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PEER EFFECTS AND MULTIPLE EQUILIBRIA IN THE RISKY BEHAVIOR OF FRIENDS

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ABSTRACT

We study social interactions in the risky behavior of best-friend pairs in the National Longitudinal Study of Adolescent Health (Add Health). Focusing on friends who had not yet initiated a particular behavior (sex, smoking, marijuana use, truancy) by the first wave of the survey, we estimate bivariate discrete choice models for their subsequent decisions that include peer effects and unobserved heterogeneity. Social interactions can lead to multiple equilibria in friends' choices: we consider simple equilibrium selection models as well as partial likelihood models that remain agnostic about the choice of equilibrium. Our identification strategy assumes that there is at least one individual characteristic (e.g., physical development) that does not directly affect a friend's propensity to engage in a risky activity. Our estimates suggest that patterns of initiation of risky behavior by adolescent friends exhibit significant interaction effects. The likelihood that one friend initiates intercourse within a year of the baseline interview increases by 4 percentage points (on a base of 14%) if the other also initiates intercourse, holding constant family and individual factors. Similar effects are also present for smoking, marijuana use, and truancy. We find larger peer effects for females and for pairs that are more likely to remain best friends after a year. We also find important asymmetries in the strength of the peer effects in non-reciprocated friendships.

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Parents worry that their children will imitate the bad behavior of their peers. This is especially true during adolescence when parental authority is waning and children are first exposed to risky behaviors. Peer imitation can lead to "bad" equilibria where everyone in a peer group engages in a behavior they would not choose in the absence of social pressure (Brock and Durlauf, 2001). Nevertheless, the actual magnitude of the peer effects in adolescent preferences is unclear. Social interaction effects are hard to distinguish from correlated background factors that influence individual choices (Manski, 1993; Moffitt, 2001). Recent studies have tried to sidestep this problem by focusing on interactions within randomly assigned or quasi-experimentally manipulated peer groups.[1] Unfortunately, the peer effects observed in such groups may not provide a full picture of the social interactions in naturally occurring friendships. Indeed, recent work by Carrell, Sacerdote, and West (2011) suggests that a change in the random assignment process can lead to sharply different patterns of social interactions, depending on the nature of the friendship networks that are formed *after* the group is assigned.

In this paper we attempt to directly measure the peer effects between best-friend pairs in the National Longitudinal Study of Adolescent Health (Add Health). Specifically, we focus on interactions in the decisions to initiate (or increase the intensity of participation in) sexual activity, cigarette smoking, marijuana use, and truancy. Rather than rely on random or quasi-random variation in the characteristics of one friend or the other we model the choices of the pair, allowing for interaction effects and correlated unobservable determinants of their joint behavior.[2] Econometrically the distinction between social interactions and correlated background factors is very similar to the distinction between state dependence and heterogeneity in dynamic discrete choice models (e.g., Heckman, 1978, 1981; Hyslop, 1999). Our identification strategy relies on the existence of at least one characteristic of each friend that affects their

[1] For example, studies have analyzed quasi-experimental variation in neighborhoods (e.g. Oreopoulos, 2003; Jacob, 2004; Kling, Liebman, and Katz, 2007), classmates (e.g. Argys and Rees, 2008; De Giorgi, Pelizzari and Redaelli, 2010); college roommates (e.g. Sacerdote, 2001; Zimmerman, 2003; Kremer and Lavy, 2008; Stinebrickner and Stinebrickner, 2006); and squadrons in the U.S. Air Force Academy (e.g. Carrell, Fullerton and West, 2009). Though the results of these studies vary, several find very little evidence of peer effects, including Oreopoulos (2003), Sacerdote (2001), and Zimmerman (2003).

[2] A similar approach is taken by Huang (2010) who studies participation by family members in cell-phone network service contracts. Krauth (2006, 2007) considers situations where only the choices of one member of a peer group and the average choice of the remaining members are observed, and makes an assumption about the correlation between the unobserved determinants of friends' choices.

own choice but does not directly affect their friend. An added complication in the analysis of social interactions is the possibility of multiple equilibria. Borrowing from the literature on market entry games, we estimate partial likelihood methods that remain agnostic about equilibrium selection (Bresnahan and Reiss, 1990, 1991; Tamer, 2003; Ciliberto and Tamer, 2009), as well as models that impose simple equilibrium selection rules (Bjorn and Vuong, 1984; Bajari, Hong and Ryan, 2009).

Four key features of the Add Health data set are central to our analysis. First, the study collected detailed information on networks of friends that can be used to identify dyadic relationships between sample members.[3] Second, the Add Health sample frame included a set of "saturated" high schools from which all students were included in the study. This greatly increases the number of friend pairs that can be followed over time. Third, the baseline and follow-up surveys include detailed questions on risky behaviors that provide the outcomes for our analysis. Finally, Add Health also collected a rich set of individual characteristics—including grades, measures of physical development, and risk attitudes—that plausibly have no direct effect on the behavioral choices of a friend, conditional on an existing friendship.

We develop and estimate a series of models for the joint choices of friends that allow both social interaction effects and unobserved heterogeneity across pairs. Our simplest specifications are bivariate probit models for the decision to engage in a risky behavior (e.g., sexual intercourse), conditional on neither member of the pair having engaged in that behavior at the baseline. We also consider ordered choice models that differentiate between levels of activity (e.g., intimate touching versus intercourse). We use a series of Monte Carlo simulations to evaluate the power of our models to distinguish social interaction effects from unobserved heterogeneity, given the available sample sizes and the explanatory power of the observed covariates. Models based on a dichotomous choice have relatively low power in our setting, but ordered choice specifications that impose an equilibrium selection assumption are sufficiently powerful to permit meaningful inference.

[3] See Smith and Christakis (2008) for a review of the literature on social networks and health, much of which has relied on Add Health. Other studies that have used the social network data in Add Health include Haynie (2001), Fryer and Torelli (2006), Bramoulle, Djebbari and Fortin (2007), and Halliday and Kwak (2009).

Our empirical findings suggest that the patterns of initiation of risky behavior by pairs of adolescent friends exhibit significant but modestly-sized social interaction effects. For example, in our ordered models of sexual activity, the likelihood that one friend initiates intercourse in the year following the baseline interview is increased by about 4 percentage points (on a base rate of 14 percent) if the other also initiates intercourse, holding constant family and individual factors. The estimated effects appear to be relatively robust to the "exclusion assumptions" used to identify the social interactions. The magnitude of these estimated effects implies that situations with multiple equilibria are relatively rare (typically less than a one-percent incidence rate for any of the behaviors). We also find that the strength of the peer effects varies with characteristics of the friends, and that there are potentially important asymmetries in the interactions between friends, depending on the degree of reciprocity in their relationship. [4]

The next section lays out our modeling framework and provides links to the related literatures. Section III discusses the Add Health data set and the construction of our analysis samples. We then turn to estimation issues in Section IV, beginning with a set of simulations and then developing a series of models for sexual behavior. We summarize the results for the other risky behaviors in Section V, and present some concluding remarks in Section VI.

II. Modeling the Interactions of Friends

a. Single Discrete Action

Many observers have argued that adolescents tend to emulate the behavior of their friends and peers (see e.g., Berndt, 1982 and Akerlof, 1997). To formalize this idea as simply as possible, consider a pair of friends, 1 and 2, each of whom can either initiate a behavior or not.[5] Letting $u(y_1,y_2)$ represent the payoff to #1 when she chooses action $y_1 \in \{0,1\}$ and her friend chooses action $y_2 \in \{0,1\}$ and $v(y_1,y_2)$

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[4] Others have emphasized gender differences in the magnitude of peer effects based on college roommates (Stinebrickner and Stinebrickner, 2006), classmates (Argys and Rees, 2008), and neighborhoods (Kling, et al. 2007).

[5] Soetevent and Kooreman (2006) analyze equilibria among groups of friends of size n, and show that the number of equilibria in the presence of social interaction effects grows exponentially in n. In light of this problem we focus on the simplest possible case of n=2.

represent the associated payoffs to #2, their joint decision problem can be represented by a standard matrix:

		Friend #2's Choice 0	1
Friend #1's Choice	0	u(0,0), v(0,0)	u(0,1), v(0,1)
	1	u(1,0), v(1,0)	u(1,1), v(1,1)

Depending on the payoffs, this simple game can have 0, 1, or 2 Nash equilibria in pure strategies.

Suppose that the *relative* payoffs for choosing to initiate the behavior can be parameterized as:

(1) $\quad u(1, y_2) - u(0, y_2) = X_1\beta - c(y_2) + \varepsilon_1$,

(2) $\quad v(y_1, 1) - v(y_1, 0) = X_2\beta - c(y_1) + \varepsilon_2$,

where X_1 and X_2 represent observable characteristics of the two friends, β is a parameter vector, ε_1 and ε_2 represent characteristics of the two friends that are known to them but not to an outside observer, and $c(y)$ represents the social interaction effect of one friend's choice on the other's valuation of the activity. We assume that ε_1 and ε_2 are distributed across the population with some joint distribution $F(\varepsilon_1, \varepsilon_2; \theta) > 0$, and let $\rho=\rho(\theta)$ represent their correlation coefficient. Note that the specification of (1) and (2) imposes symmetric peer effects: by assumption, the relative payoff to each friend includes the same function $c(y)$ of the other's choice. In Section IV (below) we allow for asymmetric effects in a more general ordered choice setting.

Equations (1) and (2) are equivalent to a bivariate latent choice model of the form:

(3a) $\quad y_1^* = X_1\beta + \varepsilon_1 , \qquad y_1 = 1[\, y_1^* > c(y_2)\,]$

(3b) $\quad y_2^* = X_2\beta + \varepsilon_2 , \qquad y_2 = 1[\, y_2^* > c(y_1)\,]$.

Given that y_1 and y_2 are dichotomous, a general model for $c(y)$ is

$$c(y) = c_0 - \gamma y ,$$

where γ is positive if friends prefer to imitate each other. Assuming $\gamma \geq 0$, equation (3a) implies:

$$y_1 = 1 \text{ if } \varepsilon_1 > c_0 - X_1\beta , \quad \text{regardless of the value of } y_2$$

$y_1 = 0$ if $\varepsilon_1 \leq c_0 - X_1\beta - \gamma$, regardless of the value of y_2

$y_1 = 0$ **or** 1 if $c_0 - X_1\beta - \gamma < \varepsilon_1 \leq c_0 - X_1\beta$, depending on the value of y_2.

A parallel set of conditions govern y_2, leading to the partition of $(\varepsilon_1, \varepsilon_2)$ space illustrated in Figure 1. When $\gamma > 0$ there is a region

(4) $A = \{ c_0 - X_1\beta - \gamma < \varepsilon_1 \leq c_0 - X_1\beta ,\ c_0 - X_2\beta - \gamma < \varepsilon_2 \leq c_0 - X_2\beta \}$,

in which there are two possible equilibria: either $y_1 = y_2 = 0$ or $y_1 = y_2 = 1$.

We consider three possible methods for estimating models like (3a)/(3b) for the initiation of a risky behavior by a pair of friends. The first, introduced by Bresnahan and Reiss (1990, 1991), is a *partial likelihood* approach. Notice from Figure 1 that the probabilities that the two friends make different choices can be expressed as:

(5a) $p(0,1) = p(\ (y_1, y_2) = (0,1)\ ) = p(\varepsilon_1 \leq c_0 - X_1\beta - \gamma ,\ \varepsilon_2 > c_0 - X_2\beta\ )$

(5b) $p(1,0) = p(\ (y_1, y_2) = (1,0)\ ) = p(\varepsilon_1 > c_0 - X_1\beta ,\ \varepsilon_2 \leq c_0 - X_2\beta - \gamma)$

The remaining probability mass can be then assigned to the combined event that $(y_1, y_2) \in \{(0,0), (1,1)\}$:

(5c) $p(\ (y_1, y_2) \in \{ (0,0) , (1,1) \}\ ) = 1 - p(0,1) - p(1,0)$.

Assuming that $(\varepsilon_1, \varepsilon_2)$ are independent of (X_1, X_2), and that there is at least one covariate with infinite support that appears exclusively in either X_1 or X_2, the coefficients β and γ and the parameters of $F(\cdot\ , \cdot; \theta)$ are identified, and can be estimated consistently by maximizing this partial likelihood (Tamer, 2003). As discussed below, we rely on this "exclusion-based" identification strategy throughout this paper. In our main analysis we assume that X_1 and X_2 are distinct (so none of #1's *X's* directly affect #2, and vice versa) though in Section IVf below we relax this assumption in several directions.

Tamer (2003) also notes that the efficiency of a partial likelihood approach can be enhanced by making use of auxiliary sample information on the likelihood of one of the two non-uniquely specified outcomes. Specifically, define

$H(X_1, X_2) = p(\ (y_1, y_2) = (1,1)\ \mid\ X_1, X_2)$, and let $\hat{H}$ represent a (non-parametric) estimate of H. Tamer proposes to maximize the quasi-likelihood consisting of probability statements (5a), (5b), and

(6a) $p(1,1) = \hat{H}$

(6b) $p(0,0) = 1 - p(0,1) - p(1,0) - \hat{H}$.

Tamer (2003) shows that under standard assumptions, maximization of this quasi-likelihood will yield estimates that are at least as efficient as those from a simple partial likelihood.

Our third approach is to augment the system (3a) and (3b) with a simple equilibrium selection model, yielding a "full likelihood" for the observed data. As a baseline we follow Bjorn and Vuong (1984) and assume that when there are multiple equilibria, one-half the time (0,0) is observed and one-half of the time (1,1) is observed. Under this assumption the likelihood of the observed data combines equations (5a) and (5b) with:

(7a) $p(1,1) = p(\varepsilon_1 > c_0 - X_1\beta - \gamma\ ,\ \varepsilon_2 > c_0 - X_2\beta - \gamma) - \frac{1}{2}\, p(A)$

(7b) $p(0,0) = p(\varepsilon_1 \leq c_0 - X_1\beta\ ,\ \varepsilon_2 \leq c_0 - X_2\beta\ ) - \frac{1}{2}\, p(A)$,

where $p(A) \equiv p(\ (\varepsilon_1, \varepsilon_2) \in A)$ and A is defined in (4). We also consider the limiting cases where p(A) is assigned to either p(1,1) or p(0,0). A more flexible approach is to posit a parametric model for the equilibrium selection probability that depends on the characteristics of the friends, as suggested by Bajari, Hong and Ryan (2009).

b. Ordered Intensity of Action

The preceding framework can be easily extended to model the intensity of participation in a risky behavior. In our analysis below, for example, we consider two levels of sexual activity: intimate contact without intercourse, and intercourse. Indexing the choices in order of intensity by {0,1,2}, assume that the relative payoffs for #1 are given by:

(8a) $u(1, y_2) - u(0, y_2) = X_1\beta + \varepsilon_1 - c_1(y_2)$

(8b) $u(2, y_2) - u(0, y_2) = 2(\ X_1\beta + \varepsilon_1\ ) - c_1(y_2) - c_2(y_2)$, where $c_1(y_2)$ and $c_2(y_2)$ incorporate the social interaction effects of #2's choices on #1's preferences (with $c_1(y) < c_2(y)$ for all y). Assuming similar payoffs for #2 (with the same $c_1(y)$ and $c_2(y)$ functions), the choices of the friends can be represented by a bivariate ordered choice system in which the cutoffs for the choices depend on the choices of the other friend:

(9a) $y_1^* = X_1\beta + \varepsilon_1$,

$y_1 = 0$ if $y_1^* \leq c_1(y_2)$; $y_1 = 1$ if $c_1(y_2) < y_1^* \leq c_2(y_2)$; $y_1 = 2$ if $y_1^* > c_2(y_2)$,

(9b) $y_2^* = X_2\beta + \varepsilon_2$,

$y_2 = 0$ if $y_2^* \leq c_1(y_1)$; $y_2 = 1$ if $c_1(y_1) < y_2^* \leq c_2(y_1)$; $y_2 = 2$ if $y_2^* > c_2(y_1)$.

