Haste Makes No Waste: Positive Peer Effects of Speed Competition on Classroom Learning

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Speed competition is common not only in sports but also in classrooms determining a student's success. This study investigates the peer effects of problem-solving speed on the learning outcomes of young pupils. We employ data on students' daily progress records in a self-learning program at BRAC primary schools in Bangladesh. The unique setting of the program allows us to address the reflection problem. Our results show overall positive peer effects on problem-solving times and scores, especially among peers with similar abilities, without negatively affecting the others. These results suggest that relational competition or rivalry fosters students' motivation for higher performance.
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I. Introduction

Competition for speed is everywhere — such as in sports (e.g., swimming and sprinting), in workplaces (e.g., fruit picking, cash registers, rice planting, or fish processing), and even in the classroom.[1] However, the question remains whether such competition can improve the overall performance. Only a few economics studies have investigated the role of speed competition on performance. To bridge this gap in the literature at least partially, this study investigates the peer effects of the speed of problem solving on the learning outcomes of young pupils. Using the unique setting of an individualized self-learning program conducted among primary school goers in Bangladesh, we focus on the potential compatibility, or trade-off, between the speed of problem solving and learning quality, as measured by mathematics test scores.

Related to our study, peer effects in educational settings, both positive and negative, have been of great interest to educators, parents, and researchers.[2] There is extensive literature on peer effects via learning outcomes, such as test scores and grades (Hoxby, 2000; Sacerdote, 2001; Zimmerman, 2003; Kang, 2007; Figlio, 2007; Ding and Lehrer, 2007; Carrell, Fullerton and West, 2009; Ammermueller and Pischke, 2009; Carrell and Hoekstra, 2010; Duflo, Dupas and Kremer, 2011; Arcidiacono et al., 2012; Burke and Sass, 2013; Angrist, 2014; Lu and Anderson, 2015; Feld and Zölitz, 2017).[3] However, to the best of our knowledge, no study has focused on the peer effects of speed on classroom learning with regard to scores or grades.

Problem-solving speed in an educational setting is a real-time signal of competitiveness. We frequently see a "racing"-type environment in the high-stake screening mechanism for the entry into higher quality educational institutions. However, in a learning environment, speed competition among peers can have either a positive or a negative impact on one's own learning outcomes. For example, speed competition among peers may work as an incentive to invest more effort and

[1]There exist some studies that examine peer effects where speed itself is an outcome of interest. For example, Sports economics examine peer effects through speed competitions, as seen in work done by Yamane and Hayashi (2015); Jane (2015). In workplaces, speed is used as a signal of productivity because quality can easily be monitored, and because penalties for low-quality services or production in such settings is a possibility (Bandiera, Barankay and Rasul, 2005; Mas and Moretti, 2009; Goto et al., 2015; Park, 2019). Bandiera, Barankay and Rasul (2010) show that worker's productivity in fruit picking context is significantly higher, in the presence of more-able friends, and significantly lower with less-able friends. Mas and Moretti (2009) show that cash registers' productivity increases in the presence of a highly-productive colleague. The author concludes that "social pressure can partially internalize the problems of free-riding that are built into many workplaces". Goto et al. (2015) find that non-monetary incentives including peer effects significantly enhance incentives under a fixed wage contract in rice planting. Park (2019) finds that in a fish processing plant, workers ranking higher on the conscientiousness scale exhibit less productivity declines, even if they are situated next to their friends. This suggests that peer effects on speed may vary depending on an individual's personality, which may be applicable to a student's non-cognitive abilities, such as self-esteem.

[2]In general, peer pressure works in a complicated manner: either to improve a positive norm or to hide effort (Bursztyn and Jensen, 2015; Bursztyn, Egorov and Jensen, 2019)

[3]See Epple and Romano (2011); Sacerdote (2011); Paloyo (2020) for reviews of literature on peer effects.

maintain high motivation to achieve better learning outcomes. It could also have negative impacts by inducing careless errors due to excessive time pressures as well as anxiety. Moreover, drawing upon the extensive literature on competition orientation by gender, there may be heterogeneous peer effects taking place according to gender: competition might motivate men to perform better but could discourage women from competing.[4]

In this study, we examine the peer effects of a classroom speed competition by leveraging the treatment sample of a randomized controlled trial (RCT) study on the effectiveness of self-learning at the right level program (Sawada et al., 2020).[5] One of the unique features of a Kumon session in schools is that one can observe who finishes the daily classroom assignment faster than oneself, as students individually work on their individualized worksheets and submit them to the grading assistants sitting in the front row of the classroom.[6] In this setting, we can examine the peer effects of problem-solving speed on students' learning outcomes across two dimensions: the speed of problem solving and the student's math score.[7]

In such a setting of classroom problem-solving tasks, it is not unlikely that students see themselves in a contest, form a sense of rivalry, and become motivated to outperform certain peers as well. This also instills a motivation to perform beyond the ordinary competitive spirit and/or objective stakes (Kilduff, Elfenbein and Staw, 2010). By conceptualizing "rivalry as a relationship that magnifies the subjective valence of competitive outcomes," Kilduff, Elfenbein and Staw (2010) suggest that the similarity of individuals, repeated competitive interactions, and past competitiveness can lead to rivalry. This is also consistent with the psychological theories of work motivation (Vroom, 1964; Van Eerde and Thierry, 1996), which suggest that rivalry and motivation are positively correlated, allowing competitors to succeed.

Students working on problem-solving in the same classroom might have been competing along the lines of speed, which, through visible peer pressure, may affect their learning outcomes (as measured via the score) either negatively or positively. Problem-solving speed is measured as the time until submission, which is a highly visible behavior in the classroom. Therefore, in a self-learning setting, the speed of students that work faster functions as an exogenous shock to the

[4]See, for example, Gneezy and Rustichini (2004); Niederle and Vesterlund (2007); Gneezy, Leonard and List (2009); Niederle and Vesterlund (2010, 2011); Boschini, Muren and Persson (2012); Booth and Nolen (2012); Balafoutas, Kerschbamer and Sutter (2012); Buser, Niederle and Oosterbeek (2014); Lee, Niederle and Kang (2014); Dreber, von Essen and Ranehill (2014); Bursztyn, Fujiwara and Pallais (2017); Niederle (2017); Shurchkov and Eckel (2018); Yagasaki and Nakamuro (2018); Yagasaki (2019); Gneezy, Leonard and List (2009); Ito, Kubota and Ohtake (2020).

