A Waste of Time? How Social Networking Can Sustain Better Student Job Search Equilibria

Jerry Lin

Submitted to the Department of Economics of Amherst College
In partial fulfillment of the requirements for the degree of Bachelor of Arts with Honors

Faculty Advisor: Professor Ishii

May 5th, 2011
Acknowledgments

First and foremost, I want to thank God for his provision in seeing me through this process. He brought me to Amherst and guided me through four great years and He alone deserves all the credit for anything I might have achieved.

I want to thank my advisor, Professor Ishii, whose help was invaluable to me in writing this thesis. He challenged me to do something I was truly interested in and provided me the resources to finish the task. I am especially grateful for his patience and feedback which allowed me to keep refining and developing my ideas.

I want to thank my all my friends both near and far who have been a source of encouragement during this last semester. Thanks for the jokes, the commiserations, the theses parties, the brainstorm sessions, the editing help, and much more. I especially want to thank Gregory and Megan for their advice and prayers when I needed it most.

Last, but not least, I want to thank my family for all their support from beginning to end. I want to thank my dad for reading my draft and giving me feedback despite his busy schedule. I want to thank my sister Justina for those few but encouraging phone conversations. I am blessed to have you all.
Abstract

This thesis investigates the strategic implications of social networking, an innovation that makes networking efforts visible, within the context of student job search. Students’ expected utility from job search is modeled as a function of two factors: the amount of job opportunities and the academic proficiency of the student. These factors vary with the level of networking and studying effort. Students face a time budget constraint that forces them to tradeoff between the two efforts. Since network benefits are non-excludable, a free-rider problem exists that may lead to sub-optimal levels of networking. This thesis suggests that this free-rider problem may be mitigated by monitoring afforded by the visible nature of social networking. Thus, social networking can help support higher levels of networking. The stylized model used to demonstrate this point builds on the interpretation of studying as an investment in appropriation, and networking as an investment in production. Higher levels of networking are sustainable under social networking because monitoring reduces the incentive of students to invest in appropriation. Students are first assumed to be homogeneous; the model is then extended to explore heterogeneity in innate student quality and heterogeneity in student studying ability to explore further insights in the model.
### Contents

1. Introduction ........................................................................................................................................ 1

2. Literature Review ............................................................................................................................... 4
   2.1 Background ....................................................................................................................................... 4
   2.2 Economic Literature .......................................................................................................................... 5

3. Model .................................................................................................................................................. 7
   3.1 Base Model with No Monitoring..................................................................................................... 7
   3.2 Modified Model with Monitoring .................................................................................................... 13

4. Discussion of Results ........................................................................................................................... 14
   4.1 No Monitoring Case with Student Homogeneity ............................................................................. 14
   4.2 Monitoring Case with Student Homogeneity .................................................................................. 22

5. Results Under Student Heterogeneity ................................................................................................. 27
   5.1 No Monitoring Case with Heterogeneity in Student Quality ............................................................ 27
   5.2 Monitoring Case with Heterogeneity in Student Quality ................................................................. 30
   5.3 No Monitoring Case with Heterogeneity in Student Study Ability ................................................ 32
   5.4 Monitoring Case with Heterogeneity in Student Study Ability ....................................................... 33
   5.5 Comparing Effects of Student Heterogeneity in Quality versus Ability ........................................... 34

6. Conclusion ........................................................................................................................................ 36

Appendix .............................................................................................................................................. 39

Bibliography ........................................................................................................................................ 49
1. Introduction

Studying and networking are both important activities for college students who wish to find employment after graduation. Studying is important because employers often use academic proficiency as a signal of applicant quality. Networking is significant because it can increase the amount of available opportunities by developing new contacts and drawing on their resources. While the importance of connections in job search is not a new idea, recent web-based social networking sites (SNS) have altered the landscape of networking. As one journal article notes, “What makes social network sites unique is not that they allow individuals to meet strangers, but rather that they enable users to articulate and make visible their social networks” (Boyd & Ellison 2008). This thesis investigates the strategic implications of visible social networking in a model where students from the same college allocate time between studying and networking in order to maximize their utility from job search.

In our model, we assume that firms go through the following stylized two-stage process for campus recruiting. First, firms choose the college where they will recruit at. Second, firms hire students from the college selected in the first stage. This process emphasizes the difference in opportunities across colleges. While many jobs are “open to all,” the likelihood of receiving an offer for those jobs is significantly higher if firms recruit on campus. The observation that firms often hire from the same colleges year after year is consistent with our assumption that firms usually choose colleges to recruit at before considering individual applicants.
With this setup in mind, we model students’ expected utility as dependent on the amount of opportunities and academic proficiency; these vary with the amount of networking and studying respectively. Network and studying have diminishing marginal returns, creating a tradeoff between the two.

Studying is an investment in academic proficiency and corresponds to competition in the second stage of the recruitment process. This investment is a private good whose returns depend on how much a student studies relative to their peers, reflecting how students within the same college compete for top marks. The resulting grade point averages are a relative measure of academic proficiency; they do not give an objective evaluation of academic proficiency across colleges.

Student networking is an investment in the amount of opportunities and corresponds to the first stage of the recruitment process. This investment is different than studying because of its collective nature. Instead of competing with one another, students from the same college join efforts to persuade firms to recruit at their own college. These efforts can take the form of inviting speakers, hosting info sessions, or leveraging alumni connections. Returns to networking are a function of total networking efforts by students in the same college and are shared among the entire college, allowing those who did not network to
benefit as well. While opportunities are shared by everyone within the same college, a single job can ultimately only go to a single student. As a result, the amount of opportunities is a non-excludable and rival good for students in the same college. This creates incentives for students to free-ride on the networking benefits of others, possibly leading to socially sub-optimal levels of networking.

However, membership growth at websites such as LinkedIn—a business-oriented SNS—suggest otherwise. Launched in 2003, membership reached 50 million in 2009 and recently hit the 100 million mark with over 1.3 billion connections between members (Weiner 2009, 2011). A survey of 600 recruiting professionals in 2010 also reported increased usage of social networking in their vetting and recruitment process (Jobvite 2010). Career centers have also increased their emphasis on networking by providing workshops and resources on the topic. These observations prompt the question, why is social networking growing so quickly given possible free-ridership problems?

We propose that the key to this puzzle lies in the increased visibility of social networking sites. In the past, the networking process was more informal and private. Today, social networking sites provide a formal infrastructure for networking as well as a public space to observe those efforts. This visibility allows students to monitor and determine which students are free-riders. They can then punish those formerly unobservable free-riders by restricting access to networking gains. This thesis formalizes this idea in order to gain further insight into how high levels of networking may be sustained if the benefits of networking are non-excludable.

The rest of this thesis is organized as follows. Chapter 2 provides additional background on social networking and an overview of existing job search literature on social
networks. Chapter 3 outlines the base model where monitoring is not possible and the modified model where monitoring is possible. Chapter 4 discusses the constraints generated by the model and the resulting equilibria. Chapter 5 demonstrates the robustness of our results by extending the model to explore heterogeneity in student quality and study ability. Concluding remarks are offered in Chapter 6.

2. Literature Review

2.1 Background

Social networking sites are a relatively new phenomena whose features and characteristics are still changing. It is helpful to articulate more clearly what is meant by social networking and the use of such sites. Within this thesis, we borrow the following definition from Boyd & Ellison (2008). They define social networking sites as web-based services that allow individuals to:

- construct a public or semi-public profile within a bounded system,
- articulate a list of other users with whom they share a connection,
- view and traverse their list of connections and those made by others within the system.

There are two aspects of social networking which are particularly relevant to this thesis: (1) its ability to make monitoring possible and (2) its relation to new job opportunities. The first aspect follows directly from the definition above. The second aspect is partially motivated by anecdotal evidence and by the literature on social capital and social networking.

The idea that social networks are important in job search can be traced back to Granovetter (1973) and his famous paper on the “The Strength of Weak Ties.” In this paper, he argues that “weak ties” (infrequent acquaintances) are structurally situated to have better access to useful job information than “strong ties” (persons in frequent contact with). This is
because weak tie connections are likely to be in different social networks, giving them access to information that the job-seeker cannot access on their own. This claim is supported by Granovetter’s empirical study as well as subsequent research (Granovetter 1973, 1983; Lin et al. 1981). This idea about the strength of weak ties is not limited to job search and a more generalized form of it can be found in Putnam (2000) when he speaks of bridging social capital as social capital formed between more heterogeneous agents with weaker connections. This is relevant because psychologists have found a strong association between social networking sites and the development of bridging social capital (Ellison et al. 2007; Steinfield et al. 2008; Wellman et al. 2001). This connection, coupled with the anecdotal evidence on networking, suggests that it is reasonable and likely that social networking can lead to new job opportunities.

2.2 Economic Literature

Little of the vast economics literature on job search is related to social networking. One of the first economics papers to consider personal connections was an attempt to formalize some of Granovetter’s contributions using combinatorial settings (Boorman 1975). Their attempt considers the transmission of job intelligence through a network of strong and weak ties and focuses on their comparative features. On the basis of past research, we accept the conclusion that weak ties are more important in job search and ignore strong tie relationships. This is convenient because social networking sites are not particularly relevant to forming or maintaining strong tie relationships.

Other papers have focused on the labor market and the overall effects of network interconnectedness on inequality and unemployment (Calvo-Armengol & Jackson 2004; Bramoullé & Saint-Paul 2004; Montgomery 1991). These papers are concerned with the
structure of networks as well as their formation and maintenance. They often give an explicit network structure and use graph theory to analyze their stylized example. This approach quickly becomes cumbersome as the number of connections within a network rises exponentially with network size. There are also concerns that this type of approach is not relevant in explaining socio-economic outcomes, but only useful for deriving properties of networks themselves (Rauch 2010). Rather than analyzing the properties of networks, we assume that networking has diminishing marginal returns and focus on the opportunity cost of the act of networking. This eliminates the need to use complex mathematical tools to understand the structure, formation, and maintenance of networks.

The literature most closely related to the approach we take is found in the literature on conflict economics. In particular, we make use of contest success functions (CSF) where the probability of winning a contest depends on the relative amount of invested effort. This is most often used in modeling conflict where opponents compete for a common resource. Further extensions have endogenized the prize that agents are competing over by allowing agents to invest in either appropriation or production. This type of tradeoff is commonly referred to as a “guns versus butter” tradeoff (Garfinkel & Skaperdas 2006; Skaperdas & Syropoulos 2001). Although we adopt a modified functional form, this is the core tension of this thesis. But instead of investing in “guns” for appropriation, agents invest in human capital by studying. And instead of investing in “butter,” agents invest in social capital by networking.

We differ from the basic form presented by Skaperdas by making use of two CSF to determine agents’ utility: one to model inter-college competition and one to model intra-college competition. Our approach is somewhat similar to Munster’s (2007) work on inter-
and intra-group conflict, but we do not address the question of optimal group size or
differentiate between production and intra-group appropriation. Ultimately, the biggest
differences we introduce hinge on the exogenous sharing rules motivated by our assumptions
about networking and student job search.

3. Model

We present two versions of our model in this chapter. The first model serves as our
base model in which monitoring is not feasible because student actions are private and
difficult to observe. As a result, it is possible to free-ride on the networking gains of others.
The second model assumes the presence of social networking sites which makes networking
efforts visible and allows students to monitor each other. Based on this assumption, we alter
the base model to present one approach in which the free-rider problem can be mitigated with
monitoring.

