

Estimating Various Kinds of Peer Effects on Academic Performance^{*}

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Abstract

This paper explicitly models peer network formation and explores different channels through which peer effects influence student achievement. Using unique data from a survey I designed and implemented for this study, the “Secondary Education Survey in Hong Kong” (SESHK), I estimate an econometric model to show how peer connections are formed and quantify peer effects. This paper focuses on four separate types of peer networks: friends, studymates, emotional supporters, and seatmates. Additionally, students can be affected by their peers through three different channels, namely cognitive abilities, personality traits, and behavioral spillovers. I estimate the magnitudes of these peer effects on academic performance through all three channels and all four networks. Peer effects are identified through a combination of explicitly modeling peer selection (see Brock and Durlauf (2003)) and additional set of instruments available in my data. Empirical results show that friends and studymates are endogenously formed which lead to overestimation of peer effects in traditional exogenous peer formation models. All investigated peer types show positive peer effects but the effect for seating proximity is relatively weaker. Peers are also found to have significant effects through particular cognitive abilities or personality traits. Smart studymates and conscientious friends positively affect a student’s mathematics score, while conscientious studymates and smart friends do not have such an effect. The results show that understanding the formation of different types of peers is important in peer effect estimation.

JEL Classification Numbers: D85, I21

Keywords: Peer Effect, Education, Peer Formation, Network, Inequality

^{*}I am grateful to my advisors James Heckman, Steven Durlauf and Brent Hickman for their guidance and support. I thank Tszkin Chan for his invaluable help and comments. I also thank Erik Hurst, Sacha Kapoor, Nicholas Mader, Wing Suen, Daniel Tannenbaum, Alessandra Voena, Crystal Wong for their useful suggestions. All remaining errors are mine.

[†]The dataset constructed from “Secondary Education Survey in Hong Kong” facilitates the analysis in this paper. I thank William Chan for his support to this survey. I thank all the participated secondary schools and students. I thank James Chan, Christine Kong, Chi-Yuen Lau, Eva Lee, Cheuk-Chong Tang, Chun-Keung Tang, Leo Tsui, Shun-Tak Wong and all other teachers and helpers in the schools for their help and arrangement during the survey. I also thank Siu-ling Chan, Cheng Chen, Cheuk-Wing Chow, Ka-Keung Sze, Sze-Yu Yiu and other research assistants for their excellent research assistant work.

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1 Introduction and Related Literature

Peer effects are important determinants of student outcomes.¹ A typical student learns from discussions with classmates and can be affected by their personalities and attitudes toward learning. Students can also be motivated simply by working next to each other. Economists have investigated peer effects for a variety of peer types including schoolmates (Evans et al. (1992), Hanushek et al. (2003)), roommates (Sacerdote (2001), Zimmerman (2003), Hoel et al. (2005), McEwan and Soderberg (2006)), classmates (Ammermueller and Pischke (2009), Sojourner (2009)), coursemates (Parker et al. (2008)) or friends (Cooley (2009), Bramoullé et al. (2009)).

While there is an extensive literature on peer effects in schools, research investigating multiple peer types and the channels of peer effects is scanty. The availability of friendship and classmate data largely facilitates the peer effect studies in existing economic literature. But there may be other types of peers that are unavailable in these data but are important in students' learning. For example, studymates are not necessarily friends yet studymates could have more direct effect on achievement. Being seated next to a diligent student may increase one's own work ethic and performance. Detail understanding of peer effects from different types of peers carries important policy implications. In particular, it sheds light on the evaluation of policies such as "promoting study groups" or "school activities that enhance friendship" on academic outcomes, and whether the evaluation is subject dependent. Investigating the effects of different types of peers also provides insights on whether planned seat assignment or class segregation (or desegregation) is conducive to learning.

This paper considers four types of peers, which may be important for student achievement: friends, studymates, emotional supporters, and seatmates. The model examines two different channels of peer effects. As suggested by Cooley (2009) and Cooley (2010), students can be affected by predetermined peer characteristics² and behavioral spillovers³, which are named contextual effect and endogenous effect respectively.⁴ The econometric strategy in this paper identifies these two channels separately, and allows us to understand exactly in what ways student achievement are affected by different types of peers.

To fill the gap in data availability, I designed and implemented a network-centric survey in secondary schools in Hong Kong, the "Secondary Education Survey in Hong Kong" (SESHK). The survey included mental ability tests, personality tests, and assessment scores provided by school. For network

¹The focus of this paper is on academic performance but peers and social interactions could affect a wide range of other individual behavior or outcome. For example, drinking (Rosenquist et al. (2010)), obesity (Cohen-Cole and Fletcher (2008)) or smoking (Nakajima (2007)) to even criminal behavior (Corno (2012)) or happiness (Fowler and Christakis (2008))

²McEwan and Soderberg (2006), Ammermueller and Pischke (2009)

³Graham (2008), Lee et al. (2010)

⁴These terminologies follow from Manski (1993).

data, it contains information about friends, studymates, emotional supporters, and seatmates. This newly constructed dataset is tailored to address the research question in this paper.

This paper also addresses the peer selection problem that plagues many empirical studies of peer effects. The peer selection problem arises from the possibility that students may choose friends or studymates based on academic outcomes or unobservable factors which determine both friendship choices and academic outcomes. Exogenous random assignment experiment could exist for some peer type such as randomly-assigned college roommates in Sacerdote (2001).⁵ But for other peer types such as friends, such random assignment is inconceivable. Evans et al. (1992) hint at the importance of individual choices of peer groups in peer effect estimation. As a result, many peer effect studies make use of available exogenously assigned peers or narrow down the analysis to the outcomes for which the selection problem of peer types is not a key issue (e.g. long term health outcomes).

Extending the empirical study of peer effects to more types of peers and introduction of new econometrics model which takes into account peer selection are the major contributions of this paper.

The peer selection problem has been addressed in different ways in the literature. For example, Goldsmith-Pinkham and Imbens (2011) incorporate endogenous peer formation but their model focus on datasets with multiperiods of network data. The econometric strategy of this paper follows Lee et al. (2010) and Bramoullé et al. (2009) and integrates their model with the mutual agreement peer formation. The peer formation model follows from a simplified version of the peer formation model in Christakis et al. (2010), which provides flexibility in capturing students' preference to some characteristics such as agreeableness or extraversion. It also accounts for the possible preference that students may have for similar peers.

Using arguments similar to Brock and Durlauf (2003), the nonlinearity introduced by explicitly including peer selection provides the solution for the non-identification problem studied by Manski (1993)⁶, even without an instrumental variable. However, identifiability does not imply precision. To achieve clean identification, this paper employs the number of common hobbies as an instrumental variable for friends, studymates, and emotional supporters. Height difference is used as an instrument for seatmates.

The major empirical finding in this paper is that peers are shown to be endogenously formed. It leads to overestimation of peer effects in traditional exogenous peer formation models. Positive peer effects are still present in almost all investigated peer types after controlling for peer selection but the strength of peer effect is peer type and subject dependent. Endogenous peer effects are stronger for studymates and friends, but weaker seatmates. The effects are also stronger for major subjects like Mathematics, but weaker for Visual Art.

⁵See also the randomly assigned classmates in Sojourner (2009).

⁶See also Moffitt (2001), Lee (2007), Lin (2010)

Moreover, peers are also found to affect each other through particular mental abilities or personality traits. Smart studymates and conscientious friends positively affect a student’s mathematics score, while conscientious studymates and smart friends do not have such an effect. These results show that peer effects of different peer types are different in nature apart from the difference in magnitude. It might be misleading to estimate one single peer effect and apply the results to other peer types. Studying these peers separately allows us to understand better their individual effects and nature. More details are illustrated in section 5 and 7.

Finally, basic counterfactual analysis shows that on average, students with chosen studymates are not doing better than randomly assigned studymates. However, allowing students to choose their studymates will increase the inequality among students. The correct estimation of own effects and peer effects makes it viable to perform sophisticated counterfactual analysis in future work.

The rest of the paper will be organized as follow: Section 2 introduces the econometrics model. Section 3 discusses the virtues of the unique dataset used in this paper and provide summary statistics. Section 4 summarizes the empirical specifications. Section 5 presents the empirical results and section 6 explores several alternative specifications. Section 7 discusses the implication of the empirical results. Section 8 shows the counterfactual analysis. Section 9 discusses future work and concludes.

2 Model

2.1 Setup

The peer effect model in this paper follows from specification similar to Bramoullé et al. (2009) and Lee et al. (2010):

$$Y_g = S_g\beta + W_gX_g\lambda_x + \lambda_yW_gY_g + l_{n_g}\eta_g + e_g \tag{1}$$

Y is the outcome variable (e.g. Math exam score). S is a set of student characteristics which will affect the student’s Y . X is a set of student characteristics which will affect their peer’s Y .

Each student belongs to a group g , which is a grade in a school.⁷ n_g is the number of students in group g . l_{n_g} is a n_g dimensional vector of ones. and each students in the same group are affected by the same η_g . For convenience, I omit the subscript g in the explanation.

⁷For example, there are 181 students in grade 7 of one of the participating school. These 181 students are considered to be in the same group. In this model, students are only allowed to have peer connections within their group. Notice that there are multiple classes within the same group.

$$W_{gij} = \frac{D_{gij}}{\sum_j D_{gij}} \quad (2)$$

Students may only have peer connections within the same group. D is an $n \times n$ matrix indicating the all peer connections within a group. $D_{ij} = 1$ indicates that i and j are peers while $D_{ij} = 0$ indicates that they are not. All the diagonal elements in D are 0 so that you are not having peer influence on yourself. W is the sociomatrix constructed from D . Assuming social influence comes from the average characteristics of the peers, i.e. equal interaction intensity from all peers and the intensity add up to a constant⁸, the sociomatrix can be constructed by a row normalization of D in equation (2).

Hence, WX is the weighted average characteristics X of i 's peers. WY is the weighted average outcome Y of i 's peers.

Under this specification, the formation of Y depends on the following 4 effects: β is ‘‘Own Effect’’, which is how i 's characteristics affects i 's own outcome Y ; λ_x is ‘‘Contextual Effect’’, which is how i 's average peer characteristics affect i 's outcome Y ; λ_y is ‘‘Endogenous Effect’’, which is how peers' outcome Y affect i 's outcome Y ; η is ‘‘Correlated Effect’’, which refers to unobservable factors affecting all the students in the same group.

Notice that this weighted average characteristics is not the same as the average characteristics in the traditional linear in means model context. In traditional linear in means model, students are affected by everyone within the same group with equal intensity, so students are affected by the weighted average characteristics of the whole group. In this model, I take into account the network structure within a group. Based on the data D , each students has some peers within a group and students are affected by others' X or Y only if they are peers with each other. Therefore, students are affected by the weighted average characteristics of their particular set of peers, instead of the whole group.

The peer formation process is modeled by the formation of the D matrix. Following from a simplified version of the peer formation technology in Christakis et al. (2010), students are assumed to get utility from forming peer connection. The utility and the peer formation rule take the following form:

$$D_{gij} = 1 \text{ if } U_{gij} = Z_{gij}\gamma + \epsilon_{gij} > 0 \text{ and } U_{gji} = Z_{gji}\gamma + \epsilon_{gji} > 0 \quad (3)$$

$$\epsilon_{gij} = \rho e_{gi} + v_{gij} \quad (4)$$

⁸This specification is different from Patacchini and Zenou (2012), which assumes the intensity of the interactions per peer is constant no matter how many peers a student has.

U_{ij} is the utility i get from having j as peer. Z_{ij} includes factors affecting the utility i can get from having j as peers. The construction of Z_{ij} will be illustrated more in section 2.4. Students are peers if both sides have positive utility to each others. The “peer selection problem” is modeled in the correlation between ϵ_{ij} and e_{ij} . For simplicity, I only include e_i in equation (4), which means those unobservables which affects both outcome and peers formation are constant over j .

2.2 Global Differencing

Differencing is applied to address the correlated effect in estimation. Using the global differences method in Bramoullé et al. (2009),

$$(I - H_g)Y_g = (I - H_g)S_g\beta + (I - H_g)W_gX_g\lambda_x + \lambda_y(I - H_g)W_gY_g + (I - H_g)l_{n_g}\eta_g + (I - H_g)e_g$$

where

$$H_g = \frac{1}{n_g}(l_{n_g}l'_{n_g})$$

$I - H$ is the matrix which gets the deviation from group means. And this get rid of the correlated effect from the estimation.

$$(I - H_g)Y_g = (I - H_g)S_g\beta + (I - H_g)W_gX_g\lambda_x + \lambda_y(I - H_g)W_gY_g + (I - H_g)e_g$$

For simplicity I will omit the subscript g and get

$$(I - H)Y = (I - H)S\beta + (I - H)WX\lambda_x + \lambda_y(I - H)WY + (I - H)e \quad (5)$$

and

$$W_{ij} = \frac{D_{ij}}{\sum_j D_{ij}} \quad (6)$$

$$D_{ij} = 1 \text{ if } U_{ij} = Z_{ij}\gamma + \epsilon_{ij} > 0 \text{ and } U_{ji} = Z_{ji}\gamma + \epsilon_{ji} > 0 \quad (7)$$

$$\epsilon_{ij} = \rho e_i + v_{ij} \quad (8)$$

2.3 Identification

From equation (5),

$$\begin{aligned}
 (I - H)Y &= (I - H)S\beta + (I - H)WX\lambda_x + \lambda_y(I - H)WY + (I - H)e \\
 (I - H)Y &= (I - H)(I - \lambda_y W)^{-1}S\beta + (I - H)(I - \lambda_y W)^{-1}WX\lambda_x + (I - H)(I - \lambda_y W)^{-1}e \\
 E[(I - H)Y] &= E \left[\begin{array}{c} E[(I - H)(I - \lambda_y W)^{-1}XS\beta|D] \\ + E[(I - H)(I - \lambda_y W)^{-1}WX\lambda_x|D] + (I - H)(I - \lambda_y W)^{-1}E[e|D] \end{array} \right]
 \end{aligned}$$

if $\rho \neq 0$, or in other words, peers are self-selected⁹,

$$E[(I - H)Y] = E \left[\begin{array}{c} E[(I - H)(I - \lambda_y W)^{-1}S\beta|D] \\ + E[(I - H)(I - \lambda_y W)^{-1}WX\lambda_x|D] \\ + \rho\sigma_e(I - H)E\left[\frac{e}{\rho\sigma_e}|D\right] + \rho\sigma_e(I - H)(\sum_i \lambda_y^i W^i)E\left[\frac{e}{\rho\sigma_e}|D\right] \end{array} \right] \quad (9)$$

Suppose there are k_1 elements in S and k_2 elements in X . From equation (9), there are $k_1 + k_2 + 2$ parameters (β , λ_x , λ_y and $\rho\sigma_e$). The first and second term of equation 9 contain $k_1 + k_2$ regressors. When there is peer selection, i.e. $\rho\sigma_e \neq 0$, two more regressors are introduced from the third and fourth term. Assume that $E\left[\frac{e}{\rho\sigma_e}|D\right]$ are not perfectly collinear with the first or second term of the equation, the nonlinearity introduced from $E\left[\frac{e}{\rho\sigma_e}|D\right]$ allows for identification in the same way as the method shown in Brock and Durlauf (2003)¹⁰, or earlier in Brock and Durlauf (2001)¹¹. While the selection problem is causing potential bias (if it is not correctly dealt with) in the estimation of λ_y , it facilitates identification even without the presence of an instrumental variable. However, the identifiability does not imply precision, and intuitively the model still needs an instrumental variable. In this case, the empirical specification requires at least one element in Z which is not included in X . In other words, it requires a variable which affects peer formation but not exam score. In this paper, I use the number of common hobbies as an instrumental variable for estimation of peer effects for friends, studymates, and emotional supporters. Students who play the same musical instruments or sports are considered to have higher probability to make friends so it is an element in Z . However, that does not enter into X because the number of common hobby with particular classmates are not supposed to affect exam scores. The detail description of all the element in X and Z which are used in the estimation will be illustrated in section 4.

With normality assumption of e and v , the likelihood can be written as

⁹If $\rho\sigma_e = 0$, the model is reduced to an exogenous network model, which is equivalent to the model in Bramoullé et al. (2009) or Lee et al. (2010). Identification requires require I , W , W^2 and W^3 are not perfectly collinear with each others. The network structure provides identification source in this case.

¹⁰See also Durlauf and Ioannides (2010)

¹¹which make reference to the selection correction model from Heckman (1979)

$$L = \phi(\tilde{e})\Pi(\Phi(Z_{ij}\gamma)\Phi(Z_{ij}\gamma))^{D_{ij}}(1 - \Phi(Z_{ij}\gamma)\Phi(Z_{ij}\gamma))^{1-D_{ij}} \quad (10)$$

where

$$\tilde{e} = (I - H)(I - \lambda_y W)^{-1}e$$

I apply Markov chain Monte Carlo(MCMC) to get estimates of β , λ_x , λ_y, γ, ρ . Metropolis–Hastings algorithm (Metropolis et al. (1953); Hastings (1970)) is used and I run 6 MCMC chains.¹² The MCMC chains are run until the following conditions are both met: 1. Range mean ratio of 6 chains is smaller than 0.1; 2. The ratio of average within chain standard deviation and total standard deviation is larger than 0.99.

The estimated results will be presented in section 5.

2.4 Elements in Peer Formation

This model captures the peer formation by assuming $D_{ij} = 1$ if $U_{ij} = Z_{ij}\gamma + \epsilon_{ij} > 0$ and $U_{ji} = Z_{ji}\gamma + \epsilon_{ji} > 0$. With the normality assumption of e and v (and hence ϵ), the probability for i and j are peer is given by $\Phi(Z_{ij}\gamma)\Phi(Z_{ij}\gamma)$. The construction of Z_{ij} determines which aspects of peer formation are captured in this model.

