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Sex, drugs, and ADHD: The effects of ADHD pharmacological treatment on teens' risky behaviors☆

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HIGHLIGHTS

- We investigate the effect of ADHD drugs on the probability of risky sexual behavior outcomes (STDs and pregnancy), substance use and abuse disorders, and injuries.
- Pharmacological treatment reduces the probability of every risky behavior that we were able to identify in the data.
- We find that the probability of contracting an STD decreases by 3.6 percentage points (5.8 percentage points if we include STD screening) for treated.
- The probability of having a substance abuse disorder declines by 7.3 percentage points for treated.
- The probability of injuries goes down by 2.3 percentage points per year and associated with them Medicaid costs decrease by $88.4.

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ABSTRACT

In the U.S., 8% of children are diagnosed with ADHD and 70% of those are taking medications, yet little evidence exists on the effects of ADHD treatment on children's outcomes. We use a panel of South Carolina Medicaid claims data to investigate the effects of ADHD drugs on the probability of risky sexual behavior outcomes (STDs and pregnancy), substance abuse disorders, and injuries. To overcome potential endogeneity, we instrument for treatment using physicians' preferences to prescribe medication. Our findings suggest that pharmacological treatment has substantial benefits. It reduces the probability of contracting an STD by 3.6 percentage points (5.8 percentage points if we include STD screening), reduces the probability of having a substance abuse disorder by 7.3 percentage points, reduces the probability of injuries by 2.3 percentage points per year, and associated with them Medicaid costs decrease by $88.4, or 0.054 of a standard deviation.

1. Introduction

Attention-deficit/hyperactivity disorder (ADHD) is one of the common chronic mental conditions affecting children. In the U.S., 11% of children ages 4–17(6.4 million) are estimated to have an ADHD diagnosis and almost 70% of them report taking medication for the condition (e.g. Visser et al., 2014). However, little evidence exists on the effects of ADHD treatment on children's outcomes.

The two most recently published studies produce mixed evidence on the effects of ADHD treatment. Currie et al. (2014) find that taking stimulant medication is associated with a deterioration in academic outcomes and relationship with parents. In contrast, Dalsgaard et al. (2014) show that treatment is associated with fewer hospital visits and a reduction in the number of interactions with the police.

Our paper has three major contributions to this literature. First, we are building on our earlier work to investigate the effects of ADHD medication treatment on a seldom studied set of outcomes associated with this condition: adolescent risky behaviors and the

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incidence of injuries (Chorniy, 2015). The occurrence of injuries allows us to evaluate short-term effects of ADHD treatment, while substance abuse and risky sexual behavior outcomes speak for the long-term effects of medication. Second, we use Medicaid spending on treatment of these negative events to evaluate the impact of ADHD drugs on the severity of ADHD, and compare the cost of ADHD treatment with the costs of negative health events. Finally, we provide innovative supporting evidence in favor of using provider propensity to prescribe as an instrument for medical treatment. Variants of this instrument were employed in the work by Dalsgaard et al. (2014) and Duggan (2005), as discussed in Section 5.

We use a panel data set of South Carolina Medicaid claims paid out in 2003–2013. Our sample of diagnosed and undiagnosed children includes an average of 257,000 enrollees per year, or nearly 50% of all beneficiaries and over 25% of all SC children and teens. Children enrolled in SC Medicaid are disproportionately diagnosed with ADHD. It is consistent with the earlier literature that suggests that the probability of being diagnosed with ADHD is negatively correlated with socio-economic status (e.g. Visser et al., 2014, Froehlich et al., 2007, and Dalsgaard et al., 2014). Between 2003 and 2011, the average incidence of ADHD in South Carolina was 12.6%.[1] However, for children and teens enrolled in Medicaid, the average rate in these years was 19.7%. Although we are unable to make a statement on the effectiveness of ADHD treatment in general population, our sample represents a large fraction of the state population, and even larger fraction of diagnosed children. Since children on Medicaid are disproportionately diagnosed with ADHD and their incentives are distorted in the absence of a drug price tag, this population is arguably more appropriate for this study from a policy perspective.

Nearly 80% of SC Medicaid children and teens who are diagnosed with ADHD are taking medication for their condition. Consistent with the national trend, our data also show a steep increase in Medicaid spending on ADHD prescription drugs. Between 2003 and 2013, it rose by 296% in 2013 dollars. This increase in spending is a consequence of both the increase in the number of prescriptions filled and the prices of the drugs. The number of patients who take ADHD medications rose by 68% and the number of prescriptions per person went up by 18% suggesting that the overall trend is driven by the extensive margin.[2]

Our results suggest that pharmacological treatment reduces the probability of every negative health and behavioral outcome that we identified in the data. If a patient is treated with ADHD medication the probability of contracting an STD decreases by 3.6 percentage points (5.8 percentage points if we include STD screening), having a substance abuse disorder decreases by 7.3 percentage points, becoming injured by 2.3 percentage points each year and annual injury spending decreases by $88.4, or 0.054 of a standard deviation.[3] Finally, the probability of teenage pregnancy decreases by 2.3 percentage points, though the effect is not statistically significant.

2. Background and previous research

2.1. ADHD and ADHD-associated negative health outcomes

The American Psychiatric Association defines ADHD as a neurodevelopmental condition present if either six or more of the inattention symptoms or six or more hyperactivity–impulsivity symptoms "have persisted for at least 6 months to a degree that is maladaptive and inconsistent with developmental level."[4] Inattentive symptoms include difficulty holding attention on tasks, following instructions, and distractibility among others. Hyperactivity and impulsivity criteria include excessive talking, difficulty waiting, and fidgeting. Causes of ADHD are not fully understood but genes are recognized as a major determinant of the condition.

ADHD may adversely impact major life activities from childhood to adulthood. Earlier studies have found that untreated ADHD could have severe consequences and be distressing not only for children who suffer from the condition but also for their families (Kvist et al., 2013, Fletcher and Wolfe, 2009), siblings (Breining, 2014), friends, peers (Aizer, 2008), and teachers (Barkley, 2006). Children with ADHD tend to have problems with self-control and discount the future more heavily than their unaffected peers. This makes them more injury-prone[5] and more likely to engage in risky behaviors such as: dangerous driving,[6] substance use and abuse,[7] and risky sexual behaviors.[8] Children growing up with ADHD were found to be more likely to experience teen pregnancy, sexually transmitted diseases (STDs), depression, and personality disorders as adults.

These health and behavioral outcomes can be explained in the theoretical framework of investment in child well-being. Every child is born with a multidimensional endowment of abilities. They include cognitive (e.g. IQ, memory) and noncognitive skills (e.g. self-control, patience, and time preference) (Conti and Heckman, 2014). Due to their genetic condition, children who suffer from ADHD have a relatively low initial stock of noncognitive skills. The literature on child development indicates that gaps in abilities that form early in life persist into adulthood and can explain a large array of differentials in adult outcomes. Conti and Heckman (2014) provide an extensive review of the empirical evidence on the effects of investment in the two dimensions of child human capital, cognitive and noncognitive skills, on educational attainment, asocial and risky behaviors, and health. Heckman et al. (2006) find that both cognitive and noncognitive abilities affect wages, schooling, work experience, occupational choice, and participation in a range of adolescent risky behaviors. These results have important policy

1 CDC. "Trends in the Parent-Report of Health Care Provider-Diagnosed and Medicated ADHD: United States, 2003–2011."

2 There is some evidence of ADHD being increasingly misdiagnosed (e.g. Evans et al., 2010, Elder, 2010, Schwandt and Wuppermann, 2015, and Morrill, 2016 among others). This question is out of scope of this paper. If there are false positive cases of ADHD diagnosis in our sample, our estimates of the effect of ADHD treatment on negative health outcomes outcomes can be interpreted as a lower bound of the actual effect of medication.

3 In 2013 dollars.

4 The American Psychiatric Association publishes the Diagnostic and Statistical Manual of Mental Disorders (DSM), where it sets criteria for the classification of mental disorders. It is the standard classification of mental disorders used by mental health professionals in the United States. The most current version is DSM-5 published in May 2013, a revision of DSM-IV-TR that came out in 2000.

5 Besides having more frequent injuries, these children also tend to have more severe injuries than their peers (Barkley, 2006, Swensen et al., 2004, and Marcus et al., 2008). In a recent study, Dalsgaard et al. (2015) show that children with ADHD have a higher risk of injuries, but it declines in patients treated with stimulant medications.

6 One of the strongest findings in the medical literature is that ADHD adolescents are more likely be involved in a car accident and they are more often at fault in such accidents (Barkley, 2006, Weiss and Hechtman, 1993).

7 Looby (2008) provides a review of major studies on the association of ADHD and substance use and abuse, including alcohol, tobacco, and drugs. Some of them find that teens with ADHD are on average more likely than individuals without ADHD to smoke, use and abuse alcohol and drugs, and develop health problems related to these activities. However, others conclude that there are additional related conditions that contribute to the likelihood of these negative health outcomes, e.g. conduct disorder symptoms and association with deviant peers. Despite a disagreement on the relationship between ADHD and substance use, Looby (2008) review suggests that ADHD treatment reduces the risk of substance use disorders in children with ADHD. Using a meta-analysis, Wilens et al. (2003) also find that stimulant medications reduce the risk for subsequent drug and alcohol use disorders.

8 Adolescents with untreated ADHD have difficulty controlling their impulses and planning ahead. These teens also tend to struggle with low self-esteem and for that reason, teenage girls often seek affirmation of boys through sexual attention (Arnold, 1996). Adolescent girls' symptoms of ADHD often worsen due to the hormonal changes at puberty (Resnick, 2005). Their condition makes them more likely to become sexually active earlier than their peers, have more partners on average, and use birth control inconsistently (Kessler et al., 1997, Payne, 2014). This association is also found in a more recent study by Sarver et al. (2014).

implications, but most interventions do not directly target children's noncognitive abilities. The Perry Preschool experiment may be an exception; it did not result in IQ improvements but instead had a beneficial impact on many child outcomes. Heckman et al. (2006) argue that these beneficial impacts were achieved by altering social skills.

In this paper, we focus on a variety of negative health outcomes associated with ADHD: injuries, substance use, and risky sexual behavior. Injuries is the most common outcome that affected 80% of children in our sample; it is relevant for children at all ages and the average age is around the mean age of ADHD diagnosis (9 years old). Risky sexual behavior and substance abuse outcomes are relevant for older children, with the average age being 14–16 years old, or 6–8 years after most children are diagnosed with ADHD. In other words, injury events allow us to evaluate short-term effects of ADHD treatment, while the risky behavior related events speak for long-term treatment effects.

2.2. Prior studies

An existing body of medical literature suggests that ADHD medication has positive impacts on mitigating core symptoms of ADHD, yet little is known about the effects of treatment on health, behavioral, and educational outcomes, particularly in the long run. One of the major attempts to estimate the long-term effects of ADHD treatment in a clinical setting was funded by the U.S. National Institute of Mental Health in the early 1990s. The Multimodal Treatment of Attention Deficit Hyperactivity Disorder (MTA) randomly assigned 579 ADHD-diagnosed children age 7–9.9 years old to 14 months of treatment management. The study finds that medication treatment alone and medication treatment combined with behavioral therapy reduces inattention and hyperactivity, the core symptoms of ADHD. However, there was little or no difference in academic performance, social skills and parent–child relationships. An important limitation of the study is that nearly 70% of individuals assigned to the control group also received medication. Molina et al. (2009) investigates the effects for these randomized treatment groups 6–8 years following intervention. They find that the groups do not differ significantly on any repeated measures or new measures of outcomes: contacts with the police and arrests, delinquent behavior, social skills and academic performance.

Currie et al. (2014) take advantage of a policy change in Quebec which expanded insurance coverage for prescription medications to estimate the effect of ADHD treatment on emotional functioning and academic outcomes. Using data from the 1994–2008 National Longitudinal Survey of Canadian Youth, they find that stimulant medication treatment is associated with a decrease in academic outcomes such as grade repetition, math scores, and the probability of having any post-secondary education for girls, a deterioration in relationship with parents, and an increase in the probability of depression.

Dalsgaard et al. (2014) exploit the idiosyncratic differences in physician preferences to prescribe pharmacological treatment to analyze the effects of ADHD treatment on hospital visits and criminal behavior. Consistent with Duggan (2005), they find that prescribing practices vary significantly across medical care providers. This implies that two children with identical symptoms and characteristics have a different probability of being diagnosed and treated with medications depending on their physician's preferences. Using Danish registers data and provider probability to prescribe as an instrument, Dalsgaard et al. (2014) find that treatment receipt is associated with fewer hospital visits and fewer police interactions.

