUBLE MAJORS about graduating with a GPA $\geq$ 3.5 (on a scale of 0-100) and divided by 100. (N= 78 except for Engineering which has 73 observations).

[c]Same belief as in b but of SINGLE MAJOR respondents (N= 83 except for Engineering for which there are 78 observations)

[d]Average salary in 1000s (in 2007 dollars) in 2003 of college graduates of 1993. Restricted to selective Doctoral/Research Universities with Carnegie Code 4 (Source: 1993/03 Baccalaureate and Beyond Longitudinal Study).

[e]Expected salary at the age of 30 (in 1000s) elicited from survey respondents with DOUBLE MAJORS.

[f]Same belief as in e but of SINGLE MAJOR respondents.

[g]Majors are ranked from highest GPA or expected salary (rank 1) to lowest (rank 8).

Table 5: Double Major Choice Model - Estimation Using Choice Data

Maximum Likelihood Estimates	(1)	(2)
Δu_{11} for graduating within 4 years	-1.76	-1.79
	(3.16)	(3.09)
Δu_{12} for maximum of graduating in 4 years	26.30***	25.07***
	(9.18)	(8.72)
Δu_{2} for graduating with a GPA of $\geq$3.5	4.46**	3.60*
	(2.18)	(2.07)
Δu_{31} for enjoying the coursework	12.20***	11.59***
	(2.78)	(2.67)
Δu_{32} for maximum of enjoying coursework	2.89	3.48
	(3.49)	(3.41)
γ_{11} for hours/week spent on coursework	0.137*	0.157**
	(0.076)	(0.076)
γ_{12} for min. of hours/week on coursework	-0.142**	-0.177***
	(0.061)	(0.059)
Δu_{41} for approval of parents and family	10.81***	9.27***
	(2.95)	(2.77)
Δu_{42} for maximum of approval of parents	-0.126	1.60
	(2.70)	(2.61)
Δu_{51} for finding a job upon graduation	-1.62	-3.32
	(2.44)	(2.28)
Δu_{52} for maximum of finding a job	4.07*	5.72***
	(2.15)	(1.99)
Δu_{61} for enjoying work at the jobs	5.85**	4.53**
	(2.88)	(1.99)
Δu_{62} for maximum of enjoying work at jobs	-0.664	-
	(2.95)	
Δu_{71} for reconciling family & work at jobs	0.914	1.93
	(2.94)	(2.13)
Δu_{72} for max of reconciling family & work	1.90	-
	(2.79)	
γ_{21} for hours/week spent at work	0.154***	0.048
	(0.059)	(0.038)
γ_{22} for minimum of hrs/wk spent at work	-0.104**	-
	(0.048)	
γ_{31} for the social status of the jobs	-2.99	-0.66
	(1.89)	(1.13)
γ_{32} for maximum of social status of jobs	2.57	-
	(1.65)	
γ_{41} for expected income at the age of 30	6.32 e -06	1.06 e-06
	(1.04 e -05)	(5.21 e-06)
γ_{42} for max of expected income at 30	-4.48 e -06	-
	(7.00 e -06)	
Log Likelihood	-150.24	-154.85
Number of Respondents	78	78

* significant at 10%; ** significant at 5%; *** significant at 1%
Status is on a scale of 0.1-0.9; job hrs/wk and coursework hrs/wk are on a scale of 0-100; income is in dollars; all other outcomes are on a normalized scale of 0-1.

Table 6: Extent of Specialization in Choice of Double Majors

Extent of Specialization	(1)	(2)
Graduating within 4 years	14.93***	13.96***
Graduating with a GPA of ≥3.5	-	-
Enjoying the coursework	0.236**	0.300**
Hours/week spent on coursework	1.033	1.121
Approval of parents and family	0.0116***	0.172***
Finding a job upon graduation	2.506	1.721
Enjoying work at the jobs	0.113*	-
Reconciling family & work at jobs	2.087	-
Hours/week spent at work	0.677	-
Social status of the jobs	0.860	-
Expected income at the age of 30	0.709	-

Each cell is $\left|\frac{\text{estimated parameter on max. of variable}}{\text{estimated parameter on variable}}\right|$. For example, the first cell is $\left|\frac{\Delta u_{12}}{\Delta u_{11}}\right|$.