Here, Z_{ij} is constructed by the following components,

$$Z_{ij} = [z'_i, (z'_i - z'_j)^2, z'_{ij}]$$

$$Z_{ij}\gamma = z'_i\gamma_1 + (z'_i - z'_j)^2\gamma_2 + z'_{ij}\gamma_3$$

Each component capture some features of peer formation.

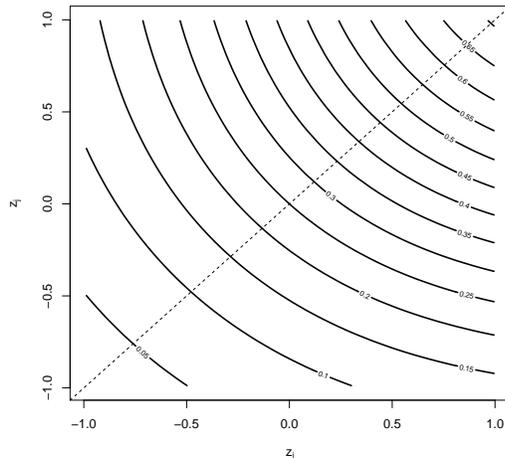
2.4.1 Characteristics of student i

z_i is a vector of characteristics of student i which affects the utility of student i in getting a peer. This indicates that there are some characteristics of a student which is good (or bad) for forming peers. For example students who are more extraverted could get more utility from getting anyone as

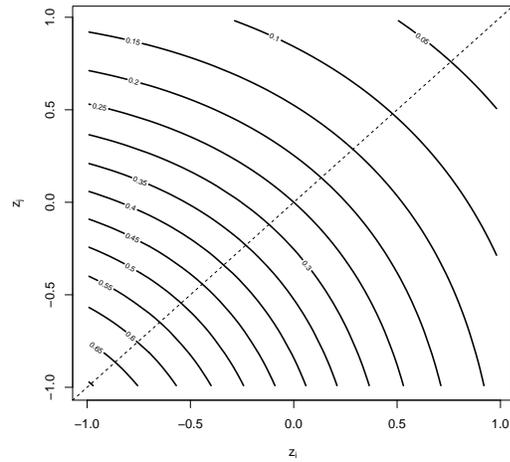
¹²More precisely, it is the Adaptive Proposal Metropolis Algorithm illustrated in Haario et al. (1999)

peer in general. Notice that the peer formation is based on mutual agreement, z_j is taken into account even if z_j do not explicitly appear in U_{ij} (It is because it appears in U_{ji}). This can be illustrated in contour maps of probability of forming peers.

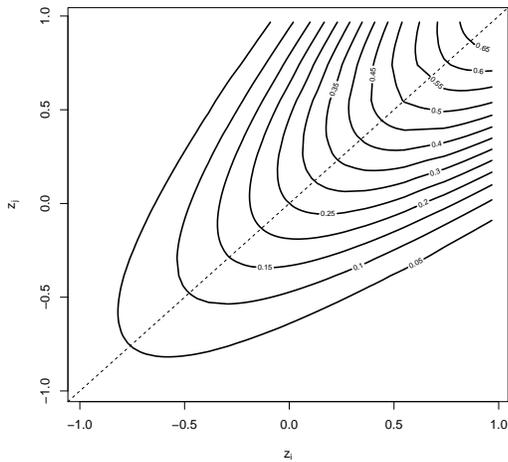
Figure 1: Probability of Peer Formation between i and j



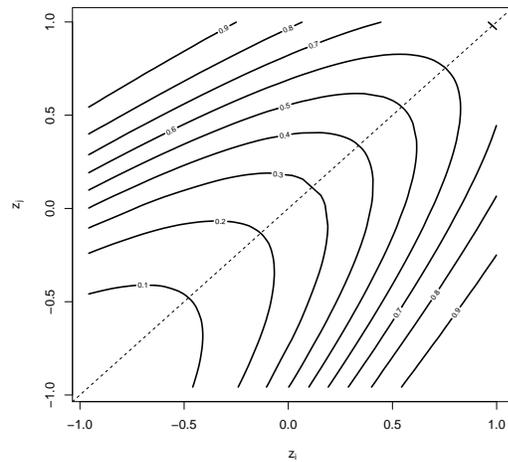
(a) $Z_{ij} = z'_i \gamma_1, \gamma_1 < 0$



(b) $Z_{ij} = z'_i \gamma_1, \gamma_1 < 0$



(c) $Z_{ij} = z'_i \gamma_1 + (z'_i - z'_j)^2 \gamma_2, \gamma_1 > 0, \gamma_2 < 0$



(d) $Z_{ij} = z'_i \gamma_1 + (z'_i - z'_j)^2 \gamma_2, \gamma_1 > 0, \gamma_2 > 0$

In figure 1a, the contour map shows the probability of i and j to be peers given their z_i and z_j , assuming $Z_{ij} \gamma = z'_i \gamma_1$. The contours are convex to the origin because if we only consider z_i , which means the mutual agreement model implicitly assumes “average is better than extreme” if the model only includes a single characteristic. Suppose extraversion is good for peer formation, and there are two students, one has extremely high extraversion and the other has extremely low extraversion. The probability for them to become peer is smaller than when they both have average level of extraversion.

Similarly if z_i is a bad for peer formation, the corresponding γ_1 would be negative. The shape of the contours is shown in figure 1b.

z_i is named “good characteristic” throughout this paper if the corresponding γ_1 is positive and “bad characteristic” if it is negative.

2.4.2 Difference in Characteristics of student i and j

Apart from the characteristics, students may also consider the difference in characteristics when they are finding peers. $(z'_i - z'_j)^2$ is the square difference between the characteristics of student i and j . γ_2 indicates that students may prefer peers who have similar (or different) characteristics to themselves. For example, one may think that student wants to find a studymate with similar mental ability to them.

Figure 1c shows the situation where z_i is a good characteristic, but students like peers with similar characteristics to them. (γ_2 is negative). The probability for i and j to be peers could decrease when z_i increases when z_j is very low. This can happen even if z_i is a good characteristic. It is because an increase in z_i makes student i more and more different from student j and student j dislikes that.

However, if student prefer difference to similarity (γ_2 positive), the contours can become the graph in figure 1d. In this case, average is not necessarily better than extreme differences between students generate extra utility.

2.4.3 Covariates not constructed from z_i and z_j

The third component z_{ij} refers to covariates that are individually defined for each student pairs, instead of forming by the characteristics of either i or j . For example, student pairs with more common hobbies are more likely to for peer. In this case, z_{ij} is formed by matching the set of hobbies of student i and student j .

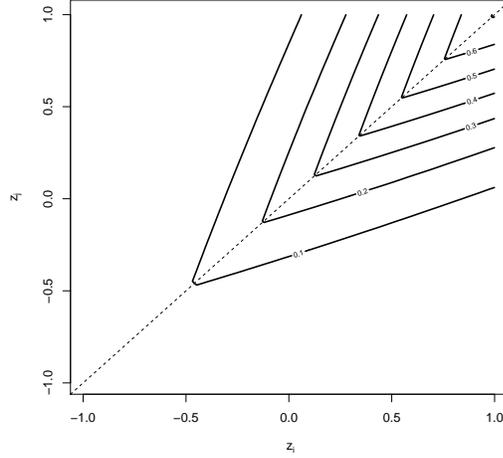
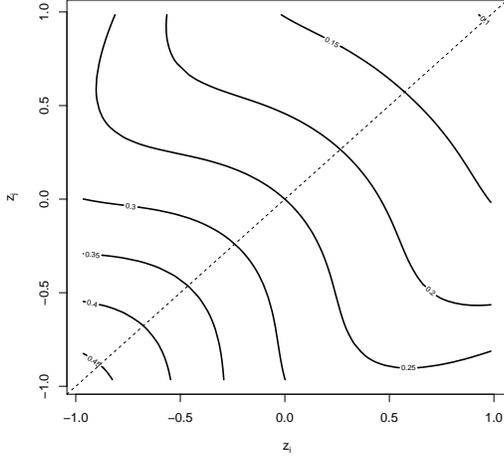
2.4.4 Complications not considered in this paper

The above 3 components are not the only components that could be used in the construction of Z_{ij} . For example, z_j can explicitly affect U_{ij} . In this case, $Z_{ij}\gamma = z'_i\gamma_1 + (z'_i - z'_j)^2\gamma_2 + z'_j\gamma_4$. This allows for change in convexity of the contours like figure 2a, which is not possible in the Utility set up in this paper.

Figure 2: Probability of Peer Formation between i and j

(a) $Z_{ij}\gamma = z'_i\gamma_1 + (z'_i - z'_j)^2\gamma_2 + z'_j\gamma_4$

(b) $Z_{ij} = z'_i\gamma_1 + |z'_i - z'_j|\gamma_2, \gamma_1 > 0, \gamma_2 < 0$



Also, to capture the difference in characteristics, one can use absolute difference instead of square difference. This will yield contours in figure 2b, which is not considered in this paper.

Interactions can be captured by including in $z_i z_j$ into Z_{ij} . More complicated construction of Z_{ij} can yield better fit in the peer formation model, but it uses more power as there are more parameters to be estimated. The empirical part of this paper will stick to the $Z_{ij} = [z'_i, (z'_i - z'_j)^2, z'_{ij}]$ specification, which allows for good or bad characteristics, preference to or against similarity among peers and certain connection specific covariates like number of common hobbies.

3 Dataset

Dataset involved in this paper are constructed from the survey “Secondary Education Survey in Hong Kong” (SESHK). SESHK is conducted during March through June 2011 to construct a unique dataset about the social network structure and academic performance of secondary school students in Hong Kong. The survey is designed to be education and network centric to fit the needs of this paper and several other related research projects. The sample size is 873.¹³ Students are from form 1 to form 3 (equivalent to grade 7 to grade 9). Data collected include students’ social network structure, personality traits, mental ability measures, assessment scores, hobbies and other demographics.

¹³The exact sample size for each estimated model are smaller than 873 because for different peer types, there are different number of students with no peers. Students with no peers are not included in the estimation of peer effects.

3.1 Features

3.1.1 Full network

The dataset allows for full network construction because it involves all the students in the schools within the participated grade. For example, for a school with grade 7 participated in the survey, all the grade 7 students in that school are included in the survey so the data can provide full network data of students within the grade.

3.1.2 Separate Peers by Type

This paper aims at comparing different peer types so information about different peer types is essential. Instead of asking students to just write down 10 friends, this survey asks students about their friends, studymates, emotional supporters. Detail separation of peers types is seldom available in common datasets.

3.1.3 Confidential Survey Process

The survey is questionnaire based. Students were required to complete an approximately one hour long questionnaire. They worked on the survey in classroom or in the assembly hall. They were not allowed to communicate with other students or leave before the survey ends. The survey is conducted in the same way as school exams, so students will not be disturbed by their classmates when they are working on the mental ability tests or personality tests. School teachers are not involved in the survey invigilation and the data collected will not be provided to the schools for any evaluation purposes. All the students are given a list of unique identification numbers provided by schools so that they can write their network information without writing their (and their schoolmates') real name. In this sense, the school only has the identification numbers but not the data, the researcher has the data but not the identification numbers. This policy keeps the data collected confidential to school and to researcher so that students are more willing to write honestly about their information.

3.1.4 Peer outside classroom

Students are assumed to have peers only within the same group. Notice that the definition of a group (denoted by g in section 2) in this dataset is a grade in a school. There are five classes in a typical grade. It means that the data allows for the flexibility that students can have peers outside their classes.

3.2 Data

3.2.1 Assessment Scores

Assessment scores of five subjects are provided by schools. They are Mathematics Exam Score, English Exam Score, Visual Art Exam Score, Physical Education Exam Score and Conduct Grades. These exams are taking place at the end of the academic year (during June to July), which are several months after the students write the survey and attempt survey (during March to June).

Table 1: Descriptive Statistics of Assessment Scores

| | Mean | SD | Max | Min | Possible Max | Possible Min |
|-----------------------|--------|--------|-------|-------|-----------------|-----------------|
| Mathematics | 69.233 | 14.363 | 99 | 25 | 100 | 0 |
| English | 67.331 | 11.325 | 89.79 | 20.36 | 100 | 0 |
| Visual art | 65.696 | 10.826 | 92 | 10 | 100 | 0 |
| Physical education | 68.227 | 11.569 | 100 | 5 | 100 | 0 |
| Conduct Grade | 67.027 | 12.088 | 80.95 | 23.81 | 100 | 0 |

Table 1 shows the descriptive statistics of the assessment scores of different subjects. All subjects are in score scale of 0 to 100. All subjects have similar mean score even without standardization.¹⁴

3.2.2 Network data

Four types of peers are constructed from the dataset. They are friends, studymates, emotional supporters, and seatmates.

For network data about friends, students are asked to write down up to 10 friends of them.¹⁵ They can only pick friends among their schoolmates within the same grade. Students are referred as friends only if both sides write each other as one of their 10 friends. Obviously one can also define friends as “either side claim they are friends”. In the empirical analysis, I stick to this “mutual agreement” types of friends and I will explore the other definition in section 6.

¹⁴Standardization could have been done by the schools before the assessment scores are provided to the author.

¹⁵Some students insist to write more than 10 and squeeze as much as 12 answers into the 10 boxes provided. Therefore there are a very small amount of students with more than 10 peers, but the extra peers make no substantial difference to the estimation.

Studymates are defined as studying with each other. In the survey students are asked to write down up to 10 schoolmates who have helped them in school work, and up to 10 schoolmates they have helped in school work. Students are defined as studying together if both sides mention each other in either of the two questions. This case is even more complicated than friends as one can argue that being helped and helping others are two different connections and should be considered separately. Similar to friends, I will be sticking to this simple definition of studymates and alternative specifications are investigated in section 6.

Similar to studymates, emotional supporters are also defined by mutual agreement. The only difference is that the survey questions for emotional supporters are “write down up to 10 schoolmates who have helped in emotional issues” and “write down up to 10 schoolmates they have helped in emotional issues”.

Seatmates are defined as sitting next to each other in classroom. Unlike other networks, students are seatmates if one of them reports that. It is because “seating next to me” is a much clearer and objective concept than “friends”. A student could forget to put down some classmates who have seated next to them, but it is very unlikely that students will report a classmate seating next to them if it is not the case.

Table 2 shows the average number of peers for each network and figure 8 in appendix E shows its distribution.

Table 2: Descriptive Statistics of Network Data

| | Mean | SD | Max | Min | Possible Max | Possible Min |
|----------------------|-------|-------|-----|-----|-----------------|-----------------|
| Friends | 4.735 | 2.209 | 10 | 0 | ∞ | 0 |
| Studymates | 4.052 | 2.497 | 12 | 0 | ∞ | 0 |
| Emotional Supporters | 2.948 | 2.339 | 12 | 0 | ∞ | 0 |
| Seatmates | 5.120 | 2.302 | 20 | 0 | ∞ | 0 |

3.2.3 Mental ability measures and personality traits

The dataset involves two mental ability tests and a personality test. The mental ability tests include a progressive matrix test and a memory test. Progressive matrix test is a series of context free logical deduction tests on space and shapes.¹⁶ Memory test involves asking students to memorize and recall

¹⁶Sample questions are shown in appendix C

12 simple English vocabularies ¹⁷. They are designed to capture different types of mental skills of the students.

Personality test includes a 44 items Big Five Inventory in John et al. (1991) which produces five personality measures, Conscientiousness, Openness, Agreeableness, Neuroticism, and Extraversion. These five measures capture different kinds of personality traits. Conscientiousness can capture elements such as self-discipline, carefulness and diligence. Openness can capture elements such as imagination and curiosity. Agreeableness captures elements such as whether someone are considerate or kind. Neuroticism captures whether someone worry or having anxiety easily. Extraversion captures whether a student is outgoing or talkative.

Table 3: Descriptive Statistics of Personality Traits

| | SESHK | | | | | | JGPS2003 | |
|-------------------|--------|-------|-----|-----|-----------------|-----------------|----------|------|
| | Mean | SD | Max | Min | Possible Max | Possible Min | Mean | SD |
| Extraversion | 26.805 | 5.035 | 39 | 10 | 40 | 8 | 21.4 | 4.52 |
| Agreeableness | 27.063 | 4.007 | 40 | 12 | 45 | 9 | 29.25 | 3.6 |
| Conscientiousness | 26.418 | 5.482 | 45 | 12 | 45 | 9 | 26.775 | 3.66 |
| Neuroticism | 22.982 | 5.589 | 38 | 8 | 40 | 8 | 21 | 4.38 |
| Openness | 35.891 | 5.473 | 51 | 18 | 50 | 10 | 37 | 3.28 |

Note: The JGP2S003 data are extracted from Srivastava et al. (2003). The numbers are presented in POMP (percentage of maximum possible) in their paper and is revert back to the point scale used in the personality tests for comparison.

Table 3 shows the mean and standard deviation of each personality measures in this dataset and the data from Srivastava et al. (2003) (JGPS2003) for comparison. Their paper collects personality and demographic data via the Gosling–Potter Internet Personality Project. This project collects data from over 100,000 people between age 21 and 60. The mean and SD shown in the above table is from the age 21 sample of this project. The sample means of personality measures are very similar in this paper and in the SESHK teenage sample, except for Extraversion. One possible explanation is that there is a reduction in extraversion from teenage to 21 (Soto et al. (2011)). The personality measures administered in SESHK is not way off from a larger scale study.

Unlike personality traits, there is no benchmark from larger scale studies of the two mental ability tests that I applied. However, figure 9 in appendix E shows the distribution of these 2 tests. It shows that the difficulty of the test is about right as most students have mid-range scores instead of having

¹⁷Vocabulary list is shown in appendix D

scores concentrated to the right (the tests are too easy) or to the left (the test are too difficult) end. Also the scores of the tests are widespread over almost all possible score range.