In a recent study, using the same data these authors and a number of co-authors estimate odds ratios for injuries, mean change in prevalence rates, and ER visits before and after the treatment with stimulant medication (Dalsgaard et al., 2015). They find that children with ADHD have a higher risk of injuries than a non-ADHD group, but it declines in patients treated with stimulant medication.

We contribute to the existing literature in three ways. First, we look at a seldom studied set of ADHD-related negative health outcomes: teenage pregnancies, incidence of STDs, substance abuse disorders, and injuries. To our knowledge, this paper and its dynamic model companion (Chorniy, 2015) are the first to directly study the effects of ADHD treatment on these outcomes in health economics literature. Our general conclusions on the effect of treatment on injuries are consistent with the medical literature (Dalsgaard et al., 2015); but we are not aware of any comparable studies on the other outcomes.

Second, we take advantage of Medicaid spending reported in the data to estimate the impact of ADHD medication on the severity of injuries, STDs, and substance abuse disorders. Medical treatment may be effective in reducing the severity of negative health outcomes even if the likelihood of having one is unchanged. Medicaid expenditures are also important from the policy perspective. In South Carolina, out-of-pocket costs for Medicaid enrollees under 19 years old are zero or negligible. This distorts the patients' incentives and puts the burden of cost–benefit analysis on policymakers. Medicaid investment in ADHD treatment might be balanced via a reduction in its spending on the ADHD-associated events. We briefly examine this question in the current work and leave the detailed study to future research.

Finally, we provide innovative supporting evidence in favor of using provider propensity to prescribe as an instrument for medical treatment. Its variants were employed in the work by Dalsgaard et al. (2014) and Duggan (2005). Our data allow us to construct a more precise measure of provider preferences and test whether there is evidence of the instrument being correlated with provider quality and whether there is evidence of provider shopping. For robustness, we also provide comparative results across a variety of instruments and treatment definitions.

3. Data

We use a large panel data set of South Carolina Medicaid claims that spans 11 years from 2003 to 2013. It includes 145,264 children and teenagers who had at least one ADHD-related claim between 3 and 18 years old during this time period. This sample makes up approximately 20% of the child population in the state.

Our data include basic demographic information collected to determine Medicaid eligibility and a complete set of health services utilization records for all individuals: hospital, outpatient, and pharmacy claims.[9] It is supplemented by several variables from the enrollees' birth certificates including mother's age, race, and education. Following earlier research work that used Medicaid or other administrative claims data (e.g. Frank et al., 2004), we compile a set of ICD-9 diagnosis codes[10] and CPT procedure codes[11] to identify individuals who have ADHD, cases of pregnancy, STDs, substance use

[9] Medicaid has two components: traditional fee-for-service (FFS) and services provided through managed care organizations (MCO). Due to the differences in reporting requirements, the complete information on all services provided to a patient are only available for those enrolled in the FFS plan. However, mental health is one of the "carved-out" conditions that is covered by the FFS component even if an individual is enrolled into a managed care plan. We use all available claims and when possible, perform robustness checks by excluding MCO enrollees.

[10] The International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes are used by Medicaid for reporting purposes in the years covered by our sample. A hospital claim may have up to 9 diagnosis codes and an outpatient claim may have up to 4 codes.

[11] The Current Procedural Terminology (CPT) codes are used to indicate services provided to a patient. A hospital claim may have up to 100 procedure codes and an outpatient claim may have up to 8 codes.

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and abuse disorders,[12] and injuries[13] from the insurance claims data. Administrative data are not well-suited for distinguishing two consecutive independent events of the same kind from continuous care for the same event. For this reason, we focus on the first occurrence of each negative health outcome: teenage pregnancy, STD contraction, STD screening, and substance use and abuse disorders. While we use the first observed negative health outcome event to identify the incidence of negative health outcomes, we track all Medicaid spending related to these events across time.[14]

We use pharmacy claims to extract information on ADHD prescription medications that were filled by a patient. Each record has a dispense date, National Drug code (NDC),[15] quantity purchased, dispense fee, and the amount paid by Medicaid. We use our previous work (Chorniy, 2015) to identify drugs that are typically prescribed to patients with ADHD and to construct our instrumental variable (Section 4).

To estimate our model, we put a number of restrictions on the original data set. First, we select individuals who are consistently enrolled for Medicaid for a year or more for us to be able to estimate the effect of treatment. For lapses in enrollment that last under three months, we assume that patients are enrolled but receive no medical treatment.[16] For inconsistent eligibility periods that result in longer lapses in coverage (48% of the enrollees experience at least one such lapse), we only keep medical history prior to the lapse. These criteria leave us with 107,062 Medicaid enrollees.

Second, due to the fact that our instrument is based on the event of the initial ADHD diagnosis, we exclude individuals for whom we are unable to identify this event. Following earlier literature (e.g. Crawford and Shum (2005)), we only look at patients who had their first ADHD-related visit within 180 days from their first appearance in the sample and patients who fill a prescription prior to their first observed ADHD-related provider visit. This restriction excludes 29,974 additional individuals from the sample. Additionally, a patient had to be diagnosed between 3 and 18 years old and be in the sample for at least one full year since the event of the first ADHD diagnosis to be included in the analysis; 62,643 patients satisfied this criteria. Our final sample has 58,685 individuals after excluding ADHD children with missing basic demographic information and children for whom we were unable to calculate provider propensity to prescribe.[17]

Table 1 shows summary statistics on individual, mother, and home environment characteristics. Boys comprise 66% of the sample, similar to the proportion of boys (69%) reported by the U.S. National Survey of Children's Health in 2011 (Visser et al., 2014). Whites and Blacks are represented nearly equally, due to the relatively higher share of Black on Medicaid. On average, children are first diagnosed with ADHD at 8 years old, and half of them are diagnosed by age of 7. Given that the population we are looking at is slightly older, this is generally consistent with the nationwide estimates. Among children age 4–17 years whose parents reported "mild" ADHD symptoms the median age of diagnosis is 7.0 years old, 6.1 years for those with "moderate" symptoms, and 4.4 years for "severe" cases of ADHD (Visser et al., 2014).

The families predominantly consist of a single adult and two children. Their reported net monthly income is $574 on average. The majority of mothers in the sample have at least some high-school education (37%) or a high school diploma (40%). Data on mother's characteristics comes from the in-state birth certificates (matched to 72% of children in our sample).

In addition to the entire cohort of children on Medicaid who are diagnosed with ADHD in SC between 2003 and 2013, we have a supplemental random sample of children on Medicaid who were never diagnosed with ADHD.[18] We use this sample to test the validity of our identification strategy (see Section 5). Summary statistics for this group of children are shown in the Appendix (Table 11 and Table 12).

Table 2 reports summary statistics on ADHD medical treatment and ADHD-related negative health outcomes that we observe in the sample. Nearly all children diagnosed with ADHD have attention-deficit disorder with hyperactivity (ICD-9: 314.01) as opposed to disorder without hyperactivity (ICD-9: 314.00). In our primary specification, we define pharmacological treatment as one or more prescriptions filled within a year of the individual's ADHD diagnosis (72% of patients). We also introduce two alternative definitions of treatment and results are reported in Table 10. We define treatment if we observe an individual ever filling a prescription after their ADHD diagnosis (79% of patients), and following Dalsgaard et al. (2014) we define treatment as a period of at least six months on medication in a given year (52% of patients).

On average, we observe every Medicaid enrollee for eight years. During this time, 1811 girls become pregnant before age 19; 3288 teens contract an STD and an additional 2184 are tested for an STD condition. For 5864 teens we observe at least one claim that indicates a substance abuse disorder. The most frequent outcome that we observe yearly are injuries. Of all ADHD-diagnosed children and teens, 80% have at least one injury while in the sample.

In order to take into account the severity of negative health events, we calculate the total Medicaid spending using the respective claims. The average annual cost of treatment for an STD condition is $400 ($354 per patient if we include all patients who were screened for an STD). The annual cost of a substance abuse condition, including spending on prescribed medications is $1499 per patient. Finally, the average cost of injuries per person per year is $704. These expenditures vary widely across patients, costing Medicaid thousands of dollars in the upper tail of the distribution.[19]

4. Empirical model

4.1. Lifetime effects of ADHD treatment

We use a linear probability model to estimate the effects of ADHD medical treatment on the incidence of adverse health and behavioral outcomes in adolescents who are diagnosed with the condition. In this experiment, we compare the outcomes of treated and not treated children with ADHD. We model outcomes as shown in Eq. (1).

$$Y_i = X_i\beta + \alpha_i Treatment_i + \gamma_1 County_i + \gamma_2 Year_i + \varepsilon_i, \qquad (1)$$

where Y represents one of the negative health outcomes that are common for individuals diagnosed with ADHD, i: STD contraction and STD screening, substance use and abuse, and teenage pregnancy.

[12] For substance use and abuse disorders we use a methodology developed in Bouchery et al. (2012).

[13] The ICD-9 codes for injuries were borrowed from Marcus et al. (2008).

[14] We disregard any out-of-pocket expenditures in this study. In 2013, most eligible individuals faced a small copay per doctor visit ($3.30), per prescription ($3.40 for adults over 19 years old and zero otherwise), and per hospital stay ($25).

[15] NDC is an 11-digit classification issued by the Food and Drug Administration (FDA) for all the approved drugs.

[16] Once eligibility for Medicaid is established, the health insurance coverage is available for an enrollee for a 12-month period (unless the enrollee becomes ineligible during this time), after which the eligibility needs to be reconfirmed. An eligible individual who received services prior to the actual enrollment can be covered retroactively for up to two months prior to the month when eligibility was established.

[17] We are unable to calculate a provider propensity to prescribe for providers who diagnose less than 2 patients with ADHD in a year.

[18] It includes eligibility information, hospital, and outpatient claims for the undiagnosed children under 19 years old with higher weights assigned to relevant birth cohorts.

[19] All spending amounts are adjusted to 2013 dollars.

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Table 1
Summary statistics: individual and family characteristics.

	N obs.	Mean	Median	SD	Min	Max
Individual characteristics						
Age 1st in sample	58,685	4.12	3.00	4.04	0	18
Age at 1st ADHD diagnosis	58,685	7.98	7.00	3.46	3	18
Male	58,685	0.66			0	1
Race: White	58,685	0.47			0	1
Black	58,685	0.43			0	1
Hispanic	58,685	0.02			0	1
Family & home environment						
Monthly family net income	58,685	573.94	408.80	584.93	0	5,189
Number of adults	58,685	1.03	1.00	0.59	0	3
Number of children	58,685	1.91	2.00	0.96	0	6
Ever in foster care	58,685	0.09			0	1
Ever had disability	58,685	0.15			0	1
Mother's characteristics						
Age when gave birth	42,488	23.41	22.00	5.47	11	48
Educ: Less than HS	42,488	0.05			0	1
Some HS	42,488	0.37			0	1
HS diploma	42,488	0.40			0	1
Some college	42,488	0.13			0	1
College degree or higher	42,488	0.05			0	1

Notes: The sample includes every SC Medicaid enrollee who was diagnosed with ADHD between 3 and 18 years old in 2003–2013 and who was eligible for Medicaid for at least one year after this event. Family characteristics are averaged per patient/eligibility year. Foster care and disability rates are calculated based on Medicaid enrollment categories. Mother characteristics are reported based on in-state birth certificate information matched to Medicaid records. They are available only for a subsample of the 42,488 patients. Mother's age and educational attainment are recorded at the time of the child's birth. "HS" stands for high school education level.

X is a vector of covariates that includes observed individual characteristics (race, gender, birth year), net monthly family income at the first ADHD diagnosis, patient age, and duration of enrollment.[20] We also control for the location (county of patient's residence at diagnosis) and the year of diagnosis. We exclude all individuals, treated or untreated, who have experienced an adverse outcome (STD, STD test, substance abuse, or pregnancy) prior to, or in the same year of, their ADHD diagnosis and estimate the model using post-diagnosis medical history to assure that the adverse events do not determine the instrument. Note that an advantage of this strategy over the specification where we would be looking at the occurrence of adverse events at a given age (e.g., at age 14), is that we include patients who were diagnosed later in life, conditional on not experiencing adverse events prior to the first diagnosis. This is particularly important for our long-term outcomes that are relevant during patient teen years.

For STD, STD screening, substance abuse, and teenage pregnancy outcomes we utilize a subsample of relevant birth cohorts of SC Medicaid enrollees. They are individuals born between 1987 and 1996, whose teen years overlap with our sample period and who are enrolled in Medicaid for at least one year during this time. *Treatment* takes a value of one if the individual fills at least one ADHD prescription within the year of their ADHD diagnosis, as described in Section 3.