3.1 Base Model with No Monitoring

In our model, three students from the same college search for jobs and maximize their
individual expected utility, $EU_i$, which is a product of two components: the amount of job
opportunities and their probability of being offered a particular job. Students maximize $EU_i$
by investing their time in networking ($x_i = 0$) or studying ($x_i = 1$); networking increases the
amount of job opportunities and studying increases the probability of receiving a particular
job. We use a binary choice model to simplify the analysis and highlight the main qualitative
results. The important point is that students are subject to a time constraint that forces them
to allocate time between activities with differing returns. We assume student decisions are
simultaneous and competition is one-shot.
The first component of $EU_i$ is the amount of job opportunities, $g$, which is expressed as:

$$g(x_1, x_2, x_3) = b + \frac{\sum_{j=1}^{3} (1 - x_j)}{c + \sum_{j=1}^{3} (1 - x_j)}$$  \hspace{1cm} (1)$$

g is a sum of the baseline amount of opportunities, $b$, and the additional opportunities gained through networking. The baseline amount represents jobs opportunities unaffected by networking efforts. These are jobs from firms that recruit at the college every year regardless of student networking efforts. $b$ is exogenous and reflects the prestige of the college and its ability to draw employers.\(^1\)

$g$ also includes additional opportunities that are endogenously determined by the total amount of student networking. This is represented by the second term of $g$. These additional opportunities are jobs from firms that are receptive to networking efforts and have not decided which college to recruit at yet. This corresponds with the first stage of the recruitment process described earlier. We express these additional opportunities as the result of an inter-college contest where students from the same college pool their networking efforts and compete as a group.

Since we are interested in the strategic implications within a single college, we hold the networking decisions of students at other colleges constant and replace it with the parameter $c$. For a given amount of networking within a college, $c$ functions to scale the networking effectiveness of that particular college relative to other colleges. Specifically, $c$ is inversely related to the college’s relative returns to networking. For example, consider a competition between Amherst and other liberal arts colleges for jobs. For a given amount of Amherst networking effort, a smaller $c$ increases Amherst’s returns since its efforts represent

\(^1b\) serves as a relative scaling factor and may take negative values; a negative value simply indicates a low amount of baseline opportunities.
a larger proportion of total effort. Conversely, a larger \( c \) will decrease Amherst’s returns. Since \( g \) is decreasing in \( x_i \) (studying) in our assumptions, we restrict \( c \) to only positive values to ensure a reasonable interpretation.\(^2\) This restriction also imposes an upper limit to the possible gains from networking.

The parameter \( c \) also plays a second role of scaling the relative marginal returns to networking for students. This relationship is not as straightforward as the first role of \( c \) because it depends on the number of students already networking. For the first networker, returns are always inversely related to \( c \) but this may not be true for subsequent networkers. On the following graph, we show the marginal returns to additional networkers over a range of \( c \) values.

\[
\frac{\partial g}{\partial x_i} = \frac{-c}{(3+c-x_i)^2}
\]

If the partial of \( g \) is positive, then students will always study since it has returns to both components of \( EU_i \).

\(^2\)Taking the partial derivative of \( g \) with respect to the total studying, we get \( \frac{\partial g}{\partial x_i} = \frac{-c}{(3+c-x_i)^2} \) which should be negative.
Note that while $c$ is inversely related to the marginal returns for the first networker, this is not true for all students. In qualitative terms, for colleges that are very effective at networking, the first unit of investment can be so effective that future gains are almost nonexistent, which dramatically lowers marginal returns for subsequent networkers. Recall that our restriction for $c$ to have a meaningful interpretation imposes an upper limit to possible gains from networking. In other words, if the first unit of investment has returns near the upper bound, additional investment will have very low returns. If networking is less effective, the marginal returns of additional networkers follow a more standard explanation.

An important implicit assumption behind the “additional opportunities” in $g$ is that these jobs are in fact non-excludable and that free-riding of networking gains exist. We find anecdotal evidence which suggests this does occur through various different channels. In the most formal setting, there are often student organizations which invest large amounts of time and energy into organizing career-related events. These efforts often result in conferences, informational sessions, or workshops which are open to students who did not contribute to these efforts. Furthermore, networking benefits which come from leveraging alumni relationships often extend to the entire college. Lastly, firms ultimately recruit on campus because of repeated positive experiences with members of that college. In that sense, every networking interaction is an investment in the school’s reputation which increases the probability of on-campus hiring. It is because these networking gains are non-excludable that $g$ is increasing in the sum of networking efforts and not only individual efforts.

---

3It is true that networking can also result in individual gains, the key point is the existence of benefits which spillover to the rest of the college. For example, I was able to secure a summer internship through networking with alumni. While I personally benefited, the following year the same firm posted job opportunities in the career center open to the whole college.
The second component of $EU_i$ is the probability of being offered a particular job, $p$, which is expressed as:

$$p_i(x_1, x_2, x_3) = \frac{a_i + x_id_i}{\sum_{j=1}^{3}(a_j + xjd_j)}$$ (2)

This represents the competitive strength of a student’s application for a particular job and models the returns from studying. As students compete for $g$, they are competing with other students from their college. Thus, receiving a job offer can be modeled as an intra-college contest where studying results in a greater probability of receiving a particular job offer. We consider two possible ways in which students may be different. First, students may differ in their intrinsic attractiveness to firms which we will refer to as student quality. Second, students may differ in their effectiveness at studying, which we will refer to as student study ability. Quality and study ability for student $i$ are represented by the exogenous parameters $a_i$ and $d_i$ respectively. The key distinction between student quality and study ability is that higher quality students (higher $a_i$) have an advantage regardless of their strategy, while high ability students (higher $d_i$) can only exercise their advantage when they study. We discuss these differences in greater detail in Chapter 5.

Having defined the two separate components of $EU_i$, we combine them to get the complete expected utility function for student $i$:

$$EU_i = p_i(x_1, x_2, x_3)g(x_1, x_2, x_3) = \left[\frac{a_i + x_id_i}{\sum_{j=1}^{3}(a_j + xjd_j)}\right]\left[b + \frac{\sum_{j=1}^{3}(1 - x_j)}{c + \sum_{j=1}^{3}(1 - x_j)}\right]$$ (3)

Borrowing from the contest success function literature, a natural interpretation would be to consider $p$ as an investment in appropriation and $g$ as an investment in production. The decision between studying and networking represents a choice between capturing a larger share of the prize and increasing the size of the prize. Note that returns to studying are zero-
sum as increases in share necessarily come at the cost of other students. That is why \( p_i \) is increasing in \( x_i \) and decreasing in the studying efforts of other students. In contrast, gains in \( g \) can benefit everyone because the returns to networking create more value to be shared by all.

Below is a graph of total job opportunities against networking effectiveness when the baseline amount of job opportunities is constant and students are homogenous (graph of \( g \) against \( c \), given \( b=1, a_i=1, d_i=1 \ \forall i \)). This graph gives further intuition on the effect of networking with respect to the size of the prize. Each line represents a different level of networking effort denoted by the subscript. While \( g \) is increasing in the amount of networking, there are diminishing returns. In particular, for a given \( c \), the difference between \( G_0 \) and \( G_1 \) is greatest and decreases with each successive pair of neighboring curves. This is consistent with our earlier graph where the marginal return of additional networkers is always lower than preceding networkers.

Figure 3.2 – Graph of \( g \) for a Given Value of \( b=1 \)
If students could collude and perfectly enforce contracts, all efforts should be spent on networking to maximize total group utility. However, information is generally imperfect and students are unable to enforce collusion. We model this by having multiple students. With only two students, each student could deduce the other’s actions from their own payoff and strategy. With three or more students, each student is unable to determine the share of the total studying done by other students. Without the knowledge of who studied, students are unable to punish defectors and the collusive equilibrium becomes unsustainable. As a result, students face the following tradeoff: a smaller share of a larger prize or a larger share of a smaller prize. In equilibrium, students network until gains in the size of the prize are offset by the loss of a reduced share. Depending on the parameter values, these tipping points can vary; we express these as incentive compatible constraints in Chapter 4.

3.2 Modified Model with Monitoring

The visibility of social networking provides a manner by which students can monitor each other and punish free-riders. The particular rule we introduce here is the exclusion of non-contributors from networking gains. These changes modify the expected utility function as follows:

\[ EU'_i = p_i(x_1, x_2, x_3) g'_i(x_1, x_2, x_3) \]

where

\[ g'_i(x_1, x_2, x_3) = b + p_i^{-1} \left[ \frac{(1 - x_i)a_i}{\sum_{j=1}^{3} \left( (1 - x_j)a_j \right)} \right] \left[ \frac{\sum_{j=1}^{3} (1 - x_j)}{c + \sum_{j=1}^{3} (1 - x_j)} \right] \]

\[ (4) \]

---

4 We choose to analyze the interactions of three students as adding additional students greatly increases the complexity while yielding limited new insight.

5 If everyone studies, the third term is undefined because of zeros in the denominator. Thus, we define \( g'(0,0,0) = b. \)
The difference between $g$ and $g'$ is that the old allocation rule for networking gains is nullified by a new one. Instead of dividing network gains among everyone, gains are only shared among those who network. Since those who network cannot study, division is based on innate student quality. This new allocation rule applies only to the additional opportunities gained from networking (the fourth term in $g'$). Those who study continue to appropriate a larger share of the baseline opportunities available to everyone. The purpose of the modified expected utility function is to represent how non-contributors can be prevented from unfairly appropriating the gains of networkers. We rewrite $EU'_i$ in a more convenient form as the sum of a share of baseline opportunities and a share of additional opportunities from networking.

$$EU'_i = \left[ \frac{a_i + x_id_i}{\sum_{j=1}^{3}(a_j + xjd_j)} \right] b + \left[ \frac{(1 - x_i)a_i}{\sum_{j=1}^{3}((1 - x_j)a_j)} \right] \left[ \frac{\sum_{j=1}^{3}(1 - x_j)}{c + \sum_{j=1}^{3}(1 - x_j)} \right]$$

Having fully specified the model, we consider possible equilibria using the pure strategy Nash equilibrium concept. For each possible scenario, we consider students’ unilateral incentives to change or maintain their strategy while holding the strategies of other students constant. This provides us with the range of parameter values for which a given possible equilibrium holds. We begin with the base case model where monitoring is not possible, and then consider the modified model where monitoring is possible.

4. Discussion of Results

4.1 No Monitoring Case with Student Homogeneity

We begin by assuming students are homogenous and hold $a_i, d_i = 1$, for all $i$. We relax this assumption in Chapter 5. With three students facing two options, there are eight possible scenarios: one scenario where three students network, three scenarios where different
combinations of two students network, three scenarios where a single student networks, and
one scenario where no students network. Under homogeneity, four of these cases are
redundant. This leaves four cases of interest, one corresponding to each unique value of \( g \)
which we refer to as \( \{G_0, G_1, G_2, G_3\} \) where the subscript denotes the number of networkers.
We examine these cases from the perspective of student 1 without loss of generality because
of student homogeneity.

The constraints are expressed in terms of \( b \) because it has the most intuitive
interpretation, namely, the amount of baseline job opportunities that must be available in
order for a student to maintain their strategy. It is also easier to interpret shifts in \( b \) (economic
downturn, career center initiatives, etc.) than shifts in \( c \).

**Equilibrium #1 with No Monitoring: No Networking**

In order for “no students networking” to be a pure strategy Nash equilibrium, no
student should want to deviate (network) unilaterally given the strategies of the other
students (study). In terms of expected utility for student 1 (similarly for student 2 and 3) this
is expressed as:

\[
p_1(0,1,1)G_1 < p_1(1,1,1)G_0
\]

\[
\frac{1}{5} \left( b + \frac{1}{c+1} \right) < \frac{1}{3} (b)
\]

\[
b > \frac{3}{2c+2}
\]  

(6)

The left-hand side and right-hand side of the first and second lines represent student
1’s payoffs from networking and studying respectively. The size of the prize is always at
least the baseline amount and increases by \( \frac{1}{c+1} \) if student 1 networks. However, the cost is a
loss in appropriation ability as \( p_1 \) decreases from \( \frac{1}{3} \) to \( \frac{1}{5} \). Two forces counteract student 1’s
incentives to network: an inability to retain most of the network gains and a smaller share of $b$. Thinking back to the “guns versus butter” analogy, investment in production leaves one vulnerable to appropriation from others. It is advantageous to produce only if the increase from production is large enough to offset the expected loss from appropriation. We use the baseline amount of opportunities to gauge the relative gains from networking (a larger $b$ means networking gains are relatively smaller and vice versa). The inequality (6) indicates the tipping point for $b$ when networking costs outweigh its benefits.

So for a large enough $b$, no one has incentives to invest in production and all efforts are spent on appropriation. This outcome is a classic example of the Prisoner’s Dilemma. Even though all students would be better off if they all networked, no student is willing to be the first to network as that could make them worse off. Without repeated interaction or any other means of enforcing cooperation, all students study and are worse off than if they all networked.