Table 4: Descriptive Statistics of Mental Ability Tests

| | Mean | SD | Max | Min | Possible Max | Possible Min |
|-------------------------|--------|-------|-----|-----|--------------|--------------|
| Progressive Matrix Test | 8.556 | 1.911 | 14 | 1 | 16 | 0 |
| Memory Test | 14.734 | 4.085 | 24 | 1 | 24 | 0 |

3.2.4 Hobby and other information

In the survey, students are asked to write down their hobbies and their hobbies are grouped into 120 different hobbies. These hobbies include musical instruments like piano or violin, or sports like basketball or badminton. It also includes participation in youth movements like boy scouts or girl guides. Appendix B shows the list of hobbies. The dataset also provide other information such as height, weight, gender and siblings. Descriptive statistics are shown in 5.

Table 5: Descriptive Statistics of Hobby and other variables

| | Mean | SD | Max | Min | Possible Max | Possible Min |
|----------------------------------|---------|--------|-------|------|--------------|--------------|
| Number of Hobby for Each Student | 3.699 | 1.654 | 12 | 0 | ∞ | 0 |
| Height | 159.668 | 8.907 | 208.3 | 100 | ∞ | 0 |
| Weight | 47.780 | 10.571 | 130 | 26.3 | ∞ | 0 |
| Male | 0.444 | 0.497 | 1 | 0 | 1 | 0 |
| Number of Elder Brother/Sister | 0.607 | 0.843 | 7 | 0 | ∞ | 0 |
| Number of Younger Brother/Sister | 0.420 | 0.604 | 3 | 0 | ∞ | 0 |

4 Empirical Specifications

In this paper, I estimate the model described in section 2 under different specifications to investigate peer effects for different peer groups and different subjects. Every estimated model involves five sets

of data: Outcome variable (Y), Network (D), Score Formation Characteristics (S), Peer Influence Characteristics (X) and Peer Formation Characteristics (Z). In this section, I will be illustrating all the variables involved in the estimation.

4.1 Outcome variable (Y)

Peer effects are defined very broadly in social science literature. They can be referred to the effects that affect academic achievements, health outcome, crime or even the development of personality traits. In the paper, I am focusing on peer effects on academic achievements and in particular the exam scores of five subjects. They are Mathematics, English, Visual Art, Physical Education and Conduct grade. All scores are standardized to $mean = 0$ and $SD = 1$ in all estimations in this paper.

4.2 Network (D)

The network matrix D is an $n \times n$ matrix where n is the number of students in the group. $D_{ij} = 1$ only if student i and student j are peers. In this paper, I investigate the peer effects under four different types of peer. They are friends studymates and emotional supporters and seatmates.

4.3 Score Formation Characteristics (S)

Score formation characteristics refer to student characteristics which affect their own exam scores directly. In this paper, I include students' mental abilities, personality traits, number of siblings, gender and class dummies. Not all the mental abilities and personality traits are believed to be correlated with studying behavior or exam results, but they are all included in the model as some can be important for particular subjects.

The model also allows for direct effect from the type of hobbies students are involved in. It can be conceived that certain kinds of hobbies can be conducive to learning, for example playing musical instrument, or involving in youth movement program or alike. Also, number of brother and sisters, especially elder ones, could potentially be helpful to a students' learning. To be on the safe side I keep them in each model as control variables. Gender dummy is added to capture gender difference in each subject which are not captured by measured mental ability of personality traits.

4.4 Peer Influence Characteristics (X)

Peer influence characteristics refer to student characteristics which affect their peers' exam scores. In the model discussed in section 2, students' exam scores are affected by the peer average characteristics. I assume that X contains only mental ability and personality traits measured in the data, which are the progressive matrix test, memory test and the personality traits produced from the Big Five Inventory.

4.5 Peer Formation Characteristics (Z)

Peer formation characteristics refer to student characteristics which affect the utility they get from getting a peer connection. There are four different kinds of peer and the covariates used in explaining peer formation are not the same for all of them. Friends, studymates and emotional supporters are formed by the choice of students. Seatmates, on the other hand, is determined by the seating plan in classroom which is assignment by teacher. Therefore, it makes sense to apply different covariates in explaining the formation of them.

4.5.1 For Friends, Studymates and Emotional supporters

For friends, studymates and emotional supporters, Z is a list of values that can affect the utility a student gets from forming a particular peer connection.

Firstly, Z includes student characteristics that affect the utility a student can get from any peer connection. In this case, they are mental abilities, Personality traits, Gender, BMI, type of hobbies students have and number of siblings. The mental ability and personality are measured by the same set of measures mentioned before. BMI is referring to Body Mass Index which is measure by the ratio of weight(kg) and height(m) square. Type of hobbies refers to whether a student plays musical instrument, sports or involves in youth movement program or alike. Number of siblings refers to how many brothers and sisters the students have.

For each of these characteristics, both the level and the difference are used in the estimation. They are denoted as z_i and $(z_i - z_j)^2$ in section 2. For example, for matrix test, I estimate an coefficient for both z_i (how the level of matrix test score affect the utility a student i get from having a peer) and $(z_i - z_j)^2$ (how the square distance of student i 's matrix test score and that of student j 's affect the utility student i get from having j as a peer). This applies to other characteristics. For some variables, including the "difference" part in estimation is very is important. One may think that the level of matrix test score does not affect how friendships are formed, but this does not implies that

students are not looking for schoolmates who have similar intelligence as them to make friends with. Therefore both the level and the difference are important in the peer formation equation.

Secondly, Z includes variables that are not characteristics of a student, but rather a characteristics of student pairs (denoted as z_{ij} in section 2). For example, number of common hobbies. Number of common hobbies is defined for each student pairs instead of each student. Using the hobby data, I construct the number of common hobbies for each possible student pairs.

As mentioned in section 2, at least an element in Z should not appear in X so that it can be an instrument. In this case, the number of common hobbies is considered as an instrument. The validity of this instrument base on the assumption that students who have more common hobbies with each other are more likely to be forming peer connections, but having common hobbies with particular students are not supposed to affect exam scores. One may argue that students who play musical instruments may be in general better students. However, the model allows for that. (The effect is captured in β as playing musical instrument is one of the score formation characteristics). As most of the students have quite a number of hobbies, the exogeneity assumption only rely on the assumption that students who play piano are not in general better than those who play violin, rather than playing musical instrument is exogeneous to exam score.

4.5.2 For Seatmates

For seatmates, as students are not allowed to choose their seats, the interpretation of “Students form peers when having positive utility to each other” does not apply. However, the same model can be interpreted as some characteristics Z are affecting how the teachers are assigning the seats. Here, height and gender are included in the “peer formation equation” as teachers may design the seating plan according to student’s height or gender. As in other peer types, both the level and the difference are used in the estimation.

All non-dummy variables except “Number of Common Hobbies” are standardized using sample mean and sample standard deviation.

4.6 Sum up

In each model, the coefficients estimated are as follow:

- Own Effects β (How i 's own characteristics S affect i 's Y)
- Contextual Effects λ_x (How i 's peers' characteristics X affect i 's Y)

- Endogenous Effect λ_y (How i 's peers' outcome variable Y affect i 's Y)
- Selection Effect ρ
- Peer formation Coefficients γ

For each subjects and each network, we estimated a benchmark exogenous network model by assuming ρ to be zero and shutting down all γ equations, and a full model allowing for endogenous network formation.

Table 6: Summary of empirical specifications

| 5 Subjects (Y) | | Math, English, Visual Art, Physical Education, Conduct Grade | | |
|--|---|--|---|---|
| 4 networks (D) | | Friends, Studymates, Emotional Supporters | | Seatmates |
| Model | Benchmark Exogenous Model | Endogenous Network Formation Model | Benchmark Exogenous Model | Endogenous Network Formation Model |
| Score Formation Characteristics S | Mental ability, Personality, Siblings, Type of Hobbies, Gender | Mental ability, Personality, Siblings, Type of Hobbies, Gender | Mental ability, Personality, Siblings, Type of Hobbies, Gender | Mental ability, Personality, Siblings, Type of Hobbies, Gender |
| Peer Influence Characteristics X | Mental ability, Personality | Mental ability, Personality | Mental ability, Personality | Mental ability, Personality |
| Peer Formation Characteristics Z | N/A | Mental ability, Personality, Gender, BMI, Type of Hobbies, Number of Common Hobbies | N/A | Height, Gender |
| Parameters estimated | $\beta \lambda_x \lambda_y$ | $\beta \lambda_x \lambda_y \gamma \rho$ | $\beta \lambda_x \lambda_y$ | $\beta \lambda_x \lambda_y \gamma \rho$ |

5 Empirical Findings

In this section, I illustrate the empirical estimations of all the models mentioned in table 6. Each model produces estimates of own effects β , contextual effects λ_x , endogenous effect λ_y , peer formation

coefficients γ , and selection effect ρ (in benchmark exogenous network model $\rho = 0$ and γ is not estimated).

The focus of this paper is on peer effects (λ_x and λ_y), which will be illustrated in sections 5.3 and 5.4. However, I will first discuss peer formation coefficients γ and the own effects β estimations in sections 5.1 and 5.2. It is because the own effects estimation can give us a clear idea on which covariates are significant factors in determining exam scores, and the peer formation model is the basis of how the peer effect estimation takes into account selection effect.

5.1 Peer Formation Coefficients

Table 7 shows the peer formation coefficients estimates. The peer formation coefficients estimates are very similar for different subjects. For illustration purpose, table 7 only extract the estimates from the models using Math score as outcome variable.

5.1.1 Friends, Studymates and Emotional supporters

For Friends, Studymates and Emotional supporters, common hobbies and gender are most important factors in determining peer formation . Number of common hobbies shows strong positive relationship to peer formation, and strongest in friendship. This captures the effect where students with more common hobbies are more likely to make friends with each other. Students have very strong preference to form peer relationship with schoolmates of the same gender, especially for friendship.

Students who are more extraverts or agreeable are having more any types of peers. For extraversion, students also care about differences. Students are more likely to make friends with schoolmates with smaller extraversion difference, but this effect is not found for studymates.

Conscientious students are getting more studymates but not more friends. Mental ability level does not affect the number of peers a student would have. Students like to have studymates with similar mental ability, but that is not important for friends and emotional supporters.

5.1.2 Seatmates

Height difference shows negative estimates. It means that teachers take into account student height in arranging the class seating plan. Tall students are arranged to the back of the classroom so students with larger difference in height are less likely to be seating next to each other. Gender difference also

shows negative coefficient estimates. This indicates that students with the same gender are more likely to be assigned to sit next to each other.

Table 7: Peer formation coefficients

| Math Score | Studyates | Friends | Emotional Supporters | Seatmates |
|-------------------------|------------|------------|----------------------|------------|
| Peer Formation γ | | | | |
| Intercept | -0.819 *** | -0.721 *** | -0.88 *** | -0.919 *** |
| Matrix Test | | | | |
| level | 0.01 | -0.008 | 0.007 | |
| difference | -0.005 * | -0.004 | 0 | |
| Memory Test | | | | |
| level | 0.019 | -0.002 | -0.006 | |
| difference | -0.005 * | -0.002 | 0.001 | |
| Conscientiousness | | | | |
| level | 0.072 *** | -0.005 | 0.03 * | |
| difference | 0.001 | -0.003 | 0.002 | |
| Openness | | | | |
| level | -0.023 | -0.001 | -0.004 | |
| difference | -0.001 | 0 | -0.003 | |
| Agreeableness | | | | |
| level | 0.032 ** | 0.031 *** | 0.056 *** | |
| difference | 0.002 | 0.003 | 0.002 | |
| Neuroticism | | | | |
| level | 0.052 *** | 0.007 | 0.079 *** | |
| difference | 0 | -0.005 | -0.006 | |
| Extraversion | | | | |
| level | 0.032 ** | 0.033 *** | 0.086 *** | |
| difference | -0.002 | -0.009 *** | -0.009 ** | |
| BMI | | | | |
| level | -0.012 | -0.01 | -0.008 | |
| difference | -0.003 | -0.002 | -0.004 | |
| Gender | | | | |
| level | 0.006 | 0.023 | -0.029 | 0.042 ** |
| difference | -0.466 *** | -0.803 *** | -0.59 *** | -0.053 *** |
| Elder Siblings | 0.008 | 0.039 *** | 0.031 * | |
| Younger Siblings | -0.039 * | 0.003 | 0.009 | |
| Music Hobby | | | | |
| level | -0.022 | -0.063 ** | -0.022 | |
| difference | 0.014 | 0.002 | -0.021 | |
| Sports Hobby | | | | |
| level | -0.029 | -0.044 | -0.064 * | |
| difference | -0.022 | -0.012 | 0.014 | |
| Youth Movement | | | | |
| level | -0.017 | -0.065 *** | -0.013 | |
| difference | -0.019 | -0.033 * | 0.008 | |
| Common Hobbies | 0.109 *** | 0.158 *** | 0.146 *** | |
| Height | | | | |
| level | | | | -0.012 |
| difference | | | | -0.016 *** |
| Sample Size | 820 | 846 | 735 | 867 |
| Peers per Person | 4.285 | 4.853 | 3.472 | 5.105 |

Note 1: *** significant at 1% level; ** significant at 5% level; * significant at 10% level

Note 2: Extracted from the full estimation results in table 23 in appendix A.

Note 3: Estimated peer formation coefficients are very similar in model with other subjects. Here I only extract the model using Math score.

5.2 Own Effects

Another set of parameters estimated in each model are own effects (β). They refer to how students' own characteristics affect their own exam scores. Every model mentioned in table 6 contain estimates of β . The estimates are a little bit different for models with different peer definitions but they are very similar to each other. For illustration, table 8 only extracts the own effects estimated using studymates as peer definition. Ordinary Least Squares estimates of regressing the exam scores (Y) on score formation characteristics (S) are shown in table 10 for comparison.

Table 8: Own Effects

| Studymates | Math | English | Visual Art | Physical Education | Conduct Grade |
|---------------------|-----------|------------|------------|--------------------|---------------|
| Own Effects β | | | | | |
| Matrix Test | 0.268 *** | 0.132 *** | 0.028 | -0.017 | 0.001 |
| Memory Test | 0.088 *** | 0.061 * | 0.04 | 0.003 | 0.015 |
| Conscientiousness | 0.242 *** | 0.34 *** | 0.208 *** | 0.094 *** | 0.189 *** |
| Openness | -0.06* | -0.079 ** | 0.134 *** | -0.003 | -0.025 |
| Agreeableness | -0.1 *** | -0.09 *** | -0.074 ** | -0.021 | 0.013 |
| Neuroticism | 0 | 0.08 ** | 0.065 * | 0.004 | 0.029 |
| Extraversion | -0.055 | -0.042 | -0.127 *** | 0.107 *** | -0.071 ** |
| Male | 0.069 | -0.406 *** | -0.748 *** | 0.183 ** | -0.28 *** |
| Elder Siblings | 0.013 | 0.006 | 0.071 | 0.097 | -0.042 |
| Younger Siblings | 0.001 | -0.01 | -0.016 | 0.065 | -0.082 |
| Music Hobby | 0.04 | 0.105 | 0.031 | -0.174 *** | -0.015 |
| Sports Hobby | -0.074 | -0.048 | -0.134 ** | 0.462 *** | -0.159 *** |
| Youth Movement | 0.012 | -0.051 | 0.011 | -0.081 | 0.011 |
| Sample Size | 820 | 820 | 820 | 820 | 657 |
| Peers per Person | 4.285 | 4.285 | 4.285 | 4.285 | 4.381 |

Note 1: *** significant at 1% level; ** significant at 5% level; * significant at 10% level

Note 2: Extracted from the full estimation results in table 23, 24, 25, 26, and 27 in appendix A.

Note 3: Own effects are estimated in all models. Here I only extract those from the model using the studymates network.

5.2.1 Mathematics

As expected, the matrix test, which is a test for logical deduction ability, has large positive effect on math exam score. Memory test score also has positive effect but the effect is smaller. For personality traits, conscientiousness has positive effect while agreeableness and openness affect math score negatively.

5.2.2 English

Own effects for English exam score are very similar to those of Mathematics. However, for English exam score, the effect of matrix test is smaller while the effect of conscientiousness is larger. Also, male students are on average doing worse in English exam.

5.2.3 Other Subjects

The exam scores of other subjects are determined by particular personality traits rather than mental abilities. Conscientiousness has positive effect on all subjects but the effect is larger for English and Math than other subjects. Openness, which involve creativity positively affect Visual Art score. Extravert students are more likely to do well in Physical Education exam, but on average get worse conduct grades.

5.2.4 Gender

Gender difference is significant even with controls for other abilities and personality traits. Male students are better in Physical Education, but worse in English, Visual Art and conduct grade.

5.2.5 Comparison to OLS estimates

It is useful to compare the own effects to the β estimated from a OLS regression. Table 10 shows the own effects on math score for the OLS model and the models which controlled for different types of peer effects.

Table 9: Own Effects for Math Exam Score, compare to OLS

| Math Score | OLS | Studymates | Friends | Emotional Supporters | Seatmates |
|---------------------|-----------|------------|------------|----------------------|------------|
| Own Effects β | | | | | |
| Matrix Test | 0.280*** | 0.268 *** | 0.27 *** | 0.301 *** | 0.297 *** |
| Memory Test | 0.101*** | 0.088 *** | 0.074 ** | 0.076 ** | 0.104 *** |
| Conscientiousness | 0.326*** | 0.242 *** | 0.221 *** | 0.257 *** | 0.224 *** |
| Openness | -0.065** | -0.06* | -0.073 ** | -0.065 * | -0.071 * |
| Agreeableness | -0.101*** | -0.1 *** | -0.099 *** | -0.118 *** | -0.106 *** |
| Neuroticism | -0.012 | 0 | -0.001 | -0.009 | -0.004 |
| Extraversion | -0.069** | -0.055 | -0.053 | -0.074 * | -0.071 * |
| Male | 0.105* | 0.069 | 0.084 | 0.035 | 0.124 * |
| Elder Siblings | 0.019 | 0.013 | 0.012 | 0.011 | 0.009 |
| Younger Siblings | -0.011 | 0.001 | 0.002 | 0.001 | -0.001 |
| Music Hobby | 0.042 | 0.04 | 0.037 | -0.01 | 0.06 |
| Sports Hobby | -0.091 | -0.074 | -0.095 | -0.079 | -0.094 |
| Youth Movement | -0.046 | 0.012 | -0.007 | 0.022 | 0.008 |
| Sample Size | 873 | 820 | 846 | 735 | 867 |
| Peers per Person | | 4.285 | 4.853 | 3.472 | 5.105 |

Note 1: *** significant at 1% level; ** significant at 5% level; * significant at 10% level

Note 2: Extracted from the full estimation results in table 23 in appendix A.