The parameter of interest in this equation is α. In the linear probability model framework, it can be interpreted as the average impact of being treated within the year of the individual's ADHD diagnosis on the likelihood of negative health outcomes in adolescence.

Eq. (1) can be rewritten to reflect two potential sources of bias:

$$Y_i = X_i\beta + \bar{\alpha}Treatment_i + Treatment_i(\alpha_i - \bar{\alpha}) + \gamma_1 County_i + \gamma_2 Year_i + \varepsilon_i \tag{2}$$

[20] The length of the time period the individual was enrolled in Medicaid between 2003 and 2013.

First, if *Treatment* is correlated with ε, unobserved factors that make some individuals more likely to receive treatment also influence their health and behavioral outcomes. For example, relatively more caring parents might be more likely to pursue medical treatment for their child. These parents are also more likely to take measures to reduce the probability of negative health outcomes associated with ADHD. In this case, our results might be biased towards finding that ADHD treatment reduces the probability of negative health outcomes. On the contrary, if, perhaps, children with the most severe ADHD symptoms are the ones to seek treatment and are also relatively more likely to experience negative health outcomes, the effect of medication treatment would be biased towards zero.

Second, *Treatment* might be correlated with α if individuals select treatment based on expected gains. In this case, the child's outcomes may determine treatment receipt.

4.2. Identification

Following Dalsgaard et al. (2014) and Duggan (2005), we instrument for individual treatment with provider propensity to prescribe. If two equally sick patients have a different prescription outcome because they saw physicians with a respectively high or low propensity to prescribe, it provides exogenous variation necessary to evaluate the causal effect of treatment.

$$PP_{dit} = \frac{\text{N patients treated}_{dt} - 1 * (\text{Treated}_{dit} = 1)}{\text{N patients}_{dt} - 1} \tag{3}$$

We define provider d's propensity to prescribe (PP) medication to an individual i in year t as the share of all his/her patients' treatment outcomes in a given year (Eq. (3)). The outcome of the focal individual is excluded in order to reduce potential endogeneity concerns since the patient's characteristics are not a part of the provider propensity to prescribe measure. To be included in our analysis, we require the provider to diagnose two or more patients per year. In our data, a provider diagnoses 7 patients per year, on average; the median is 3 patients, conditional on being included in our sample. This skewed

Table 2
Summary statistics: medical treatment and negative health outcomes.

	N obs.	Mean	Median	SD	Min	Max
Medical diagnosis & treatment						
1st diagnosis: ADD w/ hyperactivity	58,685	0.74			0	1
ADD w/o hyperactivity	58,685	0.24			0	1
1+ Rx filled within a year (1st diag)	58,685	0.72			0	1
1+ Rx filled (ever)	58,685	0.79			0	1
6+ Rx filled within a year (ever)	58,685	0.52			0	1
Annual cost of ADHD visit	58,685	586.75	152.10	1819.20	1	151,980
Annual cost of ADHD Rx	46,355	419.33	265.38	466.81	1	7897
Years in sample	58,685	7.94	8.00	2.73	1	11
Outcome: Risky sexual behavior						
1. Teen pregnancy						
Age at 1st pregnancy	1811	16.67	17.00	1.75	11	19
Race: White	1811	0.53			0	1
Black	1811	0.43			0	1
2. STD						
Age at 1st STD	3288	14.46	14.00	2.49	11	19
Age at 1st STD (incl. screening)	5472	14.80	15.00	2.33	11	19
Male	3288	0.42			0	1
Race: White	3288	0.57			0	1
Black	3288	0.35			0	1
Annual cost of STD	3288	399.84	152.32	1129.51	4	19,728
Annual cost of STD+ test	5472	353.88	181.80	777.86	2	19,728
Outcome: Substance abuse						
Age at 1st substance abuse	5864	15.12	15.00	2.11	11	19
Male	5864	0.64			0	1
Race: White	5864	0.51			0	1
Black	5864	0.42			0	1
Annual cost of substance abuse	5864	1498.32	430.45	3640.24	1	113,834
Outcome: Injuries						
Ever injured	58,685	0.80			0	1
Age at injury	46,730	9.07	8.50	3.72	3	19
Male	46,730	0.67			0	1
Race: White	46,730	0.50			0	1
Black	46,730	0.40			0	1
N of injury claims	58,685	0.37	0.27	0.44	0	12
Annual cost of injuries	46,730	704.37	247.10	4072.36	2	501,616

Notes: The sample includes every SC Medicaid enrollee who was diagnosed with ADHD between 3 and 18 years old in 2003–2013 and who was eligible for Medicaid at least one year after this event. Alternative treatment definitions are used for the robustness checks in Table 10. Annual cost of treatment and negative health outcomes are given in 2013 dollars per patient/year conditional on treatment or the occurrence of a negative health outcome. They are based on the Medicaid reimbursement payouts. The out-of-pocket patient costs are nearly zero for the population in our sample.

distribution is consistent with what is typically found in the health economics literature. Our main estimation results are robust to only considering providers who diagnosed more than 3 or more than 7 patients, respectively (available upon request).

Since we only observe filled prescriptions, our calculated provider's propensity to prescribe a drug to a patient with ADHD includes both the probability that he/she writes a prescription and the probability that the patient fills the prescription (Dalsgaard et al., 2014). Both events, conditional on the provider's engagement with the patient, are relevant provider variation.[21]

Stockl et al. (2002) survey a 1000 randomly selected physicians who prescribe stimulant medication to patients between December 2001 and May 2002. They document considerable variation in physicians' perception of the severity of ADHD medication side effects and their concern about the medication being used for purposes other than patient's medical needs. Similar to earlier research, we find that patients face significant variation in the probability of receiving a prescription (Fig. 1).

We, thus, use provider propensity to prescribe to instrument for the treatment receipt. The first stage is given by Eq. (4):

$$Treatment_i = \delta PP_i + X_i\theta + \nu_i, \tag{4}$$

where PP is a patient-specific probability to receive a prescription from the diagnosing provider; X is a vector of controls from the Eq. (1). The second stage is given by Eq. (5):

$$Y_i = \alpha \widehat{Treatment}_i + X_i\beta + \varepsilon_i, \tag{5}$$

where $\widehat{Treatment}$ is the predicted treatment from Eq. (4), and β is the marginal treatment effects of ADHD medication on adolescent's negative health outcomes.

To illustrate our identification strategy, consider two types of doctors: doctors with a high propensity to prescribe and doctors with a low propensity to prescribe. For very severe cases of ADHD, both doctors would recommend medication treatment and thus the effect of treatment on children's negative health outcomes cannot be identified. Alternatively, for children with few to no ADHD symptoms, both doctors would not recommend medication treatment. The comparison of outcomes across doctors' prescribing behaviors would thus focus on the variation of treatment among marginal cases. Eq. (5) will produce consistent estimates provided that PP influences treatment

21 In the earlier literature, physician prescribing practices were found to vary with the reimbursement mechanism (Dickstein, 2014) and their individual preferences (Hellerstein, 1998).

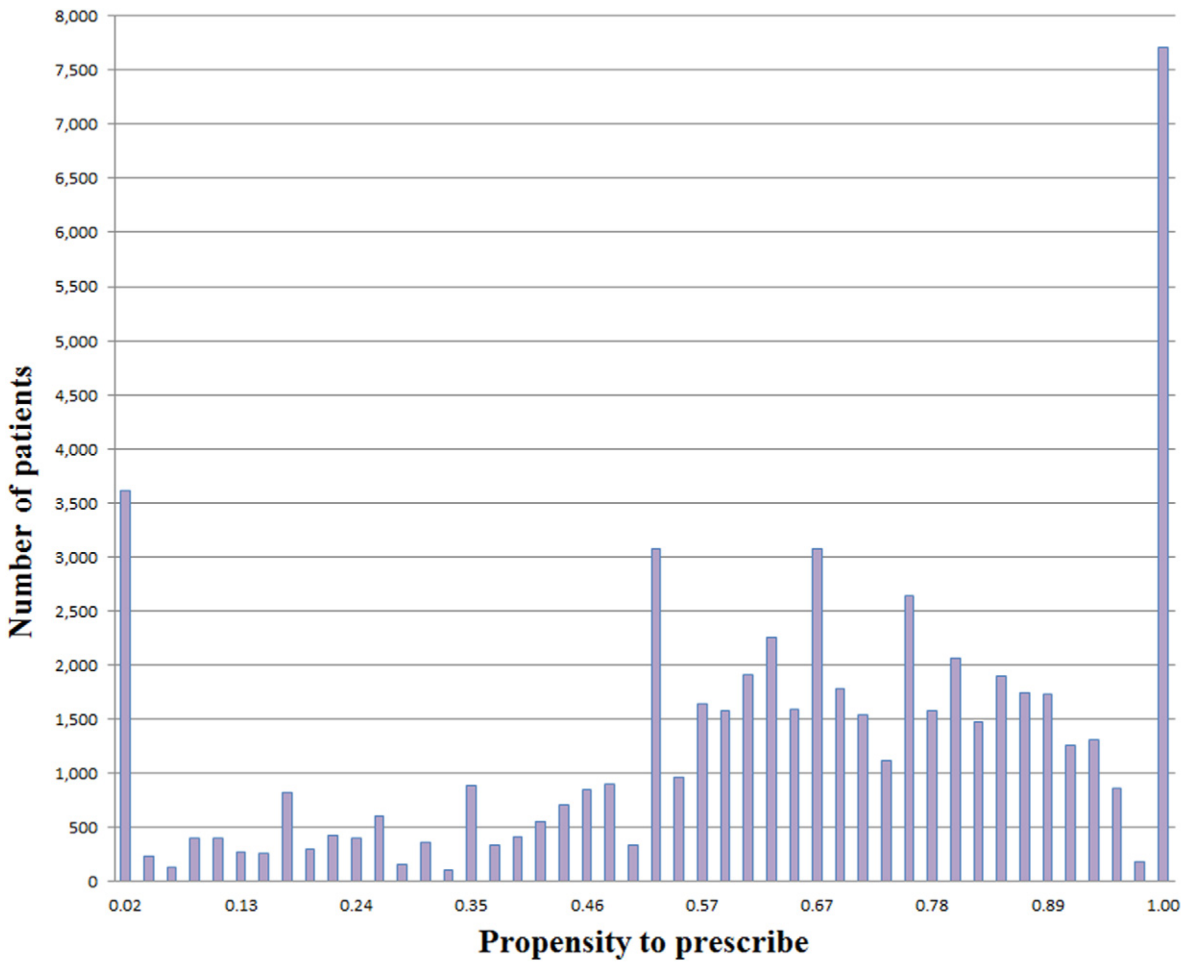

Fig. 1. Distribution of provider propensity to prescribe. Notes: The figure shows the distribution of the probability that a patient receives a prescription from a particular physician in the year she was diagnosed based on the sample of 58,685 ADHD-diagnosed patients enrolled in SC Medicaid in 2003–2013. Provider propensity to prescribe varies from zero to one.

and is uncorrelated with the error term, ε (see Section 5 for supporting evidence). Note that we also explicitly assume monotonicity of our instrument. If a patient is prescribed medication by a provider with a low propensity to prescribe, she must also be prescribed treatment by a provider with a high propensity to prescribe.

4.3. Yearly effects of ADHD treatment

Another way to look at the effects of ADHD treatment on negative health outcomes is by taking advantage of the panel feature of our data set. It allows us to control for patient's age, year-specific trends, and other observed time-varying factors that could have an effect on individual health outcomes. For example, age-specific risks of outcomes such as pregnancy, STD contraction, and substance abuse are in the fixed effects, which reduces the variance in the error term.

Moreover, this approach requires fewer assumptions about data. While in the "lifetime" analysis (cross-section setup) it is assumed that an individual had no adverse outcomes if she is not actively enrolled in Medicaid and has no claims,[22] per-year effects are identified strictly off the observed continuous Medicaid enrollment period. Due to the nature of administrative records, we are unable to reliably tell apart two separate negative health events of the same type. Thus, we do not track individuals past their first adverse outcome (except for the injuries). The empirical model is specified in the Eq. (6) below.

$$Y_{it} = \alpha \widehat{Treatment}_i + X_i\beta + Z_{it}\gamma_1 + \gamma_2 County_{it} + \gamma_3 Year_{it} + \gamma_4 Year \times County_{it} + \varepsilon_{it}, \tag{6}$$

where Y is a negative health outcome for an ADHD patient i in year t; $\widehat{Treatment}$ represents medical treatment instrumented with provider propensity to prescribe. As in the "lifetime" effects analysis, treatment is defined as "treated within a year of the individual's ADHD diagnosis" and the instrument itself does not have a time subscript. X is a vector of controls that includes individual characteristics that do not vary with time: race, sex, and birth cohort; Z includes time-varying controls: age, monthly family income; $Year$ represents year controls; $County$ stands for the county of residence;[23] $Year \times County$ are county/year interactions, and ε is a stochastic error term. Note that we exclude all individuals, treated and untreated, who have experienced an adverse outcome (STD, STD test, substance abuse, or

[22] See discussion in Section 5.2.4

[23] For robustness, we use county unemployment rate, county income, and county population density instead of county controls and our findings hold.

pregnancy) prior to their ADHD diagnosis and we estimate the model using post-ADHD diagnosis medical history. For STD, STD screening, substance abuse, and teenage pregnancy outcomes we utilize a subsample of individuals born between 1987 and 1996, whose teen years overlap with the time period of our data set.