As a baseline we assume that the functions $c_1(y)$ and $c_2(y)$ satisfy:

(10a) $c_1(y) = c_{10} - \gamma_1 (y \geq 1)$,

(10b) $c_2(y) = c_{20} - \gamma_2 (y=2)$,

where $c_{20} > c_{10}$, $\gamma_1 \geq 0$, $\gamma_2 \geq 0$, and $c_{20} - \gamma_2 > c_{10}$. Equation (10a) implies that the threshold for the intermediate level of activity falls when the other friend engages in the intermediate level of activity, but is not further affected if the friend chooses the high level of activity. Equation (10b) implies that the threshold for choosing the higher level of activity is only affected by whether or not the other friend engages in the high level. We consider more general models for $c_1(y)$ and $c_2(y)$ in Section IV, below, and show that the restrictions implied by (10a) and (10b) appear to be consistent with the data.

Figure 2 illustrates the partition of $(\varepsilon_1, \varepsilon_2)$ space associated with each of the 9 possible outcomes for (y_1, y_2). As shown in the figure there are two regions with multiple equilibria: region A where (0,0) and (1,1) are both possible; and region B where (1,1) and (2,2) are possible. Note that if the highest level of activity is treated as the main outcome of interest, and the two lower levels are pooled, then Figure 2 collapses to a (re-parameterized) variant of Figure 1. Nesting of the dichotomous model inside the ordered model arises from the assumption in (10b) that the threshold for the highest level of activity is only affected if the friend engages in the highest level of activity. Alternatively, if the two <u>higher</u> levels of activity are pooled, Figure 2 also collapses to a variant of Figure 1. Again, this arises from the assumption in (10a) that the threshold for choosing between the lowest and intermediate level of activity only depends on whether the friend is engaging in the lowest level of activity.[6]

The model represented by equations (9) and (10) can be estimated using a partial likelihood approach, a quasi-likelihood approach, or a full likelihood with a model of equilibrium selection. The partial likelihood approach uses the fact that there is a one-to-one mapping between seven distinct regions of (ε_1, ε_2) and seven *outcome sets* for (y_1,y_2). Six regions map to the unique outcomes (0,1), (0,2), (1,2), (1,0), (2,0), and (2,1), while the remaining region maps to the outcome set {(0,0), (1,1), (2,2)}. Given a distribution function for (ε_1, ε_2) and values for the parameters (β, γ_1, γ_2) the probabilities of these outcome sets can be readily evaluated.

The quasi-likelihood approach follows Tamer (2003) by introducing auxiliary functions:

(11a) $H_{11}(X_1, X_2) = p(\,(y_1, y_2) = (1,1) \mid X_1, X_2)$,

(11b) $H_{22}(X_1, X_2) = p(\,(y_1, y_2) = (2,2) \mid X_1, X_2)$,

that represent the conditional probabilities for 2 of the 3 non-unique outcomes. The quasi-likelihood function uses estimates of the $\hat{H}_{ij}$ functions as values of the likelihoods for the associated outcomes, assigns the probabilities for the unique outcomes directly, and fills in the remaining probability for the (0,0) outcome as:

(11c) $p(0,0) = p(\,(y_1, y_2) \in \{(0,0), (1,1), (2,2)\}\,) - \hat{H}_{11} - \hat{H}_{22}$.

As in the simpler case exposited by Tamer (2003) it may be necessary to "trim" the values of the $\hat{H}_{ij}$ functions to ensure that this probability is strictly positive. Finally, the full likelihood approach specifies a probability for each of the possible equilibria in the region of non-uniqueness, leading to simple expressions for the likelihood of the observed data analogous to equations (7a) and (7b).

[6] One justification for the restrictions in (10a) and (10b) is that these are necessary and sufficient to ensure that the ordered model can be collapsed to a dichotomous model by pooling either the two lowest activity levels or the two highest activity levels.

III. Data and Sample Construction

a. The Add Health Data Set

We use data from Waves 1 and 2 of the National Longitudinal Study of Adolescent Health (Add Health). This study collected longitudinal information for a sample of U.S. adolescents who were in 7th-12th grades in the 1994-95 school year (see Harris et al., 2009). It includes information on demographic and physical characteristics, personality traits, academic performance, family and household characteristics, and a wide range of behaviors. A unique feature of the data set is the ability to link respondents who identify each other as friends.

In Wave 1, the study selected a stratified random sample of 80 high schools, plus the largest middle school that fed into each high school. An in-school questionnaire was administered to all those who were present on the day of the survey (n>90,000). A subsample of enrollees was then selected to be interviewed at home: a total of 20,745 in-home interviews were completed in Wave 1.[7] One year later a second wave of in-home interviews was administered to the same group, yielding a panel of 14,736 students with data from the Wave 1 and Wave 2 in-home surveys.[8] Importantly, the Add Health sample design included 16 schools in which all students were eligible for in-home interviews. Given that most friendships occur among students who attend the same school, these "saturated" sample schools provide many of the best friend pairs who are included in both waves of in-home interviews.

b. Construction of Friend Pairs

From the subset of adolescents who completed both the Wave 1 and Wave 2 in-home interviews we constructed a sample of same-sex friend pairs, using friendship information from the Wave 1 in-home interview and the in-school questionnaire.[9] In the in-home interview, all students were asked to name a best female friend and a best male friend. Those in saturated schools were asked to list up to five female

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[7] Students were eligible for in-home interviews even if they did not complete the in-school questionnaire. A separate in-home interview was completed by their parents.

[8] The main loss of sample between Wave 1 and Wave 2 arose from the graduation of 12th –grade students. Graduates were not re-interviewed unless they had younger siblings in the school.

[9] We include non-responders to the in-school questionnaire, who represent about 20% of our sample.

friends and five male friends, with their best friend of each gender listed first. The in-school questionnaire also asked all students to list up to five friends of each gender.

To construct a sample of best friend pairs, we first matched respondents who nominated each other as best friends in the Wave 1 in-home interview. Next we matched all remaining respondents to their best friend nominees from the in-home interview, whenever those nominations were reciprocated by the nominees on the in-school questionnaire.[10] Then we matched all remaining respondents who nominated each other as best friends on the in-school questionnaire. These three steps resulted in 667 "reciprocated" best friend pairs. In a fourth and final step, all unmatched respondents were matched to their in-home or in-school best friend nominee, if the nominee was in the sample and still unmatched, with priority given to in-home nominees. This process yielded an additional 1,201 "non-reciprocated" friend pairs.[11] In all, we have 1,868 friend pairs from which we draw our outcome-specific estimation samples. The relatively small number of friend pairs reflects our requirement that both members of the pair have to be included in the initial Add Health in-home interview sample, and in the Wave 2 follow-up.

c. Behavioral Outcomes and Associated Estimation Samples

We examine four types of risky behavior: sexual activity, cigarette smoking, marijuana use, and truancy.[12] For each behavior, we define both an intermediate and a high level of intensity. The dependent variables in our analysis are either binary indicators for engaging in a behavior with a particular level of intensity, or ordered variables with three values ranging from 0 (neither level of intensity) to 2 (the highest level of intensity).

[10] We give primacy to the in-home interview both because our other baseline variables are measured at the time of this interview, and because 20% of respondents did not complete the in-school questionnaire.
[11] Data for the subset of sample members who provided multiple friendship nominations (i.e. those who completed the in-school questionnaire and/or were in a saturated school) suggest that just over half of those who received but did not reciprocate a best friend nomination listed the nominator as one of their five best friends.
[12] Initially we also examined alcohol use, but found little evidence of correlation in the initiation of alcohol use among friends. Hence we do not model the initiation of alcohol use, though we use Wave 1 information on alcohol as a control variable in some of our specifications.

In each case, the dependent variable measures behavior as of the Wave 2 interview. However, the estimation sample is restricted to pairs where neither member had engaged in the behavior as of the Wave 1 interview. This sample restriction allows us to focus on the **initiation** of each behavior, and to rule out selection of friends on the basis of pre-existing behavior as a source of correlation in the Wave 2 outcomes. Our four measures of risky behavior are:

Sexual activity: In both Waves 1 and 2 sample members were asked if they had ever had sexual intercourse. They were also asked to list all romantic and sexual relationships within the past 18 months, and check off a list of sexual activities that had occurred in each relationship.[13] We assign an intermediate level of sexual activity to those who were in at least one relationship as of Wave 2 that involved "touching each others' genitals", but not having intercourse. We assign the high level of activity to those who had intercourse.[14] Wave 1 responses are used to construct two estimation samples: the subset of 738 friend pairs who reported neither level of sexual activity in Wave 1; and the sample of 929 friend pairs who had not had intercourse as of Wave 1.

Cigarette smoking: Respondents were asked about their history of cigarette smoking in Wave 1. In Wave 2 they were asked how often they had smoked cigarettes since the Wave 1 interview. We define intermediate-level smokers those who had tried cigarettes as of Wave 2 but who were not regular smokers, and high-intensity smokers as those who smoked regularly—that is, at least one cigarette every day for 30 days.[15] For the smoking analysis, we construct a single estimation sample consisting of 738 friend pairs who had never smoked an entire cigarette as of Wave 1.

Marijuana use: Questions about marijuana use in the Wave 1 and Wave 2 interviews are similar to those about cigarette smoking. We define intermediate marijuana use as having tried marijuana as of

[13] The in-home interviews were done using a laptop computer with confidential audio-CASI sections for the more sensitive questions about illegal and other risky behavior.
[14] To avoid confusing peer effects with sexual activity between same-sex best friends, we restrict attention to activity with a partner of the opposite sex.
[15] This is the definition of regular cigarette smoking employed in the Add Health interviews. Respondents were also asked on how many of the past 30 days they had smoked. Among those who had tried smoking as of Wave 2, the distribution of days smoked is bimodal, with modes at zero at 30 (accounting for 26% of the sample each). Of those who had tried cigarettes but had *not* smoked regularly (i.e. the low-intensity smokers), 80% smoked on less than five days and the majority smoked one day or less.

Wave 2, and high level use as having used marijuana one or more times in past 30 days.[16] Our analysis sample for use of marijuana is comprised of 1,076 friend pairs who had have never tried marijuana as of Wave 1.

Truancy: In each wave of in-home interview, respondents were asked how many times during the current or most recent school year they had skipped skip school for a full day without an excuse. We define intermediate-level truancy as having skipped school only once during the Wave 2 school year (1995-96), and high-level truancy as having skipped more than once.[17] The estimation sample is comprised of 964 friend pairs who had not skipped school at all during the Wave 1 school year (1994-95).

d. Individual and Household Characteristics

In our empirical analysis we control for respondents' age, race, and gender, as well as many other individual and family characteristics. The main covariates are as follows:

- GPA is the average of the respondent's self-reported grades in English and Math for the most recent grading period as of Wave 1.[18]
- Physical development index is constructed using Wave 1 responses to 3 gender-specific questions on physical development. These are converted to z-scores and averaged.
- Attitude toward risk is based on agreement with the statement "You like to take risks."[19] This is reported on a scale from 1 (strongly disagree) to 5 (strongly agree).
- Future orientation is based on agreement with the statement: "You live your life without much thought for the future." This is reported on a scale from 1 (strongly agree) to 5 (strongly disagree).

[16] Among the "high-intensity" marijuana users in Wave 2, the distribution of times used in the past 30 days has a median of 3, a mean of 10, and a standard deviation of 20.
[17] Among "high-intensity" truants, the distribution of days skipped has a median of 4, a mean of 7, and a standard deviation of 9.9.
[18] In cases of non-response on the in-home interview, self-reported grades from the in-school questionnaire were used instead. In a few cases where a respondent took English but not Math, the Math grade was imputed.
[19] This question and the "future orientation" question were asked only in Wave 2.

- Time preference is based on self-assessed likelihood that the respondent will be killed by age 21 and/or will contact HIV/AIDS. The likelihoods of each outcome are reported on a scale from 1 (almost no chance) to 5 (almost certain): we average the two responses.
- Smokers in household is a dummy indicating that either the parent interview indicated there were smokers in the household, or the Wave 1 interviewer reported evidence of smoking in the household.
- Two-parent household is a dummy for the presence of two parents as of Wave 1.
- Frequency parents attend church is based on the Wave 1 parent interview, with four values from 0 (never) to 3 (once a week or more). Missing values are set to 0 and we include a dummy for these cases. We also assign a separate indicator for Parents not religious if the parent reported either having no religion or never going to church.
- Parental education measures are based on Wave 1 reports of parental education. We classify families with 2 indicators: (a) at least one parent has completed high school (b) at least one parent has completed college. Missing values are set to 0 and we include a dummy for missing data.

e. Sample Statistics

Table 1 presents summary statistics for the variables in our analysis. Column 1 shows data for all adolescents who completed both the Wave 1 and Wave 2 interviews, while column 2 is limited to those who are in a best friend pair, and columns 3 and 4 show characteristics for the two sub-samples we use in our analysis of the initiation of sex activities. Looking first in the upper panel of Table 1, the individual and family background characteristics of respondents who can be combined into best-friend pairs (column 2) are not too different from the overall Add Health sample (column 1), though the matched friends include more girls than boys, tend to have a slightly higher grades, and are more likely to come from religious and two-parent families. Students in the subsamples with limited sexual experience (columns 3 and 4) are younger, more likely to be female, and have higher grades and slightly better-educated parents.

The middle panel of Table 1 shows the rates of participation in various risky behaviors as of Wave 1. About 40% of Add Health respondents report intimate touching, and 35% report intercourse. These rates are a little lower for the respondents who can be matched to friend pairs, and (by definition) are 0 or close to 0 for the subsamples with limited sexual experience as of Wave 1. Incidence rates for the other risky behaviors are also in the 20-40% range, but are lower for the subsamples with limited sexual experience.