Most of the estimates on own effects are not significantly different from each other except for conscientiousness, extraversion and the male dummy. One possible explanation to this is there is omitted variable bias in OLS estimates when the peer effects are affecting the exam score and certain characteristics are correlated with the peer formation process. For example, the OLS estimate for coefficient of conscientiousness (0.326) is capturing not only the effect of how conscientiousness directly benefit a student in studying, but also through forming study groups or making friends, which turns out to be helpful to studying. Therefore, the coefficient become smaller once the model has controlled for peer effects and the OLS estimate is overestimating the own effect for conscientiousness.

Notice that the direction of the biases is not as obvious as the omitted variable biases in usual ordinary least square situations. For example, extraversion has negative effect on Math score in OLS estimate, but the effect disappear when peer effects are controlled for. It implies that the OLS estimate is underestimating the own effect for extraversion. Even though both extraversion and conscientiousness induce students to get more peers (according to the results illustrated in section 5.1), getting more peer does not imply better academic results because the quality of peers matters more than the quantity of peers. Therefore, the biases in the estimation of own effects can be in either directions when the peer effects are omitted in the analysis.

5.3 Peer Effects on Math Exam Score

Peer effect estimation is the focus of the empirical analysis. Every benchmark exogenous network model produces estimates of $\beta\lambda_x$ and λ_y , while the full endogenous network model produces also estimates of ρ and γ . In table 11, only $\lambda_x\lambda_y$ and ρ are shown for easier illustration. Full estimation results are shown in Appendix A.

Table 11: Peer effects on Math Score

| Math Score | Studymates | | Friends | | Emotional Supporters | | Seatmates | |
|--------------------------------|------------|-----------|-----------|-----------|----------------------|----------|-----------|--------|
| | Exo | Endo | Exo | Endo | Exo | Endo | Exo | Endo |
| Contextual Effects λ_x | | | | | | | | |
| Matrix Test | 0.061 | 0.107 * | 0.049 | 0.058 | 0.072 | 0.075 | -0.042 | -0.045 |
| Memory Test | 0.068 | 0.038 | 0.2 *** | 0.193 *** | 0.072 | 0.069 | 0.013 | 0.013 |
| Conscientiousness | 0.03 | -0.004 | 0.166 *** | 0.158 *** | 0.138 ** | 0.133 ** | 0.023 | 0.023 |
| Openness | -0.059 | -0.054 | -0.055 | -0.041 | -0.012 | -0.014 | -0.018 | -0.022 |
| Agreeableness | -0.031 | -0.016 | -0.066 | -0.068 | -0.04 | -0.05 | 0.048 | 0.051 |
| Neuroticism | -0.046 | -0.045 | 0.039 | 0.032 | 0.041 | 0.038 | 0.102 | 0.1 |
| Extraversion | -0.036 | -0.05 | -0.006 | -0.02 | 0.012 | 0.003 | 0.108 | 0.104 |
| Endogenous Effects λ_y | | | | | | | | |
| Selection ρ | | 0.117 *** | | 0.041 *** | | 0.035 ** | | 0.003 |
| Sample Size | 820 | 820 | 846 | 846 | 735 | 735 | 867 | 867 |
| Peers per Person | 4.285 | 4.285 | 4.853 | 4.853 | 3.472 | 3.472 | 5.105 | 5.105 |

Note 1: *** significant at 1% level; ** significant at 5% level; * significant at 10% level

Note 2: Extracted from the full estimation results in table 23 in appendix A.

There are two kinds of peer effects, endogenous effects (λ_y) and contextual effects (λ_x). Contextual Effects refers to how students' score are affected by the average characteristics of their peers. A positive estimate indicates that average peer characteristics are positively correlated with exam scores. Endogenous Effects refers to how the students' scores are affected by the average score of their peers' scores. A positive estimate indicates that peers are more likely to have similar scores. It is because their scores positively affecting each other. While contextual effect capture peer effects generated from predetermined observable characteristics of peers, endogenous effect captures peer effects which does not go through any observable characteristics in the model. It is known as behavioral spillovers.

5.3.1 Endogenous Effect

All four peer types show positive endogenous peer effects. Friends have biggest endogenous peer effect (0.216) in magnitude. The effects for studymates are smaller. Emotional supporters and seatmates

show a lot smaller endogenous peer effects. This shows that students are more likely to influence their friends and studymates in terms of math score. However, for those who are seating next to them in class or students who show emotional support to them, the influence is a lot smaller.

Friends, studymates, and emotional supporters have smaller endogenous peer effects in the “Full Endogenous network model” than in the “Benchmark exogenous network model”. This is expected given a positive selection effect (ρ) estimate. Intuitively, students who have similar achievement or characteristics are more likely to become friends or studymates. The endogenous peer effect is overestimated if we do not take into account peer selection process. Students have stronger selection effect in choosing studymates compare to getting friends or emotional support. And therefore the endogenous peer effect of studymates is overestimated more. There is no evidence showing that seat assignment is endogenously determined. The endogenous peer effects estimated in the benchmark model and the full model have minimal difference.

5.3.2 Contextual Effects

Apart from endogenous peer effects. The estimates also show differences in contextual peer effect (λ_x) between different networks. For studymates, only the contextual peer effect for Matrix Test is positive. Matrix Test is a measure of mental ability. This shows that having studymates’ average matrix test score is positively correlated with a student’s math score. On the other hand, similar effect is not found for friends and emotional supporters. Instead, they show positive contextual peer effects on the conscientiousness measure. Conscientiousness is a measure highly related to whether a student is organized, hardworking or self-disciplined. Therefore, having smarter friend is not correlated with better Math exam score, but having hardworking friends does. Finally, seatmates do not show any significant contextual peer effects.

5.4 Peers effects for Different Subjects

In section 5.3, the peer effects estimated are all about Math score. Here, I investigate the peer effects for five different subjects. All the tables in this section are constructed by extracting the relevant columns from the full estimation tables (Table 23 - 27) in appendix A. Only endogenous effects (λ_y) and contextual effects (λ_x) and selection effect (ρ) are shown for clearer illustration.

Table 12: Peer effects for different Subjects (Studymates)

| Studymates | | | | | |
|--------------------------------|-----------|-----------|------------|--------------------|---------------|
| | Math | English | Visual Art | Physical Education | Conduct Grade |
| Contextual Effects λ_x | | | | | |
| Matrix Test | 0.107 * | 0.116 * | 0.056 | -0.014 | 0.007 |
| Memory Test | 0.038 | 0.013 | 0.032 | 0.05 | 0.026 |
| Conscientiousness | -0.004 | 0.101 | -0.01 | -0.02 | 0.025 |
| Openness | -0.054 | -0.066 | -0.039 | 0.076 | -0.03 |
| Agreeableness | -0.016 | -0.012 | 0.026 | -0.064 | -0.028 |
| Neuroticism | -0.045 | 0.005 | 0.004 | 0.044 | -0.001 |
| Extraversion | -0.05 | 0.019 | -0.028 | 0.037 | -0.096 * |
| Endogenous Effects λ_y | | | | | |
| Selection Effect ρ | 0.178 *** | 0.127 *** | 0.096 ** | 0.267 *** | 0.218 *** |
| Sample Size | 820 | 820 | 820 | 820 | 657 |
| Peers per Person | 4.285 | 4.285 | 4.285 | 4.285 | 4.381 |

Note 1: *** significant at 1% level; ** significant at 5% level; * significant at 10% level

Note 2: Extracted from the full estimation results in table 23, 24, 25, 26, and 27 in appendix A.

Table 13: Peer effects for different Subjects (Friends)

| Friends | | | | | |
|--------------------------------|-----------|-----------|------------|--------------------|---------------|
| | Math | English | Visual Art | Physical Education | Conduct Grade |
| Contextual Effects λ_x | | | | | |
| Matrix Test | 0.058 | 0.034 | 0.076 | -0.025 | 0.03 |
| Memory Test | 0.193 *** | 0.095 * | 0.05 | -0.017 | 0.16 *** |
| Conscientiousness | 0.158 *** | 0.181 *** | 0.079 | -0.018 | 0.076 |
| Openness | -0.041 | -0.049 | 0.045 | 0.091 | -0.043 |
| Agreeableness | -0.068 | -0.01 | -0.016 | -0.092 | 0.008 |
| Neuroticism | 0.032 | 0.073 | 0.031 | -0.031 | 0.004 |
| Extraversion | -0.02 | -0.02 | -0.07 | 0.082 | -0.149 *** |
| Endogenous Effects λ_y | | | | | |
| Selection Effect ρ | 0.041 *** | 0.071 *** | 0.039 *** | 0.029 ** | 0.073 *** |
| Sample Size | 846 | 846 | 846 | 846 | 678 |
| Peers per Person | 4.853 | 4.853 | 4.853 | 4.853 | 4.788 |

Note 1: *** significant at 1% level; ** significant at 5% level; * significant at 10% level

Note 2: Extracted from the full estimation results in table 23, 24, 25, 26, and 27 in appendix A.

Table 14: Peer effects for different Subjects (Emotional Supporters)

| Emotional Supporters | Math | English | Visual Art | Physical Education | Conduct Grade |
|--------------------------------|-----------|-----------|------------|--------------------|---------------|
| Contextual Effects λ_x | | | | | |
| Matrix Test | 0.075 | 0.021 | 0.047 | 0.052 | 0.007 |
| Memory Test | 0.069 | 0.051 | 0.057 | -0.042 | 0.053 |
| Conscientiousness | 0.133 ** | 0.11 * | 0.101 * | 0.012 | 0.022 |
| Openness | -0.014 | 0.015 | 0.027 | 0.16 *** | 0.112 ** |
| Agreeableness | -0.05 | -0.101 | -0.052 | -0.024 | -0.116 ** |
| Neuroticism | 0.038 | -0.003 | 0.032 | 0.066 | -0.026 |
| Extraversion | 0.003 | 0.006 | -0.087 | 0.025 | -0.127 *** |
| Endogenous Effects λ_y | 0.115 *** | 0.059* | 0.08 * | 0.226 *** | 0.148 *** |
| Selection Effect ρ | 0.035 ** | 0.066 *** | 0.047 *** | 0.007 | 0.05 *** |
| Sample Size | 735 | 735 | 735 | 735 | 606 |
| Peers per Person | 3.472 | 3.472 | 3.472 | 3.472 | 3.647 |

Note 1: *** significant at 1% level; ** significant at 5% level; * significant at 10% level

Note 2: Extracted from the full estimation results in table 23, 24, 25, 26, and 27 in appendix A.

Table 15: Peer effects for different Subjects (Seatmates)

| Seatmates | Math | English | Visual Art | Physical Education | Conduct Grade |
|--------------------------------|---------|---------|------------|--------------------|---------------|
| Contextual Effects λ_x | | | | | |
| Matrix Test | -0.045 | -0.018 | 0.052 | -0.073 | 0.019 |
| Memory Test | 0.013 | 0.008 | 0.034 | 0.026 | 0.085 |
| Conscientiousness | 0.023 | 0.022 | 0.009 | -0.081 | -0.093 |
| Openness | -0.022 | -0.051 | 0.131 * | 0.042 | -0.056 |
| Agreeableness | 0.051 | 0.014 | -0.014 | 0.076 | 0.029 |
| Neuroticism | 0.1 | -0.026 | 0.013 | 0.039 | -0.027 |
| Extraversion | 0.104 | 0.088 | -0.057 | -0.117 | 0.008 |
| Endogenous Effects λ_y | 0.093 * | 0.069 | -0.039 | 0.187 *** | 0.115 ** |
| Selection Effect ρ | 0.003 | 0.017 | 0.015 | 0.005 | 0.013 |
| Sample Size | 867 | 867 | 867 | 867 | 696 |
| Peers per Person | 5.105 | 5.105 | 5.105 | 5.105 | 4.98 |

Note 1: *** significant at 1% level; ** significant at 5% level; * significant at 10% level

Note 2: Extracted from the full estimation results in table 23, 24, 25, 26, and 27 in appendix A.

For studymates, endogenous peer effects are positive for all subjects. Physical education and conduct grade show the largest endogenous peer effect, while visual art does not show as strong endogenous peer effect as other subjects.

Apart from endogenous peer effects, peer effects also work through observable characteristics in expected ways. As mentioned before contextual effect of matrix test on Math score is positive. Also, the contextual effect of Extraversion on Conduct grade is negative. It seems that students are more naughty if their studymates are extraverts. Very similar contextual effects on conduct grade are found for friends and emotional supporters.

For friends, estimates show strong positive endogenous peer effects for all subjects. But in contextual effects, It seems that friends are influencing the exam score via conscientiousness rather than matrix test score. This is valid for both Math and English. Friends also shows positive contextual effect for extraversion on the Physical education score, which does not show the same effect in studymates.

The emotional supporters show peer effects similar to friends. It has contextual effects via conscientiousness instead of matrix test score.

Seatmates do shows endogenous peer effects for Math, Physical education and Conduct grade, but no effect for English and Visual Art. Also, the estimates show almost no contextual effects in seatmates for all subjects.

6 Alternative Specifications and Sensitivity Analysis

In the analysis in previous sections, I have made several choices on the empirical specifications. For example, I define friends and studymates by “mutual agreement”, but use “either side reported” as the definition for seatmates. While these choices and assumption could be reasonable, it is useful to also explore alternative specifications to see whether the estimates mentioned above are robust or not.

6.1 Earlier Exam Score

The dataset SESHK contains 2 exam scores for each student, namely the midterm exam and final exam scores. All the empirical estimates in the rest of this paper use only the final exam score as outcome variable. It is because the final exam takes place in late June 2011 and the midterm exam is in January 2011. The survey time of SESHK is in March to June 2011. Using the final exam score ensures that the friendship (an other peer connections) reported are formed before the exam. Hence, the cause happens before the effect. Table 16 show the comparison of peer effects on final exam score and midterm exam scores.

Table 16: Peer effects on Math Score with Earlier Exam Scores

| Math Score | Studymates | | Friends | | Emotional Supporters | | Seatmates | |
|--------------------------------|------------|----------|-----------|-----------|----------------------|----------|-----------|---------|
| | Final | Midterm | Final | Midterm | Final | Midterm | Final | Midterm |
| Contextual Effects λ_x | | | | | | | | |
| Matrix Test | 0.107 * | 0.043 | 0.058 | 0.079 | 0.075 | 0.009 | -0.045 | -0.019 |
| Memory Test | 0.038 | 0.056 | 0.193 *** | 0.173 *** | 0.069 | 0.091 | 0.013 | 0.057 |
| Conscientiousness | -0.004 | 0.01 | 0.158 *** | 0.103 | 0.133 ** | 0.017 | 0.023 | 0.07 |
| Openness | -0.054 | -0.065 | -0.041 | -0.067 | -0.014 | -0.006 | -0.022 | -0.051 |
| Agreeableness | -0.016 | -0.026 | -0.068 | -0.061 | -0.05 | -0.03 | 0.051 | 0.069 |
| Neuroticism | -0.045 | -0.058 | 0.032 | -0.043 | 0.038 | -0.071 | 0.1 | 0.038 |
| Extraversion | -0.05 | -0.038 | -0.02 | -0.017 | 0.003 | -0.047 | 0.104 | 0.028 |
| Endogenous Effects λ_y | | | | | | | | |
| Selection ρ | 0.117 *** | 0.11 *** | 0.041 *** | 0.034 *** | 0.035 ** | 0.035 ** | 0.003 | 0.006 |
| Sample Size | 820 | 820 | 846 | 846 | 735 | 735 | 867 | 867 |
| Peers per Person | 4.285 | 4.285 | 4.853 | 4.853 | 3.472 | 3.472 | 5.105 | 5.105 |

Note: *** significant at 1% level; ** significant at 5% level; * significant at 10% level

Although the survey is conducted in March, it does not imply that all the friendship reported are formed in March. Students' friendship can start months before the midterm exam and last for years. Therefore it is not surprising to find some peer effects even when the outcome variable is midterm exam. However, almost all the contextual effects are gone, and the endogenous effects are smaller too. One possible explanation is that peer effect may need time to develop its effect so the earlier exam has smaller effect than a later exam. Availability of panel data in future waves of SESHK would allow deeper investigation into this hypothesis.

6.2 Alternative Peer Definition

In the original setup, studymates, friends and emotional supporters are defined using "Mutual Agreement" and seatmates are defined by "Either side reported" (denoted as "And" and "Or" in table 17). I stick to those definitions because I would like to investigate in friendship where both side acknowledges each other as friends in their subjective feeling. However, seating plan is an objective record and it is quite unlikely that a student will misreport someone sitting next to him/her. However, these while these definitions are reasonable definition of peer, it does not imply other definitions are unreasonable.

For example, one could argue that what either side claim another student as friend, they receive the peer influence already and should be counted as friends in peer effect estimation. Here in table 17,

I show the estimation of peer effects on Math score for alternative peer definitions. Almost all the sign and significance of the estimation are preserved.