For the outcomes related to teenagers' risky behavior, the parameter of interest, α can be interpreted as the average effect of receiving treatment within a year of the individual's ADHD diagnosis on the first incidence of a negative health outcome. For the incidence and number of injuries, the coefficient on treatment can be interpreted as the average annual effect of receiving treatment within a year of the individual's ADHD diagnosis.

Ideally, one would like to know how treatment length or being diagnosed at a certain age can change treatment effects. Since we are unable to address the endogeneity issues that arise with the use of treatment length or age of diagnosis with our instrument, it is left for the future research to find an identification strategy that would shed light on these questions.

5. IV Validity

5.1. Condition 1: first stage results

The first stage results for the entire sample (Table 3) and the outcome-specific results (Table 6) show that the relationship between the provider propensity to prescribe ADHD medication and the probability that the child fills a prescription within in a year of their ADHD diagnosis is positive. It holds when we include a number of controls, such as family and individual characteristics, mother's age and education level, county, and birth cohort fixed effects. The estimated magnitude of the coefficient in the specification that includes all the controls and fixed effects (Table 3, column 3) suggests that a 10 percentage point increase in the provider propensity to prescribe is associated with a 4.5 percentage points increase in the probability of treatment receipt.

This relationship does not seem to be driven by the "extreme" values of provider propensity to prescribe. When we exclude all providers who either never prescribe ADHD medication or prescribe drugs to every child they diagnose, the first-stage result becomes stronger.

5.2. Condition 2: exclusion restriction

In order for our instrumental variable approach to be valid, the exclusion restriction must hold. In our data, providers are not randomly assigned to patients but it is a necessary condition for a provider propensity to prescribe to affect patient outcomes only through pharmacological treatment.

In this section, we devise a number of tests that could be indicative of a violation of this assumption. There are three potential threats that we address and provide suggestive evidence in favor of the validity of doctor propensity to prescribe. First, provider prescribing preferences might be correlated with the provider quality and thus, would affect patient outcomes directly rather than through treatment receipt. Second, both our instrument and patient outcomes may be correlated with unobserved individual, family, and other characteristics. Finally, there might be a sample selection problem if the individual's length of enrollment in Medicaid is related to the provider propensity to prescribe. Although these tests do not ensure that the exclusion restriction is satisfied, they provide us with more confidence in that our instrument is valid.

5.2.1. Provider quality and propensity to prescribe

Physician quality, experience, and training have an impact on patient outcomes. If the propensity to prescribe medication reflects physician quality, it may confound our results. For example, it could be the case that providers who prescribe medication to every single one of their patients do not properly evaluate patient symptoms and/or determine a treatment strategy that would suit each particular case. In other words, if high prescribing providers are those of lower quality, we would expect to find that treatment has unfavorable effects on health outcomes.

To address this concern we devise a placebo test. If provider quality is not related to his or her propensity to prescribe, we should see no relationship between the instrument and health outcomes of children who were never diagnosed with ADHD. By definition, this group

Table 3
Results: first stage.

	(1)	(2)	(3)	(4)
Propensity to prescribe	0.505^{a}	0.458^{a}	0.454^{a}	0.549^{a}
	(0.006)	**(0.006)**	**(0.007)**	**(0.011)**
Male		0.043^{a}	0.047^{a}	0.047^{a}
		(0.004)	(0.004)	(0.005)
Race: Black		−0.056^{a}	−0.055^{a}	−0.057^{a}
		(0.004)	(0.005)	(0.005)
Hispanic		−0.126^{a}	−0.176^{a}	−0.184^{a}
		(0.011)	(0.016)	(0.018)
Other		−0.057^{a}	−0.071^{a}	−0.077^{a}
		(0.008)	(0.010)	(0.011)
Family net income		0.005^{b}	0.006^{c}	0.005
		(0.002)	(0.003)	(0.003)
Number of adults		−0.018	0.011	−0.001
		(0.003)	(0.004)	(0.004)
Number of children		0.001	0.001	0.002
		(0.002)	(0.002)	(0.002)
Cohort & county F.E.	N	Y	Y	Y
Mother characteristics	N	N	Y	Y
Propensity to prescribe $\in (0, 1)$	N	N	N	Y
R-squared	0.099	0.129	0.116	0.104
N obs.	58,685	58,685	42,693	34,507

Notes: The dependent variable in every specification is the binary prescription outcome for a patient. It equals one if the patient had an ADHD prescription within a year of their ADHD diagnosis while on Medicaid and zero otherwise. Controls that are not shown include individual's county of residence, foster care, and disability status at the time of the diagnosis. Mother characteristics include mother's age when she gave birth and educational attainment. Family net income is measured in ten thousands of dollars; the coefficients on the number of adults are scaled up by 10 in order to show the magnitude of the effect. Coefficient estimates that are significant at 1%, 5%, and 10% levels are denoted with *a*, *b*, and *c* respectively. Standard errors are in parentheses. They are clustered by individual's provider who diagnosed them with ADHD.

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Table 4
IV Validity: placebo test.

	STD	STD+ test	Subst. abuse	Teen preg.
Panel A. Undiagnosed children				
Propensity to prescribe	0.009	0.004	−0.003	−0.013
	(0.009)	(0.012)	(0.008)	(0.008)
Male	−0.079[a]	−0.158[a]	0.036[a]	–
	(0.006)	(0.007)	(0.006)	–
Race: Black	−0.031[a]	−0.017[c]	−0.056[a]	−0.017[b]
	(0.009)	(0.010)	(0.009)	(0.008)
Hispanic	−0.045[a]	−0.038[b]	−0.047[a]	−0.010
	(0.016)	(0.019)	(0.015)	(0.014)
Other	0.002	−0.016	−0.071[a]	−0.018
	(0.021)	(0.025)	(0.017)	(0.018)
Number of adults	0.0004	−0.004	−0.005	−0.008
	(0.005)	(0.006)	(0.005)	(0.005)
Number of children	−0.006[b]	−0.005	0.006[b]	0.013[a]
	(0.003)	(0.004)	(0.003)	(0.003)
Family net income	0.002	−0.007	−0.013[a]	−0.014[a]
	(0.004)	(0.005)	(0.004)	(0.004)
N obs.	10,743	10,743	10,743	7938
Panel B. Children diagnosed with ADHD				
Propensity to prescribe	−0.017[c]	−0.037[a]	−0.059[a]	−0.019
	(0.010)	(0.012)	(0.020)	(0.021)
Male	−0.129[a]	−0.210[a]	0.048[a]	–
	(0.007)	(0.008)	(0.008)	–
Race: Black	−0.011[c]	0.014	−0.076[a]	−0.023[c]
	(0.007)	(0.008)	(0.010)	(0.013)
Hispanic	−0.037	−0.019	−0.122[a]	−0.064[c]
	(0.022)	(0.027)	(0.027)	(0.037)
Other	−0.023[c]	−0.039[a]	−0.089[a]	−0.075[a]
	(0.012)	(0.014)	(0.016)	(0.024)
Number of adults	−0.006[c]	−0.019[a]	−0.019[a]	−0.016[c]
	(0.004)	(0.005)	(0.006)	(0.008)
Number of children	0.006[b]	0.013[a]	0.011[a]	0.034[a]
	(0.002)	(0.003)	(0.003)	(0.005)
Family net income	−0.002	−0.008	−0.028[a]	−0.023[a]
	(0.004)	(0.006)	(0.005)	(0.008)
N obs.	14,736	14,736	14,736	5570

Notes: Panels A and B show the results of the IV validity test. Propensity to prescribe ADHD medication is constructed using the individual's provider at the mean age of ADHD diagnosis for the non-ADHD sample. The coefficients in Panel A are estimated on the sample of children who do not have ADHD using OLS. The dependent variables take value of one if a child experienced each of the respective adverse events; it is zero otherwise. The coefficients in Panel B are from the reduced form equation: regressing the outcome on doctor propensity to prescribe. Coefficient estimates that are significant at 1%, 5%, and 10% levels are denoted with *a*, *b*, and *c* respectively. Standard errors are in parentheses. They are clustered by individual's provider.

has no diagnosing physician in the data. Instead, we identify the first doctor a patient who was never diagnosed with ADHD saw when he or she was eight years old. It is the mean age of ADHD diagnosis in our sample of diagnosed children.[24]

Table 4 presents results for the undiagnosed sample as well as the reduced form regression estimates for the diagnosed sample. The point estimates of the coefficients on the propensity to prescribe have large confidence intervals suggesting that there is no statistically significant relationship between provider quality and propensity to prescribe.

5.2.2. Diagnosing provider selection

Another kind of potential bias may arise if parents of children with relatively severe symptoms of ADHD seek and use prior information about the provider's propensity to prescribe. If they, on average, visit physicians with a relatively high propensity to prescribe, this could bias our findings of the effects of ADHD medication downward. Similarly, if the parents of children with relatively less severe ADHD symptoms seek pharmacological treatment, it could result in an upward bias in our findings.

We do not have a strong prior on the direction of the bias. The medical evidence on the effectiveness of ADHD medication is mixed and the evidence on long-term effects is very limited. Additionally, there is a large array of potential side effects associated with these drugs. They include sleep problems, suppressed appetite, nausea, headaches, stunted growth, aggression and irritability, and cardiac risks (Barkley, 2006). Parents have to weigh the expected benefits and costs associated with medicating their child.

Table 5 reports the estimates of the relationship between physician propensity to prescribe and observed individual, mother, and family characteristics. They include mother's age and educational attainment at the time she gave birth, family net income measured at the time of the individual's first ADHD diagnosis, the severity of ADHD, and comorbid psychiatric conditions diagnosed prior to ADHD. We find no evidence of a consistent relationship between these observed characteristics and our instrumental variable except for a tightly-estimated small in magnitude effect for the family composition, patient gender, and race. For example, a family with one child versus two children would face a doctor with only 0.3 percentage points lower prescribing probability. The estimates also suggest that boys face providers who, on average, have a 1 percentage point higher propensity to prescribe than girls; and Blacks are diagnosed by providers with 2 percentage points lower propensity to prescribe than Whites. It is hard to think of a reason why conditional on

[24] Due to a high provider mobility in and out of Medicaid, not all first-in-sample provider IDs were matched to the diagnosing provider IDs.

Table 5
IV Validity: additional evidence.

Dependent variable:	Propensity to prescribe		Enrollment length	
Regressors	Coeff.	SE	Coeff.	SE
Individual characteristics				
Male	0.011[a]	0.003	−0.081[a]	0.016
Race: Black	−0.020[a]	0.003	0.292[a]	0.017
Hispanic	−0.049[a]	0.009	0.171[a]	0.057
Other	−0.035[a]	0.005	0.187[a]	0.036
Mother & family characteristics				
Educ: Less than HS	0.002	0.006	0.103[b]	0.039
Some HS	−0.002	0.003	0.077[a]	0.018
Some college	−0.004	0.004	−0.269[a]	0.024
College degree or higher	0.003	0.006	−0.406[a]	0.036
Family net income	−0.002	0.002	−0.083[a]	0.010
Number of adults	0.004[b]	0.002	0.051[a]	0.013
Number of children	0.003[b]	0.001	0.059[a]	0.007
Comorbid condition	−0.002	0.003	0.135[a]	0.016
Severity of ADHD	−0.001	0.003		
Provider propensity to prescribe			0.006	0.028
N obs.	39,753		42,140	

Notes: This table shows two additional tests in support of our instrumental variable. Both regressions are estimated using OLS and include birth cohort and county fixed effects. Family income is measured in thousands of dollars; ADHD severity is approximated by the incidence of injuries prior to ADHD diagnosis. Family characteristics are measured and fixed at the time of the individual's first ADHD diagnosis. Coefficient estimates that are significant at 1%, 5%, and 10% levels are denoted with *a*, *b*, and *c* respectively.