Equilibrium #2 with No Monitoring: One Networking

Without loss of generality, let student 1 network while the other students study. In order for “one student networking” to be a pure strategy Nash equilibrium, neither the student networking nor the students studying should want to deviate unilaterally by playing a different strategy. For student 1, this means that the payoff from networking alone must be greater than the payoff from no one networking. This is expressed as:

$$ p_1(0,1,1)G_1 > p_1(1,1,1)G_0 $$

This is just the opposite of the constraint derived in equilibrium #1. We simplify this to:

$$ b < \frac{3}{2c + 2} \quad (7) $$
For student 2 (similarly for student 3), the payoff from studying while student 1 networks must be greater than the payoff from joining student 1. This is expressed as:

\[
p_2(0,0,1)G_2 < p_2(0,1,1)G_1
\]

\[
\frac{1}{4} \left( b + \frac{2}{c + 2} \right) < \frac{2}{5} \left( b + \frac{1}{c + 1} \right)
\]

\[
b > \frac{2c - 6}{3c^2 + 9c + 6}
\] (8)

Student 2 must decide if increasing the prize by \( \frac{2}{c+2} - \frac{1}{c+1} \) is worth the loss of \( \frac{2}{5} - \frac{1}{4} \) in appropriation ability. Note that the potential increase in the prize is smaller here than the networking contribution by student 1 because of diminishing returns. The potential loss in appropriation ability is also greater than student 1’s loss. This is because as less students study (student 1 is networking), the returns from studying increase. The tradeoff in this scenario is more complex than the tradeoff in equilibrium #1 because students who study can still benefit from networking by free-riding off the gains of student 1. This was not possible in equilibrium #1 since all students were studying.

**Equilibrium #3 with No Monitoring: Two Networking**

We can similarly derive constraints for this equilibrium as we have for equilibrium #2. These constraints are:

\[
b < \frac{2c - 6}{3c^2 + 9c + 6}
\] (9)

\[
b > \frac{-6}{c^2 + 5c + 6}
\] (10)

(9) is the constraint for the two students networking. (10) is the constraint for the one student studying.

**Equilibrium #4 with No Monitoring: All Networking**
We can similarly derive a constraint for this equilibrium as we have for equilibrium #1. This constraint is:

\[ b < \frac{-6}{c^2 + 5c + 6} \]  \hspace{1cm} (11)

There is only one constraint since the strategies are symmetric and students are homogenous. If the amount of baseline opportunities is small enough, no one has an incentive to invest in appropriation because the initial prize is so small relative to the gains from networking. Instead, all efforts are invested in production. Students are finally able to maximize the group’s expected utility, but only as a byproduct of maximizing personal utility, not due to any coordination.

The constraints for all four equilibria are summarized in the following table.

<table>
<thead>
<tr>
<th>Equilibrium</th>
<th>Lower bound</th>
<th>Upper bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 Students N</td>
<td>[ b = \frac{-6}{c^2 + 5c + 6} ]</td>
<td>[ b = \frac{-6}{c^2 + 5c + 6} ]</td>
</tr>
<tr>
<td>2 Students N</td>
<td>[ b = \frac{-6}{c^2 + 5c + 6} ]</td>
<td>[ b = \frac{2c - 6}{3c^2 + 9c + 6} ]</td>
</tr>
<tr>
<td>1 Student N</td>
<td>[ b = \frac{2c - 6}{3c^2 + 9c + 6} ]</td>
<td>[ b = \frac{3}{2c + 2} ]</td>
</tr>
<tr>
<td>0 Students N</td>
<td>[ b = \frac{3}{2c + 2} ]</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 4.1 – Summary of Constraints for no Monitoring Equilibria**

We represent these bounds and the equilibria regions they contain in the following graph where \( G_0 \) corresponds to the region where 0 students network and so on.
We make a few observations. In general, the higher the value of $b$, the less likely students will invest in networking. When baseline opportunities form a larger proportion of the total prize $g$, it is more advantageous to appropriate a larger share of the existing prize than to increase the size of the prize. Eventually, the prize is large enough such that everyone is better off trying to appropriate than trying to produce.

The effects of $c$ are less intuitive. For most positive values of $b$, a decrease in the effectiveness of networking results in a lower networking equilibrium. As networking becomes less effective, the marginal returns decrease, and it is better to invest in studying. This effect depends on the interpretation of $c$ as the effectiveness of a school’s networking. However, there are regions within $G_1$ and $G_2$ where a larger $c$ results in a higher, not lower, networking equilibrium. This is due to the secondary effect of $c$ discussed previously where if networking effectiveness is too high, it discourages students from networking after the first networker. In other words, there is an incentive to free-ride on the first student who networks.
This is why \( b_2 \) and \( b_3 \) are inverted while \( b_1 \) is not. \( b_1 \) is the constraint between 0 networking and 1 networking; for that first student, there are no network benefits to free-ride on if they study. In contrast, for \( b_2 \) and \( b_3 \), there are already one or two students networking.

The three equations do not intersect for positive values of \( c \). This means that the four equilibria are mutually exclusive and exhaustive; depending on the exogenous parameters \( b \) and \( c \), any outcome is achievable. However, the amount of baseline opportunities is more influential than the effectiveness of networking in determining the equilibrium.\(^6\) This stems from our assumption about networking that restricted negative \( c \) values.

On the following figure, we hold \( c \) constant so that the constraints are numerical thresholds and graph the expected utility of students as \( b \) varies. This visually represents the payoffs and choices that students face. Since students are homogenous, there are three possible scenarios a student may face: two students networking, one student networking, or no students networking. Since incentives differ in each scenario, there are three corresponding sets of \( EU \) curves where the subscript denotes how many students are networking. Within each set of \( EU \) curves are two equations; one corresponds to the payoff from networking and the other to the payoff from studying denoted by the superscript. For example, \( EU_0^S \) signifies the expected utility of a student who chooses to study given that zero students network. Similarly, \( EU_0^N \) signifies the expected utility of a student who chooses to network given that zero students network.

\(^6\) For a given \( c \), \( b \) can determine any of the four possible equilibria. For a given \( b \), \( c \) is not always able to determine any of the four possible equilibria.
The dotted black line shows the expected utility on the path of play. For example, consider the dotted black line in the “0 networking” region. When \( b > \frac{3}{2c+2} \), studying is a dominant strategy since \( EU_i^S > EU_i^N \) for all \( i \) and so all students study and receive \( EU_0^S \).

Although the payoff from three students networking is greater than the payoff from no students networking \( (EU_2^N > EU_0^S) \), that equilibrium is unsustainable as each student has incentives to deviate and try to receive \( EU_2^S \). This corresponds with the Prisoner’s Dilemma discussed previously.

The dotted red lines represent the numerical thresholds for the constraints for a given \( c \). Each threshold corresponds to a shift in strategy by students; this can be seen in the kinks in the path of play lines. To continue with our example, for baseline quantities between \( b_2 \) and \( b_1 \), “0 networking” is no longer a Nash equilibrium because \( b \) is low enough that one
student is willing to deviate (network) unilaterally. After one student changes their strategy to networking, the remaining students are no longer on $EU^S_0$ but $EU^S_1$ since there is one student networking. Checking their incentives, it is more advantageous for them to invest in appropriation and free-ride on the gains of one networker than to network themselves when $b$ is between $b_2$ and $b_1$. Thus, one student networking is a Nash equilibrium in this region.

Notice that the payoffs can differ between students within the same equilibrium. That is why there are two dotted lines in the middle two regions of the graph; both networking and studying are strategies on the path of play in these equilibria. It is only when students all play the same strategy that they receive the same payoff. When the students play different strategies, the payoff for those who study are always greater than the payoff for those who network because of the networking gains they appropriate. This is because students all share the same prize and those who invest in appropriation grab a larger share. So while networking can improve a student’s payoff, that student will always be worse off than a student who studies on the path of play.

4.2 Monitoring Case with Student Homogeneity

Using the same approach, we look for the 4 sets of constraints necessary to maintain $\{G_0, G_1, G_2, G_3\}$ using the modified $EU'$; given in equation (5). The main difference in this case is students’ ability to monitor each other and restrict non-contributors from sharing in networking gains.

Equilibrium #1 with Monitoring: No Networking

In order for “no students networking” to be a pure strategy Nash equilibrium, no student should want to deviate (network) unilaterally given the strategies of the other
students (study). In terms of expected utility for student 1 (similarly for student 2 and 3) this is expressed as:

\[
p_1(0,1,1)g'_1(0,1,1) < p_1(1,1,1)g'_1(1,1,1)
\]

\[
\frac{1}{5} b + \left( \frac{1}{c + 1} \right) < \frac{1}{3} b + 0
\]

\[
b > \frac{15}{2c + 2}
\]

(12)

In this scenario, student 1 is able to keep all the gains of networking if he networks. This contrasts with the no monitoring case where student 1 only received a fraction of the gains he generated. The ability to retain these gains increases student 1’s willingness to network relative to the no monitoring case.

**Equilibrium #2 with Monitoring: One Networking**

Without loss of generality, let student 1 network while the other students study. The first condition that must be satisfied in order for this equilibrium to be a pure strategy Nash equilibrium is the incentives of the student 1. This is just the opposite of the constraint derived in equilibrium #1. We simplify this to:

\[
b < \frac{15}{2c + 2}
\]

(13)

The second condition that must be satisfied are the incentives of student 2 and 3. Namely, the payoff from studying given student 1 networks must outweigh the payoff from networking. This is expressed for student 2 (similarly for student 3) as:

\[
p_2(0,0,1)g'_2(0,0,1) < p_2(0,1,1)g'_2(0,1,1)
\]

\[
\frac{1}{4} b + \left( \frac{1}{2} \right) \left( \frac{2}{c + 2} \right) < \frac{2}{5} b + 0
\]

\[
b > \frac{20}{3c + 6}
\]

(14)

Notice that investing in appropriation only increases the share of baseline opportunities since appropriation of networking gains is no longer possible. As a result, those
who network can enjoy a larger proportion of their networking gains; they do not receive all the gains but split it between other networkers based on student quality. Since students are homogenous, this is evenly divided and student 2 would receive half the network gains if he networked. The tradeoff for students is now between an investment in appropriating more of $b$ and an investment in production.

**Equilibrium #3 with Monitoring: Two Networking**

We can similarly derive constraints for this equilibrium as we have for equilibrium #2. These constraints are:

$$b < \frac{20}{3c + 6} \quad (15)$$

$$b > \frac{6}{c + 3} \quad (16)$$

(15) is the constraint for the two students networking. (16) is the constraint for the one student who studies.

**Equilibrium #4 with Monitoring: All Networking**

We can similarly derive a constraint for this equilibrium as we have for equilibrium #1. This constraint is:

$$b < \frac{6}{c + 3} \quad (17)$$

These constraints can be summarized in the following table.
We represent these bounds and the equilibria regions they contain in the following graph where $G_0$ corresponds to the region where 0 students network and so on.

<table>
<thead>
<tr>
<th>Equilibrium</th>
<th>Lower bound</th>
<th>Upper bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 Students N</td>
<td>$b = \frac{6}{c + 3}$</td>
<td></td>
</tr>
<tr>
<td>2 Students N</td>
<td>$b = \frac{6}{c + 3}$</td>
<td>$b = \frac{20}{3c + 6}$</td>
</tr>
<tr>
<td>1 Student N</td>
<td>$b = \frac{20}{3c + 6}$</td>
<td>$b = \frac{15}{2c + 2}$</td>
</tr>
<tr>
<td>0 Students N</td>
<td>$b = \frac{15}{2c + 2}$</td>
<td></td>
</tr>
</tbody>
</table>

Figure 4.4 – Summary of Constraints for Monitoring Equilibria

Most of our observations regarding the base case without monitoring still apply.

Lower $b$ values lead to more networking, and outcomes are mutually exclusive and exhaustive. The biggest difference is the effect of $c$. In this case, our more natural
interpretation of $c$ as the colleges’ networking effectiveness always holds. That is, an increase in $c$ (less effective networking) would lead to less networking. By eliminating the free-rider problem, the inverted constraints are gone, as is the secondary effect of $c$, which is only applicable in cases of free-riding. More interesting are the differences between the monitoring and no monitoring cases. We graph the constraints on the same plot below so that they share a common scale.

