Models of Peer Effects in Education **

Karl Wennberg *
Axel Norgren
Stockholm School of Economics
Center for Educational Leadership and Excellence
PO Box 6501
11383 Stockholm

Abstract: This paper summarizes the current state of research on peer effects in education. Focusing on specific models of peer effects and their underlying theoretical rationales, we review empirical evidence for these models and their implications for future research and discuss potential implications for educational policy. Our review highlights evidence for various types of peer effects to be sensitive to research design, data and study context. We propose a broader utilization of models testing various types of peer effects in specific datasets, attention to methodological issues beyond identifying cause- and effect, and further scrutiny of the theoretical mechanisms underlying identified peer effects in educational settings.

* Communicating author: Karl.Wennberg@hhs.se
** We are grateful for financial support from Magnus Bergvall foundation and to Ellen Olsson for diligent research assistance.

Table of Content

1. Introduction to Peer Effects in Education

Research on the effects of education and how learning is best achieved in differing classrooms originate from the Coleman Report (1968) which discusses the prevalent phenomenon that educational opportunities tend to vary across segregated schools even if they receive the same amount of resources. The importance of studying educational outcomes across classrooms with different student compositions has subsequently led to more research on how such differences arise and what can be done to solve them.

An increasingly prevalent topic in this line of research examined in the economics of education and other social sciences is the role of *peer effects* in education. Peer effects can be considered as *the impact that peers have on the learning of a specific person*. Peer effects are thought to operate through different channels: For example, if a student is in a class with high-ability peers, he or she might benefit from this by interacting with them, mimicking their study behavior. Peer effects may also stem from high-ability peers asking questions that enhance the overall learning environment in the class. It could also be that the ability of the class affects how the teacher behaves. The exact channels through which peer effects work are not yet uncovered but research in economics, psychology, sociology and educational science is increasingly attending to such channels.

Understanding peer effects have value for understanding important aspects of students' learning, with potential to enhance learning through classroom design and educational policies. Identifying peer effects, their relative salience, and how they operate may have an impact on how education should be conducted, if it is favorable to have classes separated by ability, to what extent policymakers should interfere to minimize school segregation, and where it is most beneficial to add resources. Extant overviews of the literature on peer effects include Sacerdote (2011), Epple and Romano (2011) and Telhaj (2018). These overviews primarily attend to the studies of peer effects using the basic 'linear-in-means' model which measure the average educational outcome of the peers. Recent research has also formulated and investigated alternative specifications to examine non-linear effects and their policy implications, as well as to better understand the underlying theoretical mechanisms behind peer effects. In this review we aim to provide a cursory but broad overview of the peer effects literature with a focus on its corresponding models and the empirical support to date around those models. Our review is non-technical oriented and aimed at the generic social science reader interested in peer effects research and their potential implication for educational policy and classroom design.

2. Models of Peer Effects in the Economics of Education

A central topic discusses across the social science literatures on peer effects concerns the theoretical mechanisms behind peer effects, and how to operationalize these. In short, *how* do peer effects actually operate, and *why*? Until recently, the bulk of research examines peer effects using the so-called 'linear-in-means' model which measures the classroom average on one or several dimensions (students' grades, test scores, behavior, etc.) as the measurement of peers' characteristics (e.g. Lavy and Schlosser 2011, Ammermueller and Pischke 2009, Hanushek et al. 2003). While documenting the existence of peer effects at all educational levels and across varying settings and subject areas, this approach rarely reveals very much about the underlying structures of peer effects. Given the empirical difficulties involved in measuring peer effects in a cause-effect framework, Hoxby and Weingarth (2005) suggest researchers to rely on the basic linear-in-means model to be able to identify peer effects in the first place, before considering alternate models. Hence, limited research to date has sought to estimate non-linear types of peer effects to further unearth underlying theoretical mechanisms of how peer effects operate. [1] Recent studies have tried to improve their specification and look at more detailed data to be able to identify through what channels peer effects work. Table 1 summarizes different models suggested by Sacerdote (2011) which we base our review in the subsequent sections on. In each section we define, discuss, and outline studies utilizing each type of model, and with what results.

Table 1: Models of Peer Effects in Education

Model	Description
Linear-in-means	Average grades in the class matters
Bad Apple	Disruptive students harm others
Shining Light	One bright student helps others
Invidious Comparison	Relative rank matters
Tracking	Students benefit from being with same-ability students
Single Crossing	All students benefit from better classmates
Rainbow	Heterogeneous classrooms are best
Focus	Homogenous classrooms are best

Source: Adapted from Sacerdote (2011)

[1] If peer effects are limited to the linear-means effects, there is no social gain to sorting individuals into peer groups since "good" peers taken from one group and placed into another will have equal and offsetting effects on both groups (Bénabou 1996).

2.1 Bad apple

The 'bad apple' theory was developed by Lazear (2001) who proposes that one or a few disruptive students may negatively affect the whole class, rather than all students contributing to classroom spillovers. This theory thus focuses on *negative peer effects*, which can be thought of as bad behavior from peers that negatively impact a focal student's learning. Such negative peer effects could happen through multiple channels: for example, by the disruptive student making it difficult for other students to focus on the lecture, by making the teacher spend additional time on disciplining the disruptive student or by the disruptive student encouraging others to act in similar manners.

Neidell and Waldfogel (2010) examine peer effects in American preschools by studying cognitive outcomes such as test scores and non-cognitive outcomes such as self-control, as well as interpersonal skills and externalizing problems among the preschoolers. Non-cognitive outcomes are measured through ratings from the children's teachers and parents. Externalizing problems are defined as the child's amount of fighting, arguing, getting angry or disturbing ongoing activities. The authors find peer effects from externalizing problems to have a negative impact on test scores in math and reading, indicating that the bad apple model could have some explanatory power. In another study on disruptive peers, Carrell et al. (2018) use American children been exposed to domestic violence as a proxy for disruptive peers. They find that exposure to disruptive peers decreases test scores and in the long run also reduce future earnings amongst classroom peers. Although they do not have the data to study non-cognitive outcomes, they suspect that impact on non-cognitive outcomes might be what drives the results, as they find heterogeneous results for different groups. This study indicates the potential of negative long-term effects of having disruptive peers, highlighting the importance of understanding the nature of negative peer effects in further research as to be able to design optimal classroom interventions to prevent it.

Two studies from Israel also examine the existence of negative peer effects and suggest that it is indeed disruptive behavior, specifically from low-ability students and from boys, that tend to underlie such effects. Lavy and Schlosser (2011) study classroom gender composition among elementary and middle school students and find that an increased proportion of girls in the classroom improve the cognitive function of both boys and girls. The negative effect exists in both elementary and middle schools but is stronger for girls than for boys in elementary school. Based on surveys conducted during the study it is suggested that the positive impact of having a larger share of girls is derived from lower classroom disruption and less teacher fatigue. Lavy and Schlosser note that the effect does not stem from

individual students changing behavior when classroom gender composition changes, but rather than the source of negative peer effects is a form of 'linear-in-means' effect stemming from girls being generally less disruptive than boys. While the documented effect sizes are not large, gender composition is generally an inexpensive or costless variable to consider in classroom or study program design compared to the effects of other, more expensive, design variables.