Finally, the bottom panel of the table reports levels of sexual experience as of Wave 2. Over the one-year interval between the waves the overall fractions of respondents who report having had intimate contact or intercourse increase by 10 percentage points. Among those with very limited sexual experience as of Wave 1 (column 3) these rates increase from zero to 22% for intimate contact and from zero to 14% for intercourse. Among those with some experience but not intercourse (column 4), both rates increase by 18 percentage points.

Appendix Table 1 shows data for subsamples with low levels of each of the other risky behaviors as of Wave 1 (e.g., those who had never smoked a cigarette). These show similar patterns to those in columns 3 and 4 of Table 1, though rates of initiation of the other activities are somewhat lower than the rate of initiation of sex. Among friend pairs who had not smoked a cigarette as of Wave 1, the initiation rates are 19% for experimental cigarette smoking and 3% for regular smoking. For marijuana use, the corresponding initiation rates are 10% for experimental use and 6% for regular use; and for truancy, they are 16% for skipping one day and 8% for skipping more than one day.

Adolescent best friends tend to be of similar age, race, and family background, and to have similar experiences in risky behaviors. This is illustrated in Table 2 where we show the within-pair correlations of the main variables in our analysis. Friendships are particularly homogeneous with respect to age and race: 90% of friends are within a year of age, and 86% of the time they are of the same race (defined as white, black or other). The correlations are also relatively high for GPA, but relatively low for the measures of attitudes toward risks, future orientation, and time preference.[20] Interestingly, the degree of correlation is not too different for pairs with low levels of sexual experience at Wave 1 than for the overall sample of friends (compare columns 2 and 3 to column 1).

IV. Main Estimation Results

a. Identification

Our empirical approach is to fit bivariate probits (equations 3a and 3b) and bivariate ordered probits (equations 8a and 8b) to data for best friend pairs on the initiation of various risky behaviors. In our main models we assume that the behavior of each friend is only affected directly by his or her own *X*'s: in other words, we assume that X_1 and X_2 are distinct. As a robustness check we also consider specifications where we rely on the exclusion of a single variable from each of X_1 and X_2 to achieve identification (i.e., we allow all but one of the *X's* of each friend to affect both his/her own choices and those of the friend). As shown by Tamer (2003), the existence of an excluded regressor with infinite support is sufficient to ensure identification of the parameters of interest for the models we are considering. In practice, with the modest sample sizes and bounded covariates available in the Add Health, the performance of any of the three estimation methods (partial likelihood, quasi-likelihood, and full likelihood with a model of equilibrium selection) is less clear, particularly when the unobserved error components (ε_1, ε_2) are allowed to have an arbitrary correlation.

To provide some guidance on this issue we conducted a small scale Monte Carlo investigation. We simulated a series of data sets with 1,000 observations (roughly the size of our Add Health samples), and a pair of normally distributed covariates, x_1 and x_2, drawn to have a correlation that (roughly) matches

[20] This may reflect in part a relatively high level of noise in these measures.

the correlation of the covariate indexes $X_1\beta$ and $X_2\beta$ observed in our samples of best-friend pairs.[21] We then assumed one of three alternative data generating processes (DGP's) for the onset of risky behavior:

DGP-1 – positive social interaction effects, ε_1 and ε_2 uncorrelated standard normals

DGP-2 – no social interaction effects, ε_1 and ε_2 correlated normals with $\rho>0$

DGP-3 – positive social interaction effects, ε_1 and ε_2 correlated normals with $\rho>0$.

In cases of multiple equilibria (which arise in DGP's 1 and 3) we assumed that one of the possible equilibria was selected with probability ½. We selected a coefficient b for the simulated covariates x_1 and x_2 and a constant (or pair of constants in the ordered response models), scaled so that the average rate of initiation of risky behavior (roughly) matches the rate observed in our samples, and the pseudo-R^2 in a probit or ordered probit for the initiation of risky behavior (roughly) matches the pseudo-R^2 coefficients observed in our sample. For each of the three DGP's we calibrated the magnitudes of the social interaction effects and the correlation coefficient ρ to (roughly) match the observed cross-tabulations of initiation rates for best friend pairs observed in the data.

Tables 3a and 3b summarize the results from estimating bivariate probit and bivariate ordered probit models using the simulated data. For each DGP we estimated models with only social interaction effects (i.e., restricting $\rho = 0$), models with no social interactions but unrestricted heterogeneity (i.e., ρ free), and models that includes both social interaction effects and correlated errors in the two equations. The estimating models impose the (correct) equilibrium selection assumption of a 50-50 chance for either possible outcome in any region of multiplicity. For each DGP and estimation method, we simulated 100 data sets and estimated the specified model. We show the median and mean estimation errors for the social interaction and error correlation parameters, along with the standard deviations of these errors.

Focusing first on Table 3a, the results suggest that even correctly specified bivariate probit models (with the correct equilibrium selection model) have limited power to distinguish social interaction

[21] We fit probits and ordered probits for the initiation of each of the risky behaviors to the pooled data of both friends in each pair, using the set of individual and family characteristics described in the upper panel of Table 1. We then estimated the correlation of the fitted covariate indexes for each of the two best friends from these models: these ranged from 0.40 to 0.45.

effects from unobserved correlations between friends. For example, when the data are generated by DGP-1 ($\gamma>0$, $\rho=0$) and a model is estimated that allows both social interaction effects and unobserved heterogeneity, the standard deviations of the errors for the estimates of γ and ρ are around 0.26 – so large as to preclude any useful inference. When DGP-2 is correct (i.e., $\gamma=0$, $\rho>0$) the standard deviations of the estimation errors are a little smaller but there is a substantial upward bias in the estimate of γ (mean estimation error = 0.12), and a downward bias in the estimate of ρ (mean error = −0.12).

The results in Table 3b for the ordered response models are considerably more encouraging. In particular, the standard deviations of the estimation errors from the general model in column 3 are much smaller than those in the corresponding column of Table 3a. Moreover, the biases evident in the probit models are nearly eliminated in the ordered probit model. Specifically, there is only a small downward bias in γ_1 and γ_2 (mean estimation error = .02) when the true DGP has no unobserved heterogeneity ($\rho=0$), and a similarly small downward bias in ρ when the true DGP has no social interaction effects.[22] When the true DGP has both correlated errors and social interaction effects, there is no evidence of any systematic bias in estimates derived from models that allow both effects (see rows 3a-c of column 3).

In the models we are considering the power to distinguish unobserved heterogeneity from social interaction effects depends critically on the explanatory power of the *X's* in each of the two equations. We calibrated the DGP's in Tables 3a and 3b relatively conservatively, setting the variances of the covariate indexes to yield pseudo R-squared coefficients that match those obtained with simple models for the initiation of sexual activities that include only the individual and family covariates summarized in the top panel of Table 1. The explanatory power of models that also include indicators for experience in the other risky behaviors at Wave 1 is substantially higher (the pseudo R-squared coefficients roughly double). If we adjust the DGP's accordingly, the biases in the estimates of γ and ρ from the bivariate probit models are somewhat smaller (particularly the biases when the true model has no interaction effects but a general model is fit to the data) and the standard deviations of the estimation errors are also

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[22] It is also worth noting that if the true DGP has $\gamma_1=\gamma_2=0$, the model that assumes $\rho=0$ results in upwardly biased estimates of γ_1 and γ_2 that are equal in size. Thus a finding of $\gamma_1 \neq \gamma_2$ would be inconsistent with $\gamma_1=\gamma_2=0$, even if the model incorrectly assumes that $\rho=0$.

reduced. These patterns suggest that it may be useful to compare the estimates of γ and ρ from the bivariate probit models as additional explanatory variables are added to the model, looking in particular for evidence that the estimates of ρ become less negative as set of controls is expanded.

b. Bivariate Probit Models for Initiation of Sex

Table 4a presents a series of estimated bivariate probit models for the initiation of intercourse among best-friend pairs. The sample includes 929 pairs in which neither friend had had intercourse as of Wave 1. A parallel set of models for the subset of 738 friend-pairs with neither intimate sexual contact nor intercourse as of Wave 1 is shown in Table 4b. To keep the tables readable we show only the estimates of ρ and γ, the maximized log likelihood, and two measures of the "fit" of the model: a simple chi-squared statistic based on the deviations between the predicted and actual number of pairs with each of the four possible outcomes (i.e., (y_1,y_2) = (0,0), (0,1), (1,0) or (1,1)) and a score test of the hypothesis γ=0 (applicable for the models that set γ=0). We present four specifications: $\rho=\gamma=0$ (columns 1 and 5); γ=0 (columns 2 and 6); ρ=0 (columns 3 and 7); and both parameters free (columns 4 and 8). The models in columns 1-4 include only individual and family characteristics, while the expanded models in columns 5-8 also include eight dummy variables for baseline use/participation in tobacco smoking, marijuana, truancy, and alcohol. Estimates of the coefficients of the covariates (i.e., the β's) and their standard errors are presented in Appendix Tables 2a and 2b.

Looking first at the reference models in column 1 of Tables 4a and 4b which ignore any unobserved error correlation or social interaction effects, the goodness of fit and score test statistics suggest that these models are unable to explain the relatively high correlations between the behaviors of friends.[23] Allowing for either a correlation in the unobserved errors (column 2) or social interaction effects (column 3) leads to an improvement in the likelihood and a reduction in the goodness of fit statistics. The maximized likelihoods are slightly bigger for models that allow a social interaction effect,

[23] As a benchmark, the simple chi-squared statistic for the outcomes of the friend-pairs in Table 4a is 25.67. The much lower chi-square statistic in column 1 of Table 4a (12.69) shows that the observed covariates explain a reasonable share of the correlation between the friends' outcomes.

but the differences are small. In the larger sample of Table 4a, which includes friends who have intermediate levels of sexual experience at Wave 1, the estimates of ρ or γ are around 0.20: the corresponding estimates for the subsample of friends with relatively little experience at Wave 1, in Table 4b, are around 0.28.

As suggested by the simulation results in column 3 of Table 3a, bivariate probit models that allow both correlated errors and social interactions are uninformative about the relative magnitudes of ρ and γ. The point estimates of ρ and γ are large in magnitude and opposite in sign, and their associated standard errors are large.[24] The large negative values for ρ, in particular, seem implausible—especially given that all of the observable covariates are positively correlated between friends.[25] Instead, we suspect that the negative estimates of ρ are due to the small sample biases identified in Table 3a.

The parameter estimates from the expanded specifications in columns 5-8, which include indicators for levels of experience in smoking, marijuana use, truancy, and drinking, suggest that some of the correlation between friend's outcomes is attributed to the similarity of their Wave 1 experience in other risky behaviors. Patterns of use of alcohol are particularly strongly related to the risk of initiating intercourse (see below), and are highly correlated between friends. Controlling for other risky behaviors at the baseline, the estimates of ρ or γ in models that allow either correlated heterogeneity or social interaction effects fall from 0.20 to about 0.14 in the larger sample (Table 4a) and from 0.28 to 0.22 in the smaller sample (Table 4b).

For the models that estimate both ρ and γ (columns 4 and 8), the addition of controls for other risky behaviors leads to more "sensible" point estimates (i.e., less negative estimates of ρ and smaller estimates of γ). We interpret this pattern as consistent with the findings from our simulation study, which

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[24] An estimate of $\gamma \approx 1$ implies that a friend who would have a 0.2 probability of initiating intercourse in the absence of peer influence would have a 0.55 probability if his/her friend also initiated intercourse.
[25] Altonji, Elder and Taber (2005) have argued that the correlation of the unobserved determinants of some outcome is likely to be similar to the correlation of the observed determinants of the same outcome. Krauth (2006) uses this idea to obtain estimates of peer effects in a setting where only mean behavior of an individual's peer group is observed. In our case, the correlation of the estimated indexes of observed determinants of intercourse for two best friends is about 0.4. Imposing this estimate in our setting would lead to estimates of γ that are negative.

showed a similar pattern of reduced estimation biases in ρ and γ as the explanatory power of the covariates was increased.

While our primary focus is on the magnitude of social interaction effects between friends, the estimated effects of the individual and family background variables on initiation of sex are also interesting. The estimates of β are very similar for the two estimation samples, and are quite robust to the treatment of correlated heterogeneity and social interaction effects. (See Appendix Tables 2a and 2b.) Age and physical development have strong positive effects on the likelihood of initiating intercourse, as does black race. In the baseline models students with a higher GPA are less likely to initiate sex, though this effect is smaller once controls are added for other risky behaviors at Wave 1. Among the three qualitative questions designed to measure attitudes to risk, future orientation, and time preference, only the risk measure is significantly related to the likelihood of initiating intercourse. Children from two-parent families and those with better-educated parents are less likely to initiate sex between the waves of the survey, while the presence of a smoker in the household has a (surprisingly large) positive effect, even controlling for Wave 1 behaviors. The expanded specifications in columns 5-8 suggest that the most important predictor of the likelihood of beginning intercourse is use of alcohol. The probability of initiating sex is about 10-12 percentage points higher if the student reports having consumed alcohol without adult supervision at Wave 1. Truancy behavior is also a significant predictor of the transition to sexual activity, whereas cigarette smoking and marijuana use are not.

c. Bivariate Ordered Probit Models for Initiation of Sex

Given the limited power of the bivariate probit models, we turn to bivariate ordered probit models. We begin with "full likelihood" models which assume equal probabilities of the 2 possible equilibria in any region of multiplicity. We then present partial likelihood models that relax the equilibrium selection assumption.

Table 5 presents estimation results for a series of eight models, similar to the ones in Tables 4a and 4b. The models are estimated on the subset of pairs in which neither friend has engaged in intimate touching or intercourse at Wave 1 (i.e., the same sample used in Table 4b). Beginning with the models in columns 1 and 5, which assume no correlation in the unobserved determinants of friends' activities and no social interaction effects, the goodness of fit summary statistics in the bottom row of the table suggest that these models are unable to adequately fit the degree of correlation between friends in their ordered outcomes.[26] Allowing for either correlated heterogeneity (columns 2 and 6) or social interaction effects (columns 3 and 7) leads to a substantial improvement in fit, but the gains are larger from the models with social interaction effects. Further improvements from the combined models which include both factors (columns 4 and 8) are relatively small. As expected, the models with social interaction effects suggest that a higher level of activity by one of the friends provides a stronger "push" on the other friend.