![Graph of Combined Equilibrium Regions](image)

Figure 4.6 – Graph of Combined Equilibrium Regions

The most obvious result is that students are all more willing to network under monitoring; this is seen in how the constraints from monitoring ($b_4$, $b_5$, $b_6$) are all above the constraints from the no monitoring case ($b_1$, $b_2$, $b_3$). Under monitoring, some level of networking becomes sustainable in regions B, C, and D while higher levels of networking can be achieved in regions E and F. To examine the effect of monitoring on constraints, we separate out two smaller effects: (1) protection from free-riding and (2) the loss of free-riding
benefits. The first effect is responsible for the general upward shifts; this is seen in the shift of $b_1$ to $b_4$ where the loss of free-riding benefits is irrelevant since there are no networkers to free-ride on. The second effect is responsible for inverting constraints; this is seen in the shifts of $b_2, b_3$ which were previously sustained in part by free-riding benefits. Shifts from $b_2, b_3$ to $b_5, b_6$ are thus the result of both effects described above.

5. Results Under Student Heterogeneity

5.1 No Monitoring Case with Heterogeneity in Student Quality

We now allow student quality to be heterogeneous by varying $a_i$ and analyze the resulting shift in constraints and equilibrium regions with no monitoring. Recall that student quality plays a role in determining a student’s share of the prize regardless of a student’s strategy under no monitoring.

We first consider a scenario with a small symmetric difference in student quality by setting $a_1=0.9, a_2=1, a_3=1.1$ where a higher $a_i$ denotes higher quality. We will refer to these students as Cal, Ben, and Ace respectively. Since Ace is the highest quality student, he enjoys an advantage compared to other players no matter the scenario. In particular there are two effects on his incentives. First, he is more willing to network because his ability to appropriate the gains of networking is higher than the others (i.e. if all three students network, he receives the largest share). Second, his opportunity cost for networking is lower than the others because his potential loss in share is the least compared to the others. These effects increase his relative willingness to invest in networking; the graphical result is an upward shift in his constraints above the others. Derivations are in the appendix.

In contrast, Cal, the lower quality student, is less willing to network because he has more to gain by studying. Even if he were to network, his gain is proportionately smaller
since the bulk of the gains are appropriated by others. This disadvantage results in a downward shift in his constraints. This particular choice of parameters maintains Ben’s incentives and his constraints do not shift relative to the case with student homogeneity. This provides a basis for comparison to Ace and Cal. Graphically, the result of these shifts is a banding effect around the original constraints derived in Chapter 4.1. Since differences between students are symmetric, Ace’s increased willingness to network is matched by Cal’s decreased willingness to network.

Since the incentives of all students need to be satisfied in a Nash equilibrium, the downward shift of Cal’s constraints increases the difficulty of achieving an equilibrium where all students network. Thus, the region of “three students networking” decreases, indicated by the shaded blue region on the graph above. Within this region, Cal is unwilling to network given Ace and Ben are networking; this increases the region of “two students networking.” However, not every combination of two students networking is possible in this...
blue region because students are no longer interchangeable. In fact, this additional region can sustain 2 networkers only if one of them is Ace. This is reasonable since Ace is more willing to network than other students holding all else equal. In fact, the equilibria of higher quality pairs (sum of $a_i$) subsume the equilibria of lower quality pairs. The graph below demonstrates this effect by showing the possible variations of 2 students networking.

![Graph of Possible Equilibria with 2 Students Networking](image)

**Figure 5.2 – Graph of Possible Equilibria with 2 Students Networking**

In the same way that Cal reduces the region where all students network, Ace’s higher constraint increases the difficulty of having an equilibrium with no networking by a similar logic. This is captured in the region shaded green in Figure 5.1. We do not go detail concerning this region as it mirrors what we have already described for Cal.

These observations are not strongly dependant on our choice of $a_i$ as we make similar observations when experimenting with a larger symmetric difference ($a_1=.5$, $a_2=1$, $a_3=1.5$). This results in a larger banding effect as the degree of inequality is greater. This may cause
some of the constraints to intersect but does not alter our findings. Lastly, we analyzed an asymmetrical case where Ace is of slightly higher quality than Ben while Cal is of significantly worse quality ($a_1=.5$, $a_2=1$, $a_3=1.1$) and our results were consistent with our remarks here. The corresponding constraints and their graphs are in the appendix.

5.2 Monitoring Case with Heterogeneity in Student Quality

We now consider the scenario with Cal, Ben, and Ace where $a_1=.9$, $a_2=1$, $a_3=1.1$, but introduce monitoring to eliminate free-riding. The directional shifts discussed earlier still apply to each student. To be explicit, Ace is more willing to network and his constraints shift upward relative to Ben’s constraints, Ben’s constraints does not change relative to the homogenous case, and Cal is less willing to network and his constraints shift downward relative to Ben’s constraints. Recall that under monitoring, quality is especially important because it is the only basis for allocation of networking gains.

We graph the constraints for the equilibrium 1 and 4. What is interesting here is the magnitude of the shifts. Under no monitoring, the spread between Cal and Ace’s constraints is similar for each constraint. Introducing monitoring reduces the spread around the upper bounds relative to the spread around the lower bounds, shown in the graph below.

---

7 We arrive at similar observations by examining a large symmetric difference ($a_1=.5$, $a_2=1$, $a_3=1.5$) and by examining an asymmetrical difference ($a_1=.5$, $a_2=1$, $a_3=1.1$). These constraints are given in the appendix.
Thinking back to the drivers behind the constraint shifts, this is a reasonable result. Ace was motivated to network because of his relative advantage in appropriating networking gains whether he studied or not. Because monitoring prevents free-riding, his relative advantage in appropriating network gains only applies when he networks. However, this advantage is more powerful when the networking gains are large. To make this point more clearly, consider Ace’s decision in the no monitoring case. Excluding any gains in $b$ and focusing just on networking gains, he can either choose to appropriate a portion of the gains from $n$ students networking (by networking himself) or he can appropriate a larger portion of the gains from $n-1$ students networking (by studying himself). If free-riding is restricted under monitoring, this decision becomes a choice between appropriating a percentage of the gains of $n$ students networking or nothing. It is clear that the former option is a better one, especially as $n$ grows. So for small $n$, Ace has less incentive to network than for large $n$. That is why his constraint shifts higher for the lower bound (when $n$ is larger) than for his upper
bound. A similar explanation can be given for why Cal’s constraints shift down less for his upper bound constraint than for his lower bound constraint.

This particular choice of parameters reduces the total amount of networking achieved under monitoring. Since the spread is larger on the lower bounds, there is a larger reduction in “three students networking” than the corresponding reduction in “zero students networking”. It would require an asymmetrical difference with a very high quality student for total networking to remain the same with respect to the homogenous case (the upper bound constraint needs to shift higher to match the spread on the lower bound). We also examine a case with larger symmetrical differences, and a case with asymmetrical differences to confirm our observations are robust. These constraints are given in the appendix.

5.3 No Monitoring Case with Heterogeneity in Student Study Ability

We now set $a_i=1$ for all $i$ and allow student study ability to be heterogeneous by varying $d_i$. Recall that study ability only makes a difference if a student studies. We first consider a scenario where a small symmetric difference in student ability exists by setting $d_1=.9, d_2=1, d_3=1.1$ where a higher $d_i$ denotes higher ability. We will refer to these students Cam, Bel, and Amy respectively.

The effects of heterogeneity in $d_i$ are straightforward since it affects incentives through only one channel: the marginal returns to studying. As one might expect, the constraints of students with better ability will shift downwards the most as their opportunity cost to networking is higher. This creates a similar banding effect as discussed in Chapter 5.1. Our other observations in 5.1 about constraints and equilibria shifts hold true here as well. The main difference is that a higher $a_i$ (Ace) is more willing to network while a lower $d_i$
(Cam) is more willing to network. Aside from this directional difference, the results are qualitatively the same. Supporting graphs and derivations can be found in the appendix.

5.4 Monitoring Case with Heterogeneity in Student Study Ability

We continue to consider the scenario with Cam, Bel and Amy where \( d_1 = 0.9, \ d_2 = 1, \ d_3 = 1.1 \) but also introduce monitoring. The crucial difference between the two types of student heterogeneity is how the networking gains are split. Under heterogeneity in study ability, gains are equally split since \( a_i \) is the same for all students. Thus, all students receive the same payoffs if they choose to network. The only factor that shifts their incentives is the opportunity cost of studying. Since \( d_i \) is a proxy for marginal returns to studying, the relative difference in opportunity cost is anchored and does not vary much across scenarios. Thus, spreads on the upper and lower bounds do not differ significantly. In comparison to the homogenous case with monitoring, the main result is the change in composition of networking as total networking does not change much since the reduction in “zero students networking” is matched by a reduction in “three students networking”. We also examine a case with larger symmetrical differences, and a case with asymmetrical differences to confirm our observations are robust. These constraints are given in the appendix.
5.5 Comparing Effects of Student Heterogeneity in Quality versus Ability

We can now compare the results from the two types of student heterogeneity by graphing the binding upper and lower bound constraints (the most restrictive constraint for “zero networking” and “three networking” to be an equilibrium) together. The following graphs indicate two interesting results. First, under either type of heterogeneity, symmetric outcomes are less likely, whether that be networking or studying (note how the upper and lower bounds of the homogenous case are always nested inside the upper and lower bounds of either heterogeneous case). The difference in student characteristics causes their preferences to move in divergent directions. This is inevitable as heterogeneity necessarily bestows some form of comparative advantage. This divergence in preferences increases the difficulty of symmetric outcomes because the incentives of each student must be satisfied in

---

8 We exclude the binding constraints for the middle equilibria. Those constraints can be found in the appendix.
order for the equilibrium to be Nash. This shift in constraints always results in a more restrictive condition for equilibrium than in the case of homogenous students.

Figure 5.5 – Comparison of Constraints with Heterogeneity with no Monitoring

Figure 5.6 – Comparison of Constraints with Heterogeneity with Monitoring
Second, under monitoring, heterogeneity in study ability leads to higher levels of networking than heterogeneity in quality (in Figure 5.6 Cam & Amy’s constraints are higher than Ace & Cal’s constraints). This result is not obvious as varying $a_i$ and $d_i$ under no monitoring resulted in constraints that nested inside each other (in Figure 5.5, Cam & Amy’s constraints are nested by Ace and Cal’s). But recalling our discussion in Chapters 5.2 and 5.4 on the spread of the upper and lower bounds, this should make sense. Amy (highest study ability) and Cal (lowest quality) are both less willing to network and their curves shift downward with respect to the homogenous case. While Amy has higher marginal returns to studying than Cal, he has additional disincentives to network because he appropriates a smaller portion of the gains from networking due to his small $a_i$. As a result, his constraints nest Amy’s. As for the upper bound, these are represented by the constraints of Ace (highest quality) and Cam (lowest study ability). Here, Cam has a lower marginal return of studying than Ace. Similar to Cal, Ace should have an additional effect on his incentives. Since he is the higher quality student, it should be an additional incentive to network. However, this incentive is absent since no one is networking. If Ace is the first to network, he would receive all the networking gains. The same is true for Cam. These nullify each other, and Cam’s constraint shifts above Ace’s constraint because of her lower marginal return to studying.

6. Conclusion

In this thesis, we model the tradeoff between networking and studying for students seeking to maximize their utility from job search. We hypothesize that social networking, which increases the visibility of networking, can help resolve an imperfect information problem by allowing students to monitor each other. This suggests that social networking can
help sustain higher and more optimal levels of networking despite a free-rider problem. We then experiment with heterogeneity to understand how networking affects the incentives of student with different characteristics.

By varying student quality, or the inherent attractiveness of student applicants, we find that higher quality students are more willing to network due to their ability to better appropriate the gains to networking and their lower opportunity cost to networking. Under the no monitoring case, the greater the difference in student characteristics, the more difficult it is to sustain symmetric outcomes (all network or all study). Overall, heterogeneity primarily affects the composition of networking equilibria and does not affect total networking unless the differences in attributes are asymmetrical. When monitoring is introduced, heterogeneity in quality leads to a reduction in total networking in comparison to the homogenous case. This is a result of the decreasing willingness of higher quality students to network as less students network.

