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Child mental health and human capital accumulation: The case of ADHD

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Abstract

One in five U.S. youngsters has a mental disorder, but we know little about the effects of these disorders on child outcomes. We examine U.S. and Canadian children with symptoms of Attention Deficit Hyperactivity Disorder (ADHD), the most common child mental health problem. Our innovations include the use of nationally representative samples of children, the use of questions administered to all children rather than focusing only on diagnosed cases, and the use of sibling fixed effects to control for omitted variables. We find large negative effects on test scores and schooling attainment suggesting that mental health conditions are a more important determinant of average outcomes than physical health conditions.

JEL classification: I19; I29

Keywords: Mental health; Attention deficit hyperactivity disorder; Human capital; Education; Children

The prevalence and importance of child mental health problems have been increasingly recognized in recent years. For example, the 1999 U.S. Surgeon General's Report (U.S. DHHS, 1999) states that approximately one in five children and adolescents in the U.S. exhibit the signs or symptoms of mental or behavioral disorders.[1] Child mental health problems, while important in their own right, also often lead directly to adult mental health problems, which are a major

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[1] Similarly, Offord et al. (1987) report that in the Canadian province of Ontario, 18% of children have moderate to severe emotional or behavioral problems.

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cause of lost work time and health care costs.[2] But mental health problems may also reduce adult earnings and employment indirectly by inhibiting the child's accumulation of human capital.

While the economics literature recognizes that physical health problems can impede children's human capital accumulation (c.f. Grossman and Kaestner, 1997), the link between mental health problems and human capital accumulation has received little attention. Yet the incidence of most physical health problems among children is small, while the incidence of mental health problems is large, suggesting that these problems are likely to have a more important impact on average educational attainments (Currie, 2005).

This paper examines the experience of North American children with symptoms of attention deficit hyperactivity disorder (ADHD), the most common chronic mental health problem among young children. It is difficult to find definitive estimates of the prevalence of ADHD. Most studies are based on diagnosed cases and there is considerable controversy about whether ADHD is over (or under) diagnosed, and even about whether it is actually an "illness". Two studies based on screeners for ADHD found in large national studies found that 4–5% of American children met the diagnostic criteria for ADHD or had clinically significant symptoms (Jensen et al., 1999; Cuffe et al., 2003). Clearly, ADHD affects large numbers of children.

The few longitudinal studies that examine the effects of ADHD on child outcomes indicate that ADHD is associated with significantly worse outcomes. But it is possible that poorer outcomes reflect other problems suffered by children with ADHD. For example, in the U.S., estimated prevalence rates are almost twice as high in families with income less than $20,000 compared to families of higher income (Cuffe et al., 2003).[3] Poor children with ADHD may also receive less effective treatment than other children, and thus be at "double jeopardy" for ill effects.

We investigate these issues using data from the Canadian National Longitudinal Survey of Children and Youth, and the American National Longitudinal Survey of Youth. Our work offers a number of new contributions. First, it is problematic to focus only on diagnosed cases.[4] Instead, we focus on a set of questions administered to all children in two large nationally representative longitudinal data sets. These questions are similar to the types of screening questions outlined by American Psychiatric Association for diagnosis of ADHD. Second, we address the possibility of omitted variables bias by estimating sibling-fixed effects models. Third, we examine a range of outcomes and compare the effects of ADHD to the effects of physical health conditions. We also examine the effects of ADHD symptoms in samples of children without any other diagnosed learning disabilities. Fourth, we ask how the effects of ADHD and the probability of treatment for ADHD are mediated by income.

We show that ADHD symptoms increase the probability of future grade repetition and special education and reduce future reading and mathematics test scores. The effects are large relative to those of physical health problems such as chronic conditions: A score at the 90th percentile of the distribution of a hyperactivity score based on symptoms increases the probability of grade

[2] For example, Ettner et al. (1997) show that psychiatric disorders reduce employment and earnings among both men and women. Currie and Madrian (1999) conclude that the labor market consequences of mental health problems are large relative to the consequences of physical health problems, since the former are more likely than the latter to afflict those of working age

[3] Other studies that find a relationship between income and ADHD prevalence include: Korenman et al. (1995), McLeod and Shanahan (1993) Dooley et al. (1998), Dooley and Stewart (2003), Phipps and Curtis (2000), and Lipman et al. (1994). Dooley et al. (1998) argue that lone parenthood has an independent effect on incidence.

[4] For example, the incidence of diagnoses of ADHD in the U.S. may have changed in response to changes in the Social Security Insurance program over the 1990s, which made it more or less difficult for children diagnosed with conditions such as ADHD to receive benefits.

repetition by 6% in Canada, and by 7% in the U.S., while having been diagnosed with a chronic condition such as asthma does not have any significant effect.

Surprisingly, income has little effect on the probability of treatment, and the test scores of higher income children are as much affected by symptoms of ADHD as those of lower income children, though higher income children are less likely to repeat grades. We find negative effects even among children whose relatively low levels of symptoms make it unlikely that they would ever be diagnosed or treated for ADHD. This finding suggests that if better ways could be found to teach the relatively small number of children diagnosed with ADHD, many other children with lower levels of symptoms might benefit.

1. Background and previous literature

ADHD is the most common chronic mental health problem among young children, and the disorder is diagnosed in more than half of all child mental health referrals (Mannuzza and Klein, 2000). The main diagnostic criteria for ADHD are laid out in the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (American Psychiatric Association, 1994). To be diagnosed with ADHD, a child must have six or more symptoms; have had symptoms by age 7; and be suffering impairment in two or more settings from the symptoms (usually home and school).

ADHD can affect children's schooling attainment through several channels. First, children whose behavior is considered disruptive or inappropriate are likely to have trouble in school. Second, people with ADHD process and organize information differently than others. They characteristically have great difficulty paying attention for long periods or completing assigned tasks. On the other hand, they are often able to make creative leaps. Research on teaching methods for ADHD children is limited, but does suggest that changes in the way that information is presented (e.g., more use of color, elimination of distracting details) can help such children learn (Fiore, Becker, and Nero, 1993), and that classroom management techniques can reduce disruptive behavior (Stage and Quiroz, 1997).

Mannuzza and Klein (2000) review three studies of the long-term outcomes of children with ADHD from the literature in medicine and psychology. In one study, children diagnosed with ADHD were matched to controls from the same school who had never exhibited *any* behavior problems and had never failed a grade; in a second study, controls were recruited at the 9-year follow up from non-psychiatric patients in the same medical center who had never had behavior problems; and in a third study, ADHD children sampled from a range of San Francisco schools were compared to non-ADHD children from the same group of schools.

These comparisons consistently show that the ADHD children had worse outcomes in adolescence and young adulthood than control children. For example, they had completed less schooling and were more likely to have continuing mental health problems. However, by excluding children with any behavior problems from the control groups, the studies might overstate the effects of ADHD. Also, the studies do not address the possibility that the negative outcomes might be caused by other factors related to a diagnosis of ADHD, such as poverty, the presence of other learning disabilities, or the fact that many people diagnosed with ADHD end up in special education.[5]

There is also a literature in sociology and economics, looking at longer term consequences of a broader set of behavior problems in larger samples than are typically used in psychology. For

[5] These studies do not address the question of whether outcomes were better for ADHD children who were treated—in fact, there appears to be virtually no research examining the longer-term effects of treatment on achievement (Wigal et al., 1999).

example, Farmer (1993, 1995) uses data from the British National Child Development Survey (the NCDS), which follows the cohort of all British children born in a single week in March 1958, to examine the consequences of childhood "externalizing" behavioral problems on men's outcomes at age 23. She finds that children who fell into the top decile of an aggregate behavior problems score at ages 7, 11, or 16 had lower educational attainment, earnings and probabilities of employment at age 23. Gregg and Machin (1998) also use the NCDS data and find that behavioral problems at age 7 are related to poorer educational attainment at age 16, which in turn is associated with poor labor market outcomes at ages 23 and 33. A similar study of a cohort of all New Zealand children born between 1971 and 1973 in Dunedin found that those with behavior problems at age 7–9 were more likely to be unemployed at age 15–21 (Caspi et al., 1998).[6]

Our work differs from the previous work using these cohort data sets in several respects. First, we estimate sibling fixed effects models to control for omitted variables bias. Fixed effects methods offer a powerful way to control for characteristics of households that might be associated both with a higher probability of ADHD and with outcomes. Second, we focus on a specific syndrome rather than a set of behavior problems.[7] Some of the behavior problems included in previous studies might be caused by poor performance at school, rather than vice versa. In contrast, we will show that the ADHD symptoms we focus on have negative effects even when they are measured before school age. Third, the NCDS has no data on family income during childhood, so it is not possible to examine the relationships between mental health problems, treatment, income, and outcomes. Fourth, we investigate outcomes in a much more recent cohort of children than previous studies.