Table 17: Peer effects on Math Score with Alternative Peer Definition

| Math Score | Studymates | | Friends | | Emotional Supporters | | Seatmates | |
|--------------------------------|------------|------------|-----------|-----------|----------------------|-----------|-----------|--------|
| | And | Or | And | Or | And | Or | Or | And |
| Contextual Effects λ_x | | | | | | | | |
| Matrix Test | 0.107 * | 0.21 ** | 0.058 | 0.155 | 0.075 | 0.025 | -0.045 | -0.056 |
| Memory Test | 0.038 | 0.099 | 0.193 *** | 0.224 *** | 0.069 | 0.175 *** | 0.013 | 0.006 |
| Conscientiousness | -0.004 | 0.156 | 0.158 *** | 0.226 ** | 0.133 ** | 0.109 * | 0.023 | 0.003 |
| Openness | -0.054 | 0.102 | -0.041 | 0.032 | -0.014 | -0.117 | -0.022 | 0.067 |
| Agreeableness | -0.016 | -0.127 | -0.068 | -0.107 | -0.05 | -0.174 * | 0.051 | 0.016 |
| Neuroticism | -0.045 | -0.1 | 0.032 | 0.031 | 0.038 | 0.045 | 0.1 | 0.018 |
| Extraversion | -0.05 | -0.288 *** | -0.02 | -0.177 * | 0.003 | -0.058 | 0.104 | 0.01 |
| Endogenous Effects λ_y | | | | | | | | |
| Selection ρ | 0.117 *** | 0.109 *** | 0.041 *** | 0.027 *** | 0.035 ** | 0.035 *** | 0.003 | -0.004 |
| Sample Size | 820 | 868 | 846 | 868 | 735 | 866 | 867 | 774 |
| Peers per Person | 4.285 | 12.961 | 4.853 | 11.947 | 3.472 | 9.679 | 5.105 | 1.793 |

Note: *** significant at 1% level; ** significant at 5% level; * significant at 10% level

Notice that the “And” and “Or” definition is not exhausting all the possible definition of peer. For example one may think that “Helping others in schoolwork” may have different effects compare to “Being help by others in schoolwork”. Or one may think that friends of friends can have direct peer influence too and should be included in the model. The possibilities are infinite. And this table is by no means implying the estimation in this paper is insensitive to all peer definitions. By changing the peer definition potentially we are changing what kind of peer the econometrician is referring to and I do expect that there are some other definitions of friends which yield different peer effects. Here, I only pick 2 important way to define a peer (and the result are robust to them). Further investigation is needed to see how peer effects are different in other definitions.

6.3 Different Definition of Hobby

The usage of the number of common hobbies as instrument is a key element in the empirical analysis of this paper. Employing a more strict definition of common hobby can yield more convincing instrument, although the variation of the instrument will be reduced. The common hobby variable is constructed by data of students claiming themselves being involved in which hobbies. There are 120 hobbies (as shown in appendix B) including sports, musical instruments and others. As the dataset also provide information about when the students start to learn the musical instrument they play, it

is possible to construct a stricter definition of hobby where I only include musical instruments as a hobby and only if they start the hobby before they enter into the secondary school.

Most of the major results still hold under the new definition of common hobby.

Table 18: Peer effects on Math Score with Alternative Instrument

| Math Score | Stuymates | | Friends | | Emotional Supporters | |
|--------------------------------|-----------|-----------|-----------|-----------|----------------------|----------|
| | Original | Strict | Original | Strict | Original | Strict |
| Contextual Effects λ_x | | | | | | |
| Matrix Test | 0.107 * | 0.098 * | 0.058 | 0.058 | 0.075 | 0.077 |
| Memory Test | 0.038 | 0.038 | 0.193 *** | 0.197 *** | 0.069 | 0.072 |
| Conscientiousness | -0.004 | 0 | 0.158 *** | 0.164 *** | 0.133 ** | 0.136 ** |
| Openness | -0.054 | -0.05 | -0.041 | -0.046 | -0.014 | -0.014 |
| Agreeableness | -0.016 | -0.017 | -0.068 | -0.072 | -0.05 | -0.048 |
| Neuroticism | -0.045 | -0.046 | 0.032 | 0.031 | 0.038 | 0.036 |
| Extraversion | -0.05 | -0.053 | -0.02 | -0.023 | 0.003 | 0.002 |
| Endogenous Effects λ_y | | | | | | |
| Selection ρ | 0.117 *** | 0.116 *** | 0.041 *** | 0.038 *** | 0.035 ** | 0.033 ** |
| Sample Size | | | | | | |
| Peers per Person | 820 | 820 | 846 | 846 | 735 | 735 |
| | 4.285 | 4.285 | 4.853 | 4.853 | 3.472 | 3.472 |

Note: *** significant at 1% level; ** significant at 5% level; * significant at 10% level

6.4 Mean Characteristics Filler

In the original setup, all the students who have no peers are dropped. The model cannot estimate peer effects for those people who has no peer. However, by assuming they are not reporting instead of having no peers, and making the assumption that they are receiving a sample mean value of social influence, I can include them into the estimation. The results shows that filling in the sample mean value for social influence has no substantial effect on the estimation of contextual and endogenous peer effects.

Table 19: Peer effects for different Subjects (Studymates)

| Studymates | Math | | English | | Visual Art | |
|--------------------------------|-----------|----------|-----------|-----------|------------|----------|
| | Drop | Meanfill | Drop | Meanfill | Drop | Meanfill |
| Contextual Effect λ_x | | | | | | |
| Matrix Test | 0.107 * | 0.103 * | 0.116 * | 0.116 * | 0.056 | 0.055 |
| Memory Test | 0.038 | 0.035 | 0.013 | 0.013 | 0.032 | 0.03 |
| Conscientiousness | -0.004 | -0.004 | 0.101 | 0.09 | -0.01 | -0.01 |
| Openness | -0.054 | -0.054 | -0.066 | -0.066 | -0.039 | -0.039 |
| Agreeableness | -0.016 | -0.01 | -0.012 | -0.012 | 0.026 | 0.026 |
| Neuroticism | -0.045 | -0.045 | 0.005 | 0.045 | 0.004 | 0.004 |
| Extraversion | -0.05 | -0.05 | 0.019 | 0.019 | -0.028 | -0.028 |
| Endogenous Effects λ_y | 0.178 *** | 0.178*** | 0.127 *** | 0.126 *** | 0.096 ** | 0.096** |
| Selection Effect ρ | 0.117 *** | 0.117*** | 0.132 *** | 0.132 *** | 0.107 *** | 0.107*** |
| Sample Size | 820 | 873 | 820 | 873 | 820 | 873 |
| Peers per Person | 4.285 | 4.285 | 4.285 | 4.285 | 4.285 | 4.285 |

Note: *** significant at 1% level; ** significant at 5% level; * significant at 10% level

6.5 Sum up

In this section I explored several alternative specifications. The estimations under these specifications are either similar (section 6.2, 6.3, and 6.4) to the main results shown in section 5 or they are different but in a reasonable manner (section 6.1).

7 Empirical Discussions

In previous sections I apply the model described in section 2 and estimate the endogenous and contextual effects on exam scores of different kinds of peers. In this section, I summarize the important implications of the empirical findings.

7.1 Overestimation of endogenous peer effects

The first important implication from the results is, for friends, studymates and emotional supporters, endogenous peer effects are positive but overestimated if the peer selection problem is not taken into

account. Endogenously formed peers are not a case specific problem here. Unlike seating assignment, the formation of friends, studymates or emotional supporters often involve individual choices and exogenous network formation is not a reasonable assumption. It is important to understand how students are selected into peer connections in order to estimate the size of peer effects correctly.

For seatmates (or other proximity based peer like college roommates), this problem is relatively less important because it is usually easier to conduct randomize experiment for them. However, in situations where the econometricians do not know exactly the seat assignment rule, it is a good practice to allow for selection to be on the safe side. Although no significant selection effect is found in this paper, it can just be case specific. Teacher are not endogenously assigning seats in my case does not imply that it is a universal rule.

7.2 Small Peer Effect for Seatmates

Second important implication is seatmates shows relatively small peer effects (statistically insignificant for some subjects). Notice that the effect is still positive so this paper is not arguing against the conventional wisdom of students could affect their seatmates in class. The evidence only shows that quality of friends and studymates has bigger impact on students' learning than the quality of students seating next to them. This result does not immediately imply a choice of policies because that would require the knowledge of what are the costs of implementing them. It is reasonable to imagine that seating plan rearrangement is less costly than engaging students into designed study groups. Therefore many teachers are still doing that despite of the small effect.

7.3 Contextual Effects

This paper also compares the contextual effects of different kinds of peers. While endogenous effect captures the behavior spillover between students, contextual effects captures how the quality of peers, measured by observable characteristics, affects a student's learning. The sign and magnitude of contextual effects are found to be subject and peer type specific. For example, studymates with high matrix test score has positive contextual effect on math score, which is not a very surprising result as one would expect that smart peers should help students to learn math. The important part is that similar effect is not found on friends or emotional supporters. Similarly, conscientious friends are found to have positive effect on Math score, but conscientious studymates do not have such effect. In some cases the signs of contextual effect are the same for different peer types, but the magnitudes are different. For example, extravert peers are negatively affecting a student's conduct grade, but friends' effect is stronger than that of studymates.

These differences show a potential problem of proxying one peer type by another. The validity of this strategy depends on the research question. Although the endogenous peer effect for different peer types has different sizes, their signs are almost the same. If the econometrician is only interested in the rough sign of endogenous peer effect, it could be reasonable to say that peer effects estimated in Sacerdote (2001), which is peer effects for roommates, can imply similar effects for friendship because roommates are often friends. However, as shown in this paper, the contextual effects can be quite different for different peer types. So if someone would like to investigate in peer effect from a particular channel, distinguishing different kinds of peer would be important.

7.4 Other implications

Apart from those main findings on peer effects, this paper also explores some other interesting empirical findings.

Firstly, selection effect is found to be strongest for studymates. As mentioned before, the (lack of) selection effect in seat assignment could be case specific because it depends on the discretion of individual teachers. However, as friends, emotional supporters and studymates are chosen by students, the size of selection effect can hint the nature of selection in these different peer types. Evidence shows that studymates are found to be more endogenously formed. Also, the selection problem is more serious when the outcome variable is Math score but less significant when it is Physical Education score. It is more important to take into account selection effect in these situations because peer effects are more likely to be overestimated in exogenous network formation setting.

Secondly, the peer formation parameters estimated hint important economic implications. The focus of this paper is to estimate peer effects correctly by controlling for peer selection, but the peer selection itself can yield important policy concern. For example, conscientious or extravert students are more likely to get more studymates, but they have no preference to whether their studymates have similar level of conscientiousness to them. On the other hand, smart students are not getting more studymates, but students like to studymates with similar level of smartness. This shows that studymates are self-selected so it is less of a concern if someone worries about students not finding studymates of similar smartness. However, if a school has found a way to boost the benefit student gain from studying together, that school may need to concern more about students who are not conscientious. It is because they are less likely to get studymates, in addition to the negative effect caused by the lack of conscientiousness.

Table 20: Simple Regression between Different Kinds of Peer

| | Stuymates | Friends | Emotional Supporters | Seatmates |
|----------------------|-----------|---------|----------------------|-----------|
| Stuymates | 1.000 | 0.489 | 0.644 | 0.188 |
| Friends | 0.569 | 1.000 | 0.731 | 0.161 |
| Emotional Supporters | 0.472 | 0.460 | 1.000 | 0.114 |
| Seatmates | 0.237 | 0.173 | 0.196 | 1.000 |

Table 21: Correlation between Different Kinds of Peer

| | Stuymates | Friends | Emotional Supporters | Seatmates |
|----------------------|-----------|---------|----------------------|-----------|
| Stuymates | 1.000 | 0.528 | 0.579 | 0.166 |
| Friends | 0.528 | 1.000 | 0.550 | 0.211 |
| Emotional Supporters | 0.579 | 0.550 | 1.000 | 0.150 |
| Seatmates | 0.166 | 0.211 | 0.150 | 1.000 |

8 Counterfactual Analysis

With the estimates of β , λ_x , λ_y , counterfactual can be constructed according to the score formation equation (equation 5). In this section, I will be comparing the following 3 situations in terms of mean value of Y .

Case 1 (Match): Students can match their studymates by mutual agreement.

Case 2 (Random): An hypothetical situation where students are having randomly assigned studymates. The mean number of connections for each student is restricted to be the same as that in Case 1. Hence, students are on average not getting more peers and this facilitates comparison between two cases.

Case 3 (No Peer): An hypothetical situation where students are not getting any social interactions.

8.1 Studymates and friends

Consider the endogenous network model on Math score with studymate as peer. Using the estimate of β , λ_x , λ_y in table 23, the case 1 is constructed from the fitted value of math score. Case 2 is

constructed by randomly assign studymates to students and restricting the number of studymates per student to be 4.285. The average math score is calculated by this hypothetically formed network. Case 3 is constructed by $S\beta$, which calculates the math score considering own effects only.

Table 22: Average Y under different counterfactuals

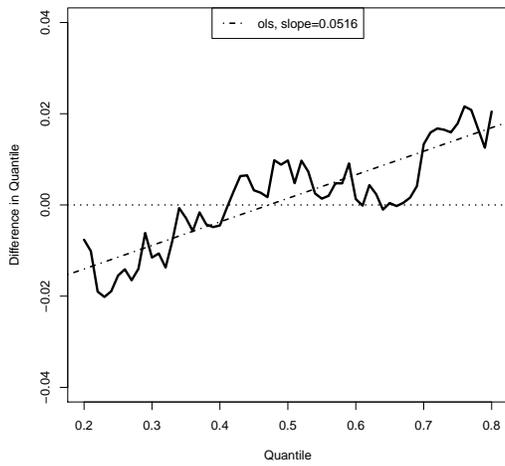
| | Mean of Y | | | |
|--------|-------------|---------|----------------------|-----------|
| | Studymates | Friends | Emotional Supporters | Seatmates |
| Case 1 | 0.004 | 0.000 | 0.000 | 0.000 |
| Case 2 | -0.002 | 0.004 | 0.002 | 0.000 |
| Case 3 | 0.000 | 0.000 | 0.000 | 0.000 |

The mean of Y under different cases are shown in table 22. Y is standardized to mean 0, and it shows that the mean of Y stays more or less the same under 3 cases. Suppose the society objective is to produce as much Y as possible, these results indicate that the network formed by students matching themselves are not significantly better than the network assigned by random. This by no means implies that students are not optimizing. Students consider several characteristics in their peer formation process. The desire to get peers with particular characteristics can be related to exam score, but also other psychological considerations. For example, students may choose to have studymates with more common hobbies. This can make them happy but it is not necessary conducive to learning. The small difference between case 1 and case 2 could merely implies that students are considering many other motives other than academic results when they pick peers.

Given that student chosen peers are not producing much more Y than random peers on average, a natural next step is to examine the change in average Y in each quantile. Figure 3a shows that good students are positively affected when they are allowed to choose studymates rather than randomizing. Figure 3b shows that the inequality is even bigger when comparing to the no peer allowed situation. This indicates that peer effects and social interactions are favoring good students. The inequality between good and bad students is bigger in situation with randomly assigned peers than no peers allowed. The inequality is even bigger when they are allowed to choose their peers. Very similar patterns are found in frienship.

Figure 3: Differences in Quantile (Studymates)

(a) Average Y in “Match” - Average Y in “Random”



(b) Average Y in “Random” - Average Y in “No Peer”

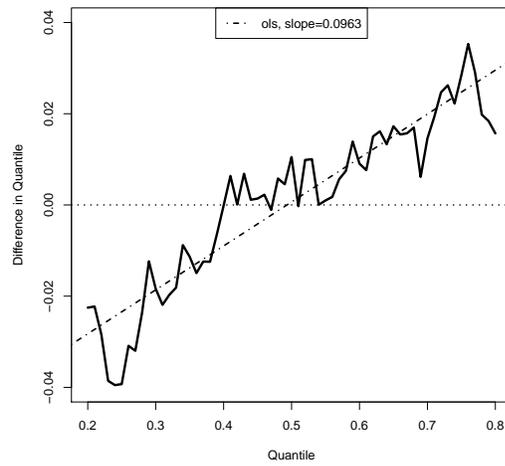
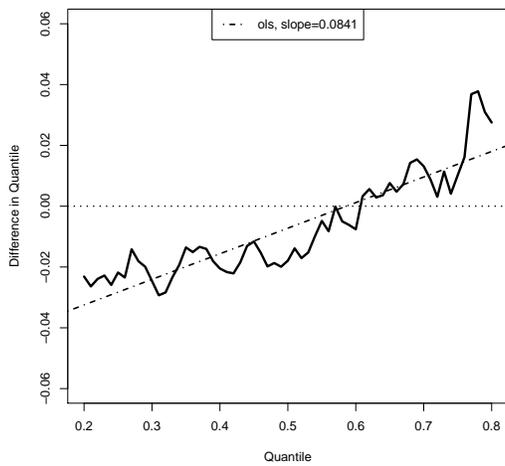
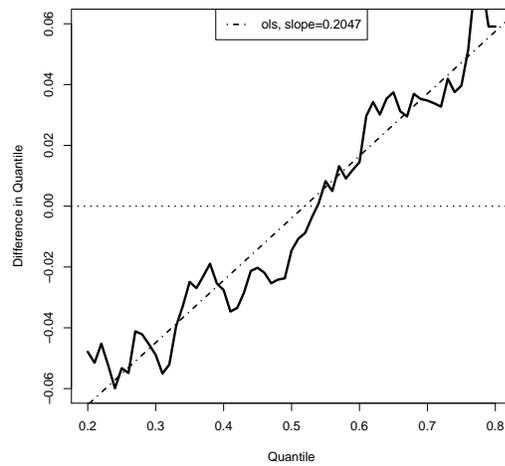


Figure 4: Differences in Quantile (Friends)

(a) Average Y in “Match” - Average Y in “Random”



(b) Average Y in “Random” - Average Y in “No Peer”



8.2 Emotional Supporters

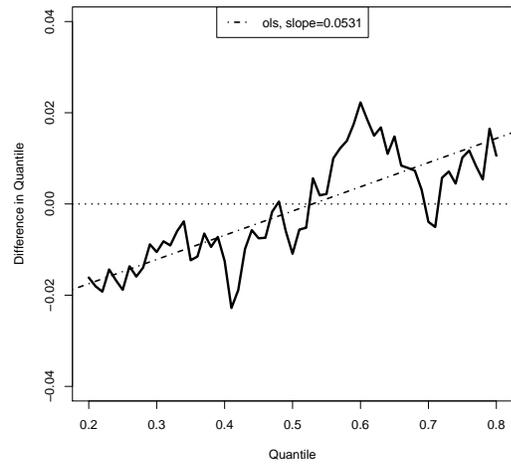
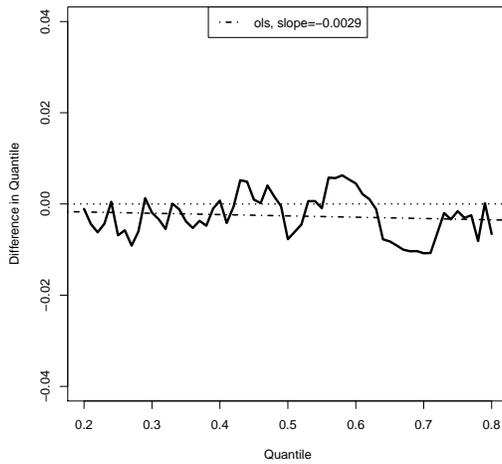
The same exercise can be repeated using emotional supporters and Math score. The results are different from studymates and friends as case 1 does not show more inequality than case 2 (as shown

in figure 5a). However, the inequality between good students and bad students are still bigger than in the situation of case 3, where no peer is allowed.