By varying student ability, or marginal returns to studying, we find that students with greater ability are less willing to network due to their comparative advantage in studying. When compared to the homogenous case, symmetric outcomes are also harder to sustain under no monitoring. However, in comparison to the case of heterogeneous quality, there are increases in total networking efforts under monitoring.

The framework we provide opens a new way of understanding how students allocate their time with respect to social networking and clears the way for future research. We suggest a few ideas below. The most immediate extension to this model would be to include continuous strategy spaces to better reflect choices faced by students and to give further insight into the types of equilibria that arise. Another aspect not explicitly modeled into this
thesis is the strategies of other colleges. Their behavior is purposely held constant in order to focus on student strategies within a college before attempting to understand the impact of students from outside colleges. This extension would endogenize the parameter \( c \), which we primarily use to measure a colleges’ networking effectiveness. The inclusion of additional colleges would also make the relative size of schools an important parameter. In dealing with a single school, size was not an issue as the model is easily extended to \( n \) students. One final idea would be to introduce heterogeneous jobs and different job rankings from students. Networking could serve not only to increase the number of jobs opportunities but play a role in improving match quality for students.

These ideas offer just a few extensions that could be incorporated into this framework to further investigate the role of social networking for college students. Social networking is an increasingly important part of modern culture and a fruitful area for further economic inquiry. This thesis is a contribution towards understanding the role that social networking plays in the lives of students and how it affects incentives and behavior.
Appendix

Example derivation of constraints for heterogeneity in \( a_i \) with no monitoring:

Equilibrium #1 with No Monitoring: No Networking with \( a_1 = .9, a_2 = 1, a_3 = 1.1 \)

Constraint for Cal to keep studying:

\[
\frac{.9}{(1 + 1.1) + (1 + 1) + .9} \left( b + \frac{1}{c + 1} \right) < \frac{1 + .9}{(1 + 1.1) + (1 + 1) + (1 + .9)} (b)
\]

\[
\frac{9}{50} \left( b + \frac{1}{c + 1} \right) < \frac{19}{60} (b)
\]

\[
b > \frac{54}{41c + 41}
\]

(18)

Constraint for Ben to keep studying:

\[
\frac{1}{(1 + 1.1) + 1 + (1 + .9)} \left( b + \frac{1}{c + 1} \right) < \frac{1 + 1}{(1 + 1.1) + (1 + 1) + (1 + .9)} (b)
\]

\[
\frac{1}{5} \left( b + \frac{1}{c + 1} \right) < \frac{1}{3} (b)
\]

\[
b > \frac{2c + 2}{5c + 2c}
\]

(19)

Constraint for Ace to keep studying:

\[
\frac{1.1}{1.1 + (1 + 1) + (1 + .9)} \left( b + \frac{1}{c + 1} \right) < \frac{1 + 1.1}{(1 + 1.1) + (1 + 1) + (1 + .9)} (b)
\]

\[
\frac{11}{50} \left( b + \frac{1}{c + 1} \right) < \frac{7}{20} (b)
\]

\[
b > \frac{22}{13c + 13}
\]

(20)

In Chapter 5.1 we discuss two effects on Ace’s incentives. First, his ability to appropriate networking gains is higher than others. Mathematically, this is demonstrated by \( \frac{p_2}{c+1} > \frac{p_3}{c+1} > \frac{p_2}{c+1} \). Second, his potential loss in share of \( b \) is smaller. Mathematically, this is demonstrated by \( \frac{2}{20} \frac{11}{50} < \frac{1}{3} \frac{1}{5} < \frac{10}{50} \frac{9}{50} \).

In order for this to be an equilibrium, all three constraints must be satisfied. Since (20) is the highest (most restrictive), that is the binding condition. Notice that Ben’s constraint (19) is exactly the same as constraint (7) was the constraint in the homogenous case in Chapter 4.1.

Graphs of Alternate Scenarios of Heterogeneity in \( a_i \) and \( d_i \)

In each of the subsequent graphs, I show the constraints of all different students for two possible equilibria: when there is no studying and when there is no networking. The set of lower bounds correspond to when there is no studying, the set of upper bounds correspond to when there is no networking. This gives a general idea of the effect of heterogeneity. I do not include the interior constraints because there are simply too many to display effectively (two equilibria with three variations with three students results in potentially an additional 18 constraints per graph). The equations for the excluded constraints are located in the table at the end of the appendix. Graphs of interior constraints (binding the equilibria of “two students networking” and “one student networking”) can be supplied upon request.
Note that the banding effect is larger in A.1 than in figure 5.1 due to a larger difference in quality. Note that the banding effect is asymmetrical in A.2 because of asymmetrical differences in quality. A greater difference results in a shift of greater magnitude. These results reinforce our earlier claim in Chapter 5.1.
These graphs show how heterogeneity in $d_i$ exhibits similar banding effects as heterogeneity in $a_i$ in when there is no monitoring.
### Master Table of Constraints

**Constraints for Heterogeneity in Student Quality without Monitoring (a)**

Let $G_0 = b$, $G_1 = b + \frac{1}{c+1}$, $G_2 = b + \frac{2}{c+2}$, $G_3 = b + \frac{3}{c+3}$

#### Equilibrium #1: 0 Networkers

<table>
<thead>
<tr>
<th>Action</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
<th>Large Symmetric Difference ($a_i=.9$, $a_j=1$, $a_k=1.1$)</th>
<th>Asymmetric Difference ($a_i=.9$, $a_j=1$, $a_k=1.1$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1 S</td>
<td>19/60($G_0$)&gt;9/50($G_1$)</td>
<td>$\frac{b}{41+41c}$</td>
<td>1/4 ($G_0$)&gt;1/10($G_1$)</td>
<td>15/56($G_0$)&gt;5/46($G_1$)</td>
</tr>
<tr>
<td>S2 S</td>
<td>1/3 ($G_0$)&gt;1/5 ($G_1$)</td>
<td>$\frac{3}{2+2c}$</td>
<td>1/3 ($G_0$)&gt;1/5 ($G_1$)</td>
<td>5/14($G_0$)&gt;5/23($G_1$)</td>
</tr>
<tr>
<td>S3 S</td>
<td>7/20($G_0$)&gt;11/50($G_1$)</td>
<td>$\frac{b}{13+13c}$</td>
<td>5/12($G_0$)&gt;3/10($G_1$)</td>
<td>3/8 ($G_3$)&gt;11/46($G_1$)</td>
</tr>
</tbody>
</table>

#### Equilibrium #2: 1 Networker

<table>
<thead>
<tr>
<th>Action</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
<th>Large Symmetric Difference ($a_i=.9$, $a_j=1$, $a_k=1.1$)</th>
<th>Asymmetric Difference ($a_i=.9$, $a_j=1$, $a_k=1.1$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1 N</td>
<td>9/50($G_1$)&gt;19/60($G_0$)</td>
<td>$\frac{b}{41+41c}$</td>
<td>1/10($G_1$)&gt;1/4 ($G_0$)</td>
<td>5/46($G_1$)&gt;15/56($G_0$)</td>
</tr>
<tr>
<td>S2 N</td>
<td>2/5 ($G_1$)&gt;1/4 ($G_2$)</td>
<td>$\frac{-6+2c}{6+9c+3c^2}$</td>
<td>2/5 ($G_1$)&gt;1/4 ($G_2$)</td>
<td>10/23($G_1$)&gt;5/18($G_2$)</td>
</tr>
<tr>
<td>S3 N</td>
<td>21/50($G_0$)&gt;11/40($G_2$)</td>
<td>$\frac{-58+26c}{58+87c+29c^2}$</td>
<td>1/2 ($G_3$)&gt;3/8 ($G_2$)</td>
<td>21/46($G_1$)&gt;11/36($G_2$)</td>
</tr>
</tbody>
</table>

#### Case 1

<table>
<thead>
<tr>
<th>Action</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
<th>Large Symmetric Difference ($a_i=.9$, $a_j=1$, $a_k=1.1$)</th>
<th>Asymmetric Difference ($a_i=.9$, $a_j=1$, $a_k=1.1$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1 N</td>
<td>9/50($G_1$)&gt;19/60($G_0$)</td>
<td>$\frac{b}{41+41c}$</td>
<td>1/10($G_1$)&gt;1/4 ($G_0$)</td>
<td>5/46($G_1$)&gt;15/56($G_0$)</td>
</tr>
<tr>
<td>S2 N</td>
<td>2/5 ($G_1$)&gt;1/4 ($G_2$)</td>
<td>$\frac{-6+2c}{6+9c+3c^2}$</td>
<td>2/5 ($G_1$)&gt;1/4 ($G_2$)</td>
<td>10/23($G_1$)&gt;5/18($G_2$)</td>
</tr>
<tr>
<td>S3 N</td>
<td>21/50($G_0$)&gt;11/40($G_2$)</td>
<td>$\frac{-58+26c}{58+87c+29c^2}$</td>
<td>1/2 ($G_3$)&gt;3/8 ($G_2$)</td>
<td>21/46($G_1$)&gt;11/36($G_2$)</td>
</tr>
</tbody>
</table>

#### Case 2

<table>
<thead>
<tr>
<th>Action</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
<th>Large Symmetric Difference ($a_i=.9$, $a_j=1$, $a_k=1.1$)</th>
<th>Asymmetric Difference ($a_i=.9$, $a_j=1$, $a_k=1.1$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1 S</td>
<td>19/50($G_1$)&gt;9/40($G_2$)</td>
<td>$\frac{-62+14c}{62+93c+31c^2}$</td>
<td>3/10($G_1$)&gt;1/8 ($G_2$)</td>
<td>15/46($G_1$)&gt;5/36($G_2$)</td>
</tr>
<tr>
<td>S2 N</td>
<td>1/5 ($G_1$)&gt;1/3 ($G_0$)</td>
<td>$\frac{3}{2+2c}$</td>
<td>1/5 ($G_1$)&gt;1/3 ($G_0$)</td>
<td>5/23($G_1$)&gt;5/14($G_0$)</td>
</tr>
<tr>
<td>S3 S</td>
<td>21/50($G_0$)&gt;11/40($G_2$)</td>
<td>$\frac{-58+26c}{58+87c+29c^2}$</td>
<td>1/2 ($G_3$)&gt;3/8 ($G_2$)</td>
<td>21/46($G_1$)&gt;11/36($G_2$)</td>
</tr>
</tbody>
</table>

#### Case 3

<table>
<thead>
<tr>
<th>Action</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
<th>Large Symmetric Difference ($a_i=.9$, $a_j=1$, $a_k=1.1$)</th>
<th>Asymmetric Difference ($a_i=.9$, $a_j=1$, $a_k=1.1$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1 S</td>
<td>19/50($G_1$)&gt;9/40($G_2$)</td>
<td>$\frac{-62+14c}{62+93c+31c^2}$</td>
<td>3/10($G_1$)&gt;1/8 ($G_2$)</td>
<td>15/46($G_1$)&gt;5/36($G_2$)</td>
</tr>
<tr>
<td>S2 S</td>
<td>2/5 ($G_1$)&gt;1/4 ($G_2$)</td>
<td>$\frac{6+9c+3c^2}{3+3c}$</td>
<td>2/5 ($G_1$)&gt;1/4 ($G_2$)</td>
<td>10/23($G_1$)&gt;5/18($G_2$)</td>
</tr>
<tr>
<td>S3 N</td>
<td>11/50($G_0$)&gt;7/20($G_0$)</td>
<td>$\frac{22}{13+13c}$</td>
<td>3/10($G_1$)&gt;5/12($G_0$)</td>
<td>11/46($G_1$)&gt;3/8 ($G_0$)</td>
</tr>
</tbody>
</table>