In a follow-up study, Lavy et al. (2012) use students who had to repeat a grade as a proxy for low-ability students, with the assumption that it is usually students who are struggling that are held back. Using this method, the authors avoid using peer characteristics or grades as the measure of peer ability, measures which have been criticized for being endogenous to disruptive behavior. Lavy et al. show that the share of repeaters in a grade has a negative effect on their classmates' middle school and high school performance. Using survey results, they propose that this is due to teachers diverting their attention to the low-ability students resulting in fewer learning opportunities for the rest of the class.

A psychological study by Rambaran et al. (2017) is also of relevance for the bad apple model. The study examined students' rating of peers throughout the school year among Californian 14- and 15-year old elementary school students using stochastic actor-oriented social network analysis (SIENA). Their results suggest the existence of negative peer effects influencing truancy behavior among students with mutual friendship ties. Thus, negatively influencing students with high social status is more likely to influence their friends' levels of truancy more than friends with lower social status.

These studies show support for the bad apple theory, suggesting that having disruptive students, students that play truant (especially if they are popular) and potentially too many low-ability students or too many boys in a class may negatively impact the rest of the class. A simple solution to reduce this negative effect seem to be to increase the proportion of girls in the class. However, moving girls from one class to another necessarily means decreasing the number of girls in the class they are moved from. More research is thus needed on classroom gender composition, ideally considering both students' behavior as well as study outcomes. One also has to consider the situation for girls in 'balancing out' problematic classrooms, so that those girls are not put into a damaging environment or an environment in which their own learning suffers, a phenomenon known as the "buffer girl" syndrome in Swedish education (Gulbrandsen 1994). Lavy and Schlosser (2011) suggest that this could be achieved by making class sizes smaller when there is a high proportion of boys, or training teachers in larger classes to handle disruption. Another solution could be to increase teacher resources,

for example by having more teachers in classes with many disruptive students. If the behavior of a specific student is targeted by teachers or other educational staff, considerations should be given to the status or the potential influence of the student on the specific class (Rambaran et al. 2017).

2.2 Shining light

An opposite model – the shining light theory – outline the idea that one high-achieving student can have a positive impact on the whole class. The effects of peers according to this theory is not due to the mean composition of the class wherein everyone affects their peers equally but rather due to one or a few high-ability students who change the environment in the classroom. This could be due to social effects such as other students wanting to mimic the good example the bright student is setting and consequently studies more or pays more attention in the classroom. It could be that the high-performing student asks better questions that help other students learn or help the other students to learn the material. To the best of our knowledge, this type of effect has not been discovered in any causally designed study so far. This could also be due to the difficulty in measuring this effect without being intrusive in the classroom setting. One study that finds that having motivated peers, more specifically by having a calm and learning-enhancing classroom environment, affect student performance is Bietenbeck (2020b). In a study of US kindergarteners, he finds short-term positive effects on reading scores from having motivated peers. He does not find any effect on self-motivation, and the effects on reading are not long-lasting. He claims this is due to motivated peers creating a better classroom environment which mean the other students can achieve better reading results. The author also hypothesizes that the lack of long-term results is due to having a motivated classmate not changing self-motivation. The study highlights the importance of being aware of motivational effects in classroom settings and how peers' motivation can be impactful. As exposure to motivated peers is short in this study, only for the first three school years, longer exposure should be studied to examine the potential existence of long-term effects.

2.3 Invidious comparison

Invidious comparison is when a student compares themselves to their classmates and evaluate their educational outcomes relative to their peers' educational achievements. This could affect students self-confidence negatively if they are surrounded by high-ability peers, and by

extension negatively impact their grades or their 'academic self-concept' (Byrne 1996). Having a lower academic self-concept could result in students not applying for prestigious programs or majors that are seen as more difficult. This effect is investigated in Jonsson and Mood (2008) who examine the correlation of peers on choosing a more demanding academic upper secondary school (high school) track in Sweden. Their results indicate that the propensity to chose a a more demanding upper secondary school program choice is lower for students with many high-achieving peers in their lower secondary school.

Similarly, in a correlational study Dryler (1999) studies how peers affect students in Swedish comprehensive schools when it comes to which high school to enroll in. She finds that having peers with high ability in natural sciences seems to influence the student to apply to the humanities track, whereas if the peers are better at humanities the student is more inclined to apply to the engineering track. This also shows that peer effects might influence students in other ways than pure test scores, e.g. through educational choices.

More recently, several studies have focused on the student's relative rank in the class, and how this affects grades and educational choices (e.g. Murphy and Weinhardt 2020, Elsner and Isphording 2017, Elsner et al. 2021). Students' relative rank can be applied to the invidious comparison model as these studies investigate if the relative ability of the student compared to the peer matter. Most of the studies find that rank does matter and affect outcomes such as subsequent grades, college enrollment and college dropout. Hence, being in a class with better peers means the student has a lower-class rank which may negatively affect his or her educational outcome. This is in opposition to what other peer effect studies find, as most of them find to some degree that having better ability peers improve the own outcome.

Murphy and Weinhardt (2020) find that English secondary school students achieved higher grades in secondary school if they had a higher rank in that subject in primary school. They compare this to the aforementioned study of disruptive peers by Carrell et al. (2018) and claims that the impact from the rank effect is four times that of having a disruptive peer that Carrell found. Murphy and Weinhardt also find that boys are more affected by rank than girls, underscoring that rank effects might be heterogeneous. From survey data, they posit that having a higher rank boosts confidence which could be a reason why having a higher rank may enhance educational outcomes. Similarly, a study of students in grades 7 to 12 in the U.S from the nationally representative AddHealth survey by Cools et al. (2019) finds varying effects on educational attainment for girls depending on if they are exposed to high-achieving girls or high-achieving boys.

A long-standing social science explanation for why invidious comparison may be beneficial is the 'Big-Fish-Little-Pond' effect described by Marsh and Parker (1984) to explain why being higher up in the class rank enhance students' academic self-concept. The mechanism posited stems from the psychology of social comparison (Festinger 1954) which has frequently been studied in educational psychology. In this literature, the most frequent social comparison in a classroom setting is upwards (Huget, et al. 2001; Dijkstra et al. 2008). Upwards social comparison may be self-enhancing if it aspires students to study harder and mimic the behavior of those they perceive as successful, but can also be ego-deflating and negatively affect students' self-concept (e.g. Collins 1996; Dijkstra et al. 2008). This indicates that upward comparison can act as a double-edged sword for the pupils, which has stark consequences for both classroom and educational policies. Further attention towards *when* and *why* students relative rank affect educational achievement is thus warranted: Whether relative rank *positively* or *negatively* affects educational achievement in specific settings has consequences for the design of school choice systems and tracking systems where students are early on sorted into specific groups based on absolute ability in specific subjects. Further research is needed to gain insight regarding what moderates the effects of the relative rank, especially on upward comparison in the classroom context.

2.4 Boutique/Tracking

The 'boutique' or 'tracking' model posits that students perform better when surrounded by other students that are on the same ability level. The underlying rationales for this type of peer effect model are that students are better able to help and teach each other at a similar level or that the teacher can better adjust the material to the class as they are all on a similar ability level. Tracking is used in several countries based on the belief that it benefits students, especially the high-ability ones who can be taught more difficult material. However, the consequences of tracking need to be studied. If low-ability students also benefit from having more able peers, this could cause further gaps in educational achievement if they are not exposed to high-achieving students.