In the models that allow both correlated heterogeneity and social interactions (columns 4 and 8) the estimated values for the correlation parameter are in both cases small and close to 0. Moreover, unlike the case in Tables 4a and 4b, the estimates of ρ, γ_1, and γ_2 are hardly affected by the addition of controls for risky behaviors at Wave 1, despite the fact that these variables add substantial explanatory power. We interpret this as evidence that the baseline *X*'s are powerful enough to reduce or eliminate any small sample bias in the estimated heterogeneity and interaction effects from a combined model. Though the estimates from the combined model are relatively imprecise, the relatively small estimated values of ρ, and the relative stability of the estimates of γ_1 and γ_2 between models that set ρ=0 (columns 3 and 5) and models that treat ρ as a free parameter (columns 4 and 8) suggest to us that social interaction effects are the primary source of the correlation in the sexual initiation patterns of adolescent friends (conditional on their observed characteristics).

The estimates in columns 4 and 8 imply statistically significant interaction effects for sexual behavior, with a slightly larger effect on the highest level of activity (intercourse) than the intermediate level (intimate contact). Specifically, the estimates imply that the likelihood of initiating intercourse increases by 4.5 percentage points (on a base rate of 14 percent) if one's best friend also initiates

[26] For comparison purposes, the simple chi-squared statistic for the outcomes of the pairs across the 9 possible cells is 28.60.

intercourse, and the likelihood of initiating intimate contact is increased by 4.1 percentage points (on a base rate of 22 percent) if one's friend does the same. The peer effect for initiating intercourse is comparable in size to the effects of living in a household with smokers, of living in a single-parent household, and of having parent(s) who did not complete high-school. It is also comparable to the effect of a one standard deviation increase in one's physical development index.

The estimated β coefficients for the models presented in Table 5 are shown in Appendix Table 3. These estimates are very similar to the corresponding estimates from the bivariate probit models in Table 4b, as would be expected given that the bivariate probit model for the highest level of activity is nested within the bivariate ordered model. As was true of the coefficient estimates from the bivariate probit models, the estimates from the ordered probit models are also very similar, regardless of the assumptions on ρ, γ_1, and γ_2.

d. Models that Do Not Impose an Assumption on Equilibrium Selection

So far we have assumed that in cases where multiple equilibria are possible, one of the two equilibria is selected at random. Table 6 presents a series of models that relax this assumption. For simplicity we focus on models that assume no correlation in the unobserved determinants of each friend's choices, and include only the baseline set of individual and family characteristics.

As a point of departure, the first column of the table reproduces the estimates from column 4 of Table 5. The second and third columns present estimates where we assume that in cases of multiple equilibria the selected outcome represents either the higher or lower intensity choice for both friends. (For example, when (0,0) and (1,1) are both possible equilibria, the higher intensity choice is (1,1) and the lower intensity choice is (0,0)). These "extreme" selection rules yield estimated peer effects, likelihoods, and goodness of fit statistics that are very similar to the "50-50 split" baseline.

Columns 4 and 5 present estimates from a partial likelihood approach (which distinguishes 7 outcome sets) and from Tamer's quasi-likelihood approach.[27] In both cases, the likelihood (or quasi-likelihood) is maximized at γ_1=0.09 and on the boundary of the parameter space for γ_2 (i.e., γ_2=0), but the likelihood functions are extremely flat. For comparison purposes we also estimated a partial likelihood model that sets $\gamma_1 = \gamma_2 = 0$ but allows a free value for ρ, and one that allows all three parameters to be estimated.[28] The first model yields an estimate of ρ=0.08 (standard error=0.37), and a log likelihood value of −787.31 (just a little lower than the value for the model in column 5). In the second, ρ=−0.40 (standard error=0.38), γ_1=0.53 (standard error=0.53) and γ_2=0.03 (standard error=0.53).[29] We interpret these estimates as suggesting that the partial likelihood approach ignores too much information for us to learn much about the relative magnitudes of γ_1 and γ_2 versus ρ in our (relatively small) sample. Interestingly, however, the estimated β coefficients from the partial likelihood models are not very different from the estimates obtained from our "full likelihood" models. Thus, it appears that a partial likelihood approach <u>is</u> useful for obtaining information about the effects of the exogenous variables.

e. More Complex Models of Social Interactions

The models estimated in Tables 4-6 assume that one friend's choice to engage in a particular level of activity only affects on the other's threshold for the same level of activity. Under that assumption, there are only two interaction effects, represented by γ_1 and γ_2. In this section we consider a more general model that allows both thresholds to be affected by both of the friend's choices, resulting in four possible interaction effects. This model replaces equations (10a) and (10b) with the more general threshold equations:

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[27] We use flexible probit models to estimate the H_{ij} functions defined in equations (11a) and (11b). In the implementation of the method, it is necessary to impose bounds on the H_{ij} functions to ensure that the probability defined in equation (11c) is strictly positive. We use the function m(a,b) = -c log (exp (-a/c) + exp(-b/c)) as a smoothed approximation of the min(a,b) function to impose these bounds while maintaining a differentiable likelihood.

[28] When $\gamma_1 = \gamma_2 = 0$ there are no regions of multiple equilibria, so there is a 1:1 mapping from (ε_1, ε_2) to the observed outcomes (y_1, y_2). However, it is still possible to define and estimate a partial likelihood defined over outcome sets.

[29] Again, similar estimates were obtained when the quasi-likelihood approach was used instead.

(12a) $c_1(y) = c_{10} - \gamma_{11}(y=1) - \gamma_{12}(y=2)$,

(12b) $c_2(y) = c_{20} - \gamma_{21}(y=1) - \gamma_{22}(y=2)$.

Our baseline model is a special case of this more general model with $\gamma_{11} = \gamma_{12}$ and $\gamma_{21}=0$.

Figure 3 shows the partition of (ε_1, ε_2) space corresponding to the generalized model under the assumptions that $0 \leq \gamma_{j1} \leq \gamma_{j2}$ and $c_{10} \leq c_{20} - \gamma_{22}$. There are now four regions with multiple equilibria: two that are similar to the regions in Figure 2, a third region in which either (0,1) or (1,2) can occur, and a fourth where (1,0) or (2,1) can occur. We estimate the model constraining the interaction coefficients to satisfy the ordering assumed in Figure 3, and assigning equal probabilities to the two possible equilibria in any region of multiplicity. For simplicity, we also assume that the error terms are uncorrelated ($\rho=0$).

The results, summarized in Table 7, support the assumptions of our baseline model. First, the similarity of the estimates of γ_{11} and γ_{12} implies that the threshold for intimate contact is lowered when the friend initiates this behavior, but is not further affected when the friend initiates intercourse.[30] Second, the estimate of γ_{21} is much smaller than the estimate of γ_{22} and is close to zero in the model that controls for wave 1 behaviors (column 2). This pattern suggests that the decision to initiate intercourse is only affected by the friend's initiation of intercourse, and not by lower-intensity sexual practices.

f. Relaxing the Identification Assumptions

As we emphasized in Section II, the ability to separately identify peer effects and unobserved heterogeneity relies on the existence of at least one (powerful) covariate that directly affects only one of the friends. Our models so far have made the assumption that all the individual *X's* for one friend are excluded from the other's equation. In this section we present two complementary checks of the robustness of our results to this assumption. First, we sequentially allow each of the individual *X's* to enter directly into the friend's list of covariates, and check whether the estimated "cross-pair" effects (e.g., the effect of #1's GPA on #2's propensity to initiate sex) are statistically significant or large in

[30] Our parameterization restricts the difference γ_{11}- γ_{12} to be strictly positive, and the parameter estimate for this difference is near the boundary of the allowable space.

magnitude. Second, we allow <u>all but one</u> of the individual *X's* to directly influence the other friend, thus narrowing the source of identification to a single excluded covariate.

The results from the first check are summarized in Appendix Table 4, where we present a series of models based on the specification in column 8 of Table 5. Only one of the covariates has a statistically significant "cross effect" on the friend's behavior -- the dummy indicating that a respondent's parents are non-religious. This variable has a large negative effect on the friend's likelihood of initiating sex (coefficient = −0.28, standard error=0.09), comparable to the own effect of this variable (coefficient = −0.23). Interestingly, however, allowing for this cross effect has no impact on the point estimates (or standard errors) of ρ, γ_1 or γ_2. Two other covariates also have relatively large and marginally significant cross effects: the dummy for being a regular user of alcohol at Wave 1 (t=1.92) and the dummy for black race (t=1.87). In both cases the cross effect has the same sign as the direct effect of the variable. In neither case, however, are the point estimates (or standard errors) of ρ, γ_1 or γ_2 much affected by the allowance for a cross effect. Overall, inferences about the relative magnitudes of the social interaction effects are robust to allowing any of the individual *X's* to have a direct cross effect.

Table 8 presents a more stringent test, where we allow all but one of an individual's *X's* to exert a direct effect on his or her friend's behavior. For reference, columns 1 and 2 reproduce the specifications from column 4 and 8 of Table 5. (Recall that these estimates are based on the assumption that none of the *X's* exerts a cross-effect.) The remaining pairs of columns present specifications that allow all the covariates except the one listed in the column heading to affect the friend. We focus on three potential variables that we think could be legitimately excluded from the friend's equation: an individual's physical development index, his/her GPA, and his/her risk preferences. In all cases the estimate of γ_2 remains relatively large and at least marginally significant. The estimate of γ_1 is more variable across specifications, but is always within ½ of a standard error of the baseline estimates of 0.14 or 0.15. The estimates of ρ from the alternative specifications is also a little higher than the estimates from the baseline models, but never significantly so. Overall, we interpret these results as confirming the relative robustness of our baseline estimates.[31]

g. Models with Heterogeneous or Asymmetric Peer Effects

Thus far all models have assumed that any peer interaction effects are constant across friend-pairs, and symmetric. In this section we consider models that relax these assumptions and allow the peer effects between a pair of friends to vary with characteristics of either the pair or the individual. We begin with specifications that a variable *Z* to affect the peer effects by estimating models in which:

(13a) $\gamma_1 = \exp(a + bZ)$,

(13b) $\gamma_2 = \exp(c + dZ)$.

For simplicity, we assume that the unobserved determinants of friends' behavioral choices are uncorrelated, though in principle models that allow heterogeneous or asymmetric peer effects and correlated heterogeneity are estimable.

The results from these models are presented in Table 9. The top panel shows the estimates for the parameters in (13a) and (13b), while the lower panel of the table shows the implied peer effects for different types of friend-pairs. The first four columns allow the peer effects to depend on the gender of the friends (columns 1-2) and their average age (columns 3-4). The estimates suggest that peer effects differ by gender but not by age. The gender interaction terms, though not significant by conventional standards, suggest that peer effects are larger for females than for males and that there are especially large gender differences in peer effects for the initiation of sexual intercourse.

The remaining columns examine the role of friendship stability and reciprocity. In columns 5-6, we allow the peer effect to depend on the predicted probability that the two friends nominate each other as best friends in the <u>second</u> wave of the survey. We estimate this probability using a simple probit model

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[31] We conducted a third check in which we added information on the fraction of each individual's classmates who had experienced intimate touching or intercourse as of Wage 1 to the choice models. The results, available on request, show that the fraction of classmates with sexual experience has a positive but imprecisely estimated effect on the rate of initiation of sex by the best friend pairs with limited sexual experience at Wave 1. Moreover the addition of this variable has a negligible impact on the estimates of ρ, γ_1 and γ_2.

that includes both the means and absolute differences in the friends' characteristics, a set of dummies indicating the source of the friendship nominations used to construct the match (Wave 1 in-home interview, in-school questionnaire, or both), and a dummy for whether the best friend nomination was reciprocated by both parties in Wave 1. The heterogeneity estimates imply significantly stronger peer effects in friendships that are more likely to be reciprocated one year later.

Reciprocity of friendship nominations at Wave 1 is a strong predictor of whether the friendship will be reciprocated at Wave 2. Hence, one explanation for the finding of smaller peer effects in the less stable friendship may be that the peer influence in unreciprocated friendships is unidirectional (or asymmetric).[32] The models in columns 7-8 allow the peer effects experienced by a student to depend on whether the student reciprocated the friendship nomination of the person we match as their friend. The estimates imply large asymmetries; indeed students who we assign to a friendship but who did not reciprocate the nomination experience negligible peer effects. This finding suggests that the average peer effects we measure in our overall sample (which includes reciprocating and non-reciprocating friend pairs) may understate the importance of peer effects between reciprocating best friends.

To further explore the differences across reciprocated and non-reciprocated friendships, we fit separate versions of our baseline model (from columns 4 and 8 of Table 5) for the two sets of friend-pairs in our sample. As shown in columns 1-4 of Table 10, the estimated social interaction effects (γ_1 and γ_2) and the estimated correlation parameter ρ are all larger for reciprocated best-friend pairs, though the estimates are relatively imprecise. In particular, the estimated peer effect for the initiation of intercourse implies that among reciprocated best friends, the likelihood of initiating intercourse increases by more than 6 percentage points if one's best friend also does so, while among non-reciprocated pairs, the corresponding increase is only about 2.5 percentage points.

We also fit an asymmetric model for the non-reciprocated pairs, allowing different values of γ_1 and γ_2 for the *nominators* (i.e., the person who named the other his/her best friend) and the *non-*

[32] Two recent papers that analyze Add Health data make the assumption that directionality of peer effects can be inferred from asymmetries in friendship nominations and use this assumption to help identify peer effects in spatial autoregressive model (Bramoulle, et al., 2009; Lin, 2010).

reciprocator (the person who failed to name the other his/her best friend). The results, in columns 5 and 6 of Table 10, suggest that the nominator experiences relatively strong social interaction effects (roughly a 3.5 percentage point change in the likelihood of initiating intercourse) whereas the non-reciprocator experiences relatively weak effects (roughly 1.5 percentage points).

V. Estimation Results for Other Risky Behaviors

In this section we briefly summarize the estimation results for models of the interactions in other forms of risky behavior by best friend pairs. We focus on bivariate ordered probit models estimated under a simple "equal probability" assumption for observed outcomes when there are multiple equilibria. Panels A, B, and C of Table 11 present results for cigarette smoking, marijuana use, and truancy, respectively. In each case, the estimation sample includes only friend pairs in which neither friend was engaging in the behavior (at either an intermediate or high level) as of Wave 1. The layout of the each panel is similar to the format of Table 5, with parallel sets of models excluding and including indicators for other risky behaviors as of Wave 1.

The results for cigarette smoking are similar to the results for initiation of sex in several ways. First, the models with social interactions provide slightly larger likelihood values and improved goodness of fit compared to the models with only correlated heterogeneity. Second, the specifications with social interactions imply stronger peer effects for the more intense level of activity (here, regular cigarette smoking). And third, as in Table 5, the specifications that control for other risky behaviors in Wave 1 produce estimates that are very similar to those from the baseline model. However, the models for cigarette smoking that include both correlated heterogeneity and peer effects (columns 4 and 8) yield larger estimates of the correlation parameter than those found in the models of sexual activity, and the social interaction estimates in these specifications are not statistically significant. These results are less conclusive than the results for sex about the presence of peer effects, and suggest that some of the correlation patterns in cigarette smoking may be due to common unobserved heterogeneity.