[5]The intervention comprised eight-month-long daily sessions of the Kumon method of learning (hereafter Kumon) introduced to non-formal primary schools operated by BRAC in Bangladesh. In a companion paper on the impact of the Kumon program, Sawada et al. (2020) found substantial improvements in students' cognitive abilities as measured by mathematics test scores.

[6]Ten worksheets are assigned as daily assignments during the thirty minutes of a Kumon session, and students submit them upon completion of all 10 worksheets.

[7]In addition, there is an incentive for students to obtain the full score to proceed to the next level.

slower students as they do not know their peers' submission timing until someone stands up and walks toward the front row where the grading assistants are seated. Furthermore, due to the nature of the program, the faster students' behavior can affect the slower students, but not vice versa. This setup allows the causal identification of the effects of a faster peer's behavior on the rest of their classmates who are still working on their assignments as well as avoids Manski's reflection problem (Manski, 1993).

Our results show positive peer effects experienced in a speed competition concerning problem-solving time for all students in a class. We also find positive peer effects on scores for students who perform similarly in terms of speed. However, the scores of the students who are slower than the class median are not affected by the speed of the fastest peer. Rather, their scores improve when the median speed of the class improves (increases). These results suggest that competition is most likely to occur sequentially: faster students compete against their fastest peers, while slower students only compete against their peers who are slightly faster than them, but who are not necessarily the fastest.

The remainder of the paper is organized as follows: in Section 2, we outline the setting of the data collection, followed by a description of the data. Section 3 presents the empirical approach, followed by the results in Section 4, and Section 5 concludes the paper.

II. Setting

The RCT study included 34 randomly selected BRAC primary schools consisting of third and fourth graders, 17 of which were offered the Kumon intervention (Sawada et al., 2020). The intervention consisted of a 30-min session on the Kumon study prior to the beginning of regular lessons. The Kumon sessions lasted for eight months, ranging from August 2015 to April 2016. We studied the detailed daily recorded data of the Kumon sessions from these 17 intervention schools.

For the intervention schools, the Kumon Institute of Education Co., Ltd. provided an intervention package consisting of mathematics materials and an instructor's manual with sheets for the BRAC teachers.[8] The full material set consists of i) mathematics worksheets with questions of various levels of difficulty (Table A1 and Figure A1 in Appendix A), and ii) a notebook to record everyday progress, including the level of the worksheet that a student worked on, time spent until submission, any repetition required before achieving a full score on

[8] BRAC field staff were assigned to assist and follow up on BRAC Primary School (BPS) teachers. Three days of preparatory training for BPS teachers and field staff were held prior to launching the program in order to familiarize teachers with the concepts and procedures pertaining to the learning method. In addition, three follow-up training sessions were conducted during the implementation period. Two marking assistants were provided for each class to support the grading and recording of the worksheets during the Kumon sessions. BPS teachers monitored the students and determined the level of worksheets for students to work on. All the materials, including numbers, were provided in the Bengali language, which is the medium of instruction for BPS teachers and students.

the worksheet, and number of worksheets that they finally completed (Figure A2 in Appendix A).[9] The starting level of each student was adjusted to the student's ability based on the initial diagnostic test, regardless of their age or grade, so that students could solve all problems correctly by themselves in a certain time frame from the very beginning. During the Kumon session each day, each student solved 10 worksheets; the sheets were numbered 1 to 10. Once they completed all 10 worksheets, the students brought their sheets to the marking assistant sitting in the front row for grading.[10] The session ended when students either achieved a full score, or until the end of the designated time frame, as they attempted to correct the answers that they had gotten wrong, finishing once they achieved a full score.

During the Kumon sessions, the BPS teachers did not provide lectures; they simply observed the students' progress. They only intervened when students were stuck on the same worksheet or could not solve a problem after many attempts. They adjusted the level of the worksheets in such cases. The BPS teachers also provided guidance when advanced students proceeded to entirely new materials beyond the regular curriculum. The marking assistants helped the teachers to grade and record the worksheets.

III. Data

We use the daily student record of the time taken to submit 10 worksheets, along with their scores, as an indication of the repetitions required before achieving a full score on the math worksheet. We focus on the first three months of daily records because the number of worksheets solved by students during these Kumon sessions is universally measured at 10 worksheets during this time.[11]

Table 1 shows the descriptive statistics of the variables used in the analysis. Panel A highlights the key demographics of the sample of 335 students. Panel B shows the descriptive statistics of the daily records. The average time is approximately 12 min, with a 5-min standard deviation. This is the amount of time needed to submit the 10 worksheets to the marking assistants, so students may spend additional time resolving the problem if they do not obtain full marks before the Kumon session ends. The likelihood of obtaining a full score is above 75 percent, even on the last three worksheets when students tend to get more challenging questions — which we discuss in detail in Figure A3 in Appendix A. The high frequency of scores reflecting full marks is simply a result of the fact that the worksheets are designed such that students learn the materials that are just right for them.

[9]Table A2 in Appendix A explains how the difficulty level of worksheet is converted into numerical values.

[10]There is some variation in the number of sheets per day, as shown in Figure A4 in Appendix A. We discuss how we address these observations in Footnote 11.

[11]See Figure A4 in Appendix A. From the fourth month until the end, there were some variations in the number of worksheets solved per student. We excluded these five months from our analysis for the sake of comparability.