In a recent study, Feld and Zölitz (2017) investigate peer effects in a Dutch university. The university's large classes are divided into smaller groups called sections that are allocated on a random basis, making it a good ground for finding causal peer effects. They find that being exposed to better peers increase the focal student grades, with a one standard deviation increase in peers' grades causing a 1.26 percent standard deviation increase in focal student grades. However, when they categorize students into three groups of low-GPA (Grade Point

Average), middle-GPA and high- GPA students, they find that middle- and high-GPA students benefit from better peer groups whilst low-GPA students do not. Based on course evaluations, Feld and Zölitz study the underlying mechanisms to these results and find that hours studied, or rating of teacher effectiveness did not change based on having a better peer group. They find instead that the effects seem to be driven by peer interaction. Complicating the matter is that the effect of peer interaction based on the survey results is linear, implying that some unknown mechanism is driving the result that low-GPA students are negatively affected by high-GPA students.

In an experimental study, Duflo et al. (2011) change class composition in Kenyan elementary schools by splitting classes into two. In half of the 120 schools studied, the authors randomly allocate students to the new classes, whilst in half, they allocate them based on ability, a 'two-way tracking'. Experimentally testing the effects of tracking assures no confounding variables interacting with the peer effects. They find that tracking raised scores for all students compared to mixed ability classes, both those assigned to the low-ability group and the high-ability group. The researchers hypothesize that the intervention reduced incentives to teach the top students that often exist in developing countries making the education more suitable for all. They hence believe the effect is due to the teachers changing behavior when having a tracked class.

A well-cited study by Carrell et al. (2013) on several cohorts of freshmen students at the US Air Force Academy sought to test whether overall student performance could be enhanced by assigning students to peer groups designed to maximize the educational performance of the lowest ability students, whom were placed into squadrons with a high fraction of peers with high verbal scores on the US Standardized Academic Test. Compared to the control group of cohorts that were randomly assigned, the authors found negative and significant treatment effect for the students they intended to help. Within the classes of students – on average quite small at about 20 students – high and low ability students in the treatment squadrons appear to have segregated themselves into separate study groups, resulting in decreased beneficial social interactions among group members. The study highlights the importance of considering students' self-selection in whom they interact with – even within classrooms – and the interactive nature of students' social networks and their overall study contexts. As a consequence, policies designed to bring about positive peer effects may be confounded by students self-segregating themselves into more homogeneous subgroups.

In a Dutch university, Booij et al. (2017) study peer effects by allocating what section a student belongs to, based on their GPA. This experimental setting allows them to create groups with varying compositions of GPAs, for example, high-GPA groups, low-GPA groups and mixed GPA groups. Studying the peer effect on outcomes such as the number of credits passed and dropouts, they find non-linear heterogeneous effects for the different groups. Thereafter they take advantage of their large sample to simulate what results would be achieved when using different grouping policies on the student population. They find that three-way tracking would increase grades the most, due to low-ability and middle-ability students raising their grades. Two-way tracking also improves scores compared to ability-mixing but to a lesser extent. Overall, high-ability students do not seem to be impacted by peers. They also try mixing two groups and tracking one. When tracking middle-ability students and mixing low- and high-ability students they find a positive effect on the middle-ability students but no effect in the mixed group, similar to Carrell et al. (2013).

Based on surveys, Booij et al. (2017) examine underlying mechanisms that could drive the peer effects and suggest that it is increased and improved student interaction that drives the positive peer effects documented among the Dutch university students. They do not find any indications of changes in teacher behavior based on their survey results. They hence conclude that three-way tracking is an easily implemented and inexpensive policy that could help low-ability students whilst not affecting higher ability students. Moreover, as both studies point toward peer effects being caused by social interactions it is important to make sure social interaction does indeed take place for peers to have any impact.

As tracking is a widely studied model there is also plenty of studies that find negative or no effects of separating based on ability. Lefgren (2004) studies the difference in outcomes for primary school students in tracked and mixed-ability classes in the US. He finds little evidence of peer effects for both, suggesting that tracking does not lead to high-ability students performing better.

Hanushek and Wößmann (2006) conduct a difference-in-difference study over several OECD countries to investigate the effects of tracking in primary and secondary school. Although they do not explicitly model peer effects the study still highlights the consequences of tracking. They find that tracking increases inequality in the country and has a mixed effect on performance that does not seem to weigh up for the increased inequality tracking produced. This suggests that even if students perform better if they are in a class with more students of their ability tracking could exacerbate inequality.

Entorf and Lauk (2008) investigate the impact of peer effects on native and immigrant students in different OECD countries using the PISA test that measures educational attainment in primary school. They conclude that in countries with tracking systems the prevailing educational inequality worsens compared to countries with ability-mixed systems.

In a large study of Swedish high school freshmen, Sund (2009) also find negative effects of tracking. The study is based on identifying peer effects by using each students' former elementary school class as peers, rather than current students with whom one has already been allocated. In this study, lower-achieving students seem to benefit more from being in a classroom with a larger spread in achievement than what higher-ability students lose.

The studies finding negative effects of tracking mostly point towards them being due to an increased educational inequality due to separating students based on ability. With some studies finding positive effects of tracking and some not finding a clear direction of the effect, further research is needed to identify the type of contexts in which tracking is beneficial or not, and why. It may be that the context is important. Duflo et al. (2011) states that teachers in developed countries have more incentives to teach to the class often because they are rewarded by how high scores the students attain, making them put their effort into the students who are less likely to drop out of school. This might not be applicable to developing countries where teachers often have the objective of not letting the weakest students fall behind. Interesting is that many of the studies show no impact on high-ability students from tracking, which is curious as the objective behind tracking is often to stimulate higher-achieving students. Moreover, the negative effects of increased educational segregation must be considered as it can potentially have long-term effects and affect more outcomes than solely students' educational achievement. A potential policy objective could be to have some subjects tracked so students can reap the benefits of being in a class with other students of the same ability, whilst also having mixed classes to reduce inequality.

In sum, it is clear that a range of studies finds evidence for both the tracking model and the invidious comparison model, models with largely opposite predictions for individual students' educational performance. Yet, the effects of both models are not necessarily mutually exclusive. It may be that students gain from being in a tracked class through learning better with like-minded classmates but at the same time comparing themselves to their classmates. This would mean both effects would have to be considered in further research, as well as in educational policy decisions. For example, specific interventions may be considered to boost academic self-concept of students in tracked classes.

The adverse result found in several studies gauging the pros and cons of tracking for the overall student population, along with the evidence of relative rank in a class positively affecting students' educational achievements indicates that further research is needed to probe the differential or multiple channels by which peer effects operate in specific educational settings. Benefits or disadvantages accruing to specific students may come with disadvantages or advantages at the population level, which needs to be considered.

2.5 Single Crossing

According to the single crossing theory, the benefits from having high-ability peers accrue to all students regardless of their own ability. Compared to the shining light theory which models the effect of one specific classmate for creating positive peer effects, the single crossing theory suggests more generally that having high-ability peers is always beneficial. This contrasts with the invidious comparison model or non-linear models where it is proposed that having better peers is not always better for all students. Evidence of the single crossing model is demonstrated in a vast number of studies using linear-in-means models that do not investigate non-linear effects. These studies find that an increase in peers' performance monotonically increases a focal student's own performance (e.g. Hanushek et al. 2003, Ammermueller and Pischke 2009, Lefgren 2004). If the single crossing model is an accurate description of peer effects, it would not be possible to change anything as the effects cannot be maximized if everyone is benefiting from the better peers.