ADHD severity, provider propensity to prescribe would be correlated with patient gender and race. In fact, when compared to the mean propensity to prescribe of 0.62, it becomes clear that our estimates reveal precisely that: nearly zero tightly-estimated relationship.

Building on the concerns identified in the earlier literature (Dalsgaard et al., 2014, Currie et al., 2014) we look at the relationship between provider propensity to prescribe and patient family socio-economic status. We find a very small and statistically insignificant correlation between family income and provider propensity to prescribe. An increase of $400 in monthly family income (median income in our sample) would imply a 0.8 percentage points lower provider propensity to prescribe. Medicaid enrollees are a relatively homogeneous group income-wise and are well-suited for our research design. Finally, we find no statistically significant relationship between provider propensity to prescribe and the severity of the underlying condition approximated by the history of injuries prior to the ADHD diagnosis.

Although there are many unobserved characteristics that could have an impact on the choice of the ADHD provider, we argue that our test has significant power. Covariates like family income and mother's characteristics have a long history of being used as predictors of health, parent quality, and other outcomes that we could be potentially concerned about.

5.2.3. Treatment shopping

About 10% patients in our sample (5734 individuals) switch their health care provider after being diagnosed with ADHD. If the reason behind a switch is a patient's desire to alter their treatment, it could undermine our research design. In particular, the concern is that patients are shopping for treatment and if the first physician did not prescribe medication, they would search for a provider who would. For these patients, we look at the relationship between prescribing practices of the diagnosing physician and their subsequent physician. Of the individuals that switch providers, 57.6% go to a subsequent provider with a higher propensity to prescribe than the diagnosing provider; 39.4% go to a subsequent provider with a lower propensity to prescribe, and 3.0% go to a subsequent provider with a propensity to prescribe equal to the first diagnosing provider. Approximately 83% of switchers receive pharmaceutical treatment and 79% of those who do not switch receive pharmaceutical treatment.

Fig. 2 plots this relationship. It shows no clear linear pattern in the switchers' behavior, suggesting that individuals who switch to a subsequent provider do so randomly or for reasons independent of the provider propensity to prescribe. We also look for the possibility of a nonlinear relationship. The coefficient on the quadratic term is small, positive and significant (0.07 (0.01)).[25] It suggests that for patients who first encounter providers with "extreme" prescribing preferences (either prescribe to no one or prescribe to all patients) and switch to another provider, their subsequent provider propensity to prescribe is slightly higher than average. If we regress the individual decision to switch on an indicator of provider being "extreme", we find that their patients are 2 percentage points more likely to switch providers (Table 13).

Further, we find no evidence of correlation between provider switching and mother's education or income (Table 13), and the mean values of mother and family characteristics do not differ significantly for individuals who go to a higher prescribing subsequent provider in relationship to individuals who go to a lower prescribing subsequent provider (Table 14). All these patterns suggest that strategic treatment shopping in our sample is not a significant issue but it also indicates that patients might be driven away from providers with the extreme preferences to prescribe ADHD medication.

5.2.4. Provider propensity to prescribe and the length of Medicaid enrollment

The final test we perform is concerned with the length an individual is enrolled in Medicaid. In the data, we observe the individual so long as they are enrolled. If the decision to enroll in Medicaid is related to doctor propensity to prescribe, it is a potential concern for the identification strategy.

For example, if a patient was diagnosed by a provider with a relatively high propensity to prescribe and received medication, it is plausible to suggest that she may remain enrolled for a longer period of time than otherwise. One might argue that the longer an individual is enrolled, the more probable it is that we will observe a negative

[25] The coefficient estimates do not change when controls from our main regression specification are included.

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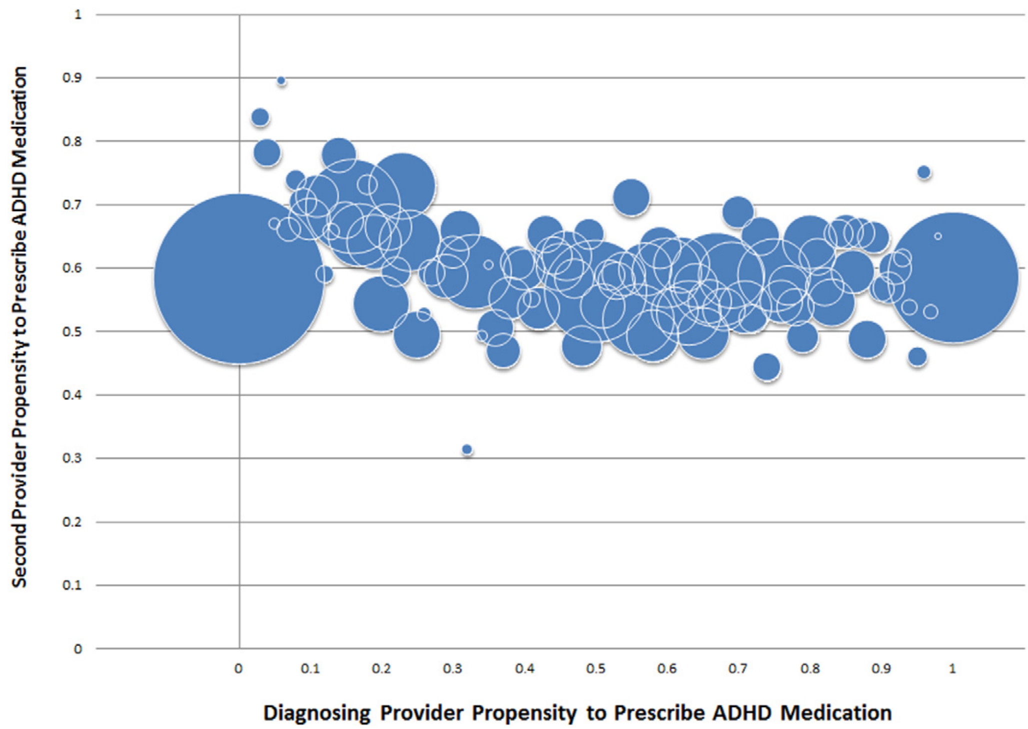

Fig. 2. Provider shopping: diagnosing and subsequent provider propensity to prescribe. Notes: In the data, 5734 patients switch health care providers. This figure shows the relationship between the individual's diagnosing provider propensity to prescribe and their subsequent provider propensity to prescribe. Prescribing propensities vary from zero to one.The bubble size indicates the number of patients for each pair of propensity scores.

health outcome for that individual: STD contraction, STD screening, substance abuse disorder, or teenage pregnancy.[26] Positive correlation between doctor propensity to prescribe and enrollment could bias our results towards finding that pharmaceutical treatment receipt, instrumented with provider propensity to prescribe, is correlated with worse patient outcomes.

Table 5 shows that the instrument is uncorrelated with the length of Medicaid enrollment. In other words, individuals are not selecting into the sample based on their diagnosing provider propensity to prescribe.

6. Results

We find evidence that ADHD medication treatment reduces the probability and severity of a wide range of short-term and lifetime negative health outcomes. It is effective in reducing the probability of an ADHD teenager contracting an STD, becoming pregnant, suffering from a substance use and abuse disorder, and having an injury.

Tables 6–9 summarize these results. For every negative health outcome we show coefficients estimated using IV and OLS, for comparison purposes. OLS estimates agree with the IV-estimated coefficients in the direction of the effect, but in most cases they understate the magnitude of the beneficial effects associated with treatment.

6.1. Lifetime effects of ADHD treatment

We first look at the effect of treatment on the incidence of negative health events over the childhood and teenage years. Table 6 summarizes the results. We find that medication is effective in reducing the probability of the outcomes produced by risky behaviors. Children with ADHD, who received pharmacological treatment are 3.6 percentage points less likely to be treated for an STD condition, 5.8 percentage points less likely to be screened for an STD/have a condition, and 7.3 percentage points less likely to receive medical attention related to a substance abuse disorder. The point estimate on the probability of teenage pregnancy is also negative (−2.3 percentage points) but not statistically significant.[27]

Compared to the OLS estimates, the coefficients obtained using IV are of the same sign for all outcomes, but are larger in absolute value and statistically significant for STD contraction, STD screening and substance abuse disorder. In other words, OLS understates the effects of treatment but indicates that treatment has favorable effects on outcomes.

The results also show that males are less likely to be treated (12.0 percentage points) or screened (20.5 percentage points) for an STD but 4.1 percentage points more likely to have medical history of substance abuse. This finding is consistent with the reports on STDs.[28] For example, the chlamydia case rate per 100,000 females in 2005 was more than three times higher than for males. Most of this difference is attributed to the fact that women are more likely to be screened than men. Whites are the most likely to suffer from one of the negative health outcomes that we focus on, which is also likely to be an outcome of higher probability of being screened.

Family characteristics that we control for include family composition (number of adults and children in the individual's household) as well as family net income at the time of the child's diagnosis. The coefficients on these controls are consistent with our prior. In

[26] Due to the easiness of enrollment in Medicaid and including the fact that the program would cover up to two months of claims retroactively, these adverse outcomes would likely result in an individual re-enrollment and would not pose a risk for the model identification.

[27] These results generally hold in a smaller sample of patients for whom we have birth certificate data. Table 15 shows the effects of ADHD treatment on negative outcomes when we control for mother's age and educational attainment.

[28] CDC, "Trends in Reportable Sexually Transmitted Diseases in the United States, 2005", http://www.cdc.gov/std/stats05/trends2005.htm. Accessed on July 14, 2015.

Table 6
Lifetime effects of ADHD treatment on negative health and behavioral outcomes.

	STD		STD+test		Subst. abuse		Pregnancy	
	OLS	IV	OLS	IV	OLS	IV	OLS	IV
First stage		0.517[a]		0.512[a]		0.516[a]		0.545[a]
		(0.033)		(0.034)		(0.034)		(0.037)
ADHD treatment	−0.012[b]	−0.036[c]	−0.015[b]	−0.058[b]	−0.004	−0.073[b]	−0.030[b]	**−0.023**
	(0.005)	**(0.019)**	(0.007)	**(0.023)**	(0.008)	**(0.036)**	(0.012)	**(0.038)**
Male	−0.121[a]	−0.120[a]	−0.207[a]	−0.205[a]	0.038[a]	0.041[a]		
	(0.007)	(0.007)	(0.008)	(0.008)	(0.008)	(0.008)		
Race: Black	−0.009	−0.012[c]	0.016[c]	0.011	−0.074[a]	−0.082[a]	−0.023[c]	−0.022
	(0.006)	(0.007)	(0.008)	(0.009)	(0.009)	(0.010)	(0.013)	(0.014)
Hispanic	−0.042[b]	−0.044[b]	−0.032	−0.036	−0.110[a]	−0.116[a]	−0.073[b]	−0.072[b]
	(0.021)	(0.021)	(0.025)	(0.025)	(0.025)	(0.025)	(0.036)	(0.036)
Other	−0.018	−0.019[c]	−0.029[b]	−0.032[b]	−0.091[a]	−0.095[a]	−0.069[a]	−0.068[a]
	(0.011)	(0.011)	(0.014)	(0.014)	(0.017)	(0.017)	(0.024)	(0.024)
Number of adults	−0.007[c]	−0.006[c]	−0.017[a]	−0.016[a]	−0.016[a]	−0.016[a]	−0.015[c]	−0.015[c]
	(0.004)	(0.004)	(0.005)	(0.005)	(0.005)	(0.006)	(0.008)	(0.008)
Number of children	0.006[a]	0.006[a]	0.012[a]	0.012[a]	0.010[a]	0.009[a]	0.034[a]	0.034[a]
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.005)	(0.005)
Family net income	−0.002	−0.002	−0.009[c]	−0.008	−0.027[a]	−0.027[a]	−0.023[a]	−0.023[a]
	(0.004)	(0.004)	(0.005)	(0.005)	(0.005)	(0.005)	(0.008)	(0.008)
Mean outcome	0.117		0.212		0.236		0.265	
N obs.	14,248		13,896		13,668		5339	

Notes: The main coefficient estimates (in bold) in this table can be interpreted as the effect of treatment within a year of the individual's ADHD diagnosis on the probability of a negative health outcome during an individual's adolescence. All specifications include individual county of residence and birth year fixed effects. We also control for the individual's age and net family income at first ADHD diagnosis, length of Medicaid eligibility, disability and foster care status. First stage coefficients show the relationship between treatment receipt within a year of the individual's ADHD diagnosis and physician propensity to prescribe medication. Negative health outcomes are considered a year or more after the individual's ADHD diagnosis. All specifications are estimated on a subsample of relevant birth cohorts of SC Medicaid enrollees and include individuals born between 1987 and 1996. Coefficient estimates that are significant at 1%, 5%, and 10% levels are denoted with a, b, and c respectively. Standard errors are in parentheses. They are clustered by individual's provider who diagnosed them with ADHD.

a family with a single adult comparing to a family with two adults, the probability of negative health outcomes is 0.6–1.6 percentage points lower depending on the type of the outcome. This result is statistically significant for the STD condition and screening combined, substance abuse, and teen pregnancy.