2. Data

We use data from the Canadian National Longitudinal Survey of Children and Youth (NLSCY) and from the American NLSY. The NLSCY is a national longitudinal data set which surveyed 22,831 children ages 0–11 and their families beginning in 1994. Follow up surveys were conducted in 1996 and 1998. We restrict our sample to those children between the ages of 4 and 11 in 1994, since only parents of children in this age range completed the ADHD screener. This restriction yields 8332 children. For our main analyses we keep only those children whose *teachers* were also given the ADHD screener in 1994, which yields a sample of just under 4000 children. Sample sizes are reduced by this criterion because children must be enrolled in school to have a teacher report, and some schools did not return completed questionnaires. We choose to focus on the teacher responses to the screener as we felt that they would be less correlated with other unobserved characteristics of the family than the parent responses. It may be the case, however, that teacher responses are influenced by school related outcome measures. We have re-estimated all our models including all children who meet the other sample inclusion criteria, and using parental responses to the ADHD screener. The results are extremely similar to those reported

[6] Other psychological studies have examined the longer-term impact of different types of behavior, such as aggression (see Richard Tremblay's many studies of a cohort of Montreal school boys). However, a survey of this literature is beyond the scope of this paper.

[7] A limited amount of work has examined the consequences of specific mental health problems in adolescents. Mullahy and Sindelar (1989) examine the impact of adolescent alcoholism on earnings and employment, and conclude that the onset of alcoholism before age 18 reduces earnings and employment through its effect on schooling attainment. Cuellar et al. (2003) show that adolescents in the Colorado state foster care program who received treatment for their mental health problems were less likely to engage in crime.

below. For analyses that use Canadian math and reading test scores we have a smaller sample of approximately 2200.[8] We use the NLSCY data to ask how the hyperactivity score in 1994 affects treatment in 1994 and outcomes in 1998.

The NLSY began in 1979 with a survey of approximately 6000 young men and 6000 young women between the ages of 14 and 21. These young people have been followed up every year up to the present. In 1986, the NLSY began assessing the children of the female NLSY respondents at 2 year intervals. Given the differences in the design of the two studies, and the large amounts of missing data in the NLSY, we use the NLSY data to see how the average hyperactivity score measured over the 1990 to 1994 period affects the average outcomes of children in the 1998 and 2000 waves. This procedure yields a maximum sample of 5348 children. We restrict the age range of the NLSY children to be greater than 4 and less than 12 years of age in 1994 to make the Canadian and U.S. samples more comparable.[9]

The measurement of ADHD is key for our analysis. The measures available in our surveys, as in most surveys, are questions that are asked to parents and/or teachers about symptoms of ADHD. ADHD is always diagnosed through the use of questions similar to those included in both surveys.[10] In the NLSCY data, the teachers and parents of all children aged 4 through 11 in 1994 were asked a series of 8 questions. The responses to these questions were added together to determine a hyperactivity score for the child. The NLSY Behavior Problems Index is asked to parents of children 4–14. There are 26 questions asked to all children, and two questions asked only to children who have been to school. Five of the questions can be used to create a hyperactivity subscale. This score is standardized by the child's sex and age. We convert this standardized score to one that has the same range as the score in the Canadian data[11].

Since the hyperactivity score is generated from a set of questions asked of all respondents, our measure captures a set of ADHD symptoms and is not dependent on whether the child has been diagnosed with ADHD. This avoids criticisms of mental health measures based on the set of children who seek treatment for their illness (Frank and Gertler, 1991).

In the NLSY, parents were also asked whether their children had any conditions that limited their normal activities. If they answered in the affirmative, parents were asked to identify the

[8] Of the 9542 children eligible to receive the tests, 86% of parents consented to have the school board administer the tests and 97% of school boards consented to conduct the tests. However, due to administrative problems, only 65% of the administered tests were returned to Statistics Canada in 1998. Therefore, of the original 9542 children eligible to take the test, we have test scores for only 5153 children (this number represents all children in the sample, including those outside the age range we investigate). The response rate for 1996 was significantly higher (closer to 75%). Using the 1996 test scores rather than the 1998 test scores yields results that are qualitatively similar to those reported below. Statistics Canada has conducted an analysis of the non-response, and finds that there is very little difference between responders and non-responders along observable dimensions (such as gender, type of school, whether the children had ever repeated a grade, or the importance that the parent respondent attaches to education).

[9] Focusing on 4–11 year olds also improves our ability to compare across outcome measures in the NLSY. The reason is that test scores are available only for children aged 5–14, while measures of delinquency are available for much older children. Estimating our models for the full available sample for each outcome measure in the NLSY yielded estimates qualitatively similar to those discussed below. The main exception is that the interaction between income and hyperactivity scores is positive in OLS using the full U.S. sample. In other words, in the sample of older NLSY children, there IS a positive relationship between income and probability of treatment conditional on hyperactivity scores.

[10] Most of the literature focuses on children who have been diagnosed with ADHD. However, Merrell and Tymms (2001) show that symptomatic children who have not been diagnosed suffer from similar problems.

[11] The list of symptoms noted by the American Psychiatric Association and the questions asked in each survey are listed in Currie and Stabile (2004).

Table 1
Definitions for outcome variables in the NLSY and NLSCY

Variable/data source	NLSY	NLSCY
Grade repetition	Repeated between 1994 (when hyperactivity is measured) and 2000	Repeated between 1994 and 1998
Math and reading scores	Scores taken from peabody individual achievement test	Tests administered in schools as part of survey based on Canadian achievement tests
Delinquency	Corresponds to Department of Justice definition including illegal drug use or sales, destroyed property, theft >$50, assault, arrest.[a] Drug questions answered by child	Same as NLSY plus questioned by policy and whether child has run away from home. Drug questions answered by child
Special education	Parental report that child was in special education in 2000	Teacher report on whether child is in SE because of a mental health condition only
Physical health measures	Do not use because chronic conditions are asked only of children who have an activity limitation and the self assessed health measure is not asked in all waves of survey	Poor health defined as respondent indicating the child is in bottom 3 measures on self-assessed health scale. Chronic condition questions include allergies, asthma, heart disease, bronchitis, epilepsy, cerebral palsy, kidney troubles, and a category for other chronic conditions. Asked of all children. Learning disabilities and psychological disabilities excluded from physical health measures
Permanent income	Mean of all available household income measures from 1990 onwards	Mean of all available household income measures from 1994 onwards

[a] DOJ definition from (Puzzanchera, 2000).

limitation.[12] The same suite of questions was used to identify children who had been diagnosed with a "learning disability". In the Canadian NLSCY we use a question on whether the child has been diagnosed with a learning disability that is asked in the series of questions on chronic conditions. Below, we examine the effects of ADHD symptoms in a sample of children that excludes those with other diagnosed learning disabilities, in an effort to isolate the effects of ADHD itself.

We focus on a set of outcomes that are intended to capture the child's human capital accumulation, broadly defined. These include: Grade repetition, mathematics scores, reading scores, and special education. Since ADHD is often thought of as a primarily behavioural affliction, we also look at delinquency, which may be more closely related to the child's behaviour problems. We describe the construction of each of these outcome variables in Table 1. Table 1 also has information about the construction of our physical health measures, and our measure of household permanent income. Further details about the construction of these variables are in Currie and Stabile (2004).

Means of all of our measures are shown for all children with non-missing hyperactivity scores in columns 1 and 4 of Table 2a. Columns 2 and 5 show means for the sample of children with siblings, who will be the focus in our fixed effects models. In the NLSY, all siblings in sampled households are interviewed, whereas in the NLSCY, one randomly chosen sibling is interviewed.

[12] We code children as having been diagnosed with ADHD if the parent identifies any of the following conditions: "minimal brain dysfunction, minimal cerebral dysfunction, attention deficit disorder", or "hyperkineses, hyperactivity". Minimal brain dysfunction is a term that was used to describe ADHD when the leading theory was that the disorder was caused by brain damage in infancy.