Moreover, many studies that have found that it is beneficial for low-ability students to be mixed with high-ability students have later found adverse effects when mixing these groups, as in Carrell et al. (2013) and Booij et al. (2017). They suggest these results stem from the low-ability people not interacting with the high-ability people when mixed but that the groups stick to themselves. These studies highlight the need to experimentally study the effects of different classroom compositions and not only rely on theoretical results.

2.6 Rainbow and Focus

The rainbow and focus theories are two opposing theories regarding the benefits of mixing students in the classroom. The focus theory postulates that homogeneity is beneficial for learning, for instance by allowing teachers to tailor the material to students of similar ability, or because a homogeneous group have similar values and characteristics that enhance learning or social interaction among them. In the rainbow theory, a heterogeneous classroom is

proposed to benefit students by exposing them to a diversity of perspectives and backgrounds. Being exposed to multiple influences is theorized to strengthen analytical skills and help students gain a deeper understanding of the material.

A study finding support for the focus theory is Lavy et al. (2012) who examine middle school students in Israel. To avoid endogeneity, they identify the number of repeaters in a cohort. They propose that this is an accurate measure of low-ability peers as it is primarily those who are not academically ready to start school that is held back in Israel. Based on this they find that having a larger share of repeaters in the class negatively affects the other students' grades. However, the effect they find is not very strong. In a study of American third-to-eighth graders, Hoxby and Weingarth (2005) does not find clear-cut results for any model but suggest that peer effects might work in a combination of the single crossing model, the focus model and the boutique model. They find that all things equal, having a better peer is better for a focal student, which supports the single crossing. However, they also find that students benefit more from gaining a classmate that is closer to their own ability than further from it, which also reinforces the median score in the classroom, which is why they propose the focus or boutique model too.

There is limited empirical research in support of the focus theory of peer effects as an exclusive mechanism, however the model may be useful when examined together with models of tracking that are more researched. From a normative perspective however, the model's implication to separate students based on characteristics or ability is a thorny issue as it leads to segregated classes, which could result in unwarranted social consequences.

In support of the rainbow theory, Bietenbeck (2020a) uses children who have repeated a grade in the US to study the effects of low-ability peers in kindergarten. Similarly to Lavy et al. (2012), Bietenbeck also finds that being exposed to repeaters have a negative impact on test score at the end of kindergarten. However, looking at long-term effects he finds that the effect fades in later grades. When looking at the long-term the author claims that non-cognitive outcomes such as effort and discipline are improved due to being exposed to repeaters, and also that the chances of graduating from high school increase. He speculates that these results are due to students with low-ability classmates learning more non-cognitive skills in kindergarten by learning to adjust their behaviors when interacting with low-ability students. This study also highlights the importance of looking at long-term effects as the results in the short-term and long-term vary in this study.

Another study that examines the rainbow theory is Chevalier et al. (2020) which look at peer effects from having ethno-linguistically diverse classrooms. They study the effect of

different compositions of native English speakers and non-native English speakers on university students in the United Kingdom. They find that the native English speakers are not affected by the number of non-native speakers in the classroom, whilst for the non-native speakers having a more diverse classroom is beneficial. They suggest this is due to non-natives interacting more in English when the classroom is more diverse as it is not only the number of native speakers that matter but also that the non-native speakers are of different ethnicity. In a similar study looking at approximately 5000 students in Swedish lower secondary schools, Diemer (2021) finds evidence of positive peer spillovers but highlights that they pertain to interacting with native high ability peers, both for native and immigrant students. This stresses the importance of desegregated schools to combat educational inequalities.

Justice et al. (2014) investigates the effect on language skills of having disabled classmates in American preschools. They find indications of peer effects impacting all children, but that the smallest effect was on non-disabled children whose peers had high language skills and the biggest negative impact was on disabled children whose peers had low language skills. The researchers theorize that the children with high language skills may act as experts and instruct their peers, both disabled and non-disabled. They conclude that it is beneficial to mix students of different abilities as they can learn from each other and that especially disabled children benefit from being in the same class as higher-ability peers.

These studies show support for the rainbow theory but most of them find that it is primarily lower-ability students or the students belonging to a minority group whom benefits from mixed student groups. Although the studies do not find any negative effects on the higher ability students, most do not find any positive effects either. Heterogenous classrooms may be an important dimension to consider to not exacerbate inequality and to promote social inclusion. As other studies based on tracking model of peer effects find detrimental effects for low-ability students to be in mixed rather than separated ability-groups (Booij et al. 2017), more research is required on the underlying mechanisms of peer effects to understand *when* and *why* such opposing results may occur, and what may the appropriate policy suggestion. As the studies presented here mostly concern younger students while the studies reviewed on tracking also concerned university students, a hypothesis could be that it is primarily younger students whom benefit from being in a mixed-ability classroom.

3. Social Outcomes

This overview is primarily focused on the educational outcomes of peer effects, but it is worth briefly mentioning peer effects found for youth in other contexts. It might be especially important in the school environment to consider other factors that affect students, both in terms of their social lives but also how that could affect their education. In a school environment, peers' decisions to drink or smoke might put social pressure on other students to do the same. This may indirectly affect educational outcomes if partying and drinking is associated with playing truant or focusing less on school activities. Fundamental to the research on peer effects for non-educational outcomes is the notion that social interaction is consequential for a range of human behavior, and especially that younger people are influenced by their peers' actions. Gaviria and Raphael (2001) study the causal effect of peers on alcohol drinking, drug use, smoking cigarettes, going to church and the likelihood of dropping out of school for American high school students. By using a linear-in-means model, the authors detect peer effects on all studied outcomes with the strongest effect found on drug use.

In a similar study, Lundborg (2006) investigates peer effects on Swedish 12-18-year-olds when it comes to binge drinking, smoking and drug use. He instruments peer behavior by different measures of the peers' engagement in these activities and finds peer effects for all three outcomes. Here, the smallest peer effect is found in drug use. The author also finds that peer effects were stronger for males than females in drinking but stronger for females in smoking. Hence, cultural expectations might play an important role in peer effects.

A correlational study by Alexander et al. (2001) on U.S adolescents in grades 7 to 12 from the nationally representative AddHealth survey also suggests peer effects for smoking behavior may in part be driven by student popularity. This could give further credit to Rambaran et al.'s (2017) finding of truancy behavior in that social status in student groups gives social leverage over peers.

Even though the research on social outcomes suffers the same identification problems as studies of educational achievement, the literature is more cohesive in that most studies find peer effects on drinking and smoking. Many scientists also speculate that peer effects might be stronger in these outcomes as it has more social impact than educational outcomes. Especially younger people are thought to be more prone to adhering to a group, and hence follow their peers' behavior.

4. Theoretical Mechanisms

While the existence of peer effects has been extensively studied, research on the underlying mechanisms behind the peer effect is still lacking. More recent studies have sought to uncover the underlying theoretical rationale for the overall effects identified, but this is often a peripheral part of the research rather than the driving force. As illustrated in the plethora of different models presented in the literature on peer effects, there is no consensus on what the underlying mechanisms may be.