Table 1— Summary Statistics

	Mean	Standard Deviation	25%-tile	Median	75%-tile	N
Panel A: Individual-level Characteristics						
Fraction of Girls	0.383					334
Fraction of Grade 4[a]	0.407					334
Initial Sheet Number[b]	637.7844	161.9249	481	681	681	334
Total Days of Attendance at Kumon Session						
From August 2015 to April 2016	131.269	25.519	123	138	149	334
From August 2015 to October 2015	36.521	7.356	33	38	41	334
Panel B: Daily-level Characteristics						
Time for Solving 10 Work Sheets	11.695	4.690	8	11	14	12110
Total Score of 10 Sheets (Full Score = 1000)[c]	985.3140	48.8839	995	1000	1000	12232
Obtaining Full Score (Full Score = 1)						
in Sheet No. 1 to 3	0.8442	0.3627	1	1	1	12232
in Sheet No. 4 to 7	0.7866	0.4097	1	1	1	12232
in Sheet No. 8 to 10	0.7869	0.4095	1	1	1	12232

Notes. Sample is selected by omitting observations with missing values in the variables on time, score, and level of the work sheets. *Significant at 10% level; **significant at 5% level; ***significant at 1% level.
a. The sample contains 3rd and 4th grade students.
b. The level is converted into numbers. See Table A1 in Appendix A.
c. The score is converted into numbers. See Table A2 in Appendix A.

IV. Empirical Strategy

In our empirical analysis, we employ the following regression model:

$$y_{ids} = \alpha + \beta m_{ds} + \eta_i + \nu_d + \varepsilon_{ids}, \tag{1}$$

where y_{ids} is the outcome variable, either the time or score of student i on day d in school s. When the time is an outcome, we use the amount of time student i spends to solve 10 worksheets and submit them for the first time to the marking assistants. For the score (as an outcome), we use the dummy variable indicating a full score in the worksheets on day d. For a more detailed analysis, we examine the first and last three worksheets separately. The peer effects proxy variable, m_{ds}, takes either the fastest or median time of classmate(s) for solving 10 worksheets on day d in school s. η_i is the fixed effects of student i, and ε_{ids} is an error term.[12] We estimate the model using ordinary least squares while clustering standard errors at the student level. In this model specification, there are two major identification challenges. The first is the direction of causality, and the second is Manski's reflection problem.

First, in terms of the Kumon sessions at BPSs, we can say that there is a clear direction of causality in terms of the time of problem-solving from students who finish earlier than those who finish later owing to the setting. The time taken by a peer to submit the worksheet is an exogenous "shock" which is unknown beforehand to other classmates because they do not know their peers' speed until

[12]Note that these students' fixed effects also control for the schools' fixed effects, given that each student is enrolled in only one school.

they see someone submit their worksheets. In other words, only at the submission point can a student learn that a peer is faster than them.[13] During the 30-minute Kumon session in the classroom, students sit in an orderly fashion from front to back in three to four lines, with spaces on either side, so that each student can focus on their own assignment and not look around or chat with friends.[14] Each student is looking down at the worksheet and, therefore, the timing concerning when a classmate finishes his or her work early can be seen as a sudden shock (Figure A5 in Appendix A). The behavior of worksheet submission to marking assistants in the front row of the classroom is highly noticeable to everyone. We exploit this property for our identification strategy.

Another identification challenge for investigating the peer effects of time on a student's performance (across both time and score) is the reflection problem discussed by Manski (1993). This is a common problem in peer effects and social interaction estimations. However, our measurement of peer effects does not consist of one's own speed. This is because student i, as a follower, would be influenced by their peer(s) speed. However, the faster student(s) do not observe the follower's time. From these viewpoints, using the fastest or faster students' time solves Manski's reflection problem.

V. Results

The first three columns of Table 2 show the peer effects of classmates' speeds at the time of solving 10 worksheets. We find that the fastest student's speed significantly improves the overall problem-solving speed of students. When the students are solving the first three worksheets, there is no significant peer effects on the score because no one is likely to have completed the 10 worksheets (columns (4) to (6) in Table 2). However, according to the score of the last three worksheets for which the fastest student's speed becomes apparent, the positive peer effects on the score become evident (columns (7) to (9) in Table 2).

The fastest student's impact on others might be heterogeneous, depending on exactly how close a student's own speed is to the fastest time in solving the worksheets. Therefore, we show the heterogeneous peer effects of classmates' speeds at the time of solving 10 worksheets in Table 3. In panel A, the measurement of peer effects uses the fastest student's time of day within the classroom. The first three columns show the results for students who solved the problems faster than the median time of the class with some variations in the control variables, such as, the individual fixed effects and the day fixed effects. The latter three columns show the results for students who solved the problems slower than the median time of the class. In panel B, for the slower-than-median-speed students,

[13]The same thing applies to faster students: a faster student can learn that they are faster than others only at the time of submission.

[14]Students of BPSs sit in a circle for the regular curriculum and are able to see each other while answering questions from the teacher, who is standing in front of the blackboard. The Kumon session's seating is unique to this intervention. In either case, there is no predetermined seating plan for a particular student.

the median time of the class for the day is also used as a proxy for peer effects.[15] We find positive and significant effects of the fastest or faster classmates' time on individual students' time, regardless of students' type (i.e., faster or slower in problem-solving than the median time of the class). Each coefficient of peers' time can be interpreted as follows: among the faster-than-median students, when the fastest student's time is shorter by one minute, an individual student's time will reduce by 0.528 to 0.785 minutes on average. We further examine whether this speed competition has a negative or positive impact on the score. In other words, we examine the existence of a trade-off, or complementarity, between speed and quality.

Table 4 shows the heterogeneous peer effects of classmates' speed on the score of the first three worksheets (worksheets 1 to 3).[16] The score is measured by an indicator variable for whether or not a full score is obtained. As was the case in Table 3, panels A and B use different measurements of a peer's time: the fastest student's time, and the median time in the class, respectively. The structure of columns is also the same as before. Overall, we do not find significant peer effects of time on the score across the first three worksheets among the faster students, nor among the slower students.[17]

Table 5 shows the heterogeneous peer effects of classmates' speed on the score of the last three worksheets (worksheets 8 to 10). The structure of rows and columns are the same as those in tables 3 and 4. We find negative and significant coefficients of the fastest peer's time on the individual students' scores among the faster students. Again, this indicates that, as the peer's time grows shorter (−), the likelihood of having a full score becomes greater (+). However, the corresponding coefficients in panel A are insignificant among the slower students. Instead, for the slower students, we observe negative and significant coefficients of the median time in panel B. For the final three worksheets, where the math problems are more challenging and require more attention and effort, the speed competition seems to work positively for both faster and slower problem-solving students. Furthermore, these speed competition effects are visible among the students who are closer to each other in speed — that is, the fastest student speed improves the faster students' scores while the median speed improves slower students' scores.