Table 2a
Means of key variables in sample with reading and math scores

	Canada all	Canada sib sample	# Canada sibs in HH w diff.	U.S. all	U.S. sib sample	U.S. # sibs in HH w diff.
Hyperactivity score 1994 reported by teacher	3.890 [4.065]	3.699 [3.931]	1300	–	–	–
Hyperactivity score reported by parent	4.508 [3.487]	4.291 [3.414]	1332	5.930 [3.797]	5.786 [3.809]	2363
Gender difference mean scores	2.216	2.039		1.248	1.269	
Probability score>90th ptile-male	15.800	13.023		12.300	12.237	
Prob. score>90th ptile-female	5.390	4.967		7.508	7.253	
Diagnosed ADHD	–	–		0.026	0.026	120
Child outcomes						
Delinquent behaviour 1998	0.307	0.282	248	0.502	0.492	135
Grade repetition 1998	0.037	0.036	88	0.075	0.072	238
Mathematics score 1998 (/100)	54.027 [23.14]	54.947 [22.81]	608	51.622 [26.912]	49.946 [26.726]	1338
Reading score 1998 (/100)	55.650 [18.2]	55.405 [18.13]	612	56.185 [28.806]	53.981 [28.943]	1332
Special education 1998/2000	0.104	0.095	32	0.071	0.078	63
Alternative health indicators						
Poor health 1994	0.135	0.134		–	–	
Chronic condition indicator 1994	0.328	0.323		–	–	
Learning disabilities	0.026	0.019		0.026	0.028	
Treatment						
Drug treatment 1994	0.014	0.010	30	0.033	0.032	155
Psychiatrist 1994 (or psychologist in NLSCY)	0.036	0.033	72	0.081	0.085	280
Any treatment 1994	0.047	0.039	92	0.096	0.099	359
Selected covariates						
Child age 1994	7.890	7.890		8.271 [2.300]	8.172 [2.259]	
Male child	0.500	0.503		0.513	0.513	
First born child	0.460	0.353		0.387	0.296	
Permanent income	54566 [33338]	56608 [32092]		41483 [25867]	42185 [26154]	
Mother high school or more	0.558	0.570		0.751	0.754	
Family size 1994	4.310 [1.063]	4.530 [0.930]		4.313 [1.212]	4.670 [1.164]	
Mother teen at child birth	0.045	0.026		0.046	0.047	
Mother's age at birth	27.220 [4.709]	27.140 [4.382]		24.689 [3.092]	24.692 [3.103]	
Mother depressed or activity limitation	0.158	0.154		0.234	0.236	
Number of observations	3925	1540		3969	2406	

Notes: Canadian data from the 1994–1995, 1996–1997 and 1998–1999 cycles of the NLSCY. Standard error in brackets. U.S. data is means for 1990–1994 and for 1998 and 2000, see text. Sample includes those with non-missing test scores.

Columns 3 and 6 show the number of siblings with a within-family difference in the variable in question, since these are the children who will identify the effects of hyperactivity in our models.

This table suggests that the sibling sample is quite similar to the "full" sample of children, and that there are sufficient numbers of siblings with differences in outcomes to pursue a fixed effects strategy for most of our outcomes. The mean difference in hyperactivity scores, where there is a difference, is 3.96 in Canada and 3.07 in the U.S., which is roughly a one standard deviation difference. Table 2a also shows that the mean difference in hyperactivity scores between boys and girls is relatively small (slightly larger in Canada than the U.S.), while there is a much greater gender difference in the probability of being above the 90th percentile of the score distribution.

The U.S. sample also has information about diagnosed cases of ADHD. Table 2a indicates that only about 2.6% of children had such a diagnosis in 1994. This is about the same fraction that has been diagnosed with "learning disabilities" and there is significant overlap in the two samples: Of the 96 children with diagnosed ADHD, 40 have other learning disabilities. We can also examine the screener score measure for children diagnosed with ADHD. In this group, only 35% have a score higher than the 90th percentile of the ADHD score distribution. These comparisons highlight difficulties with using ADHD diagnosis as a measure. On the one hand, it appears that ADHD is under-diagnosed in this population, since 2.6% is much less than the 4–5% estimated prevalence from national surveys. On the other hand, many of the children diagnosed with ADHD appear to have few behavioural symptoms (even when they are not being treated), suggesting that they have perhaps been erroneously diagnosed, or that there is potentially measurement error in the reporting of symptoms in the survey.

The table highlights similarities and differences between the U.S. and Canadian samples. The U.S. children are slightly older and born to somewhat younger mothers on average, as one would expect. They are also more likely to have mothers who are depressed or have an activity limitation. All of these differences as well as differences in other observable variables in the two data sets are controlled for in our ordinary least squares (OLS) models, and many of them will be absorbed by family fixed effects in the fixed effects models. The U.S. children are much more likely to be delinquent, and twice as likely to repeat grades. However, they are slightly less likely to be in special education.[13]

Both the NLSY and the NLSCY have information about drug and psychiatric treatment for mental health conditions, as shown in Table 2a. In 1994, only 1.4% of the Canadian children reported drug treatment compared to 3.3% of the American children. The NLSCY asks specifically about Ritalin, tranquillizers and nerve pills, whereas the NLSY asks a more general question about medications used to control activity levels or behavior.[14] The Canadian children were also less likely to have seen a psychiatrist, resulting in overall treatment rates of 4.7% compared to 9.6% for the American children.

[13] In the U.S., the math and reading scores are standardized using national norms for children of the same sex and age. Such norms are not available for these Canadian math and reading tests. However, we control for the child's sex and age in our regressions. The Canadian math and reading scores are out of 15 and 20, respectively. For ease of comparison with the U.S. results, we have multiplied the Canadian math and reading scores by 6.67 and by 5 in the means tables. We multiply coefficients and standard errors by the same factors in all the subsequent tables as well.

[14] In comparison, the Centre for Addiction and Mental Health in Ontario, which conducts a student drug use survey in 2001, found 4.2% of seventh and eighth graders in Ontario reported using Ritalin within the past 12 months (Adlaf and Paglia, 2001). However, in the NLSCY reported use of Ritalin has increased significantly since 1994. For example, among 10 year olds the incidence of Ritalin use increased from 2.5 to 4.1%, while among 11 year olds, it increased from 1.3 to 3.9% between 1994 and 1998.

Table 2b
Hyperactivity score distribution

Score	Canada teacher report % with score	Canada parent report % with score	U.S. parent report % with score
0	29.2	10.4	10.53
1	12.2	11.9	5.85
2	9.2	11.5	5.95
3	7	10.3	4.23
4	6.5	9.5	13.83
5	5.6	9.3	6.32
6	6.4	8.6	10.71
7	5.3	7.5	9.3
8	5.4	6.9	5.85
9	2.7	**4.8**	11.21
10	**1.9**	3.1	3.78
11	2	2	**4.76**
12	1.4	1.4	3.05
13	1.6	1.1	1.74
14	1.1	0.9	1.08
15	1.2	0.7	0.98
16	1.1	0.3	0.83

Note: Median score is underlined. Ninetieth percentile score indicated in bold.

These differences in mean rates of treatment are surprising in view of differences in the insurance regimes in the two countries: In Canada, psychiatric treatment is covered under public health insurance, and all of the provinces have drug plans for low-income families. In the U.S., many private insurance plans severely restrict the coverage of mental health treatment, and Medicaid (the public system of health insurance for low income children) offers only limited coverage of psychiatric treatment. The low treatment rates in Canada may reflect greater stigma attached to mental illness, less faith in the efficacy of treatment, or both. They may also be the result of differing treatment patterns and training between countries.

A comparison of the distribution of NLSCY teacher reports, NLSCY parent reports, and NLSY parent reports of hyperactivity is shown in Table 2b. The first two columns suggest that the teacher and parent reports do contain independent information-in Canada parents are much less likely to report low levels of symptoms than teachers and the correlation between the two scores is only 0.46. Half of the children receive scores of two or less from teachers, while the median parent score is 4.

The U.S. distribution indicates lower fractions of children with very low scores, and higher numbers of children with high scores since the median score is 6. The 90th percentile score is also somewhat higher in the U.S. distribution. Scores exceeding 8 have been shown in previous research to be associated (though imperfectly) with diagnosed ADHD (Baillargeon et al., 1999). In our Canadian data, a cutoff of 9 yields prevalence rates of about 14% which corresponds with Willms (2002) finding that approximately 14% of children in the NLSCY are hyperactive.[15] But since 14% is much higher than the 4–5% estimated prevalence of ADHD in the U.S., we have chosen to focus on the 90th percentile score for both the U.S. and Canada.

[15] In a survey of students in three Ontario school districts, Sgro et al. (2000) use a cutoff of 9 or higher as a "diagnosis" of ADHD and find rates around 5%. Since response rates to the survey instrument used in Sgro et al., were less than 29%, it is likely that the NLSCY numbers are more accurate.