The reason why there is such a multitude of different models proposed by researchers is that it is difficult to study the channels of peer effects. Pinpointing that peer effects exist is in itself methodologically challenging. Unearthing the social mechanisms that cause such peer effects is in itself an important area for research. While research has progressed in investigating non-linear peer effects or heterogeneity in results amongst different groups, these studies are rarely able to exactly identify how peer effect comes about. A chief issue is the lack of data that could further explain what is driving peer effects. Some use survey data to establish the underlying mechanism of peers, such as Feld and Zölitz (2017) and Lavy et al. (2012). This provides a better insight into the mechanisms at play, but it comes at the expense that self-reported surveys are often less reliable than other data types and may suffer from measurement error. Surveys are also often incomplete, leading to risks of selection bias.

One explanation behind peer effects is that the teacher changes their teaching style according to the group of students they are facing. A teacher has to adjust the material to the class and perhaps having students of very differing abilities makes it harder to find a level that is challenging enough for everyone. If there are disruptive or lower-ability classmates the teacher might have to spend more time on them, reducing the time teaching the regular material. Duflo et al. (2011) suggest that the peer effects found in their study come from teachers changing their behavior. For one, they found that in the tracked classes teachers were more likely to be present in the classroom, which should hopefully increase learning. They could also see that students in the ”low-level” class in tracking schools attained better knowledge of basic skills whilst students in the ”high-level” class gained more knowledge of advanced skills, indicating that the teacher adjusted their course content based on the students’ need. However, this paper is studied in Kenya, which is a different context than for example the US.

Another study finding a change in teacher behavior is Lavy et al. (2012) who uses a classroom survey to detect mechanisms to why repeaters have a negative effect on their classmates’ scores. The repeaters report higher levels of teacher satisfaction and getting

individualized help from the teachers, suggesting that teachers pay greater attention to the struggling students, taking away time from the other students. If the other students are getting less help in a class with more repeaters this could explain the negative effect on their grades.

It seems possible that the specific class studied impacts how the teacher structures their education, which could lead to different outcomes. Hence, study context and underlying structures seem to play an important role in evaluating how peer effects work. Research focusing on the bad apple model may thus seek to investigate how much extra time the teacher must spend on the disruptive peers. Further, attention to peers' social status is warranted when studied negative influences on other students (Rambaran et al. 2017).

Another explanation could be that better peers help other students, either by having meaningful interactions with them, teaching them the material or asking smarter questions that clarify the concepts for their classmates. Coveney and Oosterveen (2021) investigate the peer effects from close and distant peers by manipulating class groupings in a Dutch university, so students have some peers they have smaller tutorial groups with and some they only have large lectures with. They find that close peers have an impact on focal students grades and that distant peers do not and hence conclude that social interaction is important for peer effects to take place. They use survey results to further investigate how close peers affected the students and find that students with better peers decrease their lecture attendance but maintain the same level of tutorial group attendance and hours of self-study. This suggests that the peers help each other study or teach them to study more effectively as they improve their grades without increasing their time spent studying. Isphording and Zölitz (2020) measure every individual's peer value-added, a measure to estimate how much one student affects their peers, in a study on Dutch university students. They find different effects of different peers, indicating that some peers are better than others, which also points toward peer spillovers originating from students interacting with each other. Moreover, their survey data indicates that students with better peers reduce their time spent on studying whilst attaining better grades. This indicates that students learn better from peers with a high value-added. It is also shown that students know who is a good peer by valuing their peer-to-peer interaction higher.

Researchers have also tried to examine peer effects by studying how the physical distance differs. Van den Berg et al. (2012) measure the physical distance between homes among 10–12-year-old school peers in the Netherlands and find that reduced distance increased the likeability of the close peer, which could be useful in explaining increased social interactions. Keller and Takács (2019) study deskmates in secondary school in Hungary

and find that deskmates' reading scores have a positive impact on a focal students' reading scores, beyond the peer effects in the classroom as a whole. This also indicates that the social interaction between students partly underly peer effects in educational achievements. On the other hand, a study by Boucher et al. (2014) on Canadian fourth- and fifth graders indicate that peer effects are stronger in mathematics than in other subjects. The authors attribute this finding to mathematics providing more opportunity for students to interact with each other than in other subjects. This might be an indication that peer effects can also stem from social interactions of more instrumental nature.

Siblings have also been used as the peer group and such studies tend to find that older siblings' grades affect younger siblings' educational outcomes (Nicoletti and Rabe 2019, Qureshi 2011) as well as educational choices (Altmejd et al. 2021). This also indicates that peer effects primarily work through the students and not through the teacher, as siblings are usually not in the same classroom environment.

The literature also highlights contextual factors as important for whether and how strong peer effects may be in specific settings. Studies in distinct countries with different educational systems and views on schooling often find differing results, as to studies comparing different measures of educational achievements (test scores, grades, etc.) in different subject areas.

There are also indicates that peer effects work in different ways and to altering degrees for distinctive groups studies. Most prominent is research separating effects for males and females where they find that the effect usually differs across gender. Hoxby (2000) finds that both boys and girls perform better when there are more girls in the class, and Dryler (1999) finds that it is more common to choose a high school program based on what the classmates of the same gender choose. As mentioned previously, Cools et al. (2019) also find diverse effects but for educational attainment based on gender differences. This could indicate that examining peer effects at the class level encompass too diverse of a group and that the peer group needs to be narrowed to find reliable results. Anelli and Peri (2015) find that Italian male university students are more prone to choosing ”male-dominated” majors such as natural science and economics the more males there are in the class. The studies on social instead of educational outcomes also suggest that peer effects might be contextually different for boys and girls (Lundborg, 2006). This illustrates that peer effects might be governed by underlying cultural factors that need to be taken into consideration.

Also, the strength of the peer effects themselves might vary and several studies suggest these to be stronger for low-ability students, regardless of whether there are negative or

positive peer effects identified (Zimmer and Toma, 2000). A network study among Italian MBA students by Lomi et al. (2011) utilizing a Stochastic-Actor-Oriented model find heterogeneity in selection based on the outcome variable where low-performing students were much more frequently forming social network ties with each other, which could explain some of the "negative peer effects" findings by Carrell et al (2013). Similarly, Kretschmer et al. (2018) study German secondary school pupils, finding that gender moderates the selection into peer networks in schools, but not the influence effect between peers. Hence, we do not yet know if the differing results for peer effects between boys and girls are due to differing strengths of the peer effects or differing exposure to similar other students by which a focal student may be influenced. Network selection mechanisms and strengths of social influence in educational settings could be studied more extensively by researching peer effects separately based on demographic characteristics, level of the outcome variable, or other moderating variables.

Many studies also look at short-term outcomes in the short term which could affect the result obtained. Bietenbeck (2020a) finds negative effects on students' test scores in the short term from being in a class with many repeaters, but positive effects on educational attainment in the long term. Patacchini et al. (2017) sample US students in grades 7–12 followed from 1994–1995 to 2007–2008 in the nationally representative AddHealth survey conducted in 130 private and public schools. They find that peer effects in education only seem to matter when friendship last more than a year.