In Appendix B, we report robustness checks of peer effects of classmates' speed on the score for both homogeneous and heterogeneous analyses by varying the

[15]We do not report the effects of the median time of the day on the faster student (faster than median) because the faster students do not observe slower students submitting worksheets, which include the median time and this makes the interpretation difficult. Rather, the slower students, including the median, could be affected by the faster students' submission timing. Therefore, the peer effects of median time on faster student outcomes will be endogenous.

[16]In the main analysis, we use the linear probability model. We also use the Logit and the Probit models, but the result remains robust to alternative specifications.

[17]The exception is for the peers' median time with individual fixed effects. This indicates that, as the median time becomes faster (−), the likelihood of having a full score is higher (+). This makes sense if the classmates start to submit worksheets when the slower students are solving the earlier sets of worksheets.

Table 2— Peer Effects on Time for Solving 10 Sheets, on Probability of Obtaining Full Score (Worksheet No.1 – No.3), on Probability of Obtaining Full Score (WorksheetNo.8 – No.10)

Dependent Variable:	**Time for Solving 10 Sheets**			**Dummy of Full Score in All of Sheet No. 1 – 3 (Full Score = 1)**			**Dummy of Full Score in All of Sheet No. 8 – 10 (Full Score = 1)**		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Effects of the Fastest Student's Time (Daily)									
Fastest Student's Time (Daily)	0.854	0.649	0.536	-0.0006	-0.0062	-0.0050	-0.0046	-0.0087	-0.0060
	(0.090)	(0.059)	(0.059)	(0.0055)	(0.0037)	(0.0032)	(0.0057)	(0.0034)	(0.0024)
[p-value]	[0.000]	[0.000]	[0.000]	[0.9084]	[0.1139]	[0.1369]	[0.4357]	[0.0222]	[0.0226]
Individual Fixed Effects		x	x		x	x		x	x
Day Fixed Effects			x			x			x
N	10942	10942	10942	11063	11063	11063	11063	11063	11063

Notes. Estimated standard errors clustered at individual level are in parentheses. Regression coefficeints of OLS are estimated based on the Equation (1). Sample is selected by omitting observations with missing values in the variables on time, score, and level of the work sheets. *Significant at 10% level; **significant at 5% level; ***significant at 1% level.

Table 3— Peer Effects on Time for Solving 10 Sheets

Dependent Variable:	**Time for Solving 10 Sheets**					
	Faster Students than Median			Slower Students than Median		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Effects of the Fastest Student's Time (Daily)						
Fastest Student's Time (Daily)	0.785	0.590	0.528	0.827	0.591	0.445
	(0.066)	(0.037)	(0.039)	(0.120)	(0.087)	(0.067)
[p-value]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Individual Fixed Effects		x	x		x	x
Day Fixed Effects			x			x
N	5777	5777	5777	5165	5165	5165
Panel B: Effects of the Median Finishing Time (Daily)						
Median Finishing Time (Daily)				1.111	1.104	1.093
				(0.052)	(0.059)	(0.050)
[p-value]				[0.000]	[0.000]	[0.000]
Individual Fixed Effects					x	x
Day Fixed Effects						x
N				5165	5165	5165

Notes. Estimated standard errors clustered at individual level are in parentheses. Regression coefficeints of OLS are estimated based on the Equation (1). Sample is selected by omitting observations with missing values in the variables on time, score, and level of the work sheets. *Significant at 10% level; **significant at 5% level; ***significant at 1% level.

Table 4— Peer Effects of Speed on Probability of Obtaining Full Score (Worksheet No.1 – No.3)

Dependent Variable:	**Dummy of Full Score in All of Sheet No. 1 – 3 (Full Score = 1)**					
	Faster Students than Median			Slower Students than Median		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Effects of the Fastest Student's Time (Daily)						
Fastest Student's Time (Daily)	-0.0034	-0.0050	-0.0046	0.0034	-0.0058	-0.0036
	(0.0049)	(0.0037)	(0.0032)	(0.0068)	(0.0046)	(0.0048)
[p-value]	[0.4969]	[0.1926]	[0.1608]	[0.6313]	[0.2231]	[0.4681]
Individual Fixed Effects		x	x		x	x
Day Fixed Effects			x			x
N	5776	5776	5776	5287	5287	5287
Panel B: Effects of the Median Finishing Time (Daily)						
Median Finishing Time (Daily)				0.0011	-0.0079	-0.0065
				(0.0055)	(0.0045)	(0.0044)
[p-value]				[0.8496]	[0.0977]	[0.1552]
Individual Fixed Effects					x	x
Day Fixed Effects						x
N				5287	5287	5287

Notes. Estimated standard errors clustered at individual level are in parentheses. Regression coefficeints of OLS are estimated based on the Equation (1). Sample is selected by omitting observations with missing values in the variables on time, score, and level of the work sheets. *Significant at 10% level; **significant at 5% level; ***significant at 1% level.

Table 5— Peer Effects of Speed on Probability of Obtaining Full Score (Worksheet No.8 – No.10)

Dependent Variable:	**Dummy of Full Score in All of Sheet No. 8 – 10 (Full Score = 1)**					
	Faster Students than Median			Slower Students than Median		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Effects of the Fastest Student's Time (Daily)						
Fastest Student's Time (Daily)	-0.0087	-0.0080	-0.0077	0.0014	-0.0082	-0.0037
	(0.0056)	(0.0040)	(0.0037)	(0.0069)	(0.0050)	(0.0041)
[p-value]	[0.1388]	[0.0598]	[0.0548]	[0.8467]	[0.1168]	[0.3807]
Individual Fixed Effects		x	x		x	x
Day Fixed Effects			x			x
N	5776	5776	5776	5287	5287	5287
Panel B: Effects of the Median Finishing Time (Daily)						
Median Finishing Time (Daily)				-0.0019	-0.0124	-0.0089
				(0.0062)	(0.0043)	(0.0037)
[p-value]				[0.7672]	[0.0112]	[0.0308]
Individual Fixed Effects					x	x
Day Fixed Effects						x
N				5287	5287	5287

Notes. Estimated standard errors clustered at individual level are in parentheses. Regression coefficeints of OLS are estimated based on the Equation (1). Sample is selected by omitting observations with missing values in the variables on time, score, and level of the work sheets. *Significant at 10% level; **significant at 5% level; ***significant at 1% level.

definitions of the earlier and later worksheets. These results are mostly consistent with the main findings. Finally, we show the peer effects of classmates' speed by focusing on those students who have a higher competition orientation, based on the baseline survey response in Appendix C.[18] The overall results are similar to the main findings. However, the absolute values of the point estimates tend to be larger compared to that of the full sample. This indicates that peer effects are stronger among students with a higher competition orientation than average peers.