#### Equilibrium #3: 2 Networkers

<table>
<thead>
<tr>
<th>Action</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
<th>Large Symmetric Difference ($a_i=.9$, $a_j=1$, $a_k=1.1$)</th>
<th>Asymmetric Difference ($a_i=.9$, $a_j=1$, $a_k=1.1$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1 S</td>
<td>19/50($G_1$)&gt;9/40($G_2$)</td>
<td>$\frac{-62+14c}{62+93c+31c^2}$</td>
<td>3/10($G_1$)&gt;1/8 ($G_2$)</td>
<td>15/46($G_1$)&gt;5/36($G_2$)</td>
</tr>
<tr>
<td>S2 S</td>
<td>2/5 ($G_1$)&gt;1/4 ($G_2$)</td>
<td>$\frac{6+9c+3c^2}{3+3c}$</td>
<td>2/5 ($G_1$)&gt;1/4 ($G_2$)</td>
<td>10/23($G_1$)&gt;5/18($G_2$)</td>
</tr>
<tr>
<td>S3 N</td>
<td>11/50($G_0$)&gt;7/20($G_0$)</td>
<td>$\frac{22}{13+13c}$</td>
<td>3/10($G_1$)&gt;5/12($G_0$)</td>
<td>11/46($G_1$)&gt;3/8 ($G_0$)</td>
</tr>
</tbody>
</table>

### Case 1
<table>
<thead>
<tr>
<th>Action</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
<th>Constraint</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1 N</td>
<td>9/40(G₂)&gt;19/50(G₁)</td>
<td>( b &lt; \frac{-62 + 14c}{62 + 93c + 31c^2} )</td>
<td>1/8 (G₃)&gt;3/10(G₁)</td>
<td>( b &lt; \frac{-14 - 2c}{14 + 21c + 7c^2} )</td>
<td>5/36(G₂)&gt;15/46(G₁)</td>
<td>( b &lt; \frac{-62 - 8c}{62 + 93c + 31c^2} )</td>
<td></td>
</tr>
<tr>
<td>S2 N</td>
<td>1/4 (G₂)&gt;2/5 (G₁)</td>
<td>( b &lt; \frac{-6 + 2c}{6 + 9c + 3c^2} )</td>
<td>1/4 (G₃)&gt;2/5 (G₁)</td>
<td>( b &lt; \frac{-6 + 2c}{6 + 9c + 3c^2} )</td>
<td>5/18(G₂)&gt;10/23(G₁)</td>
<td>( b &lt; \frac{-26 + 10c}{26 + 29c + 13c^2} )</td>
<td></td>
</tr>
<tr>
<td>S3 S</td>
<td>21/40(G₂)&gt;11/30(G₁)</td>
<td>( b &gt; \frac{-114 + 6c}{114 + 95c + 19c^2} )</td>
<td>5/8 (G₃)&gt;1/2 (G₁)</td>
<td>( b &gt; \frac{-6 + 2c}{6 + 5c + c^2} )</td>
<td>7/12(G₂)&gt;11/26(G₁)</td>
<td>( b &gt; \frac{-150 + 16c}{150 + 125c + 25c^2} )</td>
<td></td>
</tr>
</tbody>
</table>

**Case 2**

<table>
<thead>
<tr>
<th>Action</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1 N</td>
<td>9/40(G₂)&gt;19/50(G₁)</td>
<td>( b &lt; \frac{-62 + 14c}{62 + 93c + 31c^2} )</td>
<td>1/8 (G₃)&gt;3/10(G₁)</td>
<td>( b &lt; \frac{-14 - 2c}{14 + 21c + 7c^2} )</td>
<td>5/36(G₂)&gt;15/46(G₁)</td>
<td>( b &lt; \frac{-62 - 8c}{62 + 93c + 31c^2} )</td>
</tr>
<tr>
<td>S2 S</td>
<td>1/2 (G₂)&gt;1/3 (G₁)</td>
<td>( b &gt; \frac{-6 + 2c}{6 + 6c + 5c + c^2} )</td>
<td>1/2 (G₃)&gt;1/3 (G₁)</td>
<td>( b &gt; \frac{6}{6 + 5c + c^2} )</td>
<td>5/9 (G₂)&gt;5/13(G₁)</td>
<td>( b &gt; \frac{24 + c}{24 + 20c + 4c^2} )</td>
</tr>
<tr>
<td>S3 N</td>
<td>11/40(G₂)&gt;21/50(G₁)</td>
<td>( b &lt; \frac{-58 + 26c}{58 + 87c + 29c^2} )</td>
<td>3/8 (G₃)&gt;1/2 (G₁)</td>
<td>( b &gt; \frac{-2 + 2c}{2 + 2c + 3c + c^2} )</td>
<td>11/36(G₂)&gt;21/46(G₁)</td>
<td>( b &lt; \frac{-250 + 128c}{250 + 375c + 125c^2} )</td>
</tr>
</tbody>
</table>

**Case 3**

<table>
<thead>
<tr>
<th>Action</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1 S</td>
<td>19/40(G₂)&gt;3/10(G₁)</td>
<td>( b &gt; \frac{-42 - 2c}{42 + 35c + 7c^2} )</td>
<td>3/8 (G₃)&gt;1/6 (G₃)</td>
<td>( b &gt; \frac{-30 - 6c}{30 + 25c + 5c^2} )</td>
<td>5/12(G₂)&gt;5/26(G₁)</td>
<td>( b &gt; \frac{-42 - 8c}{42 + 35 + 7c^2} )</td>
</tr>
<tr>
<td>S2 N</td>
<td>1/4 (G₂)&gt;2/5 (G₁)</td>
<td>( b &lt; \frac{-6 + 2c}{6 + 6c + 5c + c^2} )</td>
<td>1/4 (G₃)&gt;2/5 (G₁)</td>
<td>( b &lt; \frac{-6 + 2c}{6 + 5c + c^2} )</td>
<td>5/18(G₂)&gt;10/23(G₁)</td>
<td>( b &lt; \frac{-26 + 10c}{26 + 29c + 13c^2} )</td>
</tr>
<tr>
<td>S3 N</td>
<td>11/40(G₂)&gt;21/50(G₁)</td>
<td>( b &lt; \frac{-58 + 26c}{58 + 87c + 29c^2} )</td>
<td>3/8 (G₃)&gt;1/2 (G₁)</td>
<td>( b &gt; \frac{-2 + 2c}{2 + 2c + 3c + c^2} )</td>
<td>11/36(G₂)&gt;21/46(G₁)</td>
<td>( b &lt; \frac{-250 + 128c}{250 + 375c + 125c^2} )</td>
</tr>
</tbody>
</table>

**Equilibrium #4: 3 Networkers**

<table>
<thead>
<tr>
<th>Action</th>
<th>Small Symmetric Difference ( a₁=9, a₂=1, a₃=1.1 )</th>
<th>Large Symmetric Difference ( a₁=5, a₂=1, a₃=1.5 )</th>
<th>Asymmetric Difference ( a₁=5, a₂=1, a₃=1.1 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1 S</td>
<td>( 3/10(G₂)&gt;19/40(G₂) )</td>
<td>( b &lt; \frac{-42 - 2c}{42 + 35c + 7c^2} )</td>
<td>( 3/8 (G₃)&gt;1/6 (G₃) )</td>
</tr>
<tr>
<td>S2 N</td>
<td>( 1/3 (G₂)&gt;1/2 (G₂) )</td>
<td>( b &lt; \frac{-6 + 2c}{6 + 6c + 5c + c^2} )</td>
<td>( 1/3 (G₃)&gt;1/2 (G₃) )</td>
</tr>
<tr>
<td>S3 N</td>
<td>( 11/30(G₂)&gt;21/40(G₂) )</td>
<td>( b &lt; \frac{-114 + 6c}{114 + 95c + 19c^2} )</td>
<td>( 1/2 (G₃)&gt;5/8 (G₁) )</td>
</tr>
</tbody>
</table>

**Constraints for Heterogeneity in Student Quality with Monitoring (\( a \) )**

**Equilibrium #1: 0 Networkers**

<table>
<thead>
<tr>
<th>Action</th>
<th>Small Symmetric Difference ( a₁=9, a₂=1, a₃=1.1 )</th>
<th>Large Symmetric Difference ( a₁=5, a₂=1, a₃=1.5 )</th>
<th>Asymmetric Difference ( a₁=5, a₂=1, a₃=1.1 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1 S</td>
<td>( 19/60 b&gt;9/50 b+(1/(c + 1)) )</td>
<td>( b &gt; \frac{300}{41 + 41c} )</td>
<td>( 1/4 b&gt;1/10 b+(1/(c + 1)) )</td>
</tr>
<tr>
<td>S2 S</td>
<td>( 1/3 b&gt;1/5 b+(1/(c + 1)) )</td>
<td>( b &gt; \frac{15}{2 + 2c} )</td>
<td>( 1/3 b&gt;1/5 b+(1/(c + 1)) )</td>
</tr>
</tbody>
</table>
### Equilibrium #2: 1 Networker

<table>
<thead>
<tr>
<th>Case</th>
<th>Small Symmetric Difference ($a_i=.9$, $a_e=1$, $a_r=1.1$)</th>
<th>Large Symmetric Difference ($a_i=5$, $a_e=1$, $a_r=1.5$)</th>
<th>Asymmetric Difference ($a_i=.5$, $a_e=1$, $a_r=1.1$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Constraint</td>
<td>Simplified Constraint</td>
<td>Constraint</td>
</tr>
<tr>
<td>S1 N</td>
<td>$7/20 \times 11/50 \times b + (1/(c + 1))$</td>
<td>$b &gt; \frac{100}{13 + 13c}$</td>
<td>$5/12 \times b + 3/10 \times b + (1/(c + 1))$</td>
</tr>
<tr>
<td></td>
<td>$b &gt; 11/30 \times b + (1/(c + 1))$</td>
<td>$3/8 \times b + 11/46 \times b + (1/(c + 1))$</td>
<td>$b &gt; 184/25 + 25c$</td>
</tr>
</tbody>
</table>

### Equilibrium #3: 2 Networkers

<table>
<thead>
<tr>
<th>Case</th>
<th>Small Symmetric Difference ($a_i=.9$, $a_e=1$, $a_r=1.1$)</th>
<th>Large Symmetric Difference ($a_i=5$, $a_e=1$, $a_r=1.5$)</th>
<th>Asymmetric Difference ($a_i=.5$, $a_e=1$, $a_r=1.1$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Constraint</td>
<td>Simplified Constraint</td>
<td>Constraint</td>
</tr>
<tr>
<td>S1 N</td>
<td>$9/50 \times b + 1/1 \times (1/(c + 1)) + 19/60 \times b$</td>
<td>$b &gt; \frac{300}{41 + 41c}$</td>
<td>$1/10 \times b + 1/1 \times (1/(c + 1)) + 1/4 \times b$</td>
</tr>
<tr>
<td></td>
<td>$b &gt; 1/10 \times b + 1/1 \times (1/(c + 1)) + 1/4 \times b$</td>
<td>$5/46 \times b + 1/1 \times (1/(c + 1)) + 15/56 \times b$</td>
<td>$b &lt; \frac{1288}{205 + 205c}$</td>
</tr>
<tr>
<td>S2 S</td>
<td>$2/5 \times b + 1/4 \times b + 10/19 \times (2/(c + 2))$</td>
<td>$b &gt; \frac{400}{114 + 57c}$</td>
<td>$2/5 \times b + 1/4 \times b + 2/3 \times (2/(c + 2))$</td>
</tr>
<tr>
<td></td>
<td>$b &gt; \frac{80}{18 + 9c}$</td>
<td>$10/23 \times b + 5/18 \times b + 2/3 \times (2/(c + 2))$</td>
<td>$b &gt; \frac{552}{130 + 65c}$</td>
</tr>
<tr>
<td>S3 S</td>
<td>$21/50 \times b + 11/40 \times b + 11/20 \times (2/(c + 2))$</td>
<td>$b &gt; \frac{220}{58 + 29c}$</td>
<td>$1/2 \times b + 3/8 \times b + 3/4 \times (2/(c + 2))$</td>
</tr>
<tr>
<td></td>
<td>$b &gt; \frac{220}{58 + 29c}$</td>
<td>$21/46 \times b + 11/36 \times b + 11/16 \times (2/(c + 2))$</td>
<td>$b &gt; \frac{2277}{500 + 250c}$</td>
</tr>
</tbody>
</table>