In sum, a consensus on the underlying theoretical mechanisms behind peer effects has not yet been fully agreed upon in research. Further research is needed on uncovering how peer effects emerge and how they operate.

5. Methods

The difficulties in establishing causal effects make it challenging to study peer effects. The difficulties lie in identifying peer effects as the researcher must make sure no other factors are affecting the results. Moreover, the data constraints and the fact that researcher cannot easily observe peer effects has led researchers to rely on simplified econometric specifications such as linear-in-means models. Having access to more detailed data have made it possible for recent researchers to explore new methods. The difficulties in studying peer effects are one explanation to why researchers have mostly focused on identifying peer effects and not focused on the underlying mechanisms.

The two major concerns in peer effects studies are the selection problem and endogeneity problems. Selection problem occurs when students have selected into the peer group they belong to, for example, wealthier parents choosing better schools for their children or students making sure they get placed in the same class as their friends. This introduces confounding variables to the specification, as the effects found could be a result of something else than peer effects, such as the students being close friends or having highly motivated parents. Problems with endogeneity when studying peer effects, also called *the reflection problem*, was famously introduced by Manski (1993) where he portrays the difficulties for the researcher to separate the peers' effect on the individual student from the student's effect on his peers. This simultaneity makes it difficult to disentangle the effect of the class mean outcome (endogenous effect) on the individual from the effect of the class mean characteristics (exogenous effect). Due to these difficulties, several studies still estimate ' endogenous peer effects' such as the linear-in-means model by estimating the effects of current peers' educational achievements on a focal student's achievement. This has been noted to lead to upward biased in estimated results (Angrist 2014, Carrell et al. 2013). coefficients are upward biased estimates of true contemporaneous peer effects.

The *selection problem* may be addressed by identifying some source of exogenous variation in the peer group, for example by looking at variation in cohort compositions (Hoxby and Weingarth 2005). Some studies solve the problem by using an experimental method wherein the researcher randomly allocates who belongs to what group (Carrell et al. 2013, Duflo et al. 2011). This has the advantage that the researcher can be sure there is no self-selection into the group and that there are no systematic differences between the students of different classes. However, due to the sensitivity of conducting experiments on school children and the costs associated with education, this research design method is rare.

The reflection problem is often solved by using instrumental variables that proxy peer-ability by some pre-determined outcome, such as peers' earlier grades or peers' background characteristics (Sund, 2009, Ammermueler and Pischke, 2009). This approach ascertains that it is the peers that affect the student and not the other way around – reverse causality –since an already realized outcome cannot be changed. However, many of the instruments commonly used has been criticized for not accurately reflecting what they are supposed to instrument. For example, the comprehensive US study by Hoxby and Weingarth (2005) find no effect from background characteristics on the student's grade, indicating that peer characteristics might not be an appropriate instrument. Isphording and Zölitz (2020) also criticize this instrument and argue that peer characteristics are not correlated with peers'

grades. Using lagged educational outcomes as an instrument, Lavy et al. (2012) warn that endogeneity can still occur if peer groups have not changed.

A growing area of research claim that the reflection problem can be dealt with using social networks data (Calvó-Armengol et al. 2009, Bramoullé et al. 2009). By exploiting network structure, a valid instrument can be provided using 'the peers of peers' (that are not peers themselves with a focal student). There remain woes with this methodology since imperfect knowledge of the network in question may be a threat to causal identification (e.g. Griffith, 2021) and that the 'peers of peers outcome' indeed are correlated with the focal students outcome (Goldsmith-Pinkman and Imbens, 2013). Bramoullé et al. (2020) argues that such issues may potentially be dealt with by instrumenting across different social context such as neighbors of family peers on outcome of focal family member, and through more explicit assumptions of network time invariance (e.g. Snijders 2011). Social network models have been argued to solve the reflection problem by their interdependent structure between observations that allows for endogenous processes and partly by its potential to separately identify selection from influence (Lomi et al. 2011; Rambaran et al. 2017).

The most used method to study peer effects is linear-in-means where the researcher examines how the average of some outcome of peers, most commonly grades or another educational outcome measure, affect own grades. This implicitly assumes that peer effects are linear and that all peers contribute equally to peer spillovers. This only necessitates data on students' grades to examine the spillover effects of having better peers. Additionally, many researchers use natural variation in classroom size or composition to exclude self-selection and instrumental variables to deal with endogeneity. Including non-linear effects and heterogeneity is possible by dividing up the sample into different categories.

Without relying on some randomization or instrumental variables for identification, estimated effects could also accrue from 'common shocks' such as having a particularly good teacher in a year. Nevertheless, the endogenous peer effects model can provide indicative evidence of the existence of peer effects and has been utilized in prior studies (Carrell et al. 2013, Sacerdote 2001, Lyle 2007).

Experiments or other alternative specifications are getting more popular as this allows for identifying causal effects from the intervention and ruling out omitted variables. Falk and Ichino (2006) conduct a field experiment in Switzerland wherein they recruit high school students to complete a task. They randomly allocate which students complete the task alone and which do it in pairs. In this way, they claim to find clean peer effects as they can measure any positive spillovers from working in a pair. They find that students in a pair were able to

complete more of the task in the allotted time just by being in the same room, as they were instructed to work independently. However, the disadvantage of the experiment is that it is not a school setting but outside of class, meaning the results may not generalize to a real classroom setting where students spend a lot of time together.

It is also beneficial to test out educational policies related to peer effects experimentally, for example as in Duflo et al.'s (2011) study in Kenya which could examine the differences between peer effects as ability-mixing and tracking. Extending this and exploring alternate models of peer effects could leverage the experimental approach to bear on central problems discussed in the literature on peer effects. Yet, a problem with initiating specific educational policies based on non-experimental studies is that they might have unintended consequences if the researchers have not fully unearthed the mechanisms behind the peer effects. This was shown by Carrell who first conducted a study that showed that it was better for low-ability subjects to be in a group with high-ability subjects to maximize peer effects (Carrell et al. 2009). However, when they tested this experimentally (Carrell et al. 2013), they found worse results for the low-ability subjects mixed with the high-ability group than for the ability-mixed group. Even though the ability-mixed peer effects were designed to maximize educational achievement for all based on the results in the first paper, testing it showed it did not improve results due to students self-selecting into specific networks of peers within classes.

A new model is tested in Isphording and Zölitz (2020) who identify a personal 'peer-value added' measure to see if all peers are as valuable or if some peers benefit their classmates more than others. They do so by looking at all combinations of university students having classes together and calculating who has what impact on their fellow students, finding that not everyone has the same peer value but that some are better peers than others. They also find that it is possible to become a better peer by learning from someone who has a high peer value-added score and that *other students are aware of which peers that are most helpful to them*. This could prompt the research to go from linear-in-means models to studying the effects of certain good peers, and potentially survey students on *who is a good peer and why?*

Despite the many studies on peer effects, there is a discussion around the methods employed and that many identified results may be largely due to spurious effects. Feld and Zölitz (2017) argue that one reason why studies tend to show largely differing results is that the combination of social interaction and statistical effects could make outcomes look similar between peers, even if they are not causally produced by peers. Angrist (2014) emphasizes that much of the effect could be due to spurious correlation since the identification of peer

effect often involves combining two measures that tend to include measurement errors: students' own educational achievement and those of their peers. A cautionary tale is told by Bitler et al. (2021) who studied teacher effects in New York City public schools and decided to examine whether the teacher's affected students' body height. Their research showed that the teachers had almost the same causal effect on students' height as they did on their math and reading, Bitler et al. caution that other specifications might show spurious effects as well.