The findings jointly suggest that there are overall positive peer effects on students' learning outcomes— math solving speed and their scores. We do not observe a trade-off between the speed and score. Rather, we find similar ability students gain more from rivalry, without negatively affecting others.

VI. Conclusion

We investigate the peer effects of problem-solving speed on learning outcomes along two dimensions: the speed of math problem-solving time and math score. In particular, we examine whether there are potential trade-offs or complementarities between the speed and quality of learning. Our results show positive peer effects on the problem-solving time for everyone in a class, irrespective of their speed.

[18]The survey question asks about the level of agreement of the student regarding the statement, "There is someone who I do not want to lose against." The choices are 1. Strongly agree, 2. Somewhat agree, 3. Somewhat disagree, and 4. Strongly disagree. Here, we focus on the students who answered 1.

Further, we find positive peer effects of speed competition on the scores of students who have similar speeds when solving the problems.

These findings might be driven by rivalry formation that creates a motivational boost among students for higher performance while outperforming some peers. Our setting also conforms to the three conditions for the formation of rivalry: similarity, repeated competition, and competitiveness (Kilduff, Elfenbein and Staw, 2010). First, our students came from similar backgrounds and settings. Second, students engaged in problem-solving tasks for six days in a week, which is similar to the repeated competition framework. Third, with regard to competitiveness, in the baseline survey, most students stated that they have someone who they do not want to lose against, which implies competitiveness.

Our findings have important policy implications in the context of improving learning quality, particularly in developing countries. An educational setting that encourages students to engage in competition can be beneficial for learning if adopted carefully.

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Appendix A: Tables and Figures

Table A1— Level of Kumon Worksheets

	Level	Sheet Number	Contents
Highest	F	2001–2200	Addition, subtraction, multiplication, and division of fractions
	E	1801–2000	Addition of fractions
	D	1601–1800	Column division
	C	1401–1600	Column multiplication
	B	1201–1400	Column addition
	A	1001–1200	Subtraction based on mental arithmetic
	2A	801–1000	Addition based on mental arithmetic
	3A	601–800	Addition based on number tables
	4A	401–600	Writing numbers and understand the order of numbers
	5A	201–400	Counting numbers up to 50
Lowest	6A	1–200	Counting numbers from one to ten

Note: In each level, we have 200 worksheets. We convert the difficulty level of worksheet into numerical values, using the sheet numbers from 1-200 (the lowest level) to 2001-2200 (the highest level).