Figure 5: Differences in Quantile (Emotional Supporters)

(a) Average Y in “Match” - Average Y in “Random”

(b) Average Y in “Random” - Average Y in “No Peer”

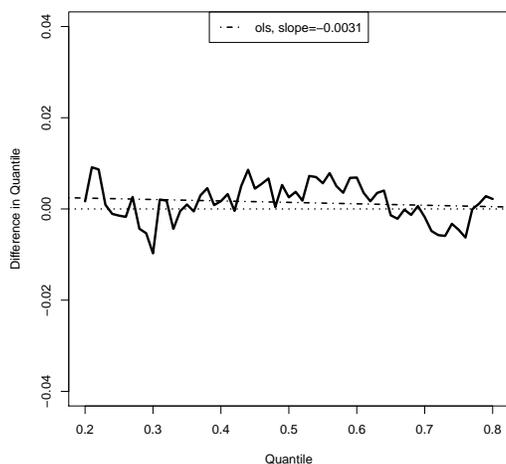


8.3 Seatmates

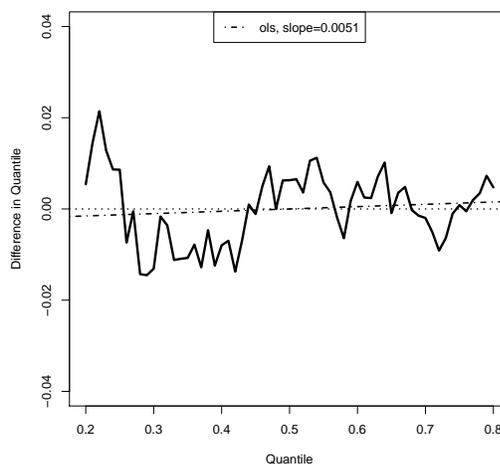
For seatmates, the mean of Y in all 3 cases considered above are statistically equivalent. So teacher assigned seating arrangement is not increasing the exam scores of students compare to random assignment. Figure 6 shows the difference in quantile for comparison of inequality. Students are generally not allowed choose their seats, therefore case 1 should be interpreted as “allowing the teachers to assign seats”. The difference in quantile curves are almost flat in figure 6, which indicates that seating arrangement has no effects on student inequality.

Figure 6: Differences in Quantile (Seatmates)

(a) Average Y in “Match” - Average Y in “Random”



(b) Average Y in “Match” - Average Y in “No Peer”



8.4 Social Optimal Peer Arrangement

Apart from the three cases mentioned before, one can imagine that there could be a social optimal peer arrangement, which maximizes the total Y produced according to the estimates of β , λ_x , λ_y . The social optimal peer arrangement intuitively could produce more Y than all the cases mentioned above. These analysis could hint whether it is possible for the students to benefit from rearranging their study groups or seat assignments and how does it affect inequality between students. The counterfactual analysis would more fruitful if the score production model allows for more flexibility, for example interaction between personalities and mental abilities, diminishing returns of abilities ... etc. This is not possible due to the relative small sample size in the first wave of SESHK. These limitations will be addressed in future research.

9 Conclusion and Future Work

This paper compares and explores peer effects of four different kinds of peers. Using unique survey data “Secondary Education Survey in Hong Kong” (SESHK) and an econometric strategy with explicitly modeled selection process, I estimate both the endogenous and contextual effects on exam scores. Peer are formed by mutual agreement and the model allows for important features of peer formation such as preference to certain good peer characteristics as well as preference to peer similarity. Selection provides source of identification but it is important to take into account this effect accordingly or the peer effect could be overestimated for some peer types. Empirical evidences show that for friends, studymates and emotional supporters, endogenous peer effects are positive but they are overestimated if selection is not taken into account. The size and direction of contextual peer effects are subject and peer type specific.

While SESHK is providing detail student peer groups information for this study, caveat of this paper also comes from the limitation of this dataset (no panel data and the lack of family background information). Future study can be enhanced when subsequent waves of SESHK data are available. Also, the econometric model can be extended to include multiple endogenously formed peer types. This can facilitates analysis related to the relationship between the formation of different peers (as shown in table 20 and 21, they are highly correlated with each other). This extension also allows for the investigation of relative importance of different peer types.

The correct estimation of peer effects and own effects opens up the possibilities to perform more sophisticated counterfactual analysis. Apart from the social optimal peer arrangement mentioned in section 8, one may simulate a class segregation or desegregation and see how students are affected by the change in policy. Also, the effect of single-gender classes can also be simulated using the same technique. These policies will be investigated under the same framework in future research.

To conclude, the comparison of peer effects is more than just there exists peer effects or not. Different peer types can yield different implications and they are not always substitutable. Understanding the formation of each types of peer is important in the correct estimation of peer effects.

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Appendix

Appendix A: Full Table of All Estimates

Table 23: Full Table of Peer Effects Estimation for Math Exam Score

| Math Score | Studyates | | Friends | | Emotional Supporters | | Seatmates | |
|--------------------------------|------------|-----------|-----------|------------|----------------------|------------|------------|------------|
| | Exo | Endo | Exo | Endo | Exo | Endo | Exo | Endo |
| Own Effects β | | | | | | | | |
| Matrix Test | 0.28 *** | 0.268 *** | 0.273 *** | 0.27 *** | 0.305 *** | 0.301 *** | 0.297 *** | 0.297 *** |
| Memory Test | 0.087 *** | 0.088 *** | 0.072 ** | 0.074 ** | 0.076 ** | 0.076 ** | 0.103 *** | 0.104 *** |
| Conscientiousness | 0.239 *** | 0.242 *** | 0.219 *** | 0.221 *** | 0.256 *** | 0.257 *** | 0.225 *** | 0.224 *** |
| Openness | -0.062 * | -0.06* | -0.073 ** | -0.073 ** | -0.065 * | -0.065 * | -0.071 ** | -0.071 * |
| Agreeableness | -0.098 *** | -0.1 *** | -0.1 *** | -0.099 *** | -0.119 *** | -0.118 *** | -0.107 *** | -0.106 *** |
| Neuroticism | 0.009 | 0 | 0.002 | -0.001 | -0.01 | -0.009 | -0.005 | -0.004 |
| Extraversion | -0.059 * | -0.055 | -0.055 | -0.053 | -0.075 ** | -0.074 * | -0.07 ** | -0.071 * |
| Male | 0.084 | 0.069 | 0.085 | 0.084 | 0.033 | 0.035 | 0.119 * | 0.124 * |
| Elder Siblings | 0.012 | 0.013 | 0.012 | 0.012 | 0.011 | 0.011 | 0.009 | 0.009 |
| Younger Siblings | 0.001 | 0.001 | -0.001 | 0.002 | 0.001 | 0.001 | 0.001 | -0.001 |
| Music Hobby | 0.035 | 0.04 | 0.031 | 0.037 | -0.006 | -0.01 | 0.06 | 0.06 |
| Sports Hobby | -0.084 | -0.074 | -0.099 | -0.095 | -0.08 | -0.079 | -0.095 | -0.094 |
| Youth Movement | 0.028 | 0.012 | -0.002 | -0.007 | 0.022 | 0.022 | 0.008 | 0.008 |
| Contextual Effects λ_x | | | | | | | | |
| Matrix Test | 0.061 | 0.107 * | 0.049 | 0.058 | 0.072 | 0.075 | -0.042 | -0.045 |
| Memory Test | 0.068 | 0.038 | 0.2 *** | 0.193 *** | 0.072 | 0.069 | 0.013 | 0.013 |
| Conscientiousness | 0.03 | -0.004 | 0.166 *** | 0.158 *** | 0.138 ** | 0.133 ** | 0.023 | 0.023 |
| Openness | -0.059 | -0.054 | -0.055 | -0.041 | -0.012 | -0.014 | -0.018 | -0.022 |
| Agreeableness | -0.031 | -0.016 | -0.066 | -0.068 | -0.04 | -0.05 | 0.048 | 0.051 |
| Neuroticism | -0.046 | -0.045 | 0.039 | 0.032 | 0.041 | 0.038 | 0.102 | 0.1 |
| Extraversion | -0.036 | -0.05 | -0.006 | -0.02 | 0.012 | 0.003 | 0.108 | 0.104 |

| | | | | | | | | |
|--------------------------------|-----------|------------|-----------|------------|-----------|-----------|---------|------------|
| Endogenous Effects λ_y | 0.197 *** | 0.178 *** | 0.226 *** | 0.216 *** | 0.117 *** | 0.115 *** | 0.094 * | 0.093 * |
| Selection ρ | | 0.117 *** | | 0.041 *** | | 0.035 ** | | 0.003 |
| Peer Formation γ | | | | | | | | |
| Intercept | | -0.819 *** | | -0.721 *** | | -0.88 *** | | -0.919 *** |
| Matrix Test | | | | | | | | |
| level | | 0.01 | | -0.008 | | 0.007 | | |
| difference | | -0.005 * | | -0.004 | | 0 | | |
| Memory Test | | | | | | | | |
| level | | 0.019 | | -0.002 | | -0.006 | | |
| difference | | -0.005 * | | -0.002 | | 0.001 | | |
| Conscientiousness | | | | | | | | |
| level | | 0.072 *** | | -0.005 | | 0.03 * | | |
| difference | | 0.001 | | -0.003 | | 0.002 | | |
| Openness | | | | | | | | |
| level | | -0.023 | | -0.001 | | -0.004 | | |
| difference | | -0.001 | | 0 | | -0.003 | | |
| Agreeableness | | | | | | | | |
| level | | 0.032 ** | | 0.031 *** | | 0.056 *** | | |
| difference | | 0.002 | | 0.003 | | 0.002 | | |
| Neuroticism | | | | | | | | |
| level | | 0.052 *** | | 0.007 | | 0.079 *** | | |
| difference | | 0 | | -0.005 | | -0.006 | | |
| Extraversion | | | | | | | | |
| level | | 0.032 ** | | 0.033 *** | | 0.086 *** | | |
| difference | | -0.002 | | -0.009 *** | | -0.009 ** | | |
| BMI | | | | | | | | |
| level | | -0.012 | | -0.01 | | -0.008 | | |
| difference | | -0.003 | | -0.002 | | -0.004 | | |
| Gender | | | | | | | | |
| level | | 0.006 | | 0.023 | | -0.029 | | 0.042 ** |
| difference | | -0.466 *** | | -0.803 *** | | -0.59 *** | | -0.053 *** |
| Elder Siblings | | 0.008 | | 0.039 *** | | 0.031 * | | |
| Younger Siblings | | -0.039 * | | 0.003 | | 0.009 | | |
| Music Hobby | | | | | | | | |
| level | | -0.022 | | -0.063 ** | | -0.022 | | |
| difference | | 0.014 | | 0.002 | | -0.021 | | |
| Sports Hobby | | | | | | | | |
| level | | -0.029 | | -0.044 | | -0.064 * | | |
| difference | | -0.022 | | -0.012 | | 0.014 | | |
| Youth Movement | | | | | | | | |
| level | | -0.017 | | -0.065 *** | | -0.013 | | |
| difference | | -0.019 | | -0.033 * | | 0.008 | | |
| Common Hobbies | | 0.109 *** | | 0.158 *** | | 0.146 *** | | |
| Height | | | | | | | | |
| level | | | | | | | | -0.012 |
| difference | | | | | | | | -0.016 *** |
| Sample Size | 820 | 820 | 846 | 846 | 735 | 735 | 867 | 867 |
| Peers per Person | 4.285 | 4.285 | 4.853 | 4.853 | 3.472 | 3.472 | 5.105 | 5.105 |
| R^2 | 0.191 | 0.182 | 0.217 | 0.212 | 0.194 | 0.192 | 0.163 | 0.163 |

Note: *** significant at 1% level; ** significant at 5% level; * significant at 10% level

Table 24: Full Table of Peer Effects Estimation for English Exam Score

| English Score | | | | | | | | |
|--------------------------------|-------------|------------|------------|------------|----------------------|------------|------------|------------|
| | Study mates | | Friends | | Emotional Supporters | | Seatmates | |
| | Exo | Endo | Exo | Endo | Exo | Endo | Exo | Endo |
| Own Effects β | | | | | | | | |
| Matrix Test | 0.145 *** | 0.132 *** | 0.146 *** | 0.137 *** | 0.151 *** | 0.147 *** | 0.159 *** | 0.161 *** |
| Memory Test | 0.056 * | 0.061 * | 0.041 | 0.043 | 0.048 | 0.049 | 0.062 * | 0.06 * |
| Conscientiousness | 0.33 *** | 0.34 *** | 0.289 *** | 0.297 *** | 0.322 *** | 0.323 *** | 0.32 *** | 0.313 *** |
| Openness | -0.078 ** | -0.079 ** | -0.085 *** | -0.081 ** | -0.061 | -0.058 | -0.084 *** | -0.085 ** |
| Agreeableness | -0.088 *** | -0.09 *** | -0.088 *** | -0.089 *** | -0.115 *** | -0.116 *** | -0.092 *** | -0.09 *** |
| Neuroticism | 0.085 ** | 0.08 ** | 0.069 ** | 0.067 * | 0.072 * | 0.072 * | 0.067 * | 0.067 * |
| Extraversion | -0.049 | -0.042 | -0.045 | -0.041 | -0.057 | -0.058 | -0.061 * | -0.062 * |
| Male | -0.383 *** | -0.406 *** | -0.283 *** | -0.299 *** | -0.397 *** | -0.405 *** | -0.409 *** | -0.411 *** |
| Elder Siblings | 0.006 | 0.006 | 0.006 | 0.007 | 0.005 | 0.006 | 0.006 | 0.006 |
| Younger Siblings | -0.011 | -0.01 | -0.013 | -0.012 | -0.012 | -0.011 | -0.005 | -0.005 |
| Music Hobby | 0.105 | 0.105 | 0.097 | 0.096 | 0.082 | 0.074 | 0.114 | 0.115 |
| Sports Hobby | -0.061 | -0.048 | -0.044 | -0.042 | -0.031 | -0.023 | -0.037 | -0.04 |
| Youth Movement | -0.03 | -0.051 | -0.041 | -0.054 | -0.044 | -0.053 | -0.023 | -0.025 |
| Contextual Effects λ_x | | | | | | | | |
| Matrix Test | 0.071 | 0.116 * | 0.018 | 0.034 | 0.015 | 0.021 | -0.016 | -0.018 |
| Memory Test | 0.055 | 0.013 | 0.107 ** | 0.095 * | 0.053 | 0.051 | 0.005 | 0.008 |
| Conscientiousness | 0.128 * | 0.101 | 0.181 *** | 0.181 *** | 0.116 * | 0.11 * | 0.024 | 0.022 |
| Openness | -0.069 | -0.066 | -0.068 | -0.049 | 0.011 | 0.015 | -0.044 | -0.051 |
| Agreeableness | -0.031 | -0.012 | -0.01 | -0.01 | -0.084 | -0.101 | 0.012 | 0.014 |
| Neuroticism | 0 | 0.005 | 0.082 | 0.073 | 0.003 | -0.003 | -0.025 | -0.026 |
| Extraversion | 0.044 | 0.019 | 0.009 | -0.02 | 0.024 | 0.006 | 0.089 | 0.088 |
| Endogenous Effects λ_y | 0.157 *** | 0.127 *** | 0.264 *** | 0.238 *** | 0.07 * | 0.059* | 0.073 | 0.069 |
| Selection ρ | | 0.132 *** | | 0.071 *** | | 0.066 *** | | 0.017 |
| Peer Formation γ | | | | | | | | |
| Intercept | | -0.827 *** | | -0.724 *** | | -0.889 *** | | -0.918 *** |
| Matrix Test | | | | | | | | |
| level | | 0.009 | | -0.008 | | 0.006 | | |
| difference | | -0.004* | | -0.004 | | 0 | | |
| Memory Test | | | | | | | | |
| level | | 0.02 | | -0.002 | | -0.005 | | |
| difference | | -0.005 | | -0.003 | | 0.001 | | |
| Conscientiousness | | | | | | | | |
| level | | 0.074 *** | | -0.005 | | 0.032 * | | |
| difference | | 0.002 | | -0.002 | | 0.002 | | |
| Openness | | | | | | | | |
| level | | -0.026 * | | -0.001 | | -0.004 | | |
| difference | | -0.001 | | 0 | | -0.003 | | |
| Agreeableness | | | | | | | | |
| level | | 0.034 *** | | 0.032 *** | | 0.057 *** | | |
| difference | | 0.001 | | 0.002 | | 0.002 | | |
| Neuroticism | | | | | | | | |
| level | | 0.051 *** | | 0.005 | | 0.078 *** | | |
| difference | | -0.001 | | -0.005 | | -0.007 * | | |
| Extraversion | | | | | | | | |
| level | | 0.033 ** | | 0.032 *** | | 0.086 *** | | |
| difference | | -0.002 | | -0.01 *** | | -0.009 ** | | |
| BMI | | | | | | | | |
| level | | -0.01 | | -0.01 | | -0.007 | | |
| difference | | -0.004 * | | -0.002 | | -0.005 | | |
| Gender | | | | | | | | |

| | | | | | | | | |
|------------------|-------|------------|-------|------------|-------|------------|-------|------------|
| level | | 0.007 | | 0.024 | | -0.028 | | 0.041 * |
| difference | | -0.467 *** | | -0.805 *** | | -0.591 *** | | -0.054 *** |
| Elder Siblings | | 0.016 | | 0.043 *** | | 0.033 ** | | |
| Younger Siblings | | -0.025 | | 0.009 | | 0.02 | | |
| Music Hobby | | | | | | | | |
| level | | -0.022 | | -0.061 ** | | -0.021 | | |
| difference | | 0.014 | | 0.002 | | -0.018 | | |
| Sports Hobby | | | | | | | | |
| level | | -0.029 | | -0.045 | | -0.062 * | | |
| difference | | -0.022 | | -0.012 | | 0.015 | | |
| Youth Movement | | | | | | | | |
| level | | -0.021 | | -0.065 *** | | -0.014 | | |
| difference | | -0.016 | | -0.034 ** | | 0.009 | | |
| Common Hobbies | | 0.11 *** | | 0.158 *** | | 0.147 *** | | |
| Height | | | | | | | | |
| level | | | | | | | | -0.01 |
| difference | | | | | | | | -0.016 *** |
| Sample Size | 820 | 820 | 846 | 846 | 735 | 735 | 867 | 867 |
| Peers per Person | 4.285 | 4.285 | 4.853 | 4.853 | 3.472 | 3.472 | 5.105 | 5.105 |
| R^2 | 0.186 | 0.179 | 0.211 | 0.204 | 0.167 | 0.166 | 0.16 | 0.158 |