Table 2c
Means of outcomes for children above and below the 90th percentile of hyperactivity score

	Canada: above	Canada: below	U.S.: above	U.S.: below
Grade repetition	0.116	0.027	0.118	0.071
Delinquent	0.427	0.293	0.602	0.493
Mathematics score	43.82	55.16	43.09	52.56
Reading score	46.80	56.15	43.26	57.60
Special education	0.380	0.070	0.143	0.063
Drug treatment 1994	0.070	0.007	0.103	0.025
Psychiatric treatment 1994	0.096	0.029	0.174	0.070
Any treatment 1994	0.147	0.035	0.199	0.084

Note: The median teacher-reported score is used for Canada.

Table 2c shows that there are large mean differences in outcomes between children above and below the 90th percentile of the hyperactivity score. In the U.S., high scores double the risk of grade repetition and special education, and are associated with a half of a standard deviation reduction in reading and mathematics scores. The difference in the probability of delinquency is more modest, which is perhaps surprising given that ADHD is thought of as a primarily behavioral disorder. In Canada, the differences in outcomes between children with high and low scores are perhaps even starker than in the U.S., with a rate of grade repetition that is more than three times higher, and a rate of special education that is more than five times higher.

An important question is whether we expect the effect of hyperactivity symptoms to be roughly linear, or whether scores above some threshold have much more deleterious effects? People often think about illness in terms of thresholds—only people with blood pressure above a set cut off are diagnosed with high blood pressure, and only people whose insulin function is subject to a certain degree of impairment are diagnosed with diabetes. However, in both of these examples, recent research has shown that persons with readings below the relevant thresholds for diagnosis still suffer from negative effects. This could also be the case with ADHD symptoms.

Fig. 1 shows non-parametric Lowess plots of outcomes against hyperactivity scores for the U.S. and Canada. There are two striking things about these pictures. First, they are remarkably similar for the U.S. and Canada despite differences in samples, educational systems, variable definitions and so on. Second, all of the outcomes except delinquency change approximately linearly with hyperactivity scores. This observation suggests that even children with scores low enough that they would never be diagnosed with ADHD, may nevertheless suffer ill effects of behaviours associated with the syndrome. Hence we look at the effect of linear ADHD scores as well as the 90th percentile.

The negative effects of ADHD on delinquency top out at around the 90th percentile of both the U.S. and Canadian distributions. We have estimated models with splines at the 90th percentile in order to take account of the effect of this non-linearity, but did not find that our results were materially affected, so these results are not reported below.

3. Methods

We begin by estimating OLS models of the relationship between hyperactivity scores in 1994 and outcomes in 1998, controlling for a wide range of other potentially confounding variables,

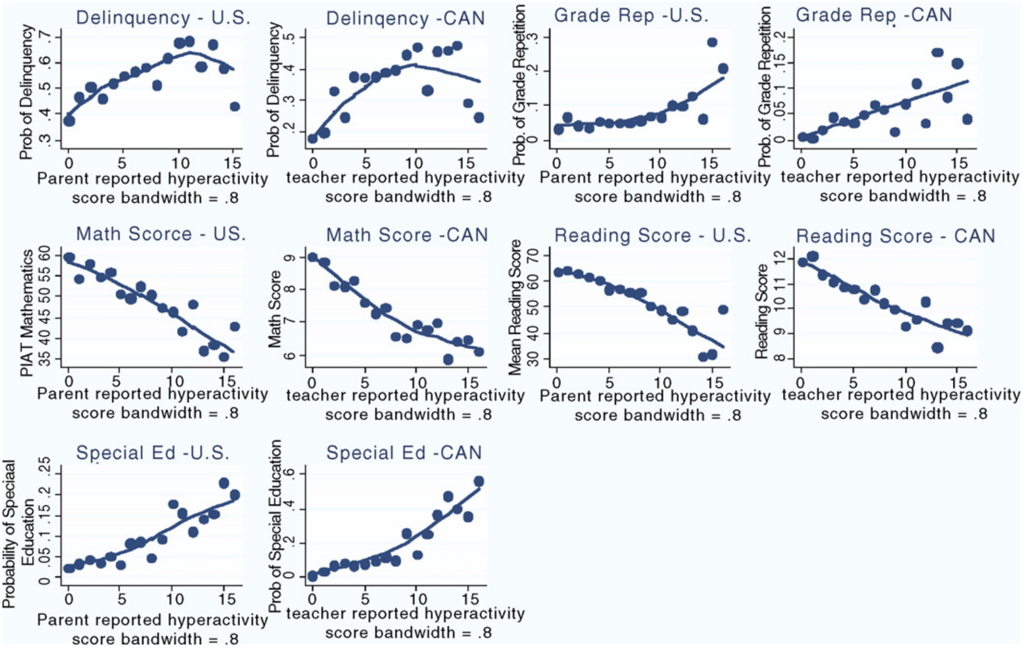

Fig. 1. Comparing U.S. and Canadian outcomes by hyperactivity score.

including permanent income; maternal health status, education and family structure (in 1994); child age (single year of age dummies), whether the child is first born, and sex.

These models have the following form:

$$\text{outcome98}_i = \alpha + \beta\text{ADHD94}_i + \lambda X94_i + \varepsilon_i \quad (1)$$

where outcome98 is one of the outcomes described above, ADHD94 is the child's hyperactivity score (either the continuous score or a cut-off for a score above the 90th percentile) and X is the vector of covariates described above. If high hyperactivity scores are positively correlated with other factors that have a negative effect on child outcomes, then these estimates will overstate the true effect of hyperactivity.

We next attempt to control for unobserved heterogeneity by estimating family fixed effects models

$$\text{outcome98}_{if} = \alpha + \beta ADHD94_{if} + \lambda Z94_{if} + \mu_f + \varepsilon_{if} \quad (2)$$

In these models, the Z vector is similar to X but omits factors common to both siblings, and the f subscript indexes families. A comparison of (1) and (2) will indicate whether OLS estimates are driven by omitted variables at the family level. Evidently, there maybe individual-level factors that are important and which will not be captured by family fixed effects. However, it is impractical to estimate models with child fixed effects because ADHD is a symptom that typically emerges before the child's 7th birthday. Thus, changes in ADHD scores over time for the same child are likely to reflect measurement error, rather than true changes in mental health status. One of the most important individual-level factors is likely to be whether the child has other learning disabilities. We deal with this problem by re-estimating models excluding children with other diagnosed learning disabilities below.

If a high hyperactivity score for one sibling has negative effects on the achievement of other siblings in the household, then the difference between the two siblings will provide an underestimate of the effects of hyperactivity. Estimates of (2) may also be biased downwards by random measurement error in the hyperactivity scores. Measurement error is a potentially important problem in this and all of the past studies relying on parental reports of children's mental health disorders (c.f. Offord et al., 1989; Garrett, 1996; Glied et al., 1997).

One way to judge the importance of measurement error is to compare the OLS and fixed effects estimates. If we believe that part of the true effect of ADHD is persistent between siblings, then the within family variation may be more "noisy" than the between family variation. In this case we might expect increased attenuation bias in the fixed effects estimates. However, as we show below, these estimates are very similar suggesting that in practice, measurement error (or potential spillover effects, as noted above) may not be such an important problem. In the Canadian data, we also adopt a second approach to measurement error, which uses the fact that this survey independently asks identical questions about the mental health of the child of both teachers and parents. Specifically, we estimate models using parent reports as instruments for teacher reports in order to correct for measurement error. The identifying assumptions are first, that conditional on the teacher report and on the family fixed effect included in the model, the parent report has no independent effect on the child's test scores and other outcomes. Second, while we assume that the "signals" in the parent and teacher reports are correlated, the instrumental variables estimates are only consistent if the errors in the parent and teacher reports are uncorrelated.[16] While we do not report these results in the paper, the IV results are similar to the OLS estimates that are presented below for grade repetition and math scores, further suggesting that measurement error is not severely biasing our estimates.

A third potential problem is that a small number of children in our samples are being treated for ADHD. Treatment for ADHD generally consists of drug treatment (with stimulants such as methylphenidate or amphetamine), psychiatric counseling for parents and children aimed at behavioral modification, or both. Drug therapy is effective in improving behavior for approximately 70–80% of children. However, Swanson et al. (1991) indicate that there is little evidence that drug treatment consistently improves cognitive performance on academic tasks in a laboratory setting.[17]

To the extent that treatment is effective in altering behavior, children who are being treated will have lower ADHD scores than they otherwise would have, since the questions used in the screener focus on behavior. But if treatment has no consistent impact on cognitive outcomes such as test scores (as Swanson's research suggests) then failing to account for treatment will bias our estimates. For example, if all ADHD children were treated, it might appear that even

[16] Given that the questions are asked independently and that they concern very specific observed behaviors, we believe this second assumption is reasonable. For example, suppose that the teacher and the parent had discussed the fact that the child might have ADHD. There is no reason why this would cause correlated errors in the responses to a set of questions about specific behaviors that are not linked to ADHD in any way in the questionnaire.