The estimated models of marijuana use are very different from the models for sex and tobacco. First, the models that include social interaction effects fit the data much better than the model with only correlated heterogeneity. Second, the estimates for γ_1 are much larger than those for γ_2, suggesting that peer effects are larger for experimental use than for regular use. And third, the models that include both correlated heterogeneity and peer effects produce negative estimates for the correlation parameter. This last result is counterintuitive and makes the estimates from the combined model difficult to interpret. One simple potential explanation is that marijuana use is less precisely measured in the Add Health survey than other risky behaviors, and as a result, our classification of individuals as experimental or regular marijuana users may be subject to a relatively large degree of measurement error.[33] For this reason, the ordered probit model may not provide the significant bias reduction over the probit model that we saw in our simulations and in the model for sexual activity.

Finally, the models for truancy behavior also differ somewhat from the models for sex and cigarette smoking. Truancy is even more highly correlated within friend pairs than the other risky behaviors. (A simple chi-squared statistic for the 3×3 table of joint truancy behavior has the highest value of all 4 behaviors, 49.4). And here, the models that allow both correlated heterogeneity and peer effects fit better than either model that allows just one of these factors. Although the parameter estimates these flexible models and are relatively imprecise, the point estimates suggest that both factors may be present. Finally, the estimates of γ_1 and γ_2 suggest that the peer for skipping school once is slightly larger than the peer effect for more regular truancy behavior.

VI. Summary and Conclusions

We have presented a simple approach to estimating social interaction effects in the risky behavior of adolescent best-friend pairs, based on econometric models of their joint outcomes that allow for

[33] Our definition of "experimental" use is based on whether the respondent indicates having tried marijuana as of the Wave 2 interview, while our definition of "regular" use is based on whether the respondent indicates having used one or more times in past 30 days. Thus, respondents who tried marijuana for the first time in the past 30 days may be misclassified as regular users, while more regular users may be classified as experimental users if they went for 30 days without using.

correlated unobserved heterogeneity. Methodologically, our approach is closely related to studies of market entry games, including Bresnahan and Reiss (1990) and Tamer (2005). As in these studies, we rely on an exclusion restriction – specifically, a variable or set of variables that directly affects only one of the friends – to empirically distinguish between social interaction effects and correlated heterogeneity. The rich set of variables collected in the Add Health data set includes several variables that plausibly exert no direct effect on a friend's choices, and our estimates of the social interaction effects in the initiation of sexual behavior are quite robust to alternative sources of identifying variation.

An important advantage of our approach is that it uses "naturally occurring" friendships of the kind that mediate many forms of adolescent behavior. An alternative identification strategy employed in a number of recent studies relies on "randomly assigned" peer groups such as college roommates. While much can be learned from such designs, it is unclear whether the social interaction effects observed from the behavior of individuals assigned to random peer groups adequately represent the peer effects experienced in naturally occurring friendships. Indeed, Carrell et al. (2011) show that the reduced-form estimates from such studies can be difficult to interpret because they depend on the patterns of association that emerge *after* random assignment, depending on the structure of the constructed peer group.

Our empirical results suggest that adolescent friends' decisions to become sexually active exhibit important but "modest-sized" interaction effects. Having a best friend who is engaging in intercourse, for example, raises the likelihood that a previously inexperienced adolescent also engages in intercourse by 4-5 percentage points (relative to a average rate of initiation of about 14 percent). Similar effects are also present for other risky behaviors, including use of tobacco and marijuana and truancy (though not for the use of alcohol). These effects are large enough to warrant parental concern but not so large as to overwhelm the influence of other individual and family characteristics.

We also find evidence of heterogeneity in the magnitude of these effects. Our estimates suggest that peer influence is strongest between best friends in "reciprocated" friendships (e.g., the likelihood that one member of a reciprocated pair of best friend initiates intercourse when the other does rises by more than 6 percentage points). In non-reciprocated pairs, the effects are asymmetric. The person who named the other as their best friend experiences relatively strong social interaction effects (roughly a 3.5 percentage point change in the likelihood of initiating intercourse), whereas the non-reciprocator experiences relatively weak effects (roughly 1.5 percentage points). This pattern suggests that the modest size of the peer effects observed in many studies that rely on random or quasi-random manipulation of "peer groups" may be due in part to smaller social interaction effects between people who are not as closely connected as best friends. More generally, these results underscore the importance of peer group structure in determining the strength of peer effects.

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Figure 1: Partition of (ε_1, ε_2) for Bivariate Probit Model

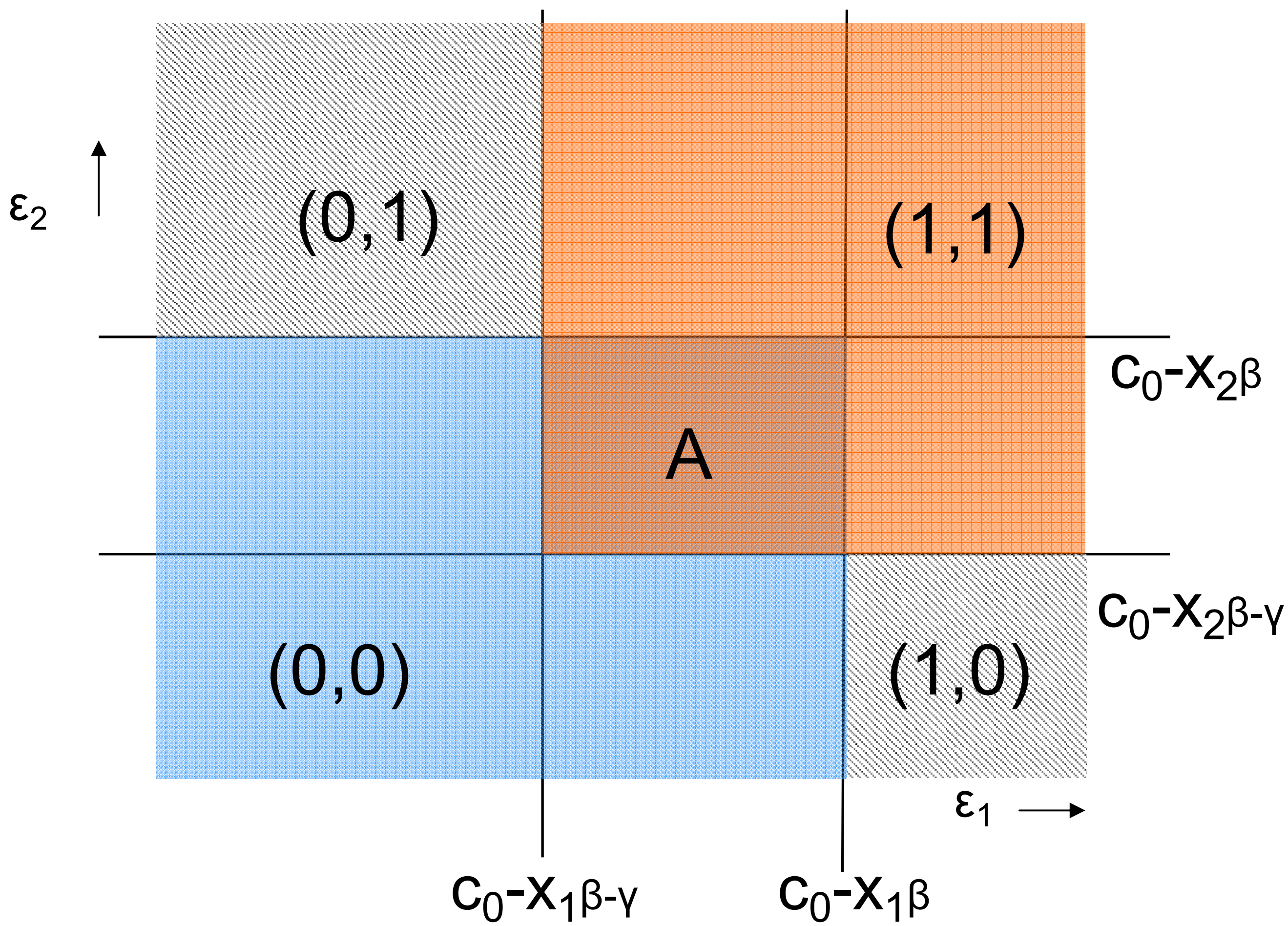

Figure 2: Partition of $(\varepsilon_1, \varepsilon_2)$ for Bivariate Ordered Probit