Note: *** significant at 1% level; ** significant at 5% level; * significant at 10% level

Table 25: Full Table of Peer Effects Estimation for Visual Art Score

| Visual Art Score | | | | | | | | |
|--------------------------------|------------|------------|------------|------------|----------------------|------------|------------|------------|
| | Studyates | | Friends | | Emotional Supporters | | Seatmates | |
| | Exo | Endo | Exo | Endo | Exo | Endo | Exo | Endo |
| Own Effects β | | | | | | | | |
| Matrix Test | 0.037 | 0.028 | 0.041 | 0.037 | 0.036 | 0.036 | 0.048 | 0.049 |
| Memory Test | 0.038 | 0.04 | 0.035 | 0.037 | 0.015 | 0.014 | 0.033 | 0.033 |
| Conscientiousness | 0.207 *** | 0.208 *** | 0.192 *** | 0.195 *** | 0.205 *** | 0.203 *** | 0.203 *** | 0.197 *** |
| Openness | 0.134 *** | 0.134 *** | 0.121 *** | 0.122 *** | 0.13 *** | 0.133 *** | 0.133 *** | 0.131 *** |
| Agreeableness | -0.073 ** | -0.074 ** | -0.055 * | -0.056 * | -0.076 ** | -0.078 ** | -0.067 ** | -0.067 ** |
| Neuroticism | 0.071 ** | 0.065 * | 0.083 *** | 0.082 *** | 0.073 ** | 0.07 * | 0.069 ** | 0.067 * |
| Extraversion | -0.129 *** | -0.127 *** | -0.127 *** | -0.124 *** | -0.132 *** | -0.133 *** | -0.15 *** | -0.152 *** |
| Male | -0.732 *** | -0.748 *** | -0.704 *** | -0.711 *** | -0.735 *** | -0.74 *** | -0.818 *** | -0.816 *** |
| Elder Siblings | 0.07 | 0.071 | 0.081 | 0.081 | 0.073 | 0.075 | 0.067 | 0.065 |
| Younger Siblings | -0.015 | -0.016 | -0.012 | -0.012 | -0.013 | 0.011 | 0 | -0.001 |
| Music Hobby | 0.023 | 0.031 | 0.018 | 0.023 | 0.01 | 0.011 | 0.016 | 0.019 |
| Sports Hobby | -0.139 ** | -0.134 ** | -0.125 * | -0.124 * | -0.11 | -0.105 | -0.106 * | -0.108 |
| Youth Movement | 0.021 | 0.011 | 0.018 | 0.012 | 0.013 | 0.013 | 0.025 | 0.025 |
| Contextual Effects λ_x | | | | | | | | |
| Matrix Test | 0.025 | 0.056 | 0.071 | 0.076 | 0.045 | 0.047 | 0.055 | 0.052 |
| Memory Test | 0.059 | 0.032 | 0.053 | 0.05 | 0.06 | 0.057 | 0.029 | 0.034 |
| Conscientiousness | 0.016 | -0.01 | 0.087 | 0.079 | 0.108 ** | 0.101 * | 0.007 | 0.009 |
| Openness | -0.046 | -0.039 | 0.029 | 0.045 | 0.029 | 0.027 | 0.14 ** | 0.131 * |
| Agreeableness | 0.014 | 0.026 | -0.015 | -0.016 | -0.046 | -0.052 | -0.019 | -0.014 |
| Neuroticism | 0.001 | 0.004 | 0.037 | 0.031 | 0.036 | 0.032 | 0.009 | 0.013 |
| Extraversion | -0.012 | -0.028 | -0.053 | -0.07 | -0.085 | -0.087 | -0.054 | -0.057 |
| Endogenous Effects λ_y | 0.108 *** | 0.096 ** | 0.14 *** | 0.129 *** | 0.079 * | 0.08 * | -0.035 | -0.039 |
| Selection ρ | | 0.107 *** | | 0.039 *** | | 0.047 *** | | 0.015 |
| Peer Formation γ | | | | | | | | |
| Intercept | | -0.818 *** | | -0.722 *** | | -0.885 *** | | -0.919 *** |
| Matrix Test | | | | | | | | |
| level | | 0.01 | | -0.008 | | 0.005 | | |
| difference | | -0.003* | | -0.004 | | 0.001 | | |
| Memory Test | | | | | | | | |
| level | | 0.019 | | -0.002 | | -0.005 | | |
| difference | | -0.005 * | | -0.002 | | 0.001 | | |
| Conscientiousness | | | | | | | | |
| level | | 0.075 *** | | -0.005 | | 0.03 * | | |
| difference | | 0.002 | | -0.003 | | 0.002 | | |
| Openness | | | | | | | | |
| level | | -0.025 * | | 0 | | -0.004 | | |
| difference | | 0 | | 0 | | -0.003 | | |
| Agreeableness | | | | | | | | |
| level | | 0.033 *** | | 0.032 *** | | 0.058 *** | | |
| difference | | 0.002 | | 0.003 | | 0.002 | | |
| Neuroticism | | | | | | | | |
| level | | 0.053 *** | | 0.006 | | 0.079 *** | | |
| difference | | 0 | | -0.005 | | -0.006 | | |
| Extraversion | | | | | | | | |
| level | | 0.033 *** | | 0.033 *** | | 0.087 *** | | |
| difference | | -0.002 | | -0.009 *** | | -0.008 ** | | |
| BMI | | | | | | | | |
| level | | -0.006 | | -0.008 | | -0.005 | | |
| difference | | -0.004 | | -0.002 | | -0.005 | | |
| Gender | | | | | | | | |

| | | | | | | | | |
|------------------|-------|------------|-------|------------|-------|------------|-------|------------|
| level | | 0.006 | | 0.022 | | -0.025 | | 0.042 * |
| difference | | -0.467 *** | | -0.804 *** | | -0.592 *** | | -0.053 *** |
| Elder Siblings | | 0.005 | | 0.038 *** | | 0.03 * | | |
| Younger Siblings | | -0.036 * | | 0.003 | | 0.008 | | |
| Music Hobby | | | | | | | | |
| level | | -0.024 | | -0.063 ** | | -0.019 | | |
| difference | | 0.014 | | 0.001 | | -0.018 | | |
| Sports Hobby | | | | | | | | |
| level | | -0.028 | | -0.042 | | -0.064 * | | |
| difference | | -0.021 | | -0.012 | | 0.014 | | |
| Youth Movement | | | | | | | | |
| level | | -0.013 | | -0.063 *** | | -0.009 | | |
| difference | | -0.021 | | -0.034 * | | 0.007 | | |
| Common Hobbies | | 0.109 *** | | 0.158 *** | | 0.146 *** | | |
| Height | | | | | | | | |
| level | | | | | | | | -0.011 |
| difference | | | | | | | | -0.016 *** |
| Sample Size | 820 | 820 | 846 | 846 | 735 | 735 | 867 | 867 |
| Peers per Person | 4.285 | 4.285 | 4.853 | 4.853 | 3.472 | 3.472 | 5.105 | 5.105 |
| R^2 | 0.256 | 0.255 | 0.266 | 0.265 | 0.26 | 0.26 | 0.255 | 0.253 |

Note: *** significant at 1% level; ** significant at 5% level; * significant at 10% level

Table 26: Full Table of Peer Effects Estimation for Physical Education Score

| Physical Education Score | | | | | | | | |
|--------------------------------|-------------|------------|-----------|------------|----------------------|------------|-----------|------------|
| | Study mates | | Friends | | Emotional Supporters | | Seatmates | |
| | Exo | Endo | Exo | Endo | Exo | Endo | Exo | Endo |
| Own Effects β | | | | | | | | |
| Matrix Test | -0.017 | -0.017 | 0.006 | 0.001 | -0.017 | -0.019 | -0.014 | -0.015 |
| Memory Test | 0.004 | 0.003 | 0.019 | 0.022 | 0.033 | 0.034 | 0.033 | 0.032 |
| Conscientiousness | 0.094 *** | 0.094 *** | 0.116 *** | 0.117 *** | 0.099 *** | 0.101 *** | 0.087 *** | 0.086 ** |
| Openness | -0.001 | -0.003 | -0.012 | -0.009 | -0.015 | -0.018 | -0.016 | -0.017 |
| Agreeableness | -0.02 | -0.021 | -0.03 | -0.032 | -0.014 | -0.014 | -0.021 | -0.021 |
| Neuroticism | 0.007 | 0.004 | 0.022 | 0.022 | 0.034 | 0.034 | 0.002 | 0.002 |
| Extraversion | 0.106 *** | 0.107 *** | 0.102 *** | 0.101 *** | 0.114 *** | 0.117 *** | 0.111 *** | 0.109 *** |
| Male | 0.184 *** | 0.183 ** | 0.124 * | 0.121 | 0.199 *** | 0.194 *** | 0.22 *** | 0.22 *** |
| Elder Siblings | 0.096 | 0.097 | 0.01 | 0.099 | 0.099 | 0.098 | 0.092 | 0.091 |
| Younger Siblings | 0.065 | 0.065 | 0.071 | 0.066 | 0.07 | 0.065 | 0.068 | 0.062 |
| Music Hobby | -0.169 ** | -0.174 *** | -0.112 | -0.116 * | -0.185 ** | -0.186 *** | -0.161 ** | -0.159 ** |
| Sports Hobby | 0.463 *** | 0.462 *** | 0.426 *** | 0.427 *** | 0.505 *** | 0.503 *** | 0.492 *** | 0.493 *** |
| Youth Movement | -0.078 | -0.081 | -0.088 | -0.092 | -0.097 | -0.1 | -0.129 * | -0.131 * |
| Contextual Effects λ_x | | | | | | | | |
| Matrix Test | -0.013 | -0.014 | -0.031 | -0.025 | 0.054 | 0.052 | -0.071 | -0.073 |
| Memory Test | 0.051 | 0.05 | -0.015 | -0.017 | -0.041 | -0.042 | 0.027 | 0.026 |
| Conscientiousness | -0.015 | -0.02 | -0.01 | -0.018 | 0.013 | 0.012 | -0.08 | -0.081 |
| Openness | 0.079 | 0.076 | 0.088 | 0.091 | 0.158 *** | 0.16 *** | 0.043 | 0.042 |
| Agreeableness | -0.064 | -0.064 | -0.088 | -0.092 | -0.025 | -0.024 | 0.073 | 0.076 |
| Neuroticism | 0.044 | 0.044 | -0.022 | -0.031 | 0.069 | 0.066 | 0.039 | 0.039 |
| Extraversion | 0.039 | 0.037 | 0.094 | 0.082 | 0.032 | 0.025 | -0.112 | -0.117 |
| Endogenous Effects λ_y | 0.27 *** | 0.267 *** | 0.372 *** | 0.373 *** | 0.225 *** | 0.226 *** | 0.188 *** | 0.187 *** |
| Selection ρ | | 0.007 | | 0.029 ** | | 0.007 | | 0.005 |
| Peer Formation γ | | | | | | | | |
| Intercept | | -0.818 *** | | -0.72 *** | | -0.88 *** | | -0.919 *** |
| Matrix Test | | | | | | | | |
| level | | 0.01 | | -0.008 | | 0.007 | | |
| difference | | -0.004* | | -0.004 | | 0 | | |
| Memory Test | | | | | | | | |
| level | | 0.02 | | -0.001 | | -0.004 | | |
| difference | | -0.004 | | -0.002 | | 0.002 | | |
| Conscientiousness | | | | | | | | |
| level | | 0.074 *** | | -0.006 | | 0.031 * | | |
| difference | | 0.001 | | -0.002 | | 0.002 | | |
| Openness | | | | | | | | |
| level | | -0.024 * | | -0.001 | | -0.005 | | |
| difference | | 0 | | 0 | | -0.003 | | |
| Agreeableness | | | | | | | | |
| level | | 0.034 *** | | 0.032 *** | | 0.055 *** | | |
| difference | | 0.001 | | 0.003 | | 0.002 | | |
| Neuroticism | | | | | | | | |
| level | | 0.053 *** | | 0.006 | | 0.078 *** | | |
| difference | | -0.001 | | -0.006 | | -0.007 | | |
| Extraversion | | | | | | | | |
| level | | 0.032 *** | | 0.033 *** | | 0.087 *** | | |
| difference | | -0.002 | | -0.009 *** | | -0.008 ** | | |
| BMI | | | | | | | | |
| level | | -0.01 | | -0.011 | | -0.006 | | |
| difference | | -0.003 | | -0.002 | | -0.005 | | |
| Gender | | | | | | | | |

| | | | | | | | | |
|------------------|-------|------------|-------|------------|-------|------------|-------|------------|
| level | | 0.009 | | 0.023 | | -0.028 | | 0.042 ** |
| difference | | -0.464 *** | | -0.804 *** | | -0.591 *** | | -0.053 *** |
| Elder Siblings | | 0.01 | | 0.037 *** | | 0.031 * | | |
| Younger Siblings | | -0.041 ** | | 0 | | 0.008 | | |
| Music Hobby | | | | | | | | |
| level | | -0.022 | | -0.063 ** | | -0.022 | | |
| difference | | 0.014 | | 0.001 | | -0.019 | | |
| Sports Hobby | | | | | | | | |
| level | | -0.027 | | -0.042 | | -0.065 * | | |
| difference | | -0.021 | | -0.012 | | 0.014 | | |
| Youth Movement | | | | | | | | |
| level | | -0.016 | | -0.063 *** | | -0.01 | | |
| difference | | -0.022 | | -0.034 ** | | 0.007 | | |
| Common Hobbies | | 0.109 *** | | 0.157 *** | | 0.145 *** | | |
| Height | | | | | | | | |
| level | | | | | | | | -0.011 |
| difference | | | | | | | | -0.016 *** |
| Sample Size | 820 | 820 | 846 | 846 | 735 | 735 | 867 | 867 |
| Peers per Person | 4.285 | 4.285 | 4.853 | 4.853 | 3.472 | 3.472 | 5.105 | 5.105 |
| R^2 | 0.153 | 0.152 | 0.182 | 0.182 | 0.168 | 0.168 | 0.133 | 0.133 |

Note: *** significant at 1% level; ** significant at 5% level; * significant at 10% level