Figure A1. Example of Problem-Solving Math Worksheet

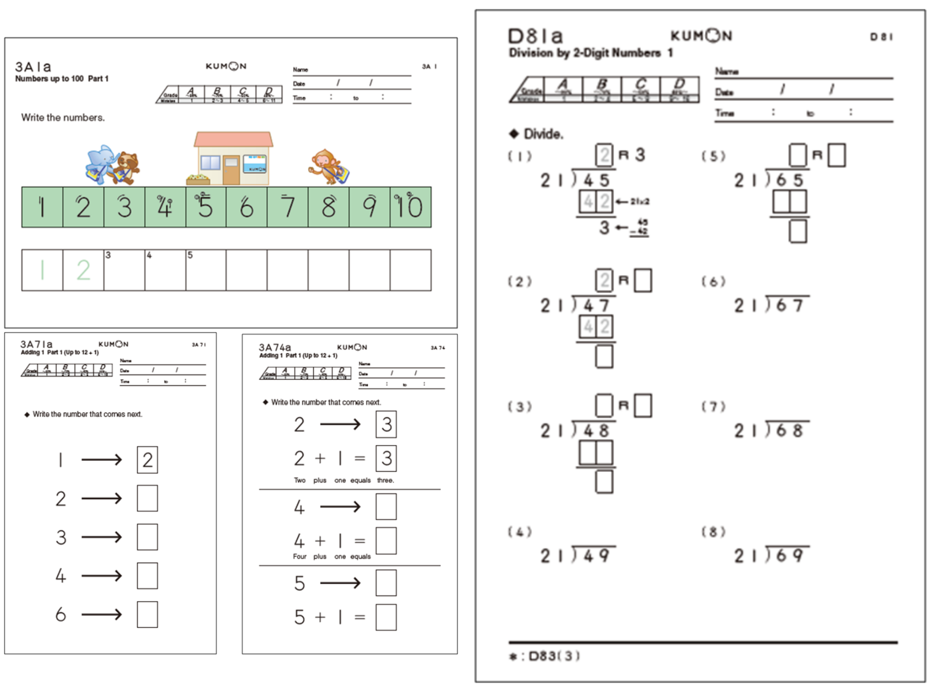


Figure A2. Example of a record sheet in a record book

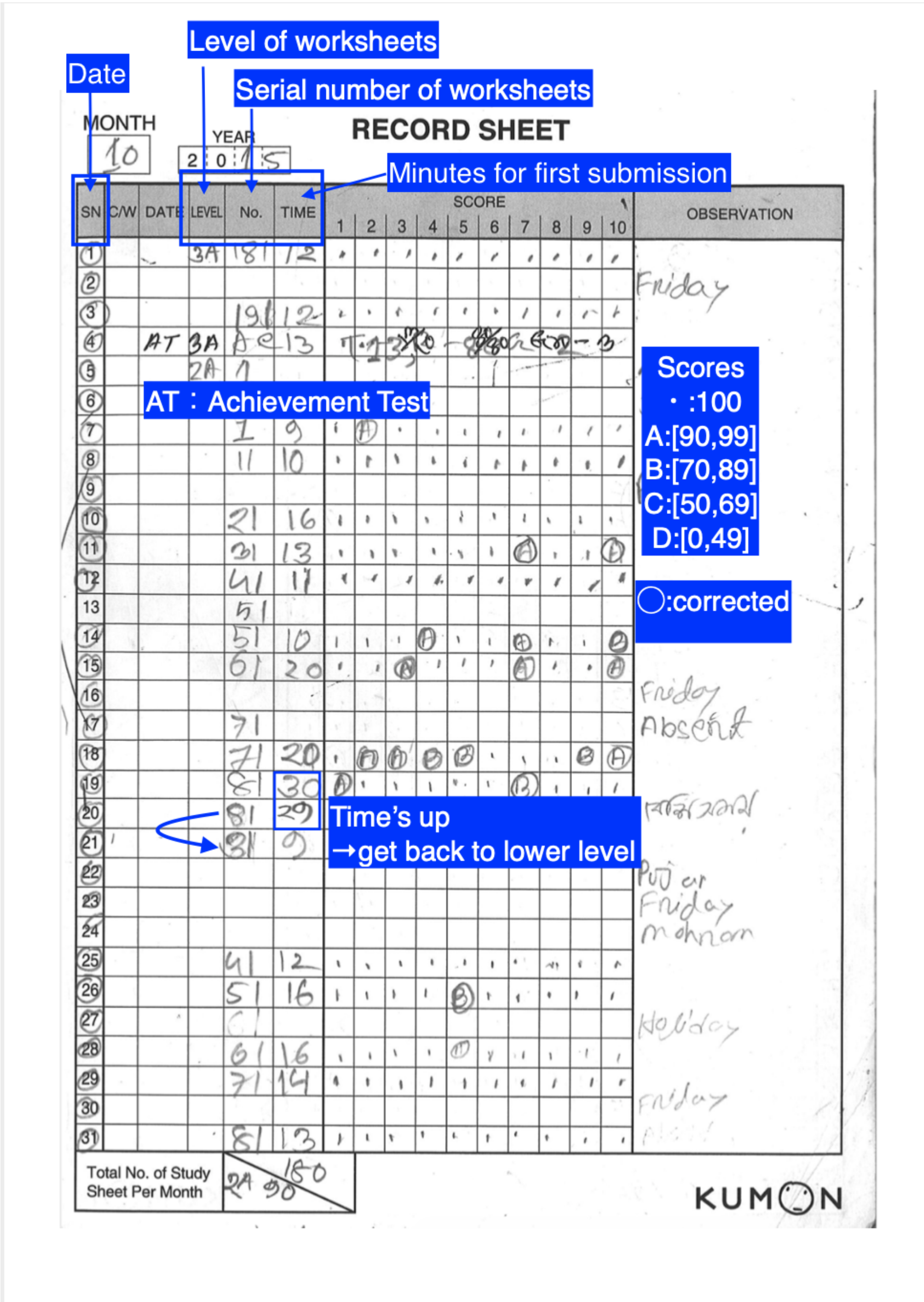


Figure A3. Average Score of 10 Sheets Which Students Solved in a Day

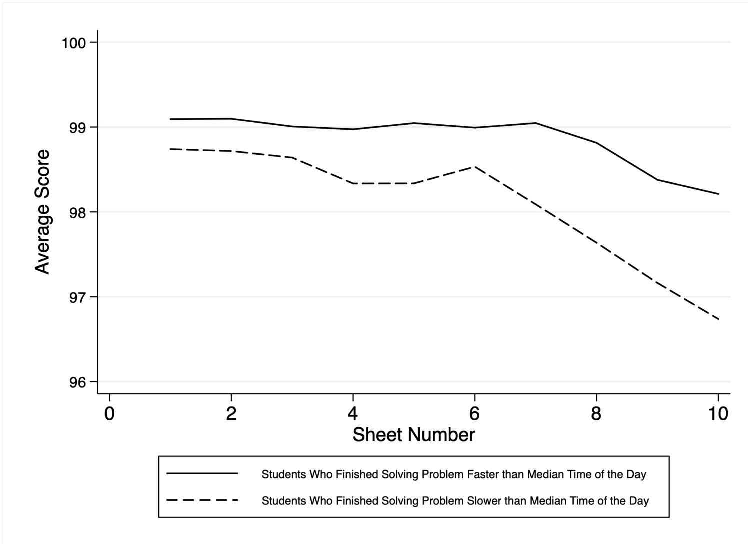


Figure A3 shows the number of worksheets on the X-axis and the score obtained in each worksheet on the Y-axis. The top line is the average score of the students who solve problems faster than the median, while the bottom line is that of slower students. Both lines decline toward the right, indicating that the score falls as a student solves worksheets 8-10. According to Kumon, the contents of the worksheets become more challenging toward the end of each 10-worksheet set. This is because the latter worksheets serve as a quiz that examine students' over all understanding of the subject that they learned that day. For example, if a student learned addition and subtraction on that day, the numbers to be added/subtracted become larger and more complicated; the case is similar for multiplication and division. Further, there are fewer hints but more questions that students have to answer and solve independently without the aid of any hints. In the results section, we show the positive effects of speed competition where students become capable of maintaining high levels of motivation to obtain full scores even toward the end.

Table A2— Scores of Work Sheets

Symbol	Score Range	Class Value
·	100	100
A	$90 \leq \text{score} < 100$	95
B	$70 \leq \text{score} < 90$	80
C	$50 \leq \text{score} < 70$	60
D	$0 \leq \text{score} < 50$	25

Notes. The symbol is written in the Record Books. Circles around alphabets on the score sheets indicate that the students obtained the full score by correcting their answer after the first grading.