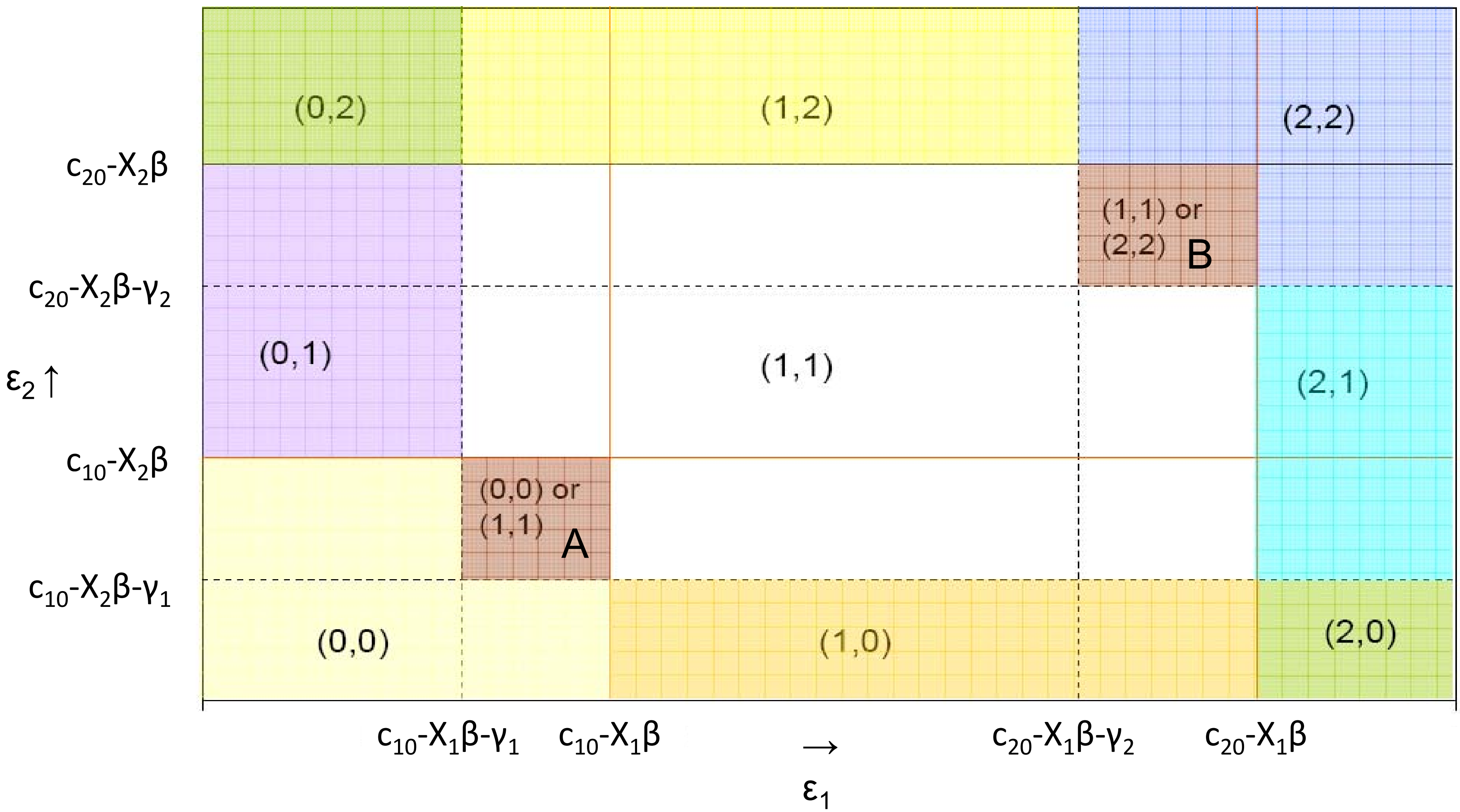

Figure 3: Partition of (ε_1, ε_2) for Generalized Bivariate Ordered Probit

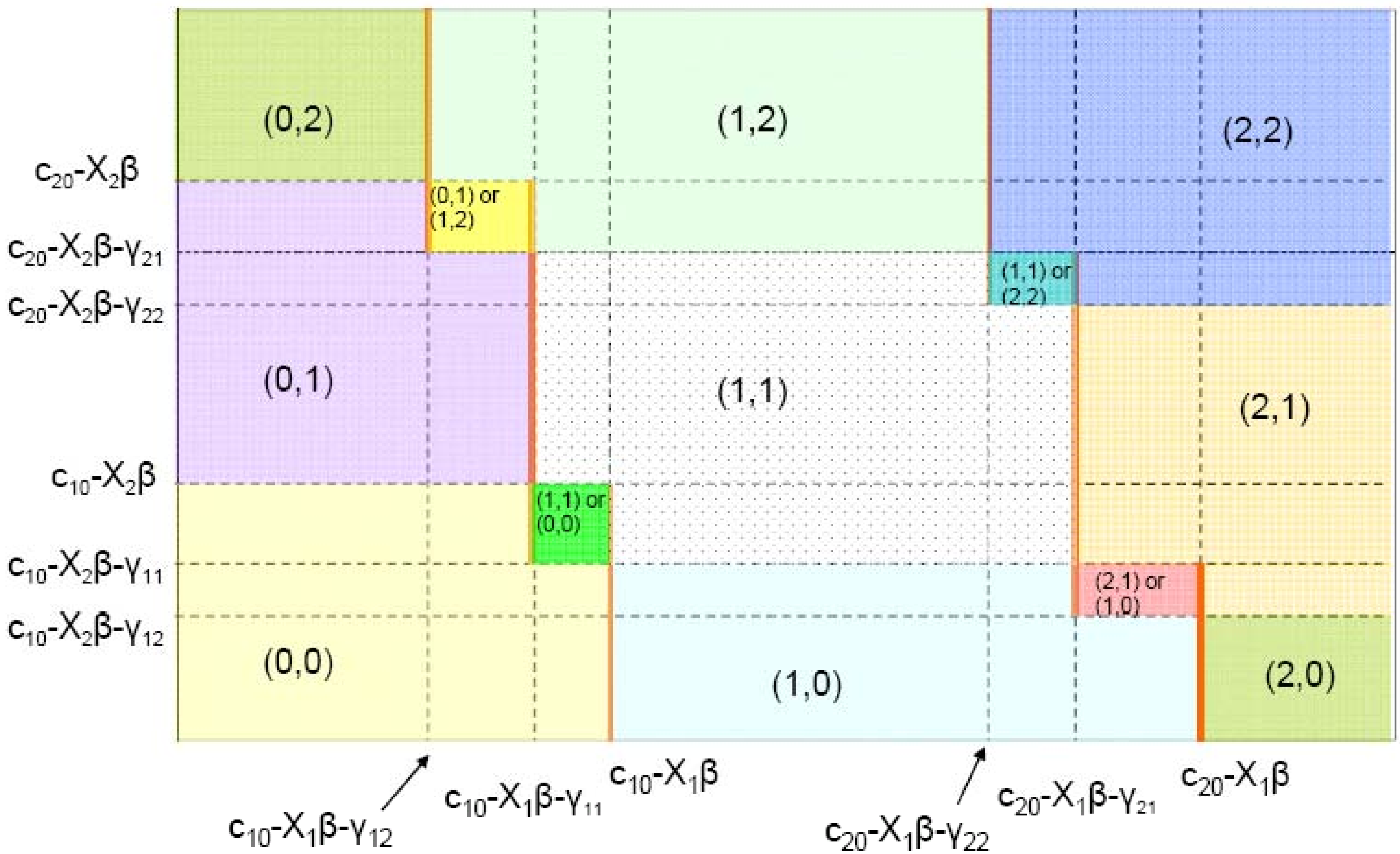

Table 1. Descriptive Statistics for Various Samples

	Full Wave 1 & 2 Sample (1)	Same-sex Best Friend Pairs (2)	BF's with no touching or intercourse at Wave 1 (3)	BF's with no intercourse at Wave 1 (4)
Individual & Family Characteristics				
Age (in years, as of wave 1)	15.80	15.79	15.14	15.28
Male	0.49	0.45	0.43	0.42
Black race	0.22	0.19	0.14	0.14
Other non-white race	0.15	0.17	0.17	0.16
GPA (1-4 scale)	2.73	2.81	3.01	2.99
Physical development index	0.13	0.16	-0.04	0.04
Attitude toward risk (1-5 scale)	3.54	3.55	3.47	3.50
Future orientation (1-5 scale)	3.58	3.60	3.65	3.64
Time preference (1-5 scale)	1.58	1.58	1.53	1.53
Smokers in household (yes/no)	0.42	0.40	0.33	0.35
Two-parent household (yes no)	0.68	0.71	0.77	0.77
Freq. parents attend church (0-3 scale)	1.76	1.82	1.89	1.85
Parents not religious (yes/no)	0.19	0.17	0.15	0.16
Parental church attendance missing	0.12	0.12	0.11	0.11
At least 1 parent finished high school	0.88	0.88	0.90	0.90
At least 1 parent finished college	0.37	0.38	0.43	0.43
Parental education missing	0.05	0.04	0.03	0.03
Risky Behaviors as of Wave 1:				
Intimate touching	0.43	0.40	0.00	0.12
Had intercourse	0.35	0.31	0.00	0.00
Tried cigarette smoking	0.41	0.39	0.24	0.28
Smoked cigarettes regularly	0.18	0.15	0.05	0.07
Tried marijuana	0.26	0.25	0.09	0.12
Used marijuana regularly	0.14	0.13	0.04	0.06
Drank alcohol without adult presence	0.38	0.38	0.21	0.26
Drank alcohol regularly	0.16	0.15	0.05	0.07
Skipped school 1 or more days	0.27	0.26	0.13	0.14
Skipped school 2 or more days	0.20	0.18	0.08	0.09
Sex Experiences as of Wave 2:				
Intimate touching w/ opposite sex	0.531	0.517	0.222	0.301
Had intercourse	0.450	0.429	0.138	0.182
Number of observations	13,836	3,368	1,476	1,856

Notes: see text for description of algorithm for identifying best friend (BF) pairs.

Table 2. Correlations in Covariates and Outcomes Between Friend Pairs

	All Same-sex Best Friend Pairs (1)	BF's with no touching or intercourse at Wave 1 (2)	BF's with no intercourse at Wave 1 (3)
Individual & Family Characteristics:			
Age (in years, as of wave 1)	0.85	0.88	0.88
Black race	0.86	0.84	0.85
GPA (1-4)	0.34	0.40	0.37
Physical development index	0.27	0.27	0.29
Attitude toward risk (1-5 scale)	0.09	0.08	0.09
Future orientation (1-5 scale)	0.14	0.15	0.16
Time preference (1-5 scale)	0.04	0.05	0.06
Smokers in household (yes/no)	0.17	0.17	0.18
Two-parent household (yes/no)	0.16	0.15	0.15
Freq. parents attend church (0-3 scale)	0.28	0.32	0.30
At least 1 parent finished high school	0.34	0.38	0.34
At least 1 parent finished college	0.31	0.27	0.30
Risky Behaviors as of Wave 1			
Intimate touching	0.33	--	0.13
Had intercourse	0.36	--	--
Tried cigarette smoking	0.29	0.25	0.26
Smoked cigarettes regularly	0.34	0.13	0.17
Tried marijuana	0.41	0.37	0.37
Used marijuana regularly	0.25	0.18	0.22
Drank alcohol without adult presence	0.29	0.26	0.29
Drank alcohol regularly	0.21	0.14	0.16
Skipped school 1 or more days	0.28	0.23	0.22
Skipped school 2 or more days	0.28	0.23	0.18

Notes: entries are simple correlation coefficients between characteristics or outcomes of best friends (BF's) in each pair. Sample sizes are the same as for columns 2-4 in Table 1.

Table 3a: Empirical Distribututions of Estimation Errors in Application of Bivariate Probit to Three DGP's

	Method 1 Assume ρ=0 (1)	Method 2 Assume γ=0 (2)	Method 3 Unrestricted (3)
1. DGP #1: γ=0.225, ρ=0			
a. Median/Mean Error in γ	0.01 / 0.00	--	-0.07 / 0.04
(std. dev)	(0.06)		(0.27)
b. Median/Mean Error in ρ	--	0.25 / 0.25	.07 / -0.02
(std. dev)		(0.06)	(0.26)
2. DGP #2: γ=0, ρ=0.21			
a. Median/Mean Error in γ	0.17 / 0.18	--	0.00 / 0.12
(std. dev)	(0.07)		(0.19)
b. Median/Mean Error in ρ	--	-0.01 / 0.00	-0.06 / -0.12
(std. dev)		(0.07)	(0.19)
3. DGP #3: γ=0.125, ρ=0.11			
a. Median/Mean Error in γ	0.09 / 0.10	--	-0.13 / 0.01
(std. dev)	(0.06)		(0.23)
b. Median/Mean Error in ρ	--	0.14 / 0.14	0.10 / 0.00
(std. dev)		(0.06)	(0.23)

Notes: based on applications of maximum likelihood estimation to simulated data under alternative estimating assumptions, with 100 simulations per DGP and estimation method. See text for details on the design of the data sets used in the simulations. Simulated data has 1000 friend pairs.

Table 3b: Empirical Distributions of Estimation Errors in Application of Bivariate Ordered Probits to Three DGP's

	Method 1 Assume $\rho=0$ (1)	Method 2 Assume $\gamma_1=\gamma_2=0$ (2)	Method 3 Unrestricted (3)
1. DGP #1: $\gamma_1=0.20$, $\gamma_2=0.25$, $\rho=0$			
a. Median/Mean Error in γ_1	0.00 / 0.00	--	-0.02 / -0.02
(std. dev)	(0.06)		(0.10)
b. Median/Mean Error in γ_2	-0.01 / -0.01	--	-0.02 / -0.02
(std. dev)	(0.07)		(0.10)
c. Median/Mean Error in ρ	--	0.21 / 0.21	0.01 / 0.02
(std. dev)		(0.06)	(0.10)
2. DGP #2: $\gamma_1=0$, $\gamma_2=0$, $\rho=0.25$			
a. Median/Mean Error in γ_1	0.17 / 0.16	--	0.00 / 0.02
(std. dev)	(0.08)		(0.04)
b. Median/Mean Error in γ_2	0.16 / 0.15	--	0.00 / 0.03
(std. dev)	(0.09)		(0.04)
c. Median/Mean Error in ρ	--	0.00 / 0.00	0.02 / -0.02
(std. dev)		(0.06)	(0.07)
3. DGP #3: $\gamma_1=0.10$ $\gamma_2=0.15$, $\rho=0.15$			
a. Median/Mean Error in γ_1	0.10 / 0.11	--	0.00 / 0.00
(std. dev)	(0.07)		(0.06)
b. Median/Mean Error in γ_2	0.10 / 0.10	--	0.00 / 0.00
(std. dev)	(0.07)		(0.09)
c. Median/Mean Error in ρ	--	0.26 / 0.26	0.00 / 0.00
(std. dev)		(0.06)	(0.09)

Notes: based on applications of maximum likelihood estimation to simulated data under alternative estimating assumptions, with 100 simulations per DGP and estimation method. See text for details on the design of the data sets used in the simulations. Simulated data has 1000 friend pairs.

Table 4a: Summary of Bivariate Probit Models for Initiation of Sexual Activity by Friend Pairs

	Baseline				Expanded Set of Covariates			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Include Wave 1 Behaviors?	no	no	no	no	yes	yes	yes	yes
Error correlation (ρ)	--	0.19	--	-0.67	--	0.13	--	-0.21
		(0.06)		(1.47)		(0.08)		(0.25)
Social Interaction Effect (γ)	--	--	0.20	0.92	--	--	0.14	0.33
(friend has had intercourse)			(0.05)	(1.80)			(0.06)	(0.23)
Log Likelihood	-798.51	-794.84	-793.55	-791.94	-733.88	-732.47	-731.88	-731.54
Goodness of Fit (4 cells)	12.69	1.89	1.20	1.07	4.47	0.57	0.12	0.09
Score Test for γ (1 d.f.)	2.58	0.45	--	--	1.66	0.35	--	--

Notes: standard errors, clustered by school, in parentheses. See text for model descriptions. Sample includes 929 friend-pairs who had not engaged in intercourse by Wave 1. Dependent variable is dummy for having had intercourse by Wave 2. (Mean across both friends is 0.181). Models in columns 1-4 include constant and 17 other person-specific controls. Models in columns 5-8 include 17 same controls plus 8 additional dummies indicating level of experience in cigarette smoking, marijuana use, truancy, and alcohol use as of Wave 1. Coefficients for covariates are shown in Appendix Table 2a.

Table 4b: Summary of Bivariate Probit Models for Sexual Activity by Friend Pairs - Subsample with Minimal Experience at Wave 1

	Baseline				Expanded Set of Covariates			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Include Wave 1 Behaviors?	no	no	no	no	yes	yes	yes	yes
Error correlation (ρ)	--	0.28	--	-0.91	--	0.22	--	-0.28
		(0.08)		(0.14)		(0.09)		(0.54)
Social Interaction Effect (γ)	--	--	0.28	1.29	--	--	0.22	0.49
(friend has had intercourse)			(0.07)	(0.17)			(0.07)	(0.57)
Log Likelihood	-537.04	-532.33	-531.52	-530.47	-494.56	-492.13	-491.54	-491.29
Goodness of Fit (4 cells)	13.32	0.69	0.40	0.58	6.44	0.38	0.03	0.02
Score Test for γ (1 d.f.)	2.59	0.29	--	--	1.98	0.29	--	--

Notes: standard errors, clustered by school, in parentheses. See text for model descriptions. Sample includes 738 friend-pairs who had not engaged in intercourse or intimate contact by Wave 1. Dependent variable is dummy for having had intercourse by Wave 2. (Mean across both friends is 0.138). Models in columns 1-4 include constant and 17 other person-specific controls. Models in columns 5-8 include 17 same controls plus 8 additional dummies indicating level of experience in cigarette smoking, marijuana use, truancy, and alcohol use as of Wave 1. Coefficients for covariates are shown in Appendix Table 2b.

Table 5: Summary of Bivariate Ordered Probit Models for Sexual Activity by Friend Pairs

	Baseline				Expanded Set of Covariates			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Include Wave 1 Behaviors?	no	no	no	no	yes	yes	yes	yes
Error correlation (ρ)	--	0.24	--	0.08	--	0.18	--	0.02
		(0.06)		(0.10)		(0.07)		(0.10)
Social Interaction Effect - Intermediate Level of Activity (γ_1)	--	--	0.20	0.14	--	--	0.16	0.15
			(0.05)	(0.08)			(0.06)	(0.08)
Social Interaction Effect - High Level of Activity (γ_2)	--	--	0.27	0.21	--	--	0.23	0.21
			(0.06)	(0.09)			(0.06)	(0.09)
Log Likelihood	-944.86	-938.57	-936.50	-936.27	-894.06	-890.85	-888.65	-888.63
Goodness of Fit (9 cells)	20.56	4.38	1.64	0.75	12.01	4.28	0.57	0.47

Notes: standard errors, clustered by school, in parentheses. See text for model descriptions. Sample includes 738 friend-pairs who had not engaged in intercourse or intimate contact by Wave 1. Dependent variable is ordered variable indicating intimate touching, intercourse, or neither. Models in columns 1-4 include 2 constants and 17 other person-specific controls. Models in columns 5-8 include 17 same controls plus 8 additional dummies indicating level of experience in cigarette smoking, marijuana use, truancy, and alcohol use as of Wave 1. Coefficients for covariates are shown in Appendix Table 3.

Table 6: Summary of Alternative Bivariate Ordered Probit Models for Sexual Activity by Friend Pairs

	Baseline Model (50-50 split of Mult. Eq.)	All Mult. Eq. Assigned to Higher Level of Activities	All Mult. Eq. Assigned to Lower Level of Activities	Partial Likelihood	Tamer Quasi-Likelihood
	(1)	(2)	(3)	(4)	(5)
Social Interaction Effect on Intermediate Level of Activity (γ_1)	0.20	0.20	0.21	0.09	0.09
	(0.05)	(0.05)	(0.06)	(0.07)	(0.08)
Social Interaction Effect on High Level of Activity (γ_2)	0.27	0.27	0.27	0.00	0.00
	(0.06)	(0.06)	(0.06)	(--)[a]	(--)[a]
Log Likelihood	-936.50	-936.26	-936.78	-786.94	-909.49
Goodness of Fit	1.64	1.69	1.68	0.43	--
(number of cells)	(9)	(9)	(9)	(7)	

Notes: standard errors, clustered by school, in parentheses. See text for model descriptions. Sample includes 738 friend-pairs who had not engaged in intercourse or intimate contact by Wave 1. Dependent variable is ordered variable indicating intimate touching, intercourse, or neither. All models include 2 constants and 17 other person-specific controls. See text for description of estimation method.

[a] Parameter estimate is near boundary of allowable space.