Table 27: Full Table of Peer Effects Estimation for Conduct Grade

| Conduct Grade | Study-mates | | Friends | | Emotional Supporters | | Seat-mates | |
|--------------------------------|-------------|------------|------------|------------|----------------------|------------|------------|------------|
| | Exo | Endo | Exo | Endo | Exo | Endo | Exo | Endo |
| Own Effects β | | | | | | | | |
| Matrix Test | 0.014 | 0.001 | 0.014 | 0.008 | 0.008 | 0.005 | 0.011 | 0.01 |
| Memory Test | 0.015 | 0.015 | -0.007 | -0.008 | -0.003 | -0.004 | 0.009 | 0.006 |
| Conscientiousness | 0.185 *** | 0.189 *** | 0.174 *** | 0.177 *** | 0.214 *** | 0.213 *** | 0.172 *** | 0.169 *** |
| Openness | -0.027 | -0.025 | -0.052 | -0.049 | -0.029 | -0.029 | -0.026 | -0.027 |
| Agreeableness | 0.011 | 0.013 | 0.025 | 0.026 | -0.013 | -0.013 | 0.021 | 0.021 |
| Neuroticism | 0.034 | 0.029 | 0.063 * | 0.065 * | 0.029 | 0.028 | 0.036 | 0.037 |
| Extraversion | -0.078 *** | -0.071 ** | -0.078 *** | -0.078 ** | -0.074 ** | -0.072 ** | -0.107 *** | -0.108 *** |
| Male | -0.271 *** | -0.28 *** | -0.247 *** | -0.265 *** | -0.282 *** | -0.287 *** | -0.348 *** | -0.353 *** |
| Elder Siblings | -0.042 | -0.042 | -0.045 | -0.046 | -0.04 | -0.04 | -0.042 | -0.042 |
| Younger Siblings | -0.083 | -0.082 | -0.085 | -0.085 | -0.081 | -0.08 | -0.075 | -0.076 |
| Music Hobby | -0.019 | -0.015 | -0.017 | -0.019 | -0.026 | -0.028 | -0.003 | -0.003 |
| Sports Hobby | -0.16 *** | -0.159 *** | -0.121 * | -0.121 * | -0.15 ** | -0.148 ** | -0.13 ** | -0.129 * |
| Youth Movement | 0.031 | 0.011 | 0.044 | 0.035 | 0.05 | 0.047 | 0.038 | 0.035 |
| Contextual Effects λ_x | | | | | | | | |
| Matrix Test | -0.027 | 0.007 | 0.019 | 0.03 | 0.001 | 0.007 | 0.017 | 0.019 |
| Memory Test | 0.053 | 0.026 | 0.17 *** | 0.16 *** | 0.057 | 0.053 | 0.083 | 0.085 |
| Conscientiousness | 0.041 | 0.025 | 0.089 | 0.076 | 0.021 | 0.022 | -0.095 | -0.093 |
| Openness | -0.038 | -0.03 | -0.056 | -0.043 | 0.111 ** | 0.112 ** | -0.05 | -0.056 |
| Agreeableness | -0.042 | -0.028 | 0.01 | 0.008 | -0.106 * | -0.116 ** | 0.024 | 0.029 |
| Neuroticism | -0.005 | -0.001 | 0.018 | 0.004 | -0.025 | -0.026 | -0.03 | -0.027 |
| Extraversion | -0.075 | -0.096 * | -0.121 ** | -0.149 *** | -0.118 ** | -0.127 *** | 0.01 | 0.008 |
| Endogenous Effects λ_y | 0.244 *** | 0.218 *** | 0.168 *** | 0.138 *** | 0.152 *** | 0.148 *** | 0.117 ** | 0.115 ** |
| Selection ρ | | 0.125 *** | | 0.073 *** | | 0.05 *** | | 0.013 |
| Peer Formation γ | | | | | | | | |
| Intercept | | -0.829 *** | | -0.754 *** | | -0.91 *** | | -0.943 *** |
| Matrix Test | | | | | | | | |
| level | | 0.003 | | -0.008 | | 0.003 | | |
| difference | | -0.004* | | -0.006 | | 0 | | |
| Memory Test | | | | | | | | |
| level | | 0.021 | | 0.01 | | -0.002 | | |
| difference | | -0.002 | | -0.001 | | 0.006 | | |
| Conscientiousness | | | | | | | | |
| level | | 0.054 *** | | -0.01 | | 0.03 * | | |
| difference | | 0 | | -0.002 | | 0.002 | | |
| Openness | | | | | | | | |
| level | | -0.021 | | 0.007 | | 0 | | |
| difference | | 0 | | 0.001 | | -0.004 | | |
| Agreeableness | | | | | | | | |
| level | | 0.031 ** | | 0.027 * | | 0.055 *** | | |
| difference | | 0.003 | | 0.003 | | 0.002 | | |
| Neuroticism | | | | | | | | |
| level | | 0.039 *** | | 0.006 | | 0.081 *** | | |
| difference | | -0.003 | | -0.004 | | -0.004 | | |
| Extraversion | | | | | | | | |
| level | | 0.043 *** | | 0.034 ** | | 0.095 *** | | |
| difference | | -0.001 | | -0.007 * | | -0.007 | | |
| BMI | | | | | | | | |
| level | | -0.007 | | -0.019 | | -0.017 | | |
| difference | | -0.003 | | -0.001 | | -0.003 | | |
| Gender | | | | | | | | |

| | | | | | | | | |
|------------------|------------|-------|-------|------------|-------|-------|------------|------------|
| level | 0.054 * | | | 0.071 *** | | | -0.011 | 0.047 * |
| difference | -0.462 *** | | | -0.814 *** | | | -0.568 *** | -0.033 * |
| Elder Siblings | 0.013 | | | 0.039 *** | | | 0.026 | |
| Younger Siblings | -0.022 | | | -0.003 | | | 0.007 | |
| Music Hobby | | | | | | | | |
| level | -0.031 | | | -0.057 * | | | -0.013 | |
| difference | 0.008 | | | 0.005 | | | -0.011 | |
| Sports Hobby | | | | | | | | |
| level | -0.036 | | | -0.048 | | | -0.067 * | |
| difference | -0.018 | | | -0.015 | | | 0.03 | |
| Youth Movement | | | | | | | | |
| level | -0.024 | | | -0.056 ** | | | -0.008 | |
| difference | -0.014 | | | -0.034 * | | | 0.009 | |
| Common Hobbies | 0.108 *** | | | 0.155 *** | | | 0.137 *** | |
| Height | | | | | | | | |
| level | | | | | | | | -0.011 |
| difference | | | | | | | | -0.012 *** |
| Sample Size | 657 | 657 | 678 | 678 | 606 | 606 | 696 | 696 |
| Peers per Person | 4.381 | 4.381 | 4.788 | 4.788 | 3.647 | 3.647 | 4.98 | 4.98 |
| R ² | 0.185 | 0.177 | 0.197 | 0.192 | 0.193 | 0.193 | 0.161 | 0.161 |

Note: *** significant at 1% level; ** significant at 5% level; * significant at 10% level

Appendix B: List of Hobbies

List of Hobbies

Violin - Piano - Guitar - Harp - Horn - Flute - Clarinet - Cello - Melodica - Bell - Erhu - Guzheng - Pipa - Yangqin - Chinese Flute - Yuan - Chinese Lo - Recorder - Xylophone - Keyboard - Electric Guitar - Harmonica - Africa Drum - Percussion - Saxophone - Drum - Ocarina - Boy Scout - Girl Guide - Boy Brigade - Girl Brigade - St John - Junior Police Call - Social Service Team - Community Youth Club - Road Safety Patrol - Red Cross - Flag Raising - Prefect - Teen - Leadership - Civil Aid - Cheerlead - Volunteer - Marching Band - British Council - Basketball - Soccer - Pingpong - Badminton - Volleyball - Golf - Bowling - Tennis - Squash - Rugby - Dodgeball - Handball - Ropeskip - Mountaineer - Athletics - Swim - Skiing - Rowing - Hurdle - Archery - Cycling - Chinese Dance - Latin Dance - Dance - Ballet - Karate - Taekwondo - Yudo - Kungfu - Taiqi - Lion Dance - Run - Gun - Slideboard - Yoyo - Shotput - Gymnastics - Fencing - Climbing - Jianzi - Calligraphy - Jewel - Drawing - Knitting - Ceramic - Knot - Textileart - Singing - Boardgame - Chess - Computer - Composing - Drama - Debate - Campus TV - Environmental - Photo - Farm - Recitation - Speech - News - Cook - Movie - Magic - Astronomy - Home Economics - Camping - Lifesave - Librarian - Japanese - Korean - Aircadet - Robot - Sign Language

List of Hobbies which classified as “Music Hobbies”

Violin - Piano - Guitar - Harp - Horn - Flute - Clarinet - Cello - Melodica - Bell - Erhu - Guzheng - Pipa - Yangqin - Chinese Flute - Yuan - Chinese Lo - Recorder - Xylophone - Keyboard - Electric Guitar - Harmonica - Africa Drum - Percussion - Saxophone - Drum - Ocarina

List of Hobbies which classified as “Sport Hobbies”

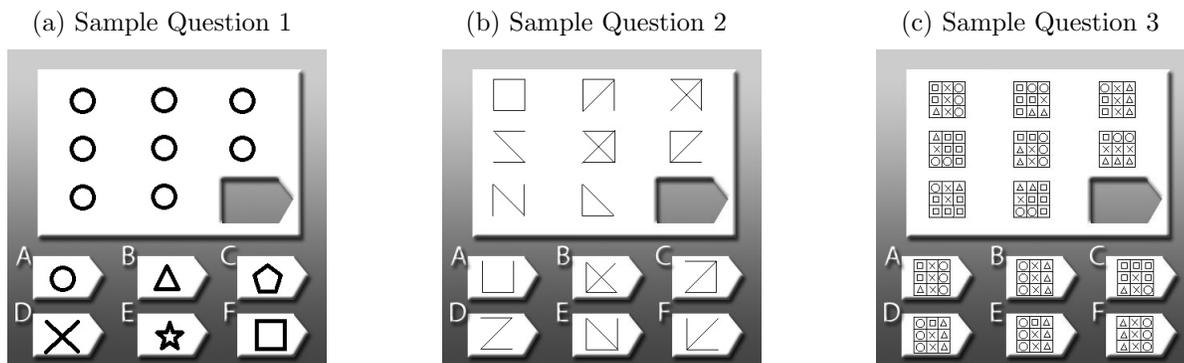
Basketball - Soccer - Pingpong - Badminton - Volleyball - Golf - Bowling - Tennis - Squash - Rugby - Dodgeball - Handball - Ropeskip - Mountaineer - Athletics - Swim - Skiing - Rowing - Hurdle - Archery - Cycling - Chinese Dance - Latin Dance - Dance - Ballet - Karate - Taekwondo - Yudo - Kungfu - Taiqi - Lion Dance - Run - Gun - Slideboard - Yoyo - Shotput - Gymnastics - Fencing - Climbing - Jianzi

List of Hobbies which classified as “Youth Movement”

Boy Scout - Girl Guide - Boy Brigade - Girl Brigade - St John - Junior Police Call - Social Service Team - Community Youth Club - Road Safety Patrol - Red Cross - Flag Raising - Prefect - Teen - Leadership - Civil Aid - Cheerlead - Volunteer - Marching Band

Appendix C: Progressive Matrix Test Sample Questions

Figure 7: Progressive Matrix Test Sample Questions



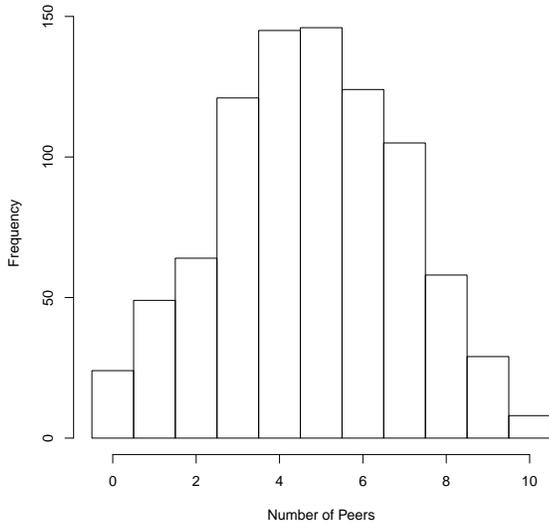
Appendix D: Memory Test Vocabulary List

Car - Dog - Box - Fat - Door - Good - Red - Tree - King - Cat - Apple - Cup

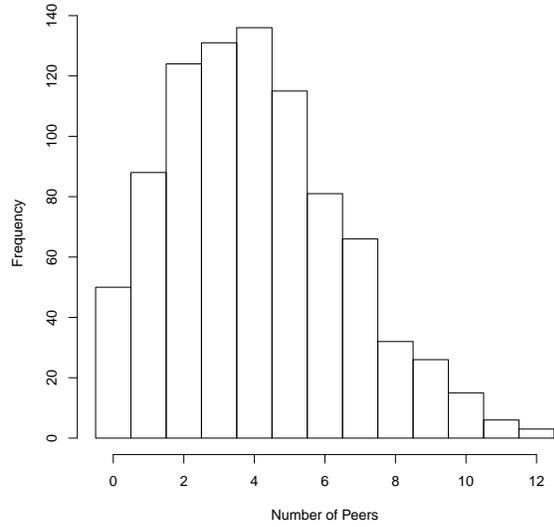
Appendix E: Histograms

Figure 8: Histograms of Network Data

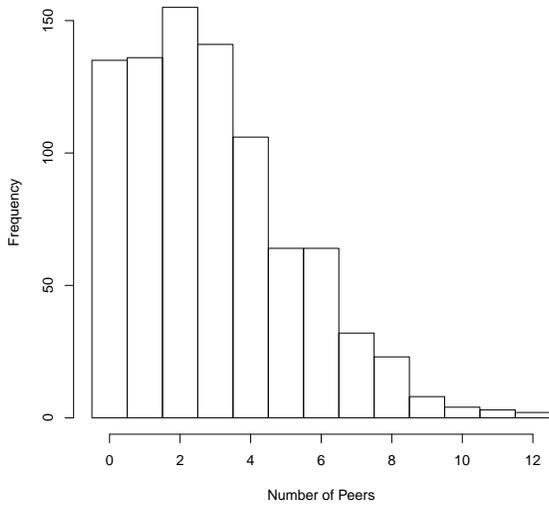
(a) Friends



(b) Studymates



(c) Emotional Supporters



(d) Seatmates

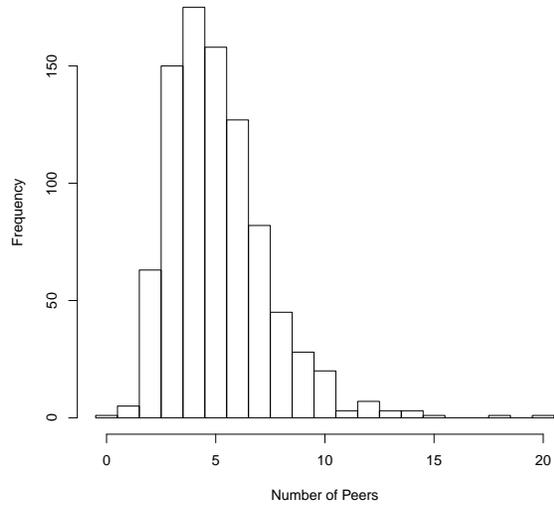
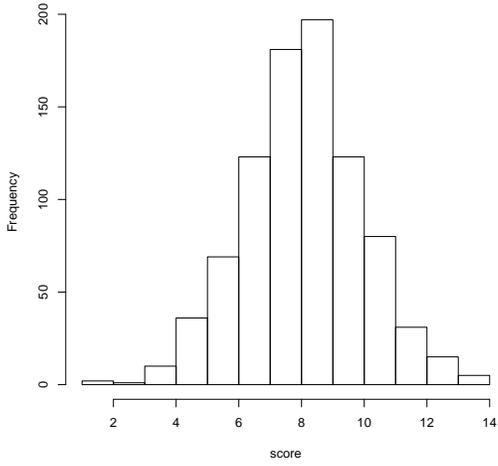


Figure 9: Histogram of Mental Ability Tests

(a) Progressive Matrix Test



(b) Memory Test

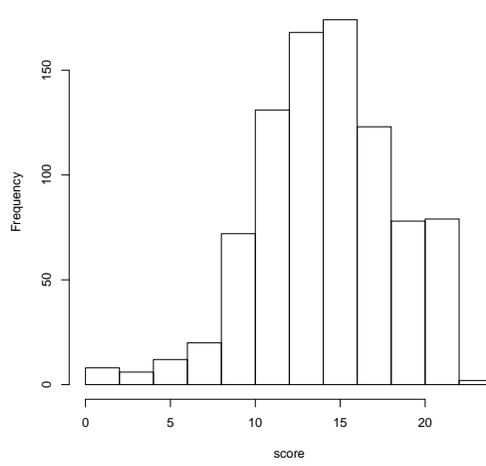
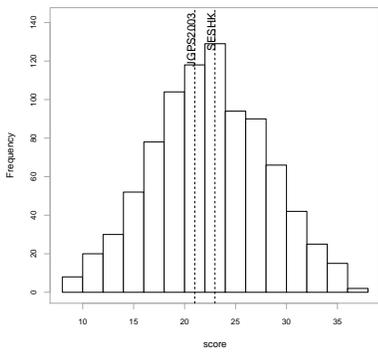
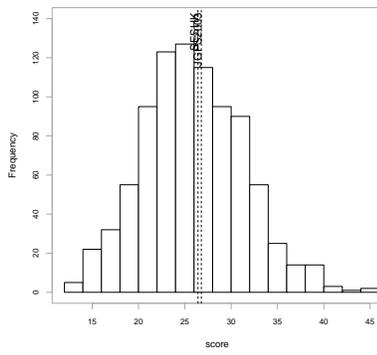


Figure 10: Histograms of Personality Traits

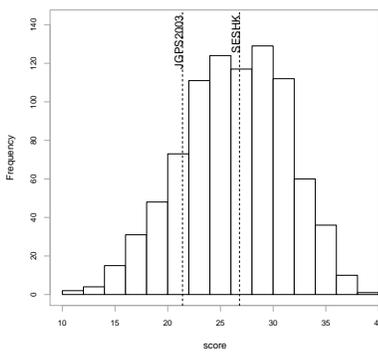
(a) Neuroticism



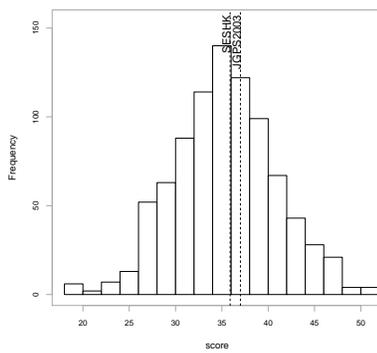
(b) Conscientiousness



(c) Extraversion



(d) Openness



(e) Agreeableness