### Equilibrium #4: 3 Networkers

<table>
<thead>
<tr>
<th>Case</th>
<th>Small Symmetric Difference ($a_i=.9$, $a_e=1$, $a_r=1.1$)</th>
<th>Large Symmetric Difference ($a_i=5$, $a_e=1$, $a_r=1.5$)</th>
<th>Asymmetric Difference ($a_i=.5$, $a_e=1$, $a_r=1.1$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Constraint</td>
<td>Simplified Constraint</td>
<td>Constraint</td>
</tr>
<tr>
<td>S1 S</td>
<td>$19/50 \times b + 9/40 \times b + 19/20 \times (2/(c + 2))$</td>
<td>$b &gt; \frac{3600}{1178 + 589c}$</td>
<td>$3/10 \times b + 1/8 \times b + 1/3 \times (2/(c + 2))$</td>
</tr>
<tr>
<td></td>
<td>$b &gt; \frac{3600}{1178 + 589c}$</td>
<td>$15/46 \times b + 5/36 \times b + 1/3 \times (2/(c + 2))$</td>
<td>$b &gt; \frac{552}{310 + 155c}$</td>
</tr>
<tr>
<td>S2 N</td>
<td>$1/5 \times b + 1/1 \times (1/(c + 1)) + 1/3 \times b$</td>
<td>$b &lt; \frac{15}{2 + 2c}$</td>
<td>$1/5 \times b + 1/1 \times (1/(c + 1)) + 1/3 \times b$</td>
</tr>
<tr>
<td></td>
<td>$b &lt; \frac{15}{2 + 2c}$</td>
<td>$5/23 \times b + 1/1 \times (1/(c + 1)) + 5/14 \times b$</td>
<td>$b &lt; \frac{322}{45 + 45c}$</td>
</tr>
<tr>
<td>S3 S</td>
<td>$21/50 \times b + 11/40 \times b + 11/21 \times (2/(c + 2))$</td>
<td>$b &gt; \frac{4400}{1218 + 609c}$</td>
<td>$1/2 \times b + 3/8 \times b + 3/5 \times (2/(c + 2))$</td>
</tr>
<tr>
<td></td>
<td>$b &gt; \frac{4400}{1218 + 609c}$</td>
<td>$21/46 \times b + 11/36 \times b + 11/21 \times (2/(c + 2))$</td>
<td>$b &gt; \frac{6072}{1750 + 875c}$</td>
</tr>
</tbody>
</table>

### Equilibrium #5: 4 Networkers

<table>
<thead>
<tr>
<th>Case</th>
<th>Small Symmetric Difference ($a_i=.9$, $a_e=1$, $a_r=1.1$)</th>
<th>Large Symmetric Difference ($a_i=5$, $a_e=1$, $a_r=1.5$)</th>
<th>Asymmetric Difference ($a_i=.5$, $a_e=1$, $a_r=1.1$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Constraint</td>
<td>Simplified Constraint</td>
<td>Constraint</td>
</tr>
<tr>
<td>S1 S</td>
<td>$19/50 \times b + 9/40 \times b + 19/20 \times (2/(c + 2))$</td>
<td>$b &gt; \frac{180}{62 + 31c}$</td>
<td>$3/10 \times b + 1/8 \times b + 1/3 \times (2/(c + 2))$</td>
</tr>
<tr>
<td></td>
<td>$b &gt; \frac{180}{62 + 31c}$</td>
<td>$15/46 \times b + 5/36 \times b + 5/16 \times (2/(c + 2))$</td>
<td>$b &gt; \frac{207}{124 + 62c}$</td>
</tr>
<tr>
<td>S2 N</td>
<td>$2/5 \times b + 1/4 \times b + 10/21 \times (2/(c + 2))$</td>
<td>$b &gt; \frac{400}{126 + 63c}$</td>
<td>$2/5 \times b + 1/4 \times b + 2/3 \times (2/(c + 2))$</td>
</tr>
<tr>
<td></td>
<td>$b &gt; \frac{400}{126 + 63c}$</td>
<td>$10/23 \times b + 5/18 \times b + 10/21 \times (2/(c + 2))$</td>
<td>$b &gt; \frac{552}{182 + 91c}$</td>
</tr>
<tr>
<td>S3 N</td>
<td>$11/50 \times b + 1/1 \times (1/(c + 1)) + 7/20 \times b$</td>
<td>$b &lt; \frac{100}{13 + 13c}$</td>
<td>$3/10 \times b + 1/1 \times (1/(c + 1)) + 5/12 \times b$</td>
</tr>
<tr>
<td></td>
<td>$b &lt; \frac{100}{13 + 13c}$</td>
<td>$11/46 \times b + 1/1 \times (1/(c + 1)) + 3/8 \times b$</td>
<td>$b &lt; \frac{184}{25 + 25c}$</td>
</tr>
</tbody>
</table>

---

44
<table>
<thead>
<tr>
<th>Case</th>
<th>Action Constraint</th>
<th>Simplified Constraint</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
<th>Constraint</th>
</tr>
</thead>
<tbody>
<tr>
<td>S2 S</td>
<td>$b &gt; \frac{6}{3 + c}$</td>
<td>$b &gt; \frac{6}{3 + c}$</td>
<td>$b &gt; \frac{27}{12 + 4c}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S3 N</td>
<td>$b &lt; \frac{220}{58 + 29c}$</td>
<td>$b &lt; \frac{12}{2 + c}$</td>
<td>$b &lt; \frac{2277}{500 + 250c}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Equilibrium #4: 3 Networkers

**Small Symmetric Difference (a₁=1, a₂=1, a₃=1.1)**

**Large Symmetric Difference (a₁=1, a₂=1.5)**

**Asymmetric Difference (a₁=1, a₂=1, a₃=1.1)**

### Constraints for Heterogeneity in Student Ability without Monitoring (d)

Let $G₀ = b$, $G₁ = b + \frac{1}{c₁v₁}$, $G₂ = b + \frac{2}{c₂v₂}$, $G₃ = b + \frac{3}{c₃v₃}$

**Equilibrium #1: 0 Networkers**

**Small Symmetric Difference (a₁=1, a₂=1, a₃=1.1)**

**Large Symmetric Difference (a₁=1, a₂=1.5)**

**Asymmetric Difference (a₁=1, a₂=1, a₃=1.1)**

### Equilibrium #2: 1 Networker

**Small Symmetric Difference (a₁=9, a₂=1, a₃=1.1)**

**Large Symmetric Difference (a₁=5, a₂=1, a₃=1.5)**

**Asymmetric Difference (a₁=5, a₂=1, a₃=1.1)**

### Equilibrium #3: 2 Networkers

**Small Symmetric Difference (a₁=9, a₂=1, a₃=1.1)**

**Large Symmetric Difference (a₁=5, a₂=1, a₃=1.5)**

**Asymmetric Difference (a₁=5, a₂=1, a₃=1.1)**

### Case 1

**Action Constraint**

<table>
<thead>
<tr>
<th>Action</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
<th>Constraint</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1 N</td>
<td>$10/51(G₀) &gt; 19/60(G₁)$</td>
<td>$b &lt; \frac{200}{123 + 123c}$</td>
<td>$b &lt; \frac{8}{3 + 3c}$</td>
<td>$b &lt; \frac{112}{41 + 41c}$</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Case 2

**Action Constraint**

<table>
<thead>
<tr>
<th>Action</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
<th>Constraint</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1 N</td>
<td>$10/51(G₀) &gt; 19/60(G₁)$</td>
<td>$b &lt; \frac{200}{123 + 123c}$</td>
<td>$b &lt; \frac{8}{3 + 3c}$</td>
<td>$b &lt; \frac{112}{41 + 41c}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Case</td>
<td>Action</td>
<td>Constraint</td>
<td>Simplified Constraint</td>
<td>Action</td>
<td>Constraint</td>
<td>Simplified Constraint</td>
<td>Action</td>
</tr>
<tr>
<td>------</td>
<td>--------</td>
<td>------------</td>
<td>-----------------------</td>
<td>--------</td>
<td>------------</td>
<td>-----------------------</td>
<td>--------</td>
</tr>
<tr>
<td>2</td>
<td>S2 S</td>
<td>$20/51(G_1) &gt; 10/41(G_2)$</td>
<td>$b &gt; \frac{-62 + 20c}{62 + 93c + 31c^2}$</td>
<td>S3 S</td>
<td>$7/17(G_1) &gt; 1/4(G_2)$</td>
<td>$b &gt; \frac{14 + 4c}{14 + 21c + 7c^2}$</td>
<td>S2 S</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$4/11(G_1) &gt; 2/9(G_2)$</td>
<td>$b &gt; \frac{-18 + 2c}{18 + 27c + 9c^2}$</td>
<td></td>
<td>$5/11(G_1) &gt; 1/4(G_2)$</td>
<td>$b &gt; \frac{-22 + 6c}{22 + 33c + 11c^2}$</td>
<td></td>
</tr>
</tbody>
</table>

### Case 2

<table>
<thead>
<tr>
<th>Case</th>
<th>Action</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
<th>Case</th>
<th>Action</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
<th>Case</th>
<th>Action</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>S1 S</td>
<td>$19/50(G_1) &gt; 10/41(G_2)$</td>
<td>$b &gt; \frac{-558 + 221c}{558 + 837c + 279c^2}$</td>
<td>S2 N</td>
<td>$1/5(G_1) &gt; 1/3(G_3)$</td>
<td>$b &lt; \frac{3}{2 + 2c}$</td>
<td>S3 S</td>
<td>$21/50(G_1) &gt; 10/39(G_2)$</td>
<td>$b &gt; \frac{-638 + 181c}{638 + 957c + 319c^2}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$3/10(G_1) &gt; 2/9(G_2)$</td>
<td>$b &gt; \frac{-13c}{14 + 21c + 7c^2}$</td>
<td></td>
<td>$1/5(G_1) &gt; 1/3(G_3)$</td>
<td>$b &lt; \frac{14}{9 + 9c}$</td>
<td></td>
<td>$1/2(G_1) &gt; 2/7(G_2)$</td>
<td>$b &lt; \frac{1}{110 + 37c}$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Equilibrium #3: 2 Networkers

<table>
<thead>
<tr>
<th>Case</th>
<th>Action</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
<th>Case</th>
<th>Action</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
<th>Case</th>
<th>Action</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>S1 S</td>
<td>$19/49(G_1) &gt; 1/4(G_3)$</td>
<td>$b &gt; \frac{-54 + 22c}{54 + 81c + 27c^2}$</td>
<td>S2 S</td>
<td>$20/49(G_1) &gt; 10/39(G_2)$</td>
<td>$b &gt; \frac{-58 - 20c}{58 + 87c + 29c^2}$</td>
<td>S3 N</td>
<td>$10/49(G_1) &gt; 7/20(G_3)$</td>
<td>$b &lt; \frac{8}{143 + 143c}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$1/3(G_1) &gt; 1/4(G_3)$</td>
<td>$b &gt; \frac{2}{2 + 3c + c^2}$</td>
<td></td>
<td>$4/9(G_1) &gt; 2/7(G_2)$</td>
<td>$b &gt; \frac{10 + 15c + 5c^2}{10 + 15c + 5c^2}$</td>
<td></td>
<td>$2/9(G_1) &gt; 5/12(G_3)$</td>
<td>$b &lt; \frac{16}{11}11c$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Equilibrium #2: 3 Networkers

<table>
<thead>
<tr>
<th>Case</th>
<th>Action</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
<th>Case</th>
<th>Action</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
<th>Case</th>
<th>Action</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>S1 N</td>
<td>$10/41(G_2) &gt; 19/50(G_1)$</td>
<td>$b &lt; \frac{-558 + 221c}{558 + 837c + 279c^2}$</td>
<td>S2 N</td>
<td>$10/41(G_2) &gt; 20/51(G_1)$</td>
<td>$b &lt; \frac{-62 + 20c}{62 + 93c + 31c^2}$</td>
<td>S3 S</td>
<td>$21/41(G_2) &gt; 1/3(G_3)$</td>
<td>$b &gt; \frac{132 + 110c + 22c^2}{132 + 110c + 22c^2}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$2/9(G_2) &gt; 3/10(G_1)$</td>
<td>$b &gt; \frac{-14 + 13c}{14 + 21c + 7c^2}$</td>
<td></td>
<td>$2/9(G_2) &gt; 4/11(G_1)$</td>
<td>$b &lt; \frac{-14 + 4c}{10 + 15c + 5c^2}$</td>
<td></td>
<td>$5/9(G_2) &gt; 1/3(G_3)$</td>
<td>$b &lt; \frac{-132 - 3c}{132 + 110c + 22c^2}$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Case 2