Table 7: Summary of Generalized Bivariate Ordered Probit Models for Sexual Activity by Friend Pairs

	(1)	(2)
Include Wave 1 Behaviors?	no	yes
Error correlation (ρ)	--	--
Social Interaction Effect - Effect of Intermediate Level of Activity by Friend on Decision to Engage in Intermediate Level Activity (γ_{11})	0.226	0.175
	(0.059)	(0.063)
Social Interaction Effect - Effect of High Level of Activity by Friend on Decision to Engage in Intermediate Level Activity (γ_{12})	0.226	0.175
	(0.059)	(0.063)
Social Interaction Effect - Effect of Intermediate Level of Activity by Friend on Decision to Engage in High Level Activity (γ_{21})	0.105	0.056
	(0.077)	(0.083)
Social Interaction Effect - Effect of High Level of Activity by Friend on Decision to Engage in High Level Activity (γ_{22})	0.201	0.191
	(0.075)	(0.079)
Log Likelihood	-935.93	-888.51
Goodness of Fit (9 cells)	0.54	0.35

Notes: standard errors, clustered by school, in parentheses. See text for model descriptions. Sample includes 738 friend-pairs who had not engaged in intercourse or intimate contact by Wave 1. Dependent variable is ordered variable indicating intimate touching, intercourse, or neither. Models in columns 1 includes 2 constants and 17 other person-specific controls. Models in column 2 includes 17 same controls plus 8 additional dummies indicating level of experience in cigarette smoking, marijuana use, truancy, and alcohol use as of Wave 1.

Table 8: Bivariate Ordered Probit Models for Sexual Activity with Only One Excluded Variable

	Baseline Models from Table 5:		Exclude Physical Development Index:		Exclude GPA:		Exclude Risk Preference Measure:	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Include Wave 1 Behaviors?	no	yes	no	yes	no	yes	no	yes
Effect of Excluded Variable on Individual Behavior	--	--	0.26	0.26	-0.14	-0.06	0.11	0.07
			(0.05)	(0.05)	(0.05)	(0.05)	(0.04)	(0.04)
Error correlation (ρ)	0.08	0.02	0.14	0.08	0.14	0.07	0.10	0.05
	(0.10)	(0.10)	(0.09)	(0.10)	(0.09)	(0.10)	(0.10)	(0.10)
Social Interaction- Interm. Level of Activity (γ_1)	0.14	0.15	0.09	0.10	0.09	0.11	0.13	0.12
	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)	(0.09)	(0.09)
Social Interaction - High Level of Activity (γ_2)	0.21	0.21	0.16	0.17	0.16	0.17	0.20	0.19
	(0.09)	(0.09)	(0.09)	(0.09)	(0.08)	(0.09)	(0.10)	(0.10)
Log Likelihood	-936.27	-888.63	-921.72	-874.33	-922.16	-875.46	-925.28	-875.62
Chi-squared	0.75	0.47	0.61	0.45	0.56	0.41	0.66	0.30

Notes: See text and notes to Table 5. Standard errors, clustered by school, in parentheses. In columns 3-8, all friend covariates except the excluded covariate identified in the column heading are allowed to directly affect the behavior of the friend.

Table 9: Bivariate Ordered Probit Models with Heterogeneity in the Peer Effects

	Heterogeneity Variable= Indicator for male friends		Heterogeneity Variable= Average age of friends		Heterogeneity Variable= Predicted Probability of Being Reciprocated Best Friends in Wave 2		Heterogeneity Variable= Indicator for respondents who did not reciprocate friend's nomination	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Equation for γ_1:								
Constant (a)	-1.25	-1.43	1.57	-7.20	-2.26	-2.69	-1.42	-1.84
	(0.25)	(0.31)	(7.79)	(12.16)	(0.27)	(0.37)	(0.26)	(0.40)
Coefficient on variable (b)	-1.01	-1.14	-0.21	0.34	3.32	4.13	-0.74	-16.00
	(0.84)	(1.14)	(0.53)	(0.72)	(0.69)	(0.81)	(0.08)	(.)
Equation for γ_2:								
Constant (c)	-0.91	-1.03	3.69	-0.48	-2.11	-2.95	-1.17	-1.46
	(0.21)	(0.26)	(4.84)	(5.05)	(0.30)	(0.54)	(0.20)	(0.27)
Coefficient on variable (d)	-1.29	-1.56	-0.33	-0.07	3.38	4.94	-0.58	-0.85
	(0.76)	(1.09)	(0.33)	(0.32)	(0.82)	(1.21)	(0.44)	(0.79)
Expanded Set of Controls for Wave 1 Behaviors	No	Yes	No	Yes	No	Yes	No	Yes
Log Likelihood	-933.47	-885.80	-933.74	-885.94	-932.40	-885.09	-935.52	-889.13
Implied Peer Effects for Representative Groups:								
	Females		Younger (age 14)		High Prob. (p=0.35)		Reciprocated	
γ_1	0.29	0.24	0.26	0.08	0.34	0.29	0.24	0.16
γ_2	0.40	0.36	0.39	0.23	0.39	0.30	0.31	0.23
	Males		Older (age 17)		Low Prob. (p=0.10)		Did not reciprocate	
γ_1	0.10	0.08	0.14	0.23	0.15	0.10	0.12	0.00
γ_2	0.11	0.07	0.14	0.19	0.17	0.09	0.17	0.10

Notes: see notes to Table 5. Standard errors, clustered by school, in parentheses. All models include 2 constants and 17 person-specific controls. Models in even-numbered columns also include 8 additional dummies indicating experience in risky behaviors as of Wave 1. Models for peer effects are parameterized as: γ_1=exp(a+bZ), γ_2=exp(c+dZ): see text.

Table 10: Estimated Bivariate Ordered Probit Models, Fit by Subgroup

	Reciprocated Pairs Only		Non-Reciprocated Pairs Only - Symmetric Effects		Non-Reciprocated Pairs Only - Asymmetric Effects	
	(1)	(2)	(3)	(4)	(5)	(6)
Include Wave 1 Behaviors?	no	yes	no	yes	no	yes
Error correlation (ρ)	0.20	0.27	0.07	0.02	0.06	0.02
	(0.25)	(0.28)	(0.14)	(0.14)	(0.14)	(0.14)
Social Interaction Effect - Intermediate Level of Activity (γ_1) (Avg)	0.23	0.18	0.06	0.06		
	(0.20)	(0.21)	(0.09)	(0.09)		
Social Interaction Effect - High Level of Activity (γ_2) (Avg)	0.33	0.26	0.10	0.11		
	(0.20)	(0.19)	(0.10)	(0.11)		
Social Interaction Effect - Intermediate Level of Activity (γ_1) - **Nominators**					0.10	0.09
					(0.12)	(0.15)
Social Interaction Effect - High Level of Activity (γ_2) - **Nominators**					0.16	0.16
					(0.12)	(0.14)
Social Interaction Effect - Intermediate Level of Activity (γ_1) - **Non-Reciprocators**					0.03	0.04
					(0.09)	(0.11)
Social Interaction Effect - High Level of Activity (γ_2) - **Non-Reciprocators**					0.05	0.07
					(0.12)	(0.13)
Log Likelihood	-313.09	-289.61	-609.17	-572.9	-608.74	-572.75
N	265	265	473	473	473	473

Notes: See notes to Table 5. Standard errors, clustered by school, in parentheses. In non-reciprocating friend pairs, the **nominator** is the friend who named the other as his/her "best friend"; the **non-reciprocator** failed to name the nominator as his/her best friend.

Table 11: Summary of Bivariate Ordered Probit Models for Risky Behaviors of Friend Pairs

	Baseline				Expanded Set of Covariates			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
A. Cigarette Smoking								
Error correlation (ρ)	--	0.23	--	0.11	--	0.21	--	0.10
		(0.10)		(0.14)		(0.10)		(0.14)
Social Interaction Effect - Intermediate	--	--	0.20	0.10	--	--	0.18	0.10
Level of Activity (γ_1)			(0.09)	(0.13)			(0.10)	(0.14)
Social Interaction Effect - High Level	--	--	0.45	0.34	--	--	0.44	0.35
of Activity (γ_2)			(0.20)	(0.22)			(0.20)	(0.22)
Log Likelihood	-807.42	-802.25	-801.29	-800.99	-782.28	-777.99	-776.99	-776.72
Goodness of Fit (9 cells)	19.68	6.72	5.66	5.02	16.99	6.90	5.57	5.13
B. Marijuana								
Error correlation (ρ)	--	0.19	--	-0.20	--	0.17	--	-0.19
		(0.07)		(0.07)		(0.08)		(0.12)
Social Interaction Effect - Intermediate	--	--	0.31	0.48	--	--	0.30	0.45
Level of Activity (γ_1)			(0.08)	(0.08)			(0.09)	(0.16)
Social Interaction Effect - High Level	--	--	0.11	0.25	--	--	0.08	0.21
of Activity (γ_2)			(0.18)	(0.04)			(0.13)	(0.20)
Log Likelihood	-767.43	-765.10	-758.01	-757.02	-712.86	-711.25	704.79	-703.96
Goodness of Fit (9 cells)	36.88	24.17	2.97	1.89	32.45	24.17	3.76	1.93
C. Truancy								
Error correlation (ρ)	--	0.32	--	0.16	--	0.33	--	0.17
		(0.06)		(0.14)		(0.07)		(0.15)
Social Interaction Effect - Intermediate	--	--	0.30	0.18	--	--	0.30	0.17
Level of Activity (γ_1)			(0.07)	(0.14)			(0.07)	(0.14)
Social Interaction Effect - High Level	--	--	0.27	0.15	--	--	0.26	0.14
of Activity (γ_2)			(0.10)	(0.14)			(0.10)	(0.14)
Log Likelihood	-968.40	-957.22	-956.16	-955.34	-952.10	-941.31	-940.43	-939.57
Goodness of Fit (9 cells)	35.40	7.21	6.43	3.95	32.52	7.78	6.64	4.55

Notes: see notes to Table 5. Standard errors clustered by school in parentheses. Sample sizes are: 738 for panel A; 1076 for panel B; 964 for panel C. In each case, sample includes only pairs in which neither friend had engaged in the intermediate or higher level of the risky behavior as of Wave 1.

Appendix Table 1. Descriptive Statistics for Samples Used in Analyses of Cigarette Smoking, Marijuana Use, and Truancy

	BFs who had never smoked a cigarette as of W1	BFs who had never tried marijuana as of W1	BFs who did not skip any days of school in W1
	(1)	(2)	(3)
Individual & Family Characteristics			
Age (in years, as of wave 1)	15.51	15.50	15.39
Male	0.43	0.43	0.43
Black race	0.27	0.20	0.19
Other non-white race	0.18	0.16	0.13
GPA (1-4 scale)	3.00	2.97	2.99
Physical development index	0.03	0.07	0.08
Attitude toward risk (1-5 scale)	3.43	3.43	3.48
Future orientation (1-5 scale)	3.72	3.69	3.70
Time preference (1-5 scale)	1.50	1.53	1.52
Smokers in household (yes/no)	0.33	0.36	0.36
Two-parent household (yes/no)	0.73	0.74	0.75
Freq. parents attend church (0-3 scale)	1.97	1.92	1.88
Parents not religious (yes/no)	0.14	0.15	0.16
Parental church attendance missing	0.12	0.12	0.10
At least 1 parent finished high school	0.89	0.89	0.91
At least 1 parent finished college	0.43	0.41	0.43
Parental education missing	0.04	0.04	0.03
Risky Behaviors as of Wave 1:			
Intimate touching	0.25	0.27	0.28
Had intercourse	0.18	0.19	0.18
Tried cigarette smoking	0.00	0.25	0.30
Smoked cigarettes regularly	0.00	0.06	0.09
Tried marijuana	0.07	0.00	0.14
Used marijuana regularly	0.04	0.00	0.07
Drank alcohol without adult presence	0.16	0.24	0.29
Drank alcohol regularly	0.03	0.06	0.09
Skipped school 1 or more days	0.15	0.16	0.00
Skipped school 2 or more days	0.10	0.10	0.00
Risky Behaviors as of Wave 2:			
Tried cigarette smoking	0.191		
Smoked cigarettes regularly	0.029		
Tried marijuana		0.098	
Used marijuana regularly		0.059	
Skipped school 1 or more days			0.155
Skipped school 2 or more days			0.081
Number of observations	1,476	2,152	1,928

Notes: see text and notes to Table 1.

Appendix Table 2a: Estimated Bivariate Probit Models for Sexual Intercourse by Friend Pairs

	Baseline				Expanded Set of Covariates			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Age	0.11	0.11	0.11	0.08	0.09	0.09	0.08	0.08
	(0.03)	(0.03)	(0.03)	(0.07)	(0.03)	(0.03)	(0.03)	(0.03)
Male	-0.05	-0.05	-0.05	-0.04	-0.01	0.00	0.00	0.00
	(0.10)	(0.10)	(0.09)	(0.08)	(0.09)	(0.09)	(0.09)	(0.09)
Black race	0.31	0.30	0.29	0.24	0.47	0.46	0.46	0.45
	(0.11)	(0.11)	(0.10)	(0.18)	(0.12)	(0.12)	(0.12)	(0.12)
GPA	-0.17	-0.17	-0.16	-0.12	-0.06	-0.07	-0.06	-0.05
	(0.05)	(0.05)	(0.05)	(0.15)	(0.05)	(0.05)	(0.05)	(0.05)
Physcial development index	0.23	0.22	0.23	0.20	0.20	0.20	0.20	0.20
	(0.05)	(0.05)	(0.05)	(0.14)	(0.05)	(0.05)	(0.05)	(0.05)
Attitude toward risk	0.15	0.14	0.15	0.14	0.10	0.10	0.10	0.10
	(0.03)	(0.03)	(0.03)	(0.07)	(0.04)	(0.04)	(0.04)	(0.04)
Future orientation	-0.07	-0.07	-0.07	-0.05	-0.04	-0.04	-0.04	-0.04
	(0.04)	(0.04)	(0.04)	(0.07)	(0.04)	(0.04)	(0.04)	(0.04)
Time preference	0.06	0.07	0.07	0.04	-0.01	-0.01	-0.01	-0.01
	(0.06)	(0.06)	(0.06)	(0.11)	(0.07)	(0.07)	(0.07)	(0.07)
Smokers in household	0.23	0.21	0.22	0.21	0.19	0.18	0.18	0.18
	(0.08)	(0.08)	(0.08)	(0.11)	(0.08)	(0.08)	(0.08)	(0.08)
Two-parent household	-0.23	-0.22	-0.22	-0.21	-0.22	-0.21	-0.21	-0.21
	(0.09)	(0.09)	(0.09)	(0.13)	(0.10)	(0.10)	(0.10)	(0.09)
Freq. parents attend church	-0.08	-0.08	-0.08	-0.07	-0.08	-0.08	-0.08	-0.08
	(0.04)	(0.04)	(0.04)	(0.04)	(0.05)	(0.05)	(0.05)	(0.04)
Parents not religious	-0.16	-0.16	-0.16	-0.16	-0.26	-0.26	-0.25	-0.25
	(0.12)	(0.12)	(0.12)	(0.10)	(0.13)	(0.13)	(0.13)	(0.12)
At least 1 parent finished high school	-0.22	-0.22	-0.22	-0.17	-0.24	-0.24	-0.23	-0.22
	(0.11)	(0.12)	(0.11)	(0.20)	(0.12)	(0.12)	(0.12)	(0.12)
At least 1 parent finished college	-0.14	-0.14	-0.14	-0.13	-0.17	-0.17	-0.17	-0.17
	(0.08)	(0.08)	(0.08)	(0.07)	(0.09)	(0.09)	(0.09)	(0.09)
Tried cigarette smoking as of W1					0.14	0.15	0.14	0.13
					(0.11)	(0.10)	(0.10)	(0.11)
Smoked cigarettes regularly as of W1					0.20	0.19	0.20	0.20
					(0.15)	(0.15)	(0.15)	(0.15)
Tried marijuana as of W1					0.21	0.22	0.21	0.18
					(0.14)	(0.14)	(0.14)	(0.15)
Used marijuana regularly as of W1					0.05	0.03	0.04	0.06
					(0.15)	(0.15)	(0.15)	(0.16)
Drank alcohol without adult presence as of W1					0.47	0.47	0.47	0.46
					(0.08)	(0.08)	(0.08)	(0.08)
Drank alcohol regularly as of W1					0.45	0.43	0.43	0.44
					(0.15)	(0.15)	(0.15)	(0.15)
Skipped school 1 or more days as of W1					0.29	0.29	0.28	0.27
					(0.12)	(0.12)	(0.12)	(0.13)
Skipped school 2 or more days as of W1					-0.10	-0.10	-0.10	-0.09
					(0.14)	(0.13)	(0.13)	(0.14)

Note: see notes to Table 4a.