Figure A4. Daily Average Score of 10 Worksheets

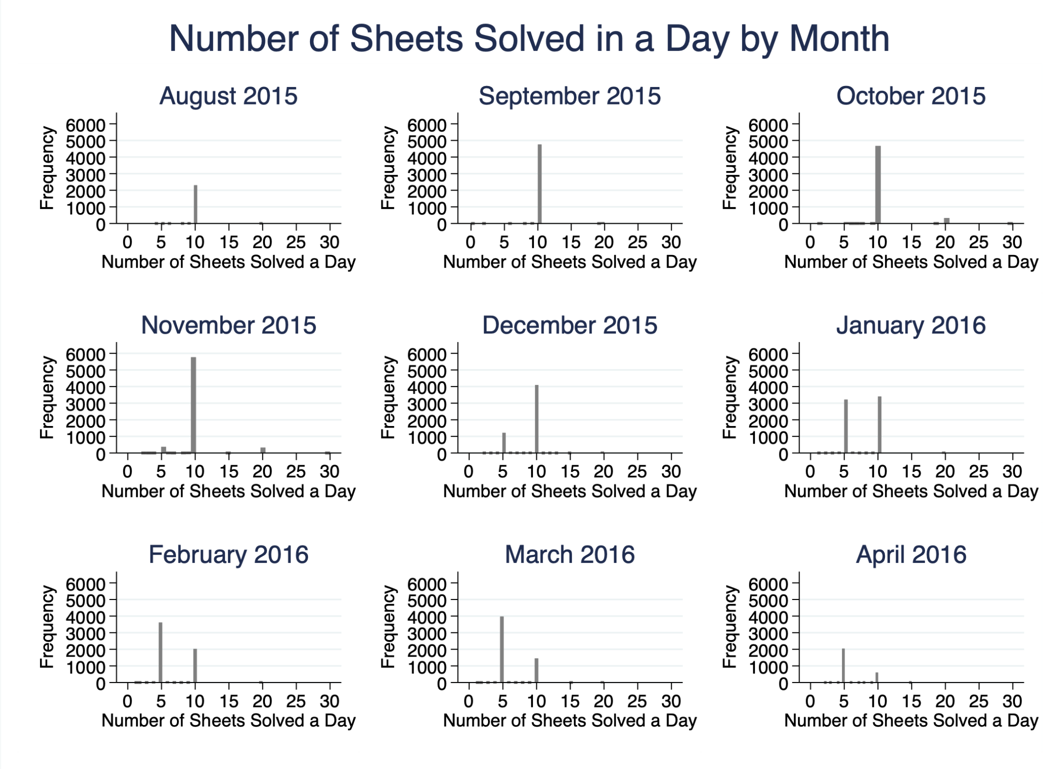
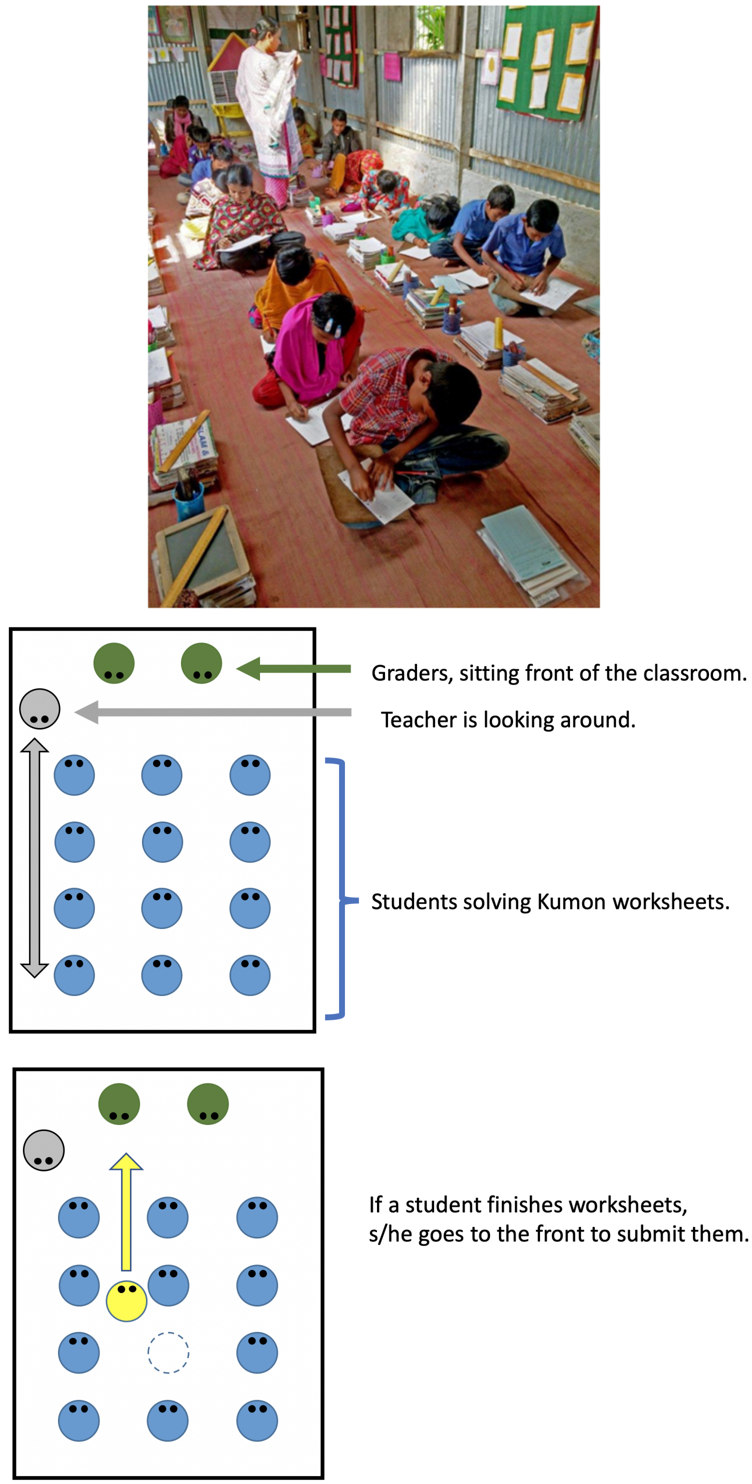


Figure A5. Classroom during Kumon Session



Appendix B: Robustness Analysis

For the earlier set of worksheets, we vary the definition from the first worksheet only, to worksheets 1–2, or to worksheets 1–3 (same as in the main analysis). Similarly, for the latter set of worksheets, we use only the final worksheet, or worksheets 9–10, or worksheets 8–10 (same as in the main analysis). Figure B1 shows the peer effects measured by the fastest peer's time on all students' scores. Although the two remaining bars that compare the peer effects on worksheet 1 vs. 10 are not clear, the latter two comparisons show that the peer effects become stronger and significant in the latter set of worksheets, in contrast to the earlier set of worksheets. The next three figures show the robustness checks of the heterogeneous analysis. Figure B2, Figure B3, and Figure B4 presents the effects of the fastest peer's time on the faster students' score, the fastest peer's time on the slower students' score, and the median student's time on slower students' scores, respectively. The results are mostly consistent with the main findings: faster students appear to improve their scores in the latter set of worksheets when the fastest student's time improves, while the fastest peer's time has no impact on the slower students. Slower students' scores improve when median students' time becomes faster only when we use the final worksheet or pool the final three worksheets together. The results become insignificant when worksheets 9–10 are used. Overall, the peer effects for the slower students are slightly more ambiguous compared to those for the faster students.