On the other hand, individuals in families with a higher number of children are more likely to experience one of the negative health outcomes. The magnitude of the effect varies from 0.6 to 3.4 percentage points, being the highest for teenage pregnancy. It is likely due to the fact that there is relatively less parental oversight in larger families. Finally, net family income is negatively correlated with the incidence of risky behavior outcomes. As we would expect, the better off the family is in terms of income, the less likely their child will experience a negative health outcome, however the magnitude of the effect is very low. A $100 increase in the net monthly income would produce a 0.02, 0.08, 0.27, and 0.23 percentage point decrease in the probability of STD, STD screening, substance abuse, and teen pregnancy respectively. Note that most families on Medicaid are relatively poor and there is not enough income variation in this population group to evaluate the effect of income on the incidence of negative health outcomes.

Table 16 in the Appendix shows that the results are robust to including a control for comorbid psychiatric conditions that an individual is diagnosed with prior to their ADHD diagnosis. When we exclude individuals who have been diagnosed with a comorbid psychiatric condition prior to their ADHD diagnosis, our results hold for all the outcomes.

We also explore how our results vary across ADHD-diagnosed patients of different gender, race, and birth cohort. The results are reported in Table 7. These stratifications provide us with interesting insights. The results for male and female subpopulations suggest that treatment reduces the probability of STD contraction and STD screening for both males and females but estimates are statistically significant only for females. As previously discussed, females have a higher prevalence of STDs likely due to the fact that they are screened for STDs more often than males. Treatment also reduces the probability of abusing substances for both males and females but the effect is only statistically significant for males.

For most outcomes we find little heterogeneity across races. Treatment reduces the probability of STD contraction, STD testing and substance abuse for both Whites and minorities; however the point estimates are imprecise for Whites. Finally, treatment is associated with a statistically insignificant reduction in the probability of teenage pregnancy for Whites; for minorities the point estimate is nearly zero and imprecise.

Following earlier research, we split patients by the year of birth into two groups: relatively "older" and "younger" cohorts. Our results are consistent with Dalsgaard et al. (2014), who find treatment to be less effective in younger cohorts. We interpret this result in light of increased incidence of ADHD diagnosis. It is suggestive of the average ADHD case being less severe in relatively younger cohorts than in older cohorts.

6.2. Yearly effects of ADHD treatment

Perhaps an even more policy-relevant question is what is the difference in outcomes for children who are treated with ADHD medication versus children who are not in per year terms. The average cost of a prescription medication is $347 per patient per year and the average cost of ADHD-related physician visits is $562 per patient per year during the sample period (measured in 2013 dollars). It is valuable to compare these treatment expenditures to what Medicaid spends on treatment of realized negative health outcomes.[29]

The results suggest that pharmaceutical treatment is associated with a 1.1 percentage point decrease in the probability of contracting an STD, a 1.9 percentage point decrease in the probability of being

[29] It is one of the goals of our future work to differentiate these effects by the year of diagnosis, adherence status, and length of treatment.

Table 7
Heterogeneity of the effects of ADHD treatment on (lifetime) outcomes

Group	STD	STD + test	Subst. abuse	Teen preg.
Panel A. Gender-based heterogeneity				
Male	−0.007	−0.035	−0.096[b]	–
	(0.020)	(0.026)	(0.042)	
Mean	0.067	0.127	0.239	–
N	8985	8887	8502	
Female	−0.089[a]	−0.117[a]	−0.047	–
	(0.032)	(0.039)	(0.045)	
Mean	0.203	0.364	0.231	–
N	5263	5009	5166	
Panel B. Race-based heterogeneity				
White	−0.032	−0.042	−0.072	−0.079
	(0.036)	(0.040)	(0.053)	(0.063)
Mean	0.122	0.199	0.266	0.280
N	6410	6256	6179	2648
Minorities	−0.043[b]	−0.068[b]	−0.084[b]	0.018
	(0.021)	(0.027)	(0.042)	(0.044)
Mean	0.115	0.225	0.216	0.255
N	7640	7450	7297	2615
Panel C. Cohort-based heterogeneity				
Old	−0.047	−0.093[b]	−0.154[b]	−0.130[c]
	(0.033)	(0.040)	(0.064)	(0.076)
Mean	0.120	0.194	0.247	0.373
N	3692	3552	3404	1359
Young	−0.027	−0.040	−0.039	0.021
	(0.022)	(0.027)	(0.035)	(0.041)
Mean	0.116	0.219	0.232	0.228
N	10,556	10,344	10,264	3980

Notes: This table reports the coefficient on ADHD treatment from Eq. (5) estimated on three subpopulations, stratified by gender, race, and birth cohort. Coefficient estimates that are significant at 1%, 5%, and 10% levels are denoted with a, b, and c respectively. Standard errors are in parentheses.

screened for an STD, a 1.8 percentage point decrease in the probability of abusing substances, and a 2.3 percentage point decrease in the probability of being injured, or a reduction of 0.081 injuries in a given year. Our findings for injuries are in line with the findings of Dalsgaard et al. (2014).

The panel analysis results reported in Table 8 are consistent with our cross-section analysis: we find that treatment is associated with a reduction in the probability of contracting an STD, being screened for an STD, and abusing substances. The magnitudes of the coefficients in the yearly effects regressions are complementary rather than directly comparable to the lifetime effects of ADHD treatment. In the former we specifically focus on the periods of the child's continuous enrollment in Medicaid, controlling for the patient's age and other time-varying parameters.

The coefficients on covariates of interest also support the earlier reported results on the lifetime effects of treatment. For the probability of injuries, the signs are as expected. Boys are 2.8 percentage points more likely than girls to have an injury in a given year. Whites are more likely to suffer from most negative health outcomes, including injuries, than Blacks and Hispanics. We posit that this is related to the likelihood of using medical services in general, as discussed earlier.

6.3. *Effects of ADHD treatment on Medicaid spending*

Only occasionally ICD-9 diagnosis codes and CPT procedure codes that we used to identify the incidence of negative health outcomes, are indicative of severity of the underlying condition. It is plausible, however, that ADHD medication has an effect not only on the incidence of the negative health events but also on their severity. A way to address this question is to look at the direct cost to Medicaid of the outcomes that we observe in the data (with an exception of pregnancy). We posit that the more visits are needed and the higher is the bill, the more severe is the patient's condition. If a patient experienced an adverse event, we use Medicaid payments to the providers to calculate the cost of this outcome. The cost is zero if a patient did not experienced a negative health outcome.[30]

Panel A of Table 9 shows the results for the average annual cost to Medicaid over the patients' lifetime enrollment period for STD, STD screening, substance abuse, and injuries. In Panel B, we look at the data in per year terms and control for patient age and other time-varying characteristics. If a patient is treated for ADHD, every patient per year would cost Medicaid \$10.34 (\$20.64) less in STD-related expenses (if we include STD tests); \$93.68 less in substance abuse-related costs, and \$88.37 fewer in injury spending. In relative terms, treatment reduces spending on substance abuse disorders by 0.061 of a standard deviation and injury spending by 0.054 of a standard deviation.

Note that both lifetime and per year effects of treatment on the incidence of STD and STD combined with screening are large and negative, but the effects on costs related to these events are rather modest. This is likely due to the difficulty of measuring STD-related costs. Our STD cost measure only includes expenses related to provider visits. The most billing procedure codes that go along with an STD diagnosis are one-time screening and the visit itself. By construction, STD spending will have no-charge periods with intermittent chargers for STD test and office visit in the absence of pharmacological treatment spending information. Thus, our STD spending measure is understating the effect.

For one of our outcomes, substance abuse, we were able to take advantage of the earlier literature to construct a comprehensive cost measure that includes medical doctor visits and the cost of pharmacological treatment. We are not aware of methodological work that would help us construct the same measure for STDs. This

30 Medicaid payments are CPI-adjusted to 2013 dollars.

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Table 8
Yearly effects of ADHD treatment on health and behavioral outcomes.

	STD		STD+ test		Subst. abuse		Pregnancy		Injury (0/1)		N injuries	
	OLS	IV	OLS	IV	OLS	IV	OLS	IV	OLS	IV	OLS	IV
First stage		0.534^a		0.534^a		0.539^a		0.570^a		0.443^a		0.443^a
		(0.039)		(0.038)		(0.040)		(0.043)		(0.027)		(0.027)
ADHD treatment	−0.004^a	**−0.011^b**	−0.005^b	**−0.019^a**	−0.002	**−0.018^c**	−0.007^b	**−0.003**	−0.006^b	**−0.023^c**	−0.025^a	**−0.081^b**
	(0.001)	**(0.004)**	(0.002)	**(0.006)**	(0.002)	**(0.009)**	(0.003)	**(0.010)**	(0.003)	**(0.013)**	(0.007)	**(0.031)**
Male	−0.028^a	−0.028^a	−0.053^a	−0.053^a	0.009^a	0.011^a	–	–	0.027^a	0.028^a	0.068^a	0.071^a
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)			(0.002)	(0.002)	(0.006)	(0.006)
Race: Black	−0.001	−0.002	0.005^b	0.004	−0.018^a	−0.020^a	−0.007^b	−0.007^c	−0.047^a	−0.049^a	−0.129^a	−0.134^a
	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.004)	(0.003)	(0.003)	(0.007)	(0.007)
	−0.010^c	−0.011^c	−0.007	−0.008	−0.027^a	−0.029^a	−0.023^c	−0.022^c	−0.070^a	−0.072^a	−0.144^a	−0.152^a
	(0.006)	(0.006)	(0.007)	(0.007)	(0.007)	(0.007)	(0.012)	(0.012)	(0.009)	(0.009)	(0.021)	(0.021)
N adults	−0.002	−0.001	−0.030^a	−0.030^a	−0.007^a	−0.007^a	−0.012^a	−0.012^a	0.009^a	0.009^a	0.017^a	0.017^a
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)	(0.004)	(0.004)
N children	0.001	0.001	−0.002	−0.004	−0.001	−0.001	0.010^a	0.010^a	0.002	0.001	−0.001	−0.002
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.002)	(0.002)
Family income	−0.002^b	−0.002^b	−0.003^a	−0.003^a	−0.006^a	−0.006^a	−0.011^a	−0.011^a	−0.008^a	−0.008^a	−0.018^a	−0.018^a
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.001)	(0.001)	(0.003)	(0.003)
Mean outcome	0.024		0.046		0.050		0.055		0.266		0.464	
N obs.	68,378		64,622		64,328		25,666		266,181		266,181	

Notes The main coefficient estimates (in bold) in this table can be interpreted as the average annual effect of treatment on the probability of a post-diagnosis negative health outcome. Treatment is defined as treated within a year of the individual's ADHD diagnosis. All specifications include individual's county of residence fixed effects, year fixed effects, and their interactions. We also control for the individual's disability and foster care status. The coefficients on the number of children and adults in the family are scaled up by 10 in the STD and STD screening regressions in order to report their magnitudes. First stage coefficient shows the relationship between treatment receipt and physician propensity to prescribe medication. Negative health outcomes are considered a year or more after the individual's ADHD diagnosis. All specifications except for injuries are estimated on a subsample of relevant birth cohorts of SC Medicaid enrollees and include individuals born between 1987 and 1996. Coefficient estimates that are significant at 1%, 5%, and 10% levels are denoted with a, b, and c respectively. Standard errors are in parentheses. They are clustered by individual's provider who diagnosed them with ADHD.

might explain the fact that the results on the incidence and cost of substance abuse are better aligned than the results for STD.

OLS estimates that we present for comparison purposes, have the same sign as the IV estimates, but are mostly noisy.

7. Robustness

We perform several robustness checks. First, we test the sensitivity of the results to alternative definitions of pharmacological treatment. Our findings have the same signs on the coefficients of interest and differ from the baseline specification results in an expected way. Second, we introduce two alternative instrumental variables: the first-in-data provider propensity to prescribe and a geographic instrument based on child's school location. The alternative IVs would be expected to have weaker explanatory power but they are arguably more exogenous. Both instruments provide evidence compatible with our preferred instrument. The summary of the results is shown in Table 10. Each row represents the three different treatment definitions; and reports both the first stage coefficient and the coefficient on treatment instrumented with an alternative IV and our preferred instrument for comparison purposes.