6. Discussion and Conclusions

Peer effects in education have received large attention and numerous studies have tried to establish its existence. With the help of statistical specifications, most studies can show some evidence of peer effects. The size of these and the underlying mechanisms are still unknown as the research does not find consistent results which makes it harder to derive policy implications. If peer effects work linearly, there is nothing that can be done to optimize their effects and hence would not be of interest to policymakers. Recent studies point toward there being non-linear effects and if the driving force behind peer effects is discovered this could be a potentially cheap way to enhance classroom learning. The bottom line is that different models of peer effects result in very different policy conclusions. If the correct model is the bad apple model and peer effects are caused by disruptive students, then schools need to invest in more teacher resources to make sure all students gain from the education and that the rowdy students do not take time away from the rest of the class. If tracking is the optimal policy to maximize peer effects, then classes should be split based on knowledge, instead of the mixed-ability grouping that is common in education today. However, this raises further questions on what specific tracking system is the best. More research needs to be carried out to decide if the optimal division is two-way tracking, three-way tracking or some other division based on ability. Moreover, many studies that find that ability-mixing is best emphasizes that tracking may increase education inequality, which is another aspect that policymakers need to consider. New studies on rank also show that it might be detrimental to be surrounded by smarter peers as that can lower own academic self-esteem which in turn can make the student shy away from academic disciplines seen as more demanding.

All in all, there is limited consensus to date on how peer effects work, as well as in what direction they operate. This makes it hard to formulate well-suited educational policy. Our review further highlights a need for understanding why specific studies are soften reaching differing results. Some researchers have pointed out the potential pitfalls with the econometric specifications used today to measure peer effects and warn that the result may

come from spurious effects. Therefore, the methods used to measure peer effects also need to be improved so that convincing results can be established. A stronger focus on detecting the underlying mechanisms would also help in understanding peer effects. Although there are still problems to overcome before establishing the true cause and effect of peers, continuing the research is an important step into furthering our understanding of the role of the classroom environment for students' educational choices and outcomes.

Our review of current research on peer effects in education suggests that it may be time to move beyond linear-in-mean models and the classical econometric specifications advocated by Hoxby and Weingarth (2005). Research should accept that heterogeneous results may be unearthed across student populations and contexts studies, stressing the need to document and describe study context and participants studies. Promising methodological avenues that may complement existing research on peer effects in education include experiments, network modelling and value-added models. Experimental studies – especially in the field – hold the promise of providing valid estimations relieved of selection problems. Network modelling offer opportunities to address some of the underlying methodological issues in peer effects research and may also provide further nuanced understanding of the social dynamics underlying peer effects in educational settings. There are also opportunities for further interdisciplinary research across the social sciences with psychology and educational science stressing the testing of underlying theoretical mechanisms around peer effects, economics contributing a framework for causally identifying whether and when peer effects exist, and sociology attending to the contexts in which peer effects may be more or less important. Given the causal complexity of peer effects, a diversity of approaches may be needed to elucidate the different channels through which a student peer may assert influence on his or her fellow students' behavior and educational achievements, how, and why.

References

Alexander, C., Piazza, M., Mekos, D., and Valente, T. (2001). Peers, schools, and adolescent cigarette smoking. *Journal of Adolescenct Health,* 29:22–30.

Altmejd, A., Barrios-Fernández, A., Drlje, M., Goodman, J., Hurwitz, M., Kovac, D., Mulhern, C., Neilson, C., and Smith, J. (2021). O Brother, Where Start Thou? Sibling Spillovers on College and Major Choice in Four Countries. *Quarterly Journal of Economics*, 136(3): 1831-1886.

Ammermueller, A. and Pischke, J.-S. (2009). Peer effects in European primary schools: Evidence from the progress in international reading literacy study. *Journal of Labor Economics*, 27(3): 315–348.

Anelli, M. and Peri, G. (2015). Peers' composition effects in the short and in the long run: College major, college performance and income. IZA Discussion Paper. Institute of Labour Eocnomics.

Angrist, J. D. (2014). The perils of peer effects. *Labour Economics*, 30: 98–108.

Benabou, R. (1996). Heterogeneity, stratification, and growth: macroeconomic implications of community structure and school finance. *The American Economic Review*, 584-609.

Bietenbeck, J. (2020a). The long-term impacts of low-achieving childhood peers: evidence from project star. *Journal of the European Economic Association*, 18(1): 392–426.

Bietenbeck, J. (2020b). Own motivation, peer motivation, and educational success. Working paper, IZA DP No. 13872. Institute of Labour Economics.

Bitler, M., Corcoran, S. P., Domina, T., and Penner, E. K. (2021). Teacher effects on student achievement and height: A cautionary tale. *Journal of Research on Educational Effectiveness*, 14(4): 900-924.

Booij, A. S., Leuven, E., and Oosterbeek, H. (2017). Ability peer effects in university: Evidence from a randomized experiment. *Review of Economic Studies*, 84(2): 547–578.

Boucher, V., Bramoullé, Y., Djebbari, H., and Fortin, B. (2014). Do peers affect student achievement? Evidence from Canada using group size variation. *Journal of Applied Economics,* 29:91–109

Bramoullé, Y., Djebbari, H., and Fortin, B. (2009). Identification of peer effects through social networks. *Journal of econometrics*, *150*(1): 41-55.

Bramoullé, Y., Djebbari, H., and Fortin, B. (2020). Peer effects in networks: A survey. *Annual Review of Economics*, *12*: 603-629.

Burke, M. A. and Sass, T. R. (2013). Classroom peer effects and student achievement. *Journal of Labor Economics*, 31(1): 51–82.

Byrne, B. M. (1996). Academic self-concept: Its structure, measurement, and relation to educational achievement. In I. B. A. Bracken (Ed.), *Handbook of self-concept: Developmental, social, and clinical considerations*: 287–316: John Wiley and Sons.

Calvó-Armengol, A., Patacchini, E., and Zenou, Y. (2009). Peer effects and social networks in education. *Review of Economic Studies*, *76*(4): 1239-1267.

Carrell, S. E., Hoekstra, M., and Kuka, E. (2018). The long-run effects of disruptive peers. *American Economic Review*, 108(11): 3377–3415.

Carrell, S. E., Sacerdote, B. I., and West, J. E. (2013). From natural variation to optimal policy? the importance of endogenous peer group formation. *Econometrica*, 81(3): 855–882.

Carrell, S. E., Fullerton, R. L., and West, J. E. (2009). Does your cohort matter? Measuring peer effects in college achievement. *Journal of Labor Economics*, 27(3): 439-464.

Chevalier, A., Isphording, I.E., and Lisauskaite, E. (2020). Peer diversity, college performance and educational choices. *Labour Economics*, 64: 101833

Coleman, J. S. (1968). Equality of educational opportunity. *Integrated education*, 6(5): 19–28.

Cools, A., Fernández, R., and Patacchini E. (2019). *Girls, boys, and high achievers*. NBER Working Paper 25763.