[17] They point to two reasons for mixed results of drug therapy. First, drug doses that are too high may impair cognitive functioning. For simple tasks, the performance of ADHD children improves linearly with dose, while for tasks that require mental effort, performance improves at low doses and then declines. Thus, they conclude that the doses administered to control behavior may be higher than optimal for improving academic performance. Second, there are children whose performance on cognitive tests does not improve with drug therapy at all, and may even be impaired. Some studies suggest that up to 40 percent of children treated with stimulant drugs do not have any favorable cognitive response.

low ADHD scores were associated with significantly poorer outcomes, and our results would be biased upwards.

It would be extremely interesting to be able to conduct our own analysis of the impact of treatment on outcomes. However, the very small number of children who are treated (especially in Canada) and the endogenous nature of treatment decisions (along with the lack of plausible instruments for treatment) make this difficult. Instead, we take two alternative approache s to the problem of treated children. First, we simply exclude the treated children. If treatment were applied randomly to the population of children, then these estimates would provide an unbiased estimate of the effects of untreated ADHD scores on outcomes. Second, we impute the 90th percentile score to all of the treated children. This is equivalent to assuming that only children with high scores are treated. As we will show, neither alternative has much impact on our estimates, given the small numbers of children being treated.

We also examine gender differences in the effects of ADHD. As Table 2a shows, on average, boys score only slightly higher on the ADHD index than girls, but are much more likely to be above the 90th percentile of the distribution. We ask whether similar levels of ADHD scores affect boys and girls similarly by interacting the dummy variable for "male" with the hyperactivity score in models of the form (2).

Finally, we turn to an investigation of the extent to which the effects of ADHD are mediated by income. The OLS models we estimate have the following form:

$$\text{outcome98}_i = \alpha + \beta(\text{income})_i + \phi\text{income}_i \times \text{ADHD94}_i + \chi\text{ADHD94}_i + \lambda X94_i + \varepsilon_i \tag{3}$$

where now income has been broken out of the X vector, and interacted with the hyperactivity score. A positive coefficient on the interaction term (in the case of a positive outcome) would suggest that the negative effects of ADHD were mitigated in high income children. If it were the case that high income children with ADHD were more likely to be treated than other children, and had either better or worse outcomes than lower income children, then models of this type would provide some evidence (albeit indirect) about the efficacy of treatment. Hence, we also estimate models of treatment probabilities that take the form (3). However, we show below that neither outcomes nor treatment probabilities vary much with income (in contrast to the strong relationship between income and treatment (or quality of treatment) that holds for most physical illnesses). While these results are interesting in and of themselves, they make it difficult to infer anything about the effectiveness of treatment from our estimates.

4. Results

Table 3 presents our baseline OLS estimates of the effects of hyperactivity on child outcomes in the U.S. and Canada. Table 3 indicates that children with higher hyperactivity scores have outcomes that are worse in all of the measured dimensions. The estimated effects of a one unit change in the hyperactivity score are generally somewhat lower for the U.S. than for Canada, though for reading scores, they are somewhat larger.

One way to think about the size of these effects is to compare them with the effect of income, which has consistently significant effects, and generally has larger effects in the U.S. than in Canada. For example, in Canada, each \$100,000 worth of permanent income is associated with a 3.8% point decrease in the probability that a child repeats a grade between 1994 and 1998. But a Canadian child with a score of only 5 out of 16 on the hyperactivity index would be 3.5%

Table 3
Effects of hyperactivity on future outcomes

	[1] Canada delinquent	[2] U.S. delinquent	[3] Canada grade rep.	[4] U.S. grade rep.	[5] Canada math	[6] U.S. math	[7] Canada reading	[8] U.S. reading	[9] Canada special ed.	[10] U.S. special ed.
Hyperactivity score 1994	0.015 [6.00]**	0.013 [2.98]**	0.007 [6.99]**	0.004 [2.49]**	−1.373 [10.85]**	−0.868 [6.57]**	−0.850 [8.18]**	−1.176 [8.14]**	0.023 [8.79]**	0.008 [3.85]**
Average income (in 100,000)	0.008 [0.33]	−0.086 [1.21]	−0.038 [4.28]**	−0.053 [2.77]**	7.117 [4.72]**	15.382 [6.87]**	5.220 [4.69]**	13.977 [5.51]**	−0.031 [1.44]	−0.024 [0.73]
Adult respondent immigrant	−0.040 [1.23]		−0.009 [0.94]		0.514 [0.28]		0.830 [0.56]		0.078 [2.00]*	
Black		−0.017 [0.46]		0.007 [0.50]		−8.787 [6.13]**		−2.835 [1.76]*		−0.023 [1.13]
Hispanic		0.03 [0.83]		0.027 [2.05]**		−12.485 [8.58]**		−9.391 [5.69]**		0.004 [0.16]
Male	0.099 [5.34]**	0.029 [1.03]	0.005 [0.79]	0.016 [1.70]*	1.721 [1.78]*	4.539 [4.65]**	−0.210 [0.27]	−0.444 [0.41]	0.023 [1.43]	0.034 [2.46]**
First born child	−0.032 [1.55]	−0.062 [1.97]*	−0.003 [0.49]	−0.003 [0.29]	3.095 [2.89]**	2.221 [1.94]*	5.185 [6.06]**	5.375 [4.42]**	−0.003 [0.19]	−0.015 [0.85]
Log family size 1994	0.059 [1.23]	−0.076 [1.35]	0.007 [0.41]	0 [0.02]	0.694 [0.27]	−8.366 [3.61]**	2.160 [1.10]	−9.785 [3.63]**	0.014 [0.34]	0.035 [0.90]
Two parent family 1994	−0.111 [3.31]**	−0.063 [1.94]*	0.000 [0.04]	−0.021 [1.83]*	0.133 [0.08]	2.128 [1.74]*	−0.210 [0.27]	1.773 [1.25]	−0.048 [1.45]	−0.027 [1.45]
Mother's age at birth	−0.001 [0.61]	−0.019 [2.55]**	0.000 [0.12]	−0.001 [0.60]	0.260 [2.16]**	0.543 [2.21]**	0.405 [4.17]**	0.477 [1.76]*	−0.001 [0.49]	0.002 [0.78]
Teen mother	0.035 [0.70]	−0.113 [1.99]**	−0.007 [0.40]	0.007 [0.22]	−5.376 [2.26]**	2.062 [0.43]	−4.820 [2.68]**	6.905 [0.95]	0.065 [1.27]	0.000 [.]
Mother high school plus	−0.021 [1.08]	−0.044 [1.25]	−0.015 [2.25]**	−0.085 [5.31]**	2.321 [2.21]**	8.487 [6.19]**	3.180 [3.84]**	11.635 [7.23]**	−0.017 [1.02]	−0.005 [0.22]
PMK depressed or activity limit in 1994	0.034 [1.29]	−0.018 [0.55]	0.004 [0.41]	0.002 [0.14]	−0.674 [0.49]	−2.499 [1.87]*	−0.700 [0.67]	−0.491 [0.33]	0.024 [0.97]	0.025 [1.19]
Age 4 (in 1994)		0 [.]	−0.036 [3.11]**	0.059 [2.46]**	6.450 [2.42]**	−2.306 [0.58]	1.145 [0.49]	−2.062 [0.50]	0.000 [0.00]	0.006 [0.16]
Age 5	−0.730 [16.02]**	0 [.]	0.005 [0.37]	0.014 [0.63]	5.176 [2.92]**	−0.533 [0.13]	−1.550 [1.12]	−4.554 [1.10]	0.032 [0.58]	0.005 [0.12]
Age 6	−0.216 [6.88]**	0 [.]	−0.010 [0.83]	−0.029 [1.66]*	5.423 [3.13]**	−0.621 [0.16]	−2.985 [2.22]**	−3.063 [0.75]	0.009 [0.16]	−0.017 [0.46]
Age 7	−0.244 [7.95]**	0 [.]	−0.017 [1.43]	−0.024 [1.38]	5.396 [3.02]**	−1.412 [0.36]	−4.985 [3.44]**	−4.855 [1.17]	0.022 [0.40]	0.009 [0.23]
Age 8	−0.224 [7.22]**	−0.187 [3.75]**	−0.019 [1.69]*	−0.002 [0.10]	−5.523 [3.33]**	−3.178 [0.80]	−4.455 [3.27]**	−3.991 [0.95]	−0.013 [0.22]	0.068 [1.64]
Age 9	−0.127 [3.92]**	−0.134 [3.71]**	−0.004 [0.32]	0.015 [0.84]	−3.682 [2.11]**	−3.866 [0.95]	−7.045 [5.20]**	−3.917 [0.93]	0.077 [1.26]	0.000 [.]
Age 10	−0.016 [0.46]	−0.104 [3.00]**	−0.024 [2.23]**	0.023 [1.18]	−6.410 [3.70]**	−1.725 [0.40]	−3.730 [2.80]**	−2.429 [0.55]	0.079 [1.03]	0.000 [.]
Constant	0.359 [3.54]**	1.165 [6.01]**	0.040 [1.15]	0.163 [2.34]**	46.276 [8.06]**	45.458 [5.38]**	44.025 [9.91]**	54.236 [5.88]**	0.063 [0.62]	−0.080 [0.75]
Observations	2516	1303	3925	3240	2209	2501	2209	2501	1357	1401
R^2	0.090	0.06	0.040	0.06	0.150	0.23	0.120	0.2	0.14	0.05

Notes: Canadian data are from the 1994–1995, 1996–1997 and 1998–1999 cycles of the NLSCY. Robust *t*-statistics in brackets. Standard errors clustered at the household level. In the U.S. data, the "1994" variables are means over the period 1988–1994, while the 1998 values are means for 1998 and 2000. Regressions for Canada also included indicators for whether the PMK was female, and for whether income was imputed.

* Significant at 90%.

** Significant at 95%.

points more likely to have repeated a grade. Thus, in Canada, the effect of hyperactivity is large relative to the effect of income. The same comparison in the U.S. data suggests that each $100,000 increase in permanent income would decrease the probability of grade repetition by 5.3% points, compared to a 2% point increase in the probability for a child with a hyperactivity score of 5 relative to a child with a hyperactivity score of zero.

Having a mother with at least a high school education is also consistently related to positive outcomes, especially in the U.S., with the effect being generally similar to that of $100,000 worth of income. Other variables with consistently significant effects are the indicator for Hispanic ethnicity, which has negative effects (in the NLSY data only; race and ethnicity are not available in the NLSCY), and having two parents in 1994, which has positive effects in the NLSY data, though in Canada it is only statistically significant in the model of delinquency. Males are more likely to be delinquent, more likely to repeat grades, and (in the U.S.) more likely to be in special education, consistent with other studies.

The robustness of these effects is investigated further in Table 4. The first panel of Table 4 repeats the OLS estimates of the effects of hyperactivity and income from Table 3. The second panel presents fixed effects estimates. Except for delinquency, these within-family estimates are very similar to those in panel 1, indicating that the OLS results for academic outcomes are not driven by unobserved heterogeneity between families (though OLS estimates for delinquency may be). The similarity between the OLS and fixed effects estimates suggests that measurement error is not driving the estimates, as discussed above.[18] It is particularly striking that while ADHD is generally considered a behavioral disorder, the fixed effects estimates suggest that the longer-term effects of ADHD are much more strongly related to academic performance than to behavior. We take this as further evidence that children with ADHD may suffer longer-term economic consequences of diminished human capital accumulation.

Panel 3 of Table 4 focuses on the children with the highest ADHD symptom scores by using a dummy variable for scores above the 90th percentile rather than the continuous hyperactivity score as the independent variable of interest. Having a high hyperactivity score has no effect on delinquency in models with fixed effects, but does affect all of the other outcomes. The coefficient estimates are consistent with roughly linear effects on grade repetition and special education, while the estimated effects on test scores are substantial but somewhat smaller than one would project on the basis of the linear models.

If high ADHD scores are correlated with having learning disabilities, or other conditions that may impair outcomes, then we may be attributing part of the effect of other disabilities to our ADHD measure, thereby overestimating the true effect of ADHD on outcomes. In the U.S., 8% of children with an ADHD score above the 90th percentile are also diagnosed with a learning disability, and in Canada, the comparable figure is 10%. We address this potential problem by estimating the effects of ADHD in a sample that excludes children with diagnosed learning disabilities. Panel 4 of Table 4 shows that excluding these children has little impact on our estimates.

We have also estimated models excluding children in special education from our samples. The rationale for this experiment is that since children with ADHD are more likely to end up in special

[18] Random measurement error would be expected to reduce the size of the fixed effects estimates relative to the OLS estimates. Correlated errors (for example, if the mother tended to consistently exaggerate reports of a particular behavior for both children) would lead to much larger fixed effects estimates. If, on the other hand, parents exaggerate differences between siblings, the fixed effects estimates could theoretically be smaller than the OLS estimates.

Table 4
Robustness of effects of hyperactivity on future outcomes

	[1] Canada delinquent	[2] U.S. delinquent	[3] Canada grade rep.	[4] U.S. grade rep.	[5] Canada math	[6] U.S. math	[7] Canada reading	[8] U.S. reading	[9] Canada special ed.	[10] U.S. special ed.
1. OLS from Table 2a										
Hyperactivity score 1994	0.015 [6.00]**	0.013 [2.98]**	0.007 [6.99]**	0.004 [2.49]*	−1.373 [10.85]**	−0.868 [6.57]**	−0.849 [8.18]**	−1.176 [8.14]**	0.023 [8.79]**	0.008 [3.85]**
Average income (100,000)	0.008 [0.33]	−0.086 [1.21]	−0.038 [4.28]**	−0.053 [2.77]**	7.117 [4.72]**	15.382 [6.87]**	5.221 [4.69]**	13.977 [5.51]**	−0.031 [1.44]	−0.024 [0.73]
Observations	2516	1303	3925	3240	2209	2501	2209	2501	1357	1401
R^2	0.090	0.06	0.040	0.06	0.150	0.23	0.120	0.2	0.140	0.050
2. Fixed effects										
Hyperactivity score 1994	0.008 [1.08]	−0.015 [1.04]	0.005 [2.46]**	0.005 [1.85]*	−1.179 [3.94]**	−0.996 [4.00]**	−0.66 [2.70]**	−0.834 [3.14]**	0.021 [2.95]**	0.009 [1.74]*
Observations	2514	1304	3923	3241	2208	2501	2208	2501	1357	1401
R^2	0.9	0.9	0.85	0.76	0.91	0.86	0.9	0.86	0.95	0.84
3. FE, dummy variable for hyperactivity above 90th percentile										
Hyperactivity score 1994 above 90th percentile	−0.087 [1.02]	0.118 [0.86]	0.064 [2.89]**	0.07 [2.68]**	−9.468 [2.59]**	−3.989 [1.46]	−5.930 [2.01]**	−5.778 [1.98]**	0.381 [4.92]**	0.121 [2.00]**
Observations	2514	1304	3923	3241	2208	2501	2208	2501	1357	1401
R^2	0.9	0.9	0.85	0.76	0.9	0.86	0.9	0.86	0.96	0.84
4. FE, dropping children with diagnosed learning disabilities										
Hyperactivity score 1994	0.006 [0.86]	−0.017 [1.16]	0.003 [1.69]*	0.004 [1.80]*	−1.294 [4.21]**	−0.954 [3.79]**	−0.675 [2.69]**	−0.762 [2.85]**	0.018 [2.65]**	0.006 [1.36]
Observations	2447	1257	3819	3152	2160	2456	2160	2456	1327	1202
R^2	0.9	0.91	0.85	0.79	0.91	0.859	0.9	0.86	0.95	0.84
5. FE, including children ages 4–7 in 1994 only										
Hperactivity score 1994			0.008 [1.85]*	0.004 [2.43]**	0.527 [0.79]	−0.826 [5.25]**	−0.695 [1.42]	−1.03 [5.97]**	0.022 [2.31]**	0.007 [3.63]**
Observations			1734	1469	998	1491	998	1490	1002	12.02
R^2			0.94	0.083	0.96	0.248	0.97	0.205	0.98	0.032
6. FE, using diagnosed ADHD cases										
Child diagnosed w ADHD		0.395 [1.62]		−0.053 [1.20]		−9.161 [1.65]*		−5.195 [0.87]		0.64 [3.49]**
Observations		1304		3240		2500		2500		1401
R^2		0.9		0.76		0.86		0.86		0.85

Notes: Robust *t*-statistics in brackets. Standard errors clustered at the household level. To compare effects on reading and math scores, multiply the Canadian coefficients by 5 and 6.67, respectively.

* Significant at 90%.

** Significant at 95%.

education, the estimated effects of ADHD might be contaminated by the effects of being in this track. However, our estimates (not shown) were very similar to those shown in panel 2.[19]

Panel 5 of Table 4 shows estimates for the sample of children who were age 4–7 in 1994. As discussed above, in order for a diagnosis of ADHD to take place, symptoms must have appeared before age 7. Among older children behavior problems that mimic ADHD might appear in response to school-related difficulties. This restriction dramatically reduces our sample sizes, particularly for the Canadian test scores. However, the U.S. estimates are very similar to those reported in panel 2, and the Canadian estimates of the effects of ADHD symptoms on grade repetition and special education are also similar for grade repetition and special education (we lose statistical significance in the Canadian test score models, but this may be because of the large reduction in sample size for these outcomes).

Panel 6 uses the measure of diagnosed ADHD rather than the screener measure. Comparing these estimates with those in panels 2 and 3 suggests that focusing on diagnosed cases greatly exaggerates the extent to which ADHD symptoms per se lead to special education. On the other hand, the extent to which ADHD symptoms are related to grade repetition is understated if we use only diagnosed cases. These two phenomena may be related if children are less likely to be retained in grade once they have been placed in special education, and if diagnosis with ADHD is often an entrée into special education.

It is interesting that judging by the point estimates, both being diagnosed, and having a score above the 90th percentile have very similar negative effects on reading scores, although only the estimates using the score measure are statistically significant because of large standard errors in the models using diagnosed cases. Again, this result suggests that there may be a good deal of measurement error in diagnosed cases. For math scores, being diagnosed has a larger negative effect than scoring highly on the screener, but both are imprecisely estimated.

We also estimate models that either exclude treated children, or impute a high hyperactivity score to these children.[20] For the most part, these alternative ways of handling the treated children produce estimates that are very similar to those shown in Table 4. The main exception is that the hyperactivity score does not have a significant effect on the probability of special education in the U.S. in these models. This result suggests once again that it is the treated children in the U.S. who end up in special education, and that untreated children with the same ADHD scores as the treated children are not more likely to end up in special education.

Table 5 asks whether effects differ for boys and girls. When we consider the linear score measure, it appears that girls suffer as much as boys from the symptoms of ADHD—none of the interaction terms are statistically significant (though most of the ADHD main effects are also insignificant). But when we use the dummy for the 90th percentile of the hyperactivity distribution, interesting gender differences emerge. In particular, in both Canada and the U.S., only hyperactive boys appear to be at risk for being placed in special education. And in the U.S., the negative effects of high hyperactivity scores on reading and math scores is confined to boys.

Table 6 offers an alternative way to think about the magnitude of these effects. In it, we compare the estimated effect of hyperactivity to the effects of physical health problems, using the Canadian data. Table 6 shows that in fixed effects models, neither having been diagnosed with a chronic health problem such as asthma (the most common chronic physical condition among children)

[19] In work in progress we are estimating models which include indicators for other types of mental disorders to examine whether the effects of mental health disorders is consistent across types of disorders and whether inclusion of other disorders affects the estimated effects of ADHD.

[20] Results available from the authors upon request.

Table 5
Differences between boys and girls

	[1] Canada delinquent	[2] U.S. delinquent	[3] Canada grade rep.	[4] U.S. grade rep.	[5] Canada math	[6] U.S. math	[7] Canada reading	[8] U.S. reading	[9] Canada special ed.	[10] U.S. special ed.
1. FE, interaction of hyperactivity score with male										
Hyperactivity score, 1994	0.008 [0.68]	−0.006 [0.38]	0.003 [1.02]	0.004 [1.43]	−0.962 [2.20]**	−0.990 [3.48]**	−0.585 [1.64]	−0.689 [2.25]**	0.007 [0.61]	0.005 [0.97]
Male × hyper score	0.000 [0.01]	−0.006 [0.60]	0.003 [0.83]	−0.001 [0.64]	−0.352 [0.68]	0.184 [0.90]	−0.122 [0.29]	−0.303 [1.38]	0.020 [1.54]	0.004 [0.89]
Observations	2514	1304	3923	3241	2207	2501	2207	2501	1356	1401
R^2	0.90	0.90	0.85	0.76	0.91	0.86	0.90	0.86	0.95	0.84
2. FE, interaction of 90th percentile of hyperactivity score with male										
Hyperactivity score, 1994	−0.064 [0.39]	0.226 [1.13]	0.097 [2.48]**	0.097 [2.45]**	−9.996 [1.57]	2.970 [0.72]	−8.268 [1.61]	−0.940 [0.21]	0.177 [1.32]	0.002 [0.02]
Male × hyper score	−0.029 [0.16]	−0.126 [.57]	−0.046 [1.03]	−0.040 [0.88]	0.745 [0.10]	−9.570 [2.03]**	3.305 [0.56]	−9.200 [1.82]*	0.287 [1.86]*	0.215 [1.98]**
Observations	2514	1304	3923	3241	2207	2501	2207	2501	1356	1401
R^2	0.90	0.90	0.85	0.75	0.91	0.86	0.90	0.85	0.96	0.84

Notes: see Table 4.

* Significant at 90%.

** Significant at 95%.

Table 6
Comparing effects of hyperactivity, poor health, and chronic conditions, Canada

Fixed effects regressions	Delinquent	Grade rep.	Math	Reading	Special ed.
Panel 1					
Hyperactivity score 1994	0.008 [1.08]	0.005 [2.46]**	−1.179 [3.94]**	−0.660 [2.70]**	0.021 [2.95]**
Observations	2514	3923	2208	2208	1357
R^2	0.9	0.85	0.91	0.9	0.95
Panel 2					
Chronic condition 1994	0.024 [0.47]	0.006 [0.45]	1.916 [0.80]	1.728 [0.90]	0.042 [0.76]
# Observations	2514	3923	2208	2208	1357
R^2	0.9	0.85	0.91	0.9	0.95
Panel 3					
Poor health in 1994	0.084 [1.15]	0.021 [0.037]	0.175 [0.05]	0.956 [0.35]	−0.035 [0.44]
# Observations	2511	3920	2206	2206	1356
R^2	0.9	0.85	0.91	0.9	0.95

Notes: see Table 4.
** Significant at 95%.

as of 1994, nor a maternal report that a child is in poor health in 1994 is predictive of poorer outcomes as of 1998.[21] These results suggest that on average ADHD has a greater impact on academic achievement than serious physical health problems.

Table 7 reports estimates of Eq. (3), which include interactions between hyperactivity scores and income. Panel 1 shows that in OLS models using the NLSY, the interactions are of the expected sign (that is, higher income appears to mitigate the effects of hyperactivity) but none of them are statistically significant. In contrast, in Canada all of the interactions are significant in the OLS models, except in the model of delinquency. Panel 2 shows, however, that once we control for heterogeneity between families, only the interaction term that remains statistically significant is for grade repetition in Canada.

Given that we are using permanent income, the interaction terms in these fixed effects models are identified by the fact that ADHD scores vary within families. What the interaction term tells us is whether the difference between the high and low ADHD score children within a family is bigger in a low income household than in a high income household. That is, if the high income household is able to do a better job assisting the high ADHD score child than the low income household, then the interaction will be significant.

Panel 3 of Table 7 indicates that the interaction of income and having a hyperactivity score above the 90th percentile is associated with a higher probability of grade repetition in both the

[21] In OLS models, chronic conditions in 1994 have no effect on future outcomes but a maternal report that a child is in poor health is predictive of poorer outcomes in 1998. We cannot be certain that mothers answer this question with only their child's physical health in mind, but the correlation between being in poor health and the hyperactivity score is very small (0.09). In OLS models, a moderate hyperactivity score generally has worse effects than being in poor health. For example, among Canadian children, being in poor health in 1994 is associated with a reduction of. 43 in 1998 mathematics scores, while a score of 5 out of 16 on the hyperactivity index is associated with reduction of 1.3 (on a mean score of 8.1).

Table 7
Interactions of income with hyperactivity

	[1] Canada delinquent	[2] U.S. delinquent	[3] Canada grade rep.	[4] U.S. grade rep.	[5] Canada math	[6] U.S. math	[7] Canada reading	[8] U.S. reading	[9] Canada special ed.	[10] U.S. special ed.
1. OLS										
Interaction hyper and income	0.000 [0.01]	−0.004 [0.23]	−0.011 [4.16]**	−0.003 [0.49]	0.752 [2.30]**	0.069 [0.15]	0.616 [2.47]**	0.614 [1.25]	−0.016 [2.72]**	−0.003 [0.34]
Hyperactivity 1994	0.015 [3.37]**	0.014 [1.83]*	0.012 [6.23]**	0.005 [1.52]	−1.758 [8.26]**	−0.896 [3.98]**	−1.164 [6.79]**	−1.428 [5.58]**	0.031 [7.23]**	0.009 [2.16]**
Average income [100,000]	0.008 [0.33]	−0.066 [0.62]	−0.006 [0.80]	−0.038 [1.45]	5.086 [3.38]**	15.039 [5.16]**	3.556 [2.79]**	10.909 [3.20]**	0.013 [0.78]	−0.011 [0.31]
Observations	2516	1303	3925	3240	2209	2501	2209	2501	1357	1401
R^2	0.09	0.06	0.04	0.06	0.15	0.23	0.13	0.2	0.15	0.05
2. Fixed effects										
Interaction hyper and income	0.024 [1.02]	−0.033 [0.44]	−0.013 [2.58]**	0.001 [0.06]	0.195 [0.28]	0.107 [0.12]	−0.625 [1.11]	0.581 [0.60]	−0.004 [0.33]	−0.021 [1.14]
Hyperactivity 1994	−0.006 [0.40]	−0.002 [0.08]	0.012 [3.51]**	0.004 [0.93]	−1.295 [2.56]**	−1.041 [2.26]**	−0.289 [0.70]	−1.083 [2.20]**	0.024 [2.19]**	0.018 [1.88]*
Observations	2514	1304	3923	3241	2208	2501	2208	2501	1357	1401
R^2	0.9	0.9	0.85	0.76	0.91	0.86	0.9	0.86	0.95	0.85
3. Fixed effects, indicator for hyperactivity score ≥90th percentile										
Interaction hyper and income	0.369 [1.19]	−0.045 [0.05]	−0.215 [3.15]**	−0.267 [1.79]*	0.455 [0.05]	−16.888 [1.10]	−9.856 [1.33]	−6.455 [0.40]	−0.139 [1.02]	−0.128 [0.41]
Hperactivity Score 1994 above 90th percentile	−0.285 [1.52]	0.132 [0.43]	0.178 [4.21]**	0.155 [2.86]**	−9.732 [1.51]	1.824 [0.31]	−0.220 [0.04]	−3.556 [0.56]	0.466 [4.11]**	0.17 [1.28]
Observations	2514	1304	3923	3241	2208	2501	2208	2501	1357	1401
R–squared	0.9	0.9	0.85	0.76	0.91	0.86	0.9	0.86	0.96	0.85

Notes: see Table 4.

* Significant at 90%.

** Significant at 95%.

Table 8
Effects of hyperactivity in 1994 and income on treatment in 1994

	[1] Canada drug	[2] Canada drug	[3] Canada psych.	[4] Canada psych.	[5] Canada any	[6] Canada any
1. OLS						
Hyper score 1994	0.005 [5.85]**	0.005 [3.89]**	0.005 [5.35]**	0.006 [3.49]**	0.009 [7.44]**	0.009 [4.73]**
Interaction hyper and income		−0.001 [0.39]		−0.002 [0.70]		−0.002 [0.58]
Average income [100,000]	−0.005 [1.26]	−0.003 [0.61]	−0.007 [0.81]	−0.002 [0.16]	−0.009 [1.01]	−0.004 [0.39]
# Observations	3925	3925	3920	3920	3920	3920
R^2	0.04	0.04	0.03	0.03	0.05	0.05
2. Fixed effects						
Hyper score 1994	0.002 [2.00]**	0.001 [0.67]	0.005 [2.77]**	0.010 [3.16]**	0.006 [3.31]**	0.01 [2.94]**
Interaction hyper and income		0.001 [0.49]		−0.009 [1.97]**		−0.007 [1.36]
# Observations	3923	3923	3918	3918	3918	3918
R^2	0.87	0.87	0.87	0.87	0.87	0.87
	[7] U.S. drug	[8] U.S. drug	[9] U.S. psych.	[10] U.S. psych.	[11] U.S. any	[12] U.S. Any
1. OLS						
Hyper score 1994	0.007 [7.02]**	0.008 [3.12]**	0.013 [8.78]**	0.009 [3.36]**	0.014 [9.53]**	0.011 [3.90]**
Interaction hyper and income		0 [0.03]		0.009 [1.48]		0.008 [1.32]
Average income [100,000]	−0.004 [0.29]	−0.003 [0.16]	0.045 [2.15]**	0.003 [0.11]	0.03 [1.35]	−0.009 [0.31]
# Observations	3749	3749	3745	3745	3745	3745
R^2	0.04	0.04	0.09	0.09	0.09	0.09
2. Fixed effects						
Hyper score 1994	0.009 [5.46]**	0.011 [3.44]**	0.015 [6.95]**	0.013 [3.11]**	0.018 [7.11]**	0.013 [2.77]**
Interaction hyper and income		−0.004 [0.60]		0.006 [0.75]		0.012 [1.25]
# Observations	3749	3749	3745	3745	3745	3745
R^2	0.72	0.72	0.789	0.789	0.77	0.77

Notes: see Table 4.
** Significant at 95%.

U.S. and Canada, and the point estimates in the two countries are quite similar (although the U.S. coefficient is significant only at the 90% level of confidence). However, the other interaction terms remain statistically insignificant. In summary then, within families with children with differing levels of hyperactivity, being in a higher income family offers little protection against the negative effects of ADHD on test scores, although the high ADHD child in the high income family is less likely repeat grades than a similar child in a low income family.

Table 8 investigates the relationship between hyperactivity scores, income, and treatment. OLS estimates indicate that income has no effect on the probability of treatment in either the U.S. or Canada. This is a surprising result, particularly in the U.S. where richer children generally have better access to medical care. The main effects of income are insignificant as well, except that in the U.S., children from wealthier families are more likely to see a psychiatrist. In the U.S., maternal education also increases the probability of treatment as does having a mother who is depressed or has an activity limitation. Children of younger mothers and Hispanic children are much less likely to be treated, as are children in two parent families.

The second panel of Table 8 presents fixed effects estimates. In order to interpret our fixed effects models it may be useful to consider an example. Consider two families, one with high income and the other with low income. Each family has two children, one with a high ADHD score, and one with a low ADHD score. The question posed by the interactive models is: Is the child with the high score more likely to be treated in a high income family? The answer is no, in these models, the only interaction that is statistically significant suggests that conditional on their hyperactivity score, richer Canadian children are actually less likely to see a psychiatrist than other children.

It is useful to think about the estimation biases that the effects of treatment of ADHD might create. Suppose for example, that high income children really were more likely to be treated, and that treatment lowered their hyperactivity scores. Then we would see high income children with relatively low scores being treated, suggesting that conditional on their score, high income children were even more likely than low income children to be treated. This argument suggests that if anything the estimates in Table 8 over-estimate the true interaction between income and ADHD scores, suggesting that there really is a very weak effect of ADHD scores on the probability of being treated.

5. Discussion and conclusions

Children with symptoms of hyperactivity suffer large negative consequences in terms of their achievement test scores and schooling attainment. Hyperactivity is a more important determinant of reduced human capital accumulation than physical health problems. These results are qualitatively similar in the U.S. and Canada and are robust to many changes in specification.

We also find that a given level of symptoms has similar effects on the test scores of rich and poor children although richer children are less likely to be retained in grade, which may be a significant advantage. Boys and girls with moderate levels of symptoms also suffer equally in terms of academic outcomes, though boys with high hyperactivity scores do worse than girls, especially in the U.S.

A silver lining is that there is no evidence that poor children suffer from “double jeopardy”. Even if we assume that treatment is effective, there is surprisingly little relationship between income and treatment probabilities in these data. The lack of a strong relationship between income and drug treatment for ADHD contrasts sharply with a large literature showing that richer children are more likely to be treated for physical health problems, conditional on the need for such treatment.

It is interesting to speculate on why rich parents appear to be relatively less likely to seek treatment for ADHD than for other ailments. One reason may be that a diagnosis of ADHD is strongly related to placement in special education, and wealthier parents may wish to avoid this outcome. At the same time, drug treatment for ADHD has become more commonly available to low income children through Medicaid and schools may face strong financial incentives to have low-achieving children diagnosed and treated for ADHD so that they can be placed in special education (Cullen, 2003).

Finally, we find that even children whose relatively low level of symptoms make them unlikely candidates for diagnosis will suffer significant ill effects. The severity of the problems associated with ADHD and the pervasiveness of its symptoms suggest that efforts to find better ways to teach the relatively small number of children diagnosed with ADHD could have a large payoff in terms of improving the academic outcomes of many children with milder symptoms.

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