Table 9
Effects of ADHD treatment on the costs of ADHD-associated negative health outcomes to Medicaid.

	STD		STD+ test		Subst. abuse		Injury	
	OLS	IV	OLS	IV	OLS	IV	OLS	IV
Panel A: Effects of ADHD treatment on Medicaid costs of negative health outcomes per year of enrollment								
First stage		0.539^a		0.539^a		0.539^a		0.458^a
		(0.032)		(0.032)		(0.032)		(0.025)
Treatment	−2.81	**8.76**	−6.84	**1.95**	−27.83	−162.70^b	−17.79	**−58.13**
	(6.250)	**(16.05)**	(6.26)	**(17.04)**	(21.13)	**(79.15)**	(11.12)	**(39.75)**
Mean outcome	20.18		34.83		224.13		191.38	
	(251.72)		(261.26)		(1028.60)		(1145.76)	
N obs.	9575		9575		9575		58,405	
Panel B: Yearly effects of ADHD treatment on Medicaid costs of negative health outcomes (Panel)								
First stage		0.540^a		0.540^a		0.540^a		0.438^a
		(0.037)		(0.037)		(0.037)		(0.027)
Treatment	−6.31	**−10.34**	−8.53^c	−20.64^c	−19.11	−93.68^c	−26.23	−88.37^b
	(4.65)	**(10.96)**	(4.35)	**(11.63)**	(14.25)	**(50.78)**	(10.33)	**(36.96)**
Mean outcome	17.85		31.37		158.84		191.29	
	(328.97)		(345.42)		(1524.39)		(1647.51)	
N obs.	74,016		74,016		74,016		233,149	

Notes: The main coefficient estimates (in bold) in Panel A can be interpreted as the effect of treatment within a year of the individual's ADHD diagnosis on the average cost of ADHD-related post-diagnosis negative health outcomes to Medicaid per year of uninterrupted individual's enrollment. In Panel B, we control for time-varying characteristics and the coefficients can be interpreted as the effect of ADHD treatment within a year of the individual's ADHD diagnosis on the average annual cost of negative health outcomes to Medicaid. All specifications in Panel B include individual county of residence fixed effects, year fixed effects, and their interactions. Medicaid spending is adjusted to 2013 dollars. First stage coefficients show the relationship between treatment receipt and physician propensity to prescribe medication. All specifications except for injuries are estimated on a subsample of relevant birth cohorts of SC Medicaid enrollees and include individuals born between 1987 and 1996 who were eligible for Medicaid at age of 11 years old or later. Coefficient estimates that are significant at 1%, 5%, and 10% levels are denoted with a, b, and c respectively. Standard errors are in parentheses. They are clustered by individual's provider who diagnosed them with ADHD.

Table 10
Robustness: alternative instrumental variable and treatment definitions.

Treatment definition	STD			STD+test			Subst. abuse		
	Baseline	1st provider	School PP	Baseline	1st provider	School PP	Baseline	1st provider	School PP
Baseline: 1+ Rx within the 1st year									
First stage	0.517[a]	0.123[a]	0.092[a]	0.512[a]	0.123[a]	0.089[a]	0.516[a]	0.126[a]	0.093[a]
	(0.014)	(0.018)	(0.014)	(0.014)	(0.018)	(0.015)	(0.014)	(0.018)	(0.015)
ADHD treatment	−0.036[c]	−0.041	−0.091	−0.058[b]	−0.126	−0.195	−0.073[b]	−0.046	−0.082
	(0.020)	(0.099)	(0.116)	(0.023)	(0.110)	(0.146)	(0.040)	(0.149)	(0.147)
Ever treated									
First stage	0.468[a]	0.122[a]	0.085[a]	0.463[a]	0.122[a]	0.083[a]	0.465[a]	0.122[a]	0.088[a]
	(0.014)	(0.018)	(0.014)	(0.014)	(0.018)	(0.014)	(0.014)	(0.018)	(0.014)
ADHD treatment	−0.040[c]	−0.042	−0.098	−0.064[b]	−0.127	−0.210	−0.081[b]	−0.046	−0.087
	(0.021)	(0.099)	(0.125)	(0.026)	(0.111)	(0.158)	(0.040)	(0.150)	(0.155)
6+ Rx ever (Dalsgaard et al., 2014)									
First stage	0.200[a]	0.071[a]		0.201[a]	0.071[a]		0.199[a]	0.071[a]	
	(0.013)	(0.017)		(0.014)	(0.017)		(0.014)	(0.017)	
ADHD treatment	−0.088[c]	−0.072		−0.130[b]	−0.218		−0.145	−0.079	
	(0.051)	(0.172)		(0.060)	(0.202)		(0.094)	(0.256)	
N obs.	14,248	7338	12,299	13,896	7338	12,183	13,668	7338	12,178

Notes: "Baseline" column contains estimates for our preferred instrument — diagnosing provider propensity to prescribe. First provider IV uses prescribing preferences of the first-in-data provider. Coefficient estimates that are significant at 1%, 5%, and 10% levels are denoted with *a*, *b*, and *c* respectively. Standard errors are in parentheses. Standard errors are clustered by diagnosing provider for specification using diagnosing provider propensity to prescribe; standard errors are clustered by first provider for specification using first-in-data provider propensity to prescribe.

7.1. Alternative definition of treatment

Pharmacological treatment can be defined in a number of ways. Our baseline definition considers an individual as treated if they have a record of taking any medication approved for ADHD within a year of their ADHD diagnosis. Alternatively, we could assign the treated status to individuals who ever take a prescription after their ADHD diagnosis. Whereas our baseline definition of treatment assumes that the instrument only has an effect on treatment receipt within a year of the individual's ADHD diagnosis (and has no effect on outside treatment channels), this definition of treatment requires a less strict assumption of the exclusion restriction. The relationship between the provider propensity to prescribe medication and treatment under this definition is weaker, as expected (Table 10). The estimation yields relatively larger point estimates for treatment in absolute value compared to our baseline specification. This result might be explained by the fact that 7% patients receive treatment later than a year since the initial diagnosis and did not experience negative outcomes, but are being coded as never treated in our baseline specification.

For the second test, we follow earlier literature (see Dalsgaard et al., 2014) and assign treatment status to the individuals who were treated for at least 6 months in a given year. This definition captures the idea of the importance of treatment adherence. Indeed, one prescription would not cure or even alleviate the condition, but half a year of treatment is more likely to have an impact on the child's health and behavioral outcomes. Again, by construction, the instrument based on patient adherence has a weaker predicting power of a

Table 11
Summary statistics: individual and family characteristics; undiagnosed children.

	N obs.	Mean	Median	SD	Min	Max
Individual characteristics						
Age 1st in sample	134,075	7.83	8.00	5.02	1	19
Male	134,075	0.45			0	1
Race: White	134,075	0.35			0	1
Black	134,075	0.55			0	1
Hispanic	134,075	0.05			0	1
Family & home environment						
Monthly family net income	134,075	717.06	573.5	660.72	0	6356
Number of adults	134,075	1.25	1.14	0.58	0	3
Number of children	134,075	2.07	2.00	1.06	0	6
Ever in foster care	134,075	0.04			0	1
Ever had disability	134,075	0.05			0	1
Mother's characteristics						
Age when gave birth	73,923	23.60	22.00	5.62	11	48
Educ: Less than HS	73,923	0.06			0	1
Some HS	73,923	0.33			0	1
HS diploma	73,923	0.42			0	1
Some college	73,923	0.14			0	1
College degree or higher	73,923	0.05			0	1

Notes: The sample includes a random group of SC Medicaid enrollees, who were eligible for Medicaid for at least one year at any age between 3 and 18years old in 2003–2013 and who did not have an ADHD-related medical history during this time period. Family characteristics are reported on average per patient/eligibility year. Foster care and disability rates are calculated based on the Medicaid enrollment categories. Mother characteristics are reported based on in-state birth certificate information matched to Medicaid records. They are available only for a subsample of the 73,923 patients. Mother's age and educational attainment are recorded at the time of the child's birth. "HS" stands for high school education level.

Table 12
Summary statistics: negative health outcomes; undiagnosed children.

	N obs.	Mean	Median	SD	Min	Max
Years in sample	134,075	6.72	6.00	3.08	1	11
Outcome: risky sexual behavior						
1. Teen Pregnancy						
Age at 1st pregnancy	19,750	17.47	18.00	1.42	11	19
Race: White	19,750	0.42			0	1
Black	19,750	0.53			0	1
2. STD						
Age at 1st STD	14,687	16.02	17.00	2.46	11	19
Age at 1st STD (incl. screening)	26,334	16.33	17.00	2.21	11	19
Male	14,687	0.23			0	1
Race: White	14,687	0.38			0	1
Black	14,687	0.56			0	1
Annual cost of STD	14,687	397.61	143.49	1283.26	1	90,461
Annual cost of STD+ test	26,334	341.62	169.70	932.95	1	90,461
Outcome: substance abuse						
Age at 1st substance abuse	15,073	16.53	17.00	1.92	11	19
Male	15,073	0.47			0	1
Race: White	15,073	0.50			0	1
Black	15,073	0.45			0	1
Annual cost of substance abuse	15,073	1501.46	439.32	3736.11	1	109,293
Outcome: injuries						
Ever injured	134,075	0.86			0	1
Age at injury	115,526	10.92	11.00	4.41	3	19
Male	115,526	0.48			0	1
Race: White	115,526	0.39			0	1
Black	115,526	0.51			0	1
N of injury claims	134,075	0.36	0.25	0.42	0	11
Annual cost of injuries	115,526	702.09	213.11	3463.53	2	394,516

Notes: The sample includes a random group of SC Medicaid enrollees, who were eligible for Medicaid for at least one year at any age between 3 and 18years old in 2003–2013 and who did not have an ADHD-related medical history during this time period. Annual costs of negative health outcomes are given in 2013 dollars per patient/year conditional on the occurrence of a negative health outcome. They are based on the Medicaid reimbursement. The out-of-pocket patient costs are nearly zero for our population of interest.

take up of any treatment than the baseline IV (Table 10). Perhaps not surprising, when we define the treated population as only those who adhere to treatment for six months, we find treatment to be more effective.

We present these results for comparison purposes and we argue that our baseline definition of treatment accounts for the timing of treatment and occurrence of negative health events. Under the definition of "ever treated", we can not exclude a possibility that some individuals would be first diagnosed with ADHD, then experience an adverse outcome, and only then receive treatment. The other alternative treatment definition, "filling 6 prescriptions or more in a given year", is hard to defend against the argument that the provider might influence adherence to treatment and health outcomes through channels other than the act of simply prescribing medication. In other words, our IV estimates can be interpreted as a lower bound on the effects of treatment on negative health outcomes.

Table 13
Evidence of treatment shopping: predictors of provider switching

Regressors	Coeff	SE
"Extreme" provider	0.020[a]	0.004
Race: Black	−0.001	0.004
Hispanic	−0.009	0.012
Other	−0.010	0.007
Mother's Educ: Some HS	0.010	0.008
HS degree	−0.001	0.008
Some college	−0.001	0.009
College degree or higher	0.008	0.010
Family net income	0.0003	0.002
Number of children	−0.006[a]	0.002
Number of adults	−0.006[b]	0.003
N obs.	42,693	
R^2	0.016	

Notes: The dependent variable is equal to 1 if an individual switches providers; 0 otherwise. The variable "extreme" provider is equal to 1 if the individual's first provider diagnoses all of his patients or none of his patients; 0 otherwise. Coefficient estimates that are significant at 1%, 5%, and 10% levels are denoted with a, b, and c respectively.

7.2. Alternative instrumental variables

We construct two alternative instrumental variables and test them on the treatment definitions described above. First, we calculate provider propensity to prescribe index for the the first-in-data provider rather than the diagnosing provider. The purpose behind this IV is to address potential concerns about the provider selection based on the probability they would prescribe medication. We argue that children visit their pediatrician or family physician routinely, for most health issues, including ADHD, rather than selecting a specific provider to go to with ADHD-related concerns. We calculate a measure of prescribing preferences for the first-in-data provider based on all patients with ADHD the provider diagnosed in that year. Note that not all providers have patients with ADHD every year and there is also a significant provider mobility in and out of Medicaid. For this reason, we do not have a first-in-data provider propensity to prescribe for everyone who was diagnosed with ADHD in our sample.