Coveney, M. and Oosterveen, M. (2021). What drives ability peer effects? *European Economic Review*, 136: 103763.

Diemer, A. (2021). Endogenous peer effects in diverse friendship networks: Evidence from Swedish classrooms. Unpublished Manuscript.

Dryler, H. (1999). The impact of school and classroom characteristics on educational choices by boys and girls: A multilevel analysis. *Acta Sociologica*, 42(4): 299–318.

Duflo, E., Dupas, P., and Kremer, M. (2011). Peer effects, teacher incentives, and the impact of tracking: Evidence from a randomized evaluation in Kenya. *American Economic Review*, 101(5): 1739–74.

Elsner, B. and Isphording, I. E. (2017). A big fish in a small pond: Ability rank and human capital investment. *Journal of Labor Economics*, 35(3): 787–828.

Elsner, B., Isphording, I. E., and Zölitz, U. (2021). Achievement rank affects performance and major choices in college. CEPR Discussion Paper No. DP16066.

Entorf, H. and Lauk, M. (2008). Peer effects, social multipliers and migrants at school: An international comparison. *Journal of Ethnic and Migration Studies*, 34(4): 633–654.

Epple, D. and Romano, R. E. (2011). Peer effects in education: A survey of the theory and evidence. In Handbook of Social Economics, volume 1, pages 1053–1163. Elsevier.

Falk, A. and Ichino, A. (2006). Clean evidence on peer effects. *Journal of Labor Economics*, 24(1): 39–57.

Festinger, L. (1954). A theory of social comparison processes. *Human Relations*, 7: 117—140.

Feld, J. and Zölitz, U. (2017). Understanding peer effects: On the nature, estimation, and channels of peer effects. *Journal of Labor Economics*, 35(2): 387–428.

Gaviria, A. and Raphael, S. (2001). School-based peer effects and juvenile behavior. *Review of Economics and Statistics*, 83(2): 257–268.

Goldsmith-Pinkham, P. and Imbens, G.W. (2013). Social networks and the identification of peer effects. *Journal of Business Economincs and Statistics,* 31:253–64

Griffith, A. (2021). Name Your Friends, but Only Five? The Importance of Censoring in Peer Effects Estimates using Social Network Data. *Journal of Labor Economics*, DOI: 10.1086/717935.

Gulbrandsen, J. (1994). *Är skolan till för Karin eller Erik?* Lund: Studentlitteratur.

Hanushek, E. A., Kain, J. F., Markman, J. M., and Rivkin, S. G. (2003). Does peer ability affect student achievement? *Journal of Applied Econometrics*, 18(5): 527–544.

Hanushek, E. A. and Wößmann, L. (2006). Does educational tracking affect performance and inequality? differences-in-differences evidence across countries. *Economic Journal*, 116(510): C63–C76.

Patacchini, E., Rainone, E., and Zenou, Y. (2017). Heterogeneous peer effects in education. *Journal of Economic Behavior and Organization*, 134: 190-227.

Hoxby, C. M. (2000). Peer effects in the classroom: Learning from gender and race variation. NBER Working Papers 7867. National Bureau of Economic Research

Hoxby, C. M. and Weingarth, G. (2005). Taking race out of the equation: School reassignment and the structure of peer effects. Technical report, Citeseer.

Isphording, I. E. and Zölitz, U. (2020). The value of a peer. University of Zurich, Department of Economics, Working Paper, (342).

Jonsson, J. O. and Mood, C. (2008). Choice by contrast in Swedish schools: How peers' achievement affects educational choice. *Social Forces*, 87(2): 741–765.

Justice, L. M., Logan, J. A., Lin, T.-J., and Kaderavek, J. N. (2014). Peer effects in early childhood education: Testing the assumptions of special-education inclusion. *Psychological Science*, 25(9): 1722–1729.

Keller, T. and Takács, K. (2019). Peers that count: The influence of deskmates on test scores. *Research in Social Stratification and Mobility*, 62:100408.

Kretschmer, D., Leszczensky, L., and Pink, S. (2018). Selection and influence processes in educational achievement—more pronounced for girls?. *Social Networks*, 52: 251-260.

Lavy, V., Paserman, M. D., and Schlosser, A. (2012). Inside the black box of ability peer effects: Evidence from variation in the proportion of low achievers in the classroom. *Economic Journal*, 122(559): 208–237.

Lavy, V. and Schlosser, A. (2011). Mechanisms and impacts of gender peer effects at school. *American Economic Journal: Applied Economics*, 3(2): 1–33.

Lazear, E. P. (2001). Educational production. *Quarterly Journal of Economics*, 116(3): 777–803.

Lefgren, L. (2004). Educational peer effects and the Chicago public schools. *Journal of Urban Economics,* 56(2): 169–191.

Lomi, A., Snijders, T. A., Steglich, C. E., and Torló, V. J. (2011). Why are some more peer than others? Evidence from a longitudinal study of social networks and individual academic performance. *Social Science Research*, 40(6): 1506-1520.

Lundborg, P. (2006). Having the wrong friends? peer effects in adolescent substance use. *Journal of Health Economics*, 25(2): 214–233.

Lyle, D. S. (2007). Estimating and interpreting peer and role model effects from randomly assigned social groups at West Point. *The Review of Economics and Statistics*, 89(2): 289-299.

Manski, C. F. (1993). Identification of endogenous social effects: The reflection problem. *Review of Economic Studies*, 60(3): 531–542.

Marsh, H. W. and Parker, J. W. (1984). Determinants of student self-concept: Is it better to be a relatively large fish in a small pond even if you don't learn to swim as well? *Journal of Personality and Social psychology*, 47(1):213.

Murphy, R. and Weinhardt, F. (2020). Top of the class: The importance of ordinal rank. *The Review of Economic Studies*, 87(6):2777–2826.

Neidell, M. and Waldfogel, J. (2010). Cognitive and noncognitive peer effects in early education. *Review of Economics and Statistics*, 92(3): 562–576.

Nicoletti, C. and Rabe, B. (2019). Sibling spillover effects in school achievement. *Journal of Applied Econometrics*, 34(4): 482–501.

Qureshi, J. A. (2011). Additional returns to investing in girls' education: Impact on younger sibling human capital. Chicago: University of Chicago (Mimeo).

Rambaran, J. A., Hopmeyer, A., Schwartz, D., Steglich, C., Badaly, D., and Veenstra, R. (2017). Academic functioning and peer influences: A short-term longitudinal study of network–behavior dynamics in middle adolescence. *Child Development*, 88(2): 523-543.

Sacerdote, B. (2011). Peer effects in education: How might they work, how big are they and how much do we know thus far? In *Handbook of the Economics of Education*, volume 3, pages 249–277. Elsevier.

Snijders, T. A. (2011). Statistical models for social networks. *Annual Review of Sociology*, 37: 131-153.

Sund, K. (2009). Estimating peer effects in Swedish high school using school, teacher, and student fixed effects. *Economics of Education Review*, 28(3): 329-336.

Telhaj, S. (2018) Do social interactions in the classroom improve academic attainment? Working paper, IZA World of Labor.

Van den Berg, Y. H., Segers, E., and Cillessen, A. H. (2012). Changing peer perceptions and victimization through classroom arrangements: A field experiment. *Journal of abnormal child psychology*, 40(3): 403–412.