Economic Inquiry

RISING AUTISM PREVALENCE: REAL OR DISPLACING OTHER MENTAL DISORDERS? EVIDENCE FROM DEMAND FOR AUXILIARY HEALTHCARE WORKERS IN CALIFORNIA

DHAVAL M. DAVE and JOSE M. FERNANDEZ*

Autism is a development disorder that has increased in prevalence from 0.5 to 14.7 per 1,000 children over 1970–2010. Using annual wages and provider counts from the American Community Survey and information from 21 regional development centers in California, we estimate the labor demand for auxiliary health providers. We focus on this subset of providers because, unlike physicians and psychologists who can diagnose autism, these workers cannot induce their own demand. If the incidence of autism is increasing independently of other mental disorders, then the demand for auxiliary health providers should increase, leading to higher wages and labor supply. Otherwise, the increase in autism diagnosis is merely displacing other mental disorders. We find that a 100% increase in autism cases increases the wages of auxiliary health workers over non-autism health occupations by 8–11% and the number of providers by 9–14%. Furthermore, we find that one of every three new autism diagnoses is merely supplanting mental retardation diagnoses, but does not displace other mental disorders. These estimates suggest that at least part of the increase in autism diagnoses, about