Ratio is statistically different from 1 (* at 10%; ** at 5%; *** at 1%) using a Wald test.

Table 7: Decomposition Analysis

	(1)	(2)	(3)	(4)
Attributed to:				
Outcomes in College				
Graduating in 4 Years	6.00%	7.15%	14.70%	17.05%
Graduating with a GPA of $\geq$3.5	7.10%	6.45%	8.20%	6.70%
Enjoying Coursework	24.60%	27.10%	10.70%	14.95%
Hours per Week spent on Coursework	8.15%	11.85%	10.45%	10.00%
Approval of Parents	17.90%	20.00%	9.10%	11.05%
Total	**63.75%**	**72.55%**	**53.15%**	**59.75%**
Outcomes in the Workplace				
Finding a Job Upon Graduation	8.30%	14.15%	9.40%	8.10%
Enjoying Work at Jobs	6.00%	5.00%	9.25%	8.00%
Reconciling Work and Family	3.45%	2.30%	10.60%	8.35%
Hours per Week Spent at Work	8.95%	3.65%	10.05%	8.75%
Social Status of Jobs	8.10%	1.95%	5.05%	5.90%
Expected Income at Age 30	1.45%	0.40%	2.50%	1.15%
Total	**36.25%**	**27.45%**	**46.85%**	**40.25%**

Table 8: Double Major Choice Model with Error Components

Variables	(1)	(2)
Δu_{11} for graduating within 4 years	21.79*	20.54*
	(12.72)	(11.94)
Δu_{12} for maximum of graduating within 4 years	32.15*	28.69*
	(18.44)	(16.92)
Δu_{2} for graduating with a GPA of at least 3.5	1.59	1.64
	(3.52)	(3.33)
Δu_{31} for enjoying the coursework	17.62***	17.73***
	(6.79)	(6.30)
Δu_{32} for maximum of enjoying the coursework	10.37	8.54
	(7.93)	(5.52)
γ_{11} for hours/week spent on coursework	0.243***	0.215**
	(0.121)	(0.099)
γ_{12} for minimum of hours/week on coursework	-0.031	-0.033
	(0.026)	(0.024)
Δu_{41} for approval of parents and family	21.63**	20.24***
	(8.96)	(6.57)
Δu_{42} for maximum of approval of parents	-3.67	-3.59
	(5.14)	(4.43)
Δu_{51} for finding a job upon graduation	-2.52	-2.16
	(4.34)	(3.99)
Δu_{52} for maximum of finding a job	5.28	4.90
	(3.71)	(3.38)
Δu_{61} for enjoying work at the available jobs	8.92*	6.48*
	(5.00)	(3.36)
Δu_{62} for maximum of enjoying work at jobs	-2.35	-
	(4.43)	
Δu_{71} for reconciling family and work at jobs	2.52	6.23
	(5.67)	(4.31)
Δu_{72} for max of reconciling family & work	5.40	-
	(5.01)	
γ_{21} for hours/week spent at work	0.072	0.075
	(0.079)	(0.073)
γ_{22} for minimum of hours/week spent at work	-0.0019	-
	(0.0169)	
γ_{31} for the social status of the available jobs	4.74	1.63
	(4.26)	(2.07)
γ_{32} for maximum of social status of jobs	-3.10	-
	(3.15)	
γ_{41} for expected income at the age of 30	-2.61e-06	-1.62e-06
	(18.97e-06)	(7.86e-06)
γ_{42} for max of expected income at 30	5.4e-07	-
	(11.32e-06)	
Log Likelihood	-113.05	-114.46
Number of Respondents	76	76

Estimation includes Error Components for each major category (estimates not shown).
* significant at 10%; ** significant at 5%; *** significant at 1%