Appendix Table 2b: Estimated Bivariate Probit Models for Sexual Intercourse by Friend Pairs

	Baseline				Expanded Set of Covariates			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Age	0.09	0.08	0.08	0.05	0.05	0.05	0.05	0.04
	(0.04)	(0.04)	(0.04)	(0.03)	(0.04)	(0.04)	(0.04)	(0.03)
Male	0.05	0.06	0.05	0.03	0.09	0.10	0.10	0.09
	(0.11)	(0.10)	(0.10)	(0.07)	(0.11)	(0.11)	(0.10)	(0.09)
Black race	0.34	0.31	0.30	0.23	0.48	0.46	0.45	0.44
	(0.14)	(0.14)	(0.13)	(0.08)	(0.16)	(0.16)	(0.15)	(0.15)
GPA	-0.19	-0.20	-0.19	-0.10	-0.10	-0.12	-0.11	-0.09
	(0.06)	(0.06)	(0.06)	(0.05)	(0.06)	(0.06)	(0.06)	(0.08)
Physcial development index	0.22	0.22	0.22	0.17	0.22	0.22	0.22	0.21
	(0.06)	(0.06)	(0.06)	(0.05)	(0.06)	(0.06)	(0.06)	(0.06)
Attitude toward risk	0.12	0.11	0.12	0.11	0.07	0.07	0.07	0.07
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
Future orientation	-0.08	-0.08	-0.08	-0.05	-0.05	-0.05	-0.05	-0.04
	(0.04)	(0.04)	(0.04)	(0.03)	(0.05)	(0.05)	(0.05)	(0.05)
Time preference	0.11	0.12	0.12	0.06	0.07	0.08	0.08	0.06
	(0.09)	(0.08)	(0.09)	(0.07)	(0.09)	(0.09)	(0.09)	(0.09)
Smokers in household	0.29	0.27	0.28	0.26	0.23	0.22	0.22	0.22
	(0.10)	(0.10)	(0.10)	(0.08)	(0.11)	(0.10)	(0.10)	(0.10)
Two-parent household	-0.22	-0.20	-0.21	-0.20	-0.24	-0.22	-0.23	-0.23
	(0.12)	(0.12)	(0.12)	(0.09)	(0.13)	(0.13)	(0.13)	(0.13)
Freq. parents attend church	-0.05	-0.03	-0.04	-0.06	-0.05	-0.05	-0.05	-0.05
	(0.07)	(0.06)	(0.06)	(0.05)	(0.06)	(0.06)	(0.06)	(0.06)
Parents not religious	-0.17	-0.11	-0.14	-0.21	-0.28	-0.25	-0.26	-0.27
	(0.23)	(0.22)	(0.22)	(0.18)	(0.21)	(0.20)	(0.20)	(0.21)
At least 1 parent finished high school	-0.22	-0.23	-0.22	-0.13	-0.26	-0.27	-0.26	-0.24
	(0.13)	(0.14)	(0.14)	(0.09)	(0.14)	(0.15)	(0.15)	(0.14)
At least 1 parent finished college	-0.08	-0.06	-0.07	-0.10	-0.10	-0.09	-0.09	-0.10
	(0.09)	(0.09)	(0.09)	(0.08)	(0.09)	(0.09)	(0.09)	(0.09)
Tried cigarette smoking as of W1					0.14	0.14	0.13	0.12
					(0.11)	(0.11)	(0.11)	(0.11)
Smoked cigarettes regularly as of W1					0.36	0.35	0.36	0.36
					(0.18)	(0.18)	(0.18)	(0.18)
Tried marijuana as of W1					0.15	0.16	0.14	0.11
					(0.20)	(0.19)	(0.19)	(0.20)
Used marijuana regularly as of W1					0.03	0.01	0.02	0.04
					(0.21)	(0.21)	(0.21)	(0.22)
Drank alcohol without adult presence					0.52	0.52	0.52	0.51
as of W1					(0.11)	(0.11)	(0.11)	(0.11)
Drank alcohol regularly as of W1					0.21	0.18	0.19	0.19
					(0.20)	(0.20)	(0.20)	(0.20)
Skipped school 1 or more days as of W1					0.45	0.47	0.46	0.43
					(0.16)	(0.15)	(0.15)	(0.18)
Skipped school 2 or more days as of W1					-0.16	-0.17	-0.18	-0.17
					(0.17)	(0.17)	(0.17)	(0.17)

Note: see notes to Table 4b.

Appendix Table 3: Estimated Bivariate Ordered Probit Models for Sexual Activity by Friend Pairs

	Baseline				Expanded Set of Covariates			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Age	0.06	0.06	0.05	0.05	0.03	0.03	0.02	0.02
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
Male	0.01	0.02	0.02	0.02	0.03	0.04	0.04	0.04
	(0.09)	(0.09)	(0.09)	(0.09)	(0.09)	(0.09)	(0.09)	(0.09)
Black race	0.22	0.21	0.20	0.20	0.34	0.33	0.32	0.32
	(0.13)	(0.13)	(0.12)	(0.12)	(0.14)	(0.14)	(0.13)	(0.14)
GPA	-0.16	-0.16	-0.15	-0.16	-0.08	-0.08	-0.08	-0.08
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)
Physcial development index	0.24	0.25	0.24	0.24	0.23	0.24	0.24	0.24
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)
Attitude toward risk	0.11	0.10	0.11	0.10	0.07	0.06	0.07	0.07
	(0.03)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
Future orientation	-0.05	-0.05	-0.05	-0.05	-0.02	-0.02	-0.02	-0.02
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
Time preference	0.09	0.09	0.10	0.09	0.04	0.04	0.05	0.05
	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)
Smokers in household	0.22	0.22	0.22	0.22	0.16	0.16	0.16	0.16
	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)
Two-parent household	-0.18	-0.18	-0.18	-0.18	-0.20	-0.20	-0.20	-0.20
	(0.11)	(0.10)	(0.10)	(0.10)	(0.11)	(0.11)	(0.11)	(0.11)
Freq. parents attend church	-0.06	-0.04	-0.05	-0.05	-0.06	-0.05	-0.05	-0.05
	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)
Parents not religious	-0.17	-0.11	-0.14	-0.13	-0.26	-0.22	-0.23	-0.23
	(0.23)	(0.22)	(0.22)	(0.22)	(0.20)	(0.20)	(0.20)	(0.20)
At least 1 parent finished high school	-0.23	-0.23	-0.23	-0.23	-0.26	-0.27	-0.26	-0.26
	(0.12)	(0.12)	(0.12)	(0.12)	(0.12)	(0.13)	(0.13)	(0.13)
At least 1 parent finished college	-0.08	-0.07	-0.07	-0.07	-0.08	-0.08	-0.08	-0.08
	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)
Tried cigarette smoking as of W1					0.21	0.20	0.20	0.20
					(0.10)	(0.10)	(0.10)	(0.10)
Smoked cigarettes regularly as of W1					0.32	0.31	0.32	0.32
					(0.18)	(0.18)	(0.18)	(0.18)
Tried marijuana as of W1					0.12	0.12	0.11	0.11
					(0.17)	(0.17)	(0.17)	(0.17)
Used marijuana regularly as of W1					0.10	0.09	0.10	0.09
					(0.21)	(0.21)	(0.21)	(0.21)
Drank alcohol without adult presence as of W1					0.47	0.48	0.47	0.47
					(0.10)	(0.10)	(0.10)	(0.10)
Drank alcohol regularly as of W1					0.17	0.15	0.15	0.15
					(0.18)	(0.18)	(0.18)	(0.18)
Skipped school 1 or more days as of W1					0.37	0.37	0.36	0.36
					(0.14)	(0.14)	(0.14)	(0.14)
Skipped school 2 or more days as of W1					-0.06	-0.07	-0.07	-0.07
					(0.21)	(0.20)	(0.20)	(0.20)

Note: see notes to Table 5.

Appendix Table 4: Robustness of Estimation Results to Sequentially Allowing Individual Covariates to Directly Affect Friend

	Effects of Covariate:		Heterogeneity/Social Interaction Parameters:				Chi-squared
	Direct Effect	Cross Effect	ρ	γ_1	γ_2	Log Likelihod	(9 d.f.)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Baseline Model (Table 5, column 8)	--	--	0.02	0.15	0.21	-888.63	0.47
			(0.10)	(0.08)	(0.09)		
<u>Covariate Allowed to Have Cross-Effect on Friend:</u>							
1. Age	0.05	-0.03	0.02	0.15	0.21	-888.52	0.50
	(0.07)	(0.07)	(0.11)	(0.09)	(0.10)		
2. Black	0.09	0.28	0.03	0.14	0.21	-887.51	0.41
	(0.18)	(0.15)	(0.11)	(0.09)	(0.09)		
3. GPA	-0.10	0.08	0.01	0.16	0.23	-887.5	0.65
	(0.06)	(0.05)	(0.11)	(0.09)	(0.10)		
4. Physical Development Index	0.25	-0.06	0.01	0.16	0.22	-888.09	0.62
	(0.05)	(0.06)	(0.11)	(0.09)	(0.10)		
5. Attitude to Risk	0.07	0.06	0.04	0.13	0.19	-887.14	0.38
	(0.04)	(0.04)	(0.11)	(0.08)	(0.09)		
6. Attitude to Future	-0.02	0.04	0.02	0.15	0.21	-888.11	0.52
	(0.04)	(0.04)	(0.11)	(0.09)	(0.10)		
7. Time Preference	0.05	-0.04	0.02	0.15	0.21	-888.46	0.49
	(0.07)	(0.06)	(0.11)	(0.09)	(0.09)		
8. Two-parent Household	-0.20	-0.03	0.03	0.14	0.21	-888.58	0.44
	(0.11)	(0.09)	(0.11)	(0.09)	(0.10)		
9. Any Smokers in Household	0.16	0.03	0.03	0.14	0.21	-888.56	0.43
	(0.08)	(0.08)	(0.11)	(0.09)	(0.09)		
10. Parental Church Attendence (Freq.)	-0.07	0.05	0.02	0.15	0.22	-887.52	0.48
	(0.06)	(0.03)	(0.11)	(0.09)	(0.10)		
11. Dummy if Parents Non-religious	-0.23	-0.28	0.02	0.15	0.21	-884.3	0.44
	(0.19)	(0.09)	(0.11)	(0.09)	(0.10)		
12. At Least One Parent High School Grad	-0.26	-0.01	0.02	0.15	0.21	-888.63	0.46
	(0.14)	(0.11)	(0.11)	(0.09)	(0.09)		
13. At least One Parent College Grad.	-0.06	-0.10	0.03	0.14	0.20	-887.94	0.40
	(0.08)	(0.09)	(0.11)	(0.09)	(0.09)		

Note: table continues. See notes at end.

Appendix Table 4, continued.

	Effects of Covariate:		Heterogeneity/Social Interaction Parameters:				Chi-squared
	Direct Effect	Cross Effect	ρ	γ_1	γ_2	Log Likelihod	(9 d.f.)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
<u>Covariate Allowed to Have Cross-Effect on Friend:</u>							
14. Tried Smoking Tobacco	0.19	0.08	0.04	0.13	0.20	-888.28	0.36
	(0.10)	(0.07)	(0.11)	(0.08)	(0.09)		
15. Regular Tobacco Smoker	0.32	0.18	0.04	0.13	0.19	-887.99	0.34
	(0.18)	(0.15)	(0.10)	(0.08)	(0.09)		
16. Tried Marijuana	0.09	0.10	0.04	0.13	0.19	-888.35	0.36
	(0.17)	(0.12)	(0.11)	(0.09)	(0.09)		
17. Regular Marijuana User	0.10	0.16	0.04	0.13	0.20	-888.22	0.37
	(0.21)	(0.17)	(0.11)	(0.09)	(0.09)		
18. Skipped 1 Day Last Year	0.36	0.00	0.02	0.15	0.21	-888.63	0.46
	(0.14)	(0.12)	(0.11)	(0.08)	(94.00)		
19. Skipped 2 or More Days Last Year	-0.07	0.08	0.03	0.14	0.20	-888.48	0.40
	(0.20)	(0.14)	(0.10)	(0.08)	(0.09)		
20. Tried Alcohol	0.47	0.00	0.02	0.15	0.21	-888.63	0.46
	(0.10)	(0.09)	(0.11)	(0.09)	(0.10)		
21. Regular Alcohol User	0.15	0.23	0.04	0.12	0.19	-887.61	0.33
	(0.18)	(0.12)	(0.10)	(0.08)	(0.09)		

Notes: Standard errors in parentheses. Specifications are the same as in column 8 of Table 5, except that each individual covariate indicated in the row heading is also allowed to have a direct effect on the individual's friend. Entry in column 1 is the effect of the indicated covariate for a given individual on his/her own behavior. Entry in column 2 is the effect of the covariate for a given individual on his/her best friend. (Cross effects from #1 to #2 and from #2 to #1 are restricted to be equal.)