<table>
<thead>
<tr>
<th>Case</th>
<th>Action</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
<th>Case</th>
<th>Action</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
<th>Case</th>
<th>Action</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>S1 N</td>
<td>$1/4(G_3) &gt; 19/49(G_1)$</td>
<td>$b &lt; \frac{-54 + 22c}{54 + 81c + 27c^2}$</td>
<td>S2 S</td>
<td>$1/2(G_1) &gt; 1/3(G_3)$</td>
<td>$b &lt; \frac{6}{6}1c$</td>
<td>S3 N</td>
<td>$1/4(G_3) &gt; 7/17(G_1)$</td>
<td>$b &lt; \frac{-22 + 6c}{22 + 33c + 11c^2}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$1/4(G_2) &gt; 1/3(G_3)$</td>
<td>$b &lt; \frac{-2 + 2c}{2 + 3c + c^2}$</td>
<td></td>
<td>$1/2(G_2) &gt; 1/3(G_3)$</td>
<td>$b &lt; \frac{6}{6}1c$</td>
<td></td>
<td>$1/4(G_2) &gt; 5/11(G_1)$</td>
<td>$b &lt; \frac{-18 + 2c}{18 + 27c + 9c^2}$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Case 3

<table>
<thead>
<tr>
<th>Case</th>
<th>Action</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
<th>Case</th>
<th>Action</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
<th>Case</th>
<th>Action</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>S1 S</td>
<td>$19/39(G_1) &gt; 1/3(G_3)$</td>
<td>$b &gt; \frac{-36 + c}{36 + 30c + 6c^2}$</td>
<td>S2 N</td>
<td>$10/39(G_1) &gt; 20/49(G_3)$</td>
<td>$b &lt; \frac{-58 + 20c}{58 + 87c + 29c^2}$</td>
<td>S2 S</td>
<td>$3/7(G_2) &gt; 1/3(G_3)$</td>
<td>$b &gt; \frac{-10 + 4c}{10 + 15c + 5c^2}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$3/7(G_2) &gt; 1/3(G_3)$</td>
<td>$b &gt; \frac{-12 + 3c}{12 + 10c + 2c^2}$</td>
<td></td>
<td>$4/9(G_1)$</td>
<td>$b &lt; \frac{-10 + 4c}{10 + 15c + 5c^2}$</td>
<td></td>
<td>$4/9(G_1)$</td>
<td>$b &lt; \frac{-10 + 4c}{10 + 15c + 5c^2}$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Equilibrium #4: 3 Networkers

<table>
<thead>
<tr>
<th>Action</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
<th>Constraint</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1 N</td>
<td>$1/3 (G_3) &gt; 19/39(G_2)$</td>
<td>$b &lt; \frac{-36 + c}{36 + 30c + 6c^2}$</td>
<td>$1/3 (G_3) &gt; 3/7 (G_2)$</td>
<td>$b &lt; \frac{-12 + 3c}{12 + 10c + 2c^2}$</td>
<td>$1/3 (G_3) &gt; 3/7 (G_2)$</td>
<td>$b &lt; \frac{-12 + 3c}{12 + 10c + 2c^2}$</td>
<td>$1/3 (G_3) &gt; 3/7 (G_2)$</td>
</tr>
<tr>
<td>S2 N</td>
<td>$1/3 (G_3) &gt; 1/2 (G_2)$</td>
<td>$b &lt; \frac{-6 + 5c + c^2}{6}$</td>
<td>$1/3 (G_3) &gt; 1/2 (G_2)$</td>
<td>$b &lt; \frac{-6 + 5c + c^2}{6}$</td>
<td>$1/3 (G_3) &gt; 1/2 (G_2)$</td>
<td>$b &lt; \frac{-6 + 5c + c^2}{6}$</td>
<td>$1/3 (G_3) &gt; 1/2 (G_2)$</td>
</tr>
<tr>
<td>S3 N</td>
<td>$1/3 (G_3) &gt; 21/41(G_1)$</td>
<td>$b &lt; \frac{-132 - 3c}{132 + 110c + 22c^2}$</td>
<td>$1/3 (G_3) &gt; 5/9 (G_2)$</td>
<td>$b &lt; \frac{-12 - c}{12 + 10c + 2c^2}$</td>
<td>$1/3 (G_3) &gt; 21/41(G_1)$</td>
<td>$b &lt; \frac{-132 - 3c}{132 + 110c + 22c^2}$</td>
<td>$1/3 (G_3) &gt; 5/9 (G_2)$</td>
</tr>
</tbody>
</table>

### Constraints for Heterogeneity in Student Quality with Monitoring ($d$)

#### Equilibrium #1: 0 Networkers

<table>
<thead>
<tr>
<th>Action</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
<th>Constraint</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1 S</td>
<td>$19/60 b &gt; 10/51 b + (1/(c+1))$</td>
<td>$b &gt; \frac{340}{41 + 41c}$</td>
<td>$1/4 b &gt; 2/11 b + (1/(c+1))$</td>
<td>$b &gt; \frac{15}{3 + 2c}$</td>
<td>$15/56 b &gt; 10/51 b + (1/(c+1))$</td>
<td>$b &gt; \frac{15}{3 + 2c}$</td>
<td>$b &gt; \frac{2856}{205 + 205c}$</td>
</tr>
<tr>
<td>S2 S</td>
<td>$1/3 b &gt; 1/5 b + (1/(c+1))$</td>
<td>$b &gt; \frac{24 + 2c}{2}$</td>
<td>$1/3 b &gt; 1/5 b + (1/(c+1))$</td>
<td>$b &gt; \frac{24 + 2c}{2}$</td>
<td>$5/14 b &gt; 5/23 b + (1/(c+1))$</td>
<td>$b &gt; \frac{24 + 2c}{2}$</td>
<td>$b &gt; \frac{322}{45 + 45c}$</td>
</tr>
<tr>
<td>S3 S</td>
<td>$7/20 b &gt; 10/49 b + (1/(c+1))$</td>
<td>$b &gt; \frac{980}{143 + 143c}$</td>
<td>$5/12 b &gt; 2/9 b + (1/(c+1))$</td>
<td>$b &gt; \frac{36}{7 + 7c}$</td>
<td>$3/8 b &gt; 2/9 b + (1/(c+1))$</td>
<td>$b &gt; \frac{36}{7 + 7c}$</td>
<td>$b &gt; \frac{72}{11 + 11c}$</td>
</tr>
</tbody>
</table>

#### Equilibrium #2: 1 Networker

### Case 1

<table>
<thead>
<tr>
<th>Action</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
<th>Constraint</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1 N</td>
<td>$10/51 b + (1/(c+1)) &gt; 19/60 b$</td>
<td>$b &lt; \frac{340}{41 + 41c}$</td>
<td>$2/11 b + (1/(c+1)) &gt; 1/4 b$</td>
<td>$b &lt; \frac{15}{3 + 2c}$</td>
<td>$10/51 b + (1/(c+1)) &gt; 15/56 b$</td>
<td>$b &lt; \frac{15}{3 + 2c}$</td>
<td>$b &lt; \frac{2856}{205 + 205c}$</td>
</tr>
<tr>
<td>S2 S</td>
<td>$20/51 b &gt; 10/41 b + 1/2(2/(c+2))$</td>
<td>$b &gt; \frac{2091}{620 + 310c}$</td>
<td>$4/11 b &gt; 2/9 b + 1/2(2/(c+2))$</td>
<td>$b &gt; \frac{28 + 14c}{28 + 14c}$</td>
<td>$20/51 b &gt; 10/41 b + 1/2(2/(c+2))$</td>
<td>$b &gt; \frac{28 + 14c}{28 + 14c}$</td>
<td>$b &gt; \frac{2091}{620 + 310c}$</td>
</tr>
<tr>
<td>S3 S</td>
<td>$7/17 b &gt; 1/4 b + 1/2(2/(c+2))$</td>
<td>$b &gt; \frac{68}{22 + 11c}$</td>
<td>$5/11 b &gt; 1/4 b + 1/2(2/(c+2))$</td>
<td>$b &gt; \frac{44}{18 + 9c}$</td>
<td>$7/17 b &gt; 1/4 b + 1/2(2/(c+2))$</td>
<td>$b &gt; \frac{44}{18 + 9c}$</td>
<td>$b &gt; \frac{68}{22 + 11c}$</td>
</tr>
</tbody>
</table>

#### Case 2

<table>
<thead>
<tr>
<th>Action</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
<th>Constraint</th>
<th>Simplified Constraint</th>
<th>Constraint</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1 S</td>
<td>$19/50 b &gt; 10/41 b + 1/2(2/(c+2))$</td>
<td>$b &gt; \frac{2050}{558 + 279c}$</td>
<td>$3/10 b &gt; 2/9 b + 1/2(2/(c+2))$</td>
<td>$b &gt; \frac{90}{14 + 7c}$</td>
<td>$15/46 b &gt; 10/41 b + 1/2(2/(c+2))$</td>
<td>$b &gt; \frac{90}{14 + 7c}$</td>
<td>$b &gt; \frac{1886}{310 + 155c}$</td>
</tr>
<tr>
<td>S2 N</td>
<td>$1/5 b + (1/(c+1)) &gt; 1/3 b$</td>
<td>$b &lt; \frac{15}{2 + 2c}$</td>
<td>$1/5 b + (1/(c+1)) &gt; 1/3 b$</td>
<td>$b &lt; \frac{15}{2 + 2c}$</td>
<td>$5/23 b + (1/(c+1)) &gt; 5/14 b$</td>
<td>$b &lt; \frac{15}{2 + 2c}$</td>
<td>$b &lt; \frac{322}{45 + 45c}$</td>
</tr>
<tr>
<td>S3 S</td>
<td>$21/50 b &gt; 10/39 b + 1/2(2/(c+2))$</td>
<td>$b &gt; \frac{1950}{638 + 319c}$</td>
<td>$1/2 b &gt; 2/7 b + 1/2(2/(c+2))$</td>
<td>$b &gt; \frac{14}{6 + 3c}$</td>
<td>$21/46 b &gt; 2/7 b + 1/2(2/(c+2))$</td>
<td>$b &gt; \frac{14}{6 + 3c}$</td>
<td>$b &gt; \frac{322}{110 + 55c}$</td>
</tr>
</tbody>
</table>

#### Case 3
<table>
<thead>
<tr>
<th>Equilibrium #3: 2 Networkers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Case 1</strong></td>
</tr>
<tr>
<td><strong>Action</strong></td>
</tr>
<tr>
<td><strong>S1 S</strong></td>
</tr>
<tr>
<td><strong>S2 S</strong></td>
</tr>
<tr>
<td><strong>S3 S</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Equilibrium #4: 3 Networkers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Case 2</strong></td>
</tr>
<tr>
<td><strong>Action</strong></td>
</tr>
<tr>
<td><strong>S1 N</strong></td>
</tr>
<tr>
<td><strong>S2 N</strong></td>
</tr>
<tr>
<td><strong>S3 S</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Equilibrium #4: 3 Networkers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Case 3</strong></td>
</tr>
<tr>
<td><strong>Action</strong></td>
</tr>
<tr>
<td><strong>S1 S</strong></td>
</tr>
<tr>
<td><strong>S2 N</strong></td>
</tr>
<tr>
<td><strong>S3 N</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Equilibrium #4: 3 Networkers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Case 3</strong></td>
</tr>
<tr>
<td><strong>Action</strong></td>
</tr>
<tr>
<td><strong>S1 N</strong></td>
</tr>
<tr>
<td><strong>S2 N</strong></td>
</tr>
<tr>
<td><strong>S3 N</strong></td>
</tr>
</tbody>
</table>
**Bibliography**