B1. Changing the Number of Sheets in Analyses

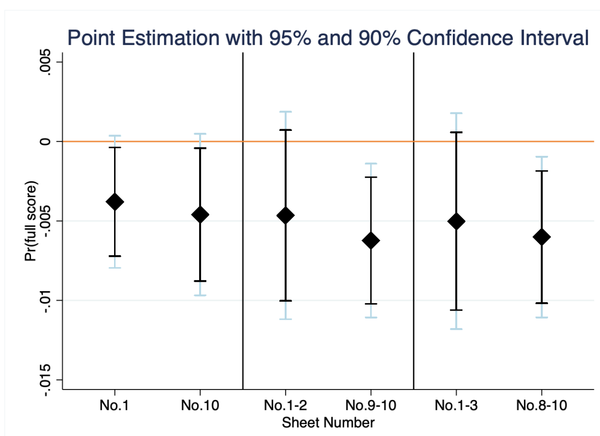


Figure B1. Peer Effects (Fastest Student's Time) on Probability of Obtaining Full Score with Varying Definitions of the Earlier and Latter Worksheets

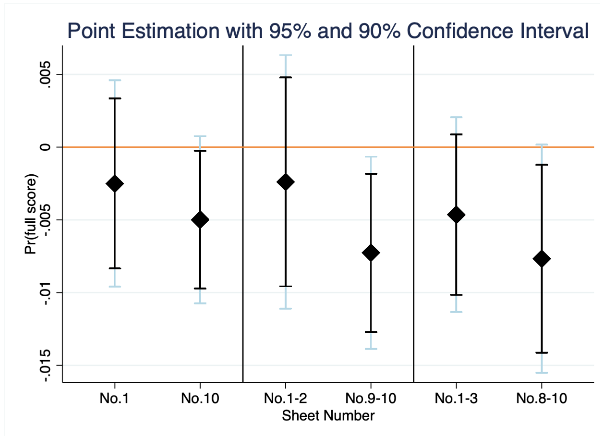


Figure B2. Heterogeneous Peer Effects (Fastest Student's Time) on Probability of Obtaining Full Score by Faster Students with Varying Definitions of the Earlier and Latter Worksheets

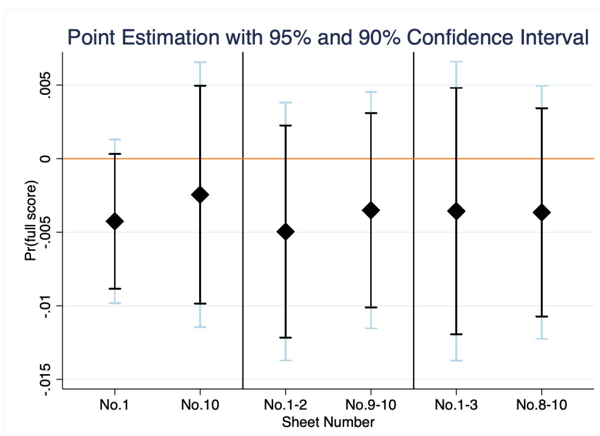


Figure B3. Heterogeneous Peer Effects (Fastest Student's Time) on Probability of Obtaining Full Score by Slower Students with Varying Definitions of the Earlier and Latter Worksheets

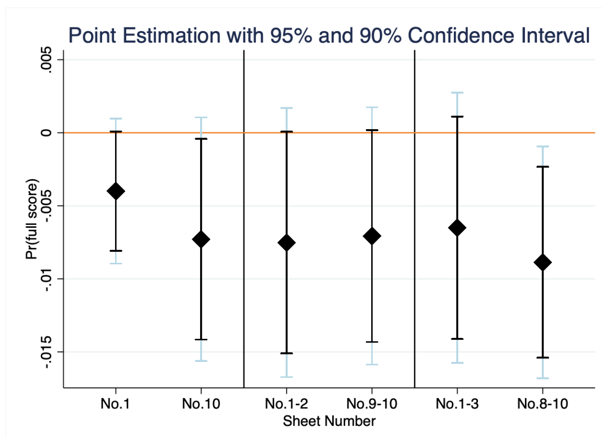


Figure B4. Heterogeneous Peer Effects (Median Student's Time) on Probability of Obtaining Full Score by Slower Students with Varying Definitions of the Earlier and Latter Worksheets

Appendix C: Preference for Competition

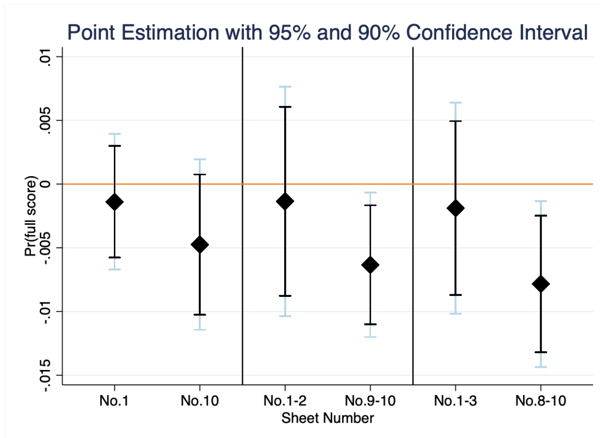


Figure C1. Peer Effects (Fastest Student's Time) on Probability of Obtaining Full Score with Varying Definitions of the Earlier and Latter Worksheets