In line with our main specification findings, the results utilizing the first-in-data provider preferences suggest that treatment reduces the probability of STD contraction, STD screening, and substance abuse disorders (Table 10). A smaller sample size likely explains the increase in the noisiness of our coefficient estimates. These results provide additional support to the evidence we presented on the absence of provider selection (Section 5).

Next, we define a geographic area-based alternative instrument. It is constructed using the school a patient is attending. We take the fraction of other students treated with medication divided by the total number of students diagnosed with ADHD in the individual's

Table 14
Summary statistics: switchers.

Variable	$PP_1 > PP_2$ Mean	SD	N obs.	$PP_1 < PP_2$ Mean	SD	N obs.
Mother's educ: less than HS	0.042	0.200	1,635	0.047	0.211	2,486
Some HS	0.391	0.488	1,635	0.395	0.489	2,486
HS degree	0.376	0.484	1,635	0.385	0.487	2,486
Some college	0.125	0.331	1,635	0.125	0.331	2,486
College degree	0.065	0.246	1,635	0.048	0.214	2,486
Mother's age	23.691	5.614	1,646	23.356	5.409	2,504
Family net income	0.518	0.756	2,262	0.541	0.778	3,291
Number of children	1.971	1.088	2,262	2.028	1.086	3,291
Number of adults	0.912	0.742	2,262	0.929	0.753	3,291

Notes: This table reports summary statistics for individuals who switch providers. PP_1 stands for the first (diagnosing) provider propensity to prescribe, and PP_2 stands for the individuals' subsequent provider propensity to prescribe.

year of diagnosis at the school. The results suggest that treatment reduces the probability of STD contraction, STD screening, and abusing substances, however the estimates are noisy likely due to the relatively weaker first stage. The first stage estimates are statistically weak for treatment defined as treated for at least 6 months in a given year and for this reason are not reported.

8. Conclusion

This paper investigates the effectiveness of ADHD medication in reducing the probability of short-term and long-term negative health outcomes associated with the disorder. Over the past decade, SC Medicaid spending on prescription drugs increased nearly threefold to $69 million in 2013. It is important to understand whether the increased expenditures on treatment produced any benefit in terms of improved health (fewer and less severe injuries), reduction in risky behaviors that potentially lead to teen pregnancies, STDs, and substance use and abuse. The focus population of our study are children from relatively disadvantaged families who are enrolled in SC Medicaid and who are diagnosed with ADHD. This population is particularly vulnerable: up to a quarter of Medicaid enrollees are diagnosed with ADHD in their birth cohort. Although we are unable to make a statement on the effectiveness of ADHD treatment in general population, our sample represents a large fraction of the state population, and an even larger fraction of diagnosed children. Since children on Medicaid are disproportionately diagnosed with ADHD and their incentives are distorted in the absence of a drug price tag, this population should be of primary focus.

Our panel data set includes all SC Medicaid claims between 2003 and 2013. To overcome potential endogeneity of treatment take-up, we use variation in physician prescribing preferences for ADHD. Our findings suggest that ADHD medication is effective in reducing the probability of the negative health and behavioral outcomes that we are able to identify in administrative data. Based on our preferred specification, over the course of teenage years the probability of contracting an STD decreases by 3.6 percentage points; an individual is 5.8 percentage points less likely to be screened for an STD/have a condition; and 7.3 percentage points less likely to receive medical attention related to a substance abuse disorder if treated with ADHD medication. The point estimate on the probability of teenage pregnancy is also negative (−2.3 percentage points) but not statistically significant.

Table 15
Lifetime effects of ADHD treatment on negative health and behavioral outcomes; with mother characteristics.

	STD		STD+ test		Subst. abuse		Pregnancy	
	OLS	IV	OLS	IV	OLS	IV	OLS	IV
First stage		0.535[a]		0.530[a]		0.544[a]		0.575[a]
		(0.020)		(0.020)		(0.020)		(0.031)
ADHD treatment	−0.018[b]	**−0.024**	−0.022[b]	**−0.046**	−0.011	**−0.057**	−0.040[b]	**0.004**
	(0.008)	**(0.026)**	(0.010)	**(0.030)**	(0.012)	**(0.041)**	(0.017)	**(0.047)**
Male	−0.120[a]	−0.120[a]	−0.203[a]	−0.202[a]	0.045[a]	0.048[a]	–	–
	(0.009)	(0.009)	(0.011)	(0.011)	(0.010)	(0.010)		
Race: Black	−0.021[b]	−0.022[b]	0.022[c]	0.019	−0.073[a]	−0.078[a]	−0.026	−0.020
	(0.009)	(0.010)	(0.012)	(0.013)	(0.012)	(0.012)	(0.018)	(0.019)
Hispanic	−0.037	−0.038	−0.046	−0.050	−0.170[a]	−0.179[a]	−0.191[b]	−0.173[b]
	(0.035)	(0.035)	(0.044)	(0.044)	(0.051)	(0.051)	(0.080)	(0.081)
Other	−0.031[c]	−0.032[c]	−0.024	−0.026	−0.098[a]	−0.102[a]	−0.102[b]	−0.099[b]
	(0.018)	(0.018)	(0.024)	(0.024)	(0.024)	(0.024)	(0.040)	(0.040)
Number of adults	−0.009	−0.009	−0.019[b]	−0.019[b]	−0.005	−0.004	−0.005	−0.006
	(0.006)	(0.006)	(0.008)	(0.008)	(0.008)	(0.008)	(0.013)	(0.012)
Number of children	0.002	0.002	0.012[a]	0.012[a]	0.009	0.009	0.038[a]	0.038[a]
	(0.003)	(0.003)	(0.004)	(0.004)	(0.006)	(0.006)	(0.008)	(0.008)
Family net income	−0.001]	−0.001	−0.008	−0.008	−0.023[a]	−0.023[a]	−0.025[b]	−0.025[b]
	(0.005)	(0.005)	(0.007)	(0.007)	(0.006)	(0.006)	(0.011)	(0.011)
Mean outcome	0.117		0.221		0.237		0.220	
N obs.	6,815		6,694		6,656		2,519	

Notes: The main coefficient estimates (in bold) in this table can be interpreted as the effect of treatment within a year of the individual's ADHD diagnosis on the probability of a negative health outcome during an individual's adolescence. All specifications include individual's county of residence and birth year fixed effects. We also control for the individual's age of the first ADHD diagnosis, Medicaid eligibility timing and length, disability and foster care status, mother's educational attainment, and age when she gave birth. First stage coefficients show the relationship between treatment receipt and physician propensity to prescribe medication. All specifications are estimated on a subsample of relevant birth cohorts of SC Medicaid enrollees and include individuals born between 1987 and 1996. Coefficient estimates that are significant at 1%, 5%, and 10% levels are denoted with a, b, and c respectively. Standard errors are in parentheses. They are clustered by individual's provider who diagnosed them with ADHD.

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Table 16
Lifetime effects of ADHD treatment on outcomes; children with mental health condition prior to ADHD diagnosis.

	Control				Exclude			
	STD	STD+ test	Subst. abuse	Pregn.	STD	STD+ test	Subst. abuse	Pregn.
ADHD treatment	−0.036[c]	−0.059[b]	−0.068[c]	**−0.013**	**−0.034**	−0.079[b]	**−0.011**	**−0.080**
	(0.019)	**(0.023)**	**(0.036)**	**(0.038)**	**(0.025)**	**(0.033)**	**(0.040)**	**(0.052)**
Male	−0.120[a]	−0.205[a]	0.041[a]	–	−0.120[a]	−0.198[a]	0.042[a]	–
	(0.007)	(0.008)	(0.008)		(0.009)	(0.010)	(0.011)	
Race: Black	−0.012[c]	0.011	−0.081[a]	−0.020	−0.020[b]	0.009	−0.066[a]	−0.037[c]
	(0.007)	(0.009)	(0.010)	(0.014)	(0.008)	(0.011)	(0.012)	(0.019)
Hispanic	−0.044[b]	−0.036	−0.115[a]	−0.071[c]	−0.040	−0.034	−0.077[b]	−0.063
	(0.021)	(0.025)	(0.025)	(0.036)	(0.030)	(0.033)	(0.031)	(0.048)
Other	−0.019[c]	−0.032[b]	−0.096[a]	−0.069[a]	0.012	−0.013	−0.082[a]	−0.031
	(0.011)	(0.014)	(0.017)	(0.024)	(0.020)	(0.025)	(0.025)	(0.042)
Number of adults	−0.007[c]	−0.016[a]	−0.015[a]	−0.012	0.001	−0.011[c]	−0.011[c]	−0.006
	(0.003)	(0.005)	(0.006)	(0.008)	(0.005)	(0.006)	(0.007)	(0.012)
Number of children	0.007[a]	0.011[a]	0.010[a]	0.035[a]	0.005	0.014[a]	0.006	0.024[a]
	(0.003)	(0.003)	(0.003)	(0.005)	(0.004)	(0.005)	(0.004)	(0.007)
Family net income	−0.002	−0.009	−0.027[a]	−0.023[a]	−0.004	−0.009	−0.024[a]	−0.010
	(0.004)	(0.005)	(0.005)	(0.007)	(0.005)	(0.006)	(0.006)	(0.010)
Mental health condition	−0.001	−0.004	0.017[b]	0.034[a]	–	–	–	–
	(0.006)	(0.008)	(0.008)	(0.012)				
Mean outcome	0.117	0.212	0.236	0.265	0.115	0.207	0.224	0.254
N obs.	14,248	13,896	13,668	5,339	7,509	7,408	7,472	2737

Notes: The main coefficient estimates (in bold) in this table can be interpreted as the effect of treatment within a year of the individual's ADHD diagnosis on the probability of a negative health outcome during an individual's adolescence. All specifications include individual county of residence and birth year fixed effects. We also control for the individual's age and net family income at first ADHD diagnosis, length of Medicaid eligibility, disability, comorbid conditions, and foster care status. First stage coefficients show the relationship between treatment receipt and physician propensity to prescribe medication. All specifications are estimated on a subsample of relevant birth cohorts of SC Medicaid enrollees and include individuals born between 1987 and 1996. Coefficient estimates that are significant at 1%, 5%, and 10% levels are denoted with a, b, and c respectively. Standard errors are in parentheses. They are clustered by individual's provider who diagnosed them with ADHD.

Controlling for time-varying characteristics, these findings translate into a 1.1 percentage point decrease in the probability of contracting an STD, a 1.9 percentage point decrease in the probability of being screened for an STD, a 1.8 percentage point decrease in the probability of abusing substances, and a 2.3 percentage point decrease in the probability of being injured, or 0.081 reduction in the number of injury-related medical procedures in a given year.

These results generally agree with the findings of Dalsgaard et al. (2014), who find that medication is effective in reducing the number of hospital contacts and the likelihood of criminal activity. However, Currie et al. (2014) find that an increase in medication use is associated with negative effects on children's educational outcomes, deterioration in relationships with parents, and increase in the probability of depression. These differences are suggestive of ADHD medication having varying effects on noncognitive human capital in comparison to cognitive abilities.

It is plausible to suggest that ADHD medication has an effect not only on the incidence of negative health outcomes but also on their severity. We go beyond the existing literature and address this question by looking at the direct cost to Medicaid of all outcomes that we observe in the data (except for pregnancy). We posit that the more visits are needed and the costlier they are, the more severe is the patient's condition. For every patient treated for ADHD, each year of eligibility would cost Medicaid an estimated $10.34 ($20.64) less in STD-related expenses (if we include STD tests); $93.68 less in substance abuse-related costs and $88.37 in injury spending. In per year terms, when we control for patient age and other time-varying characteristics, the results tell the same story and are very similar in magnitude.

The limitations of this study that we hope to address in future research include the scope of the effects of interest and external validity. First, our results reflect the effect of treatment of a marginal patient and do not attempt to measure the benefit of pharmaceutical treatment for children with ADHD that will inevitably be treated. Second, although our sample of Medicaid children makes up a large proportion of the population diagnosed with ADHD, the results are not necessarily generalizable to the non-Medicaid population. At the same time, the population in our study is the most affected by the negative health outcomes that children with ADHD are prone to, which makes our findings even more policy-relevant.

On average, SC Medicaid spent $347 for prescription medication and $562 on ADHD-related physician visits, including behavioral therapy, while the total savings across all negative health outcomes summed up to $221 on average per child per year. However, these "savings" do not include the costs associated with teenage pregnancies, any indirect benefits that stem from preventing negative health and behavioral outcomes, or any indirect benefits that accrue to the patients' peers. We are also not able to estimate costs of side effects of the medication. With the increasing rates of ADHD diagnosis and respective government spending on programs like Medicaid as well as Medicaid expansion, comparison of treatment costs and benefits deserve special investigation in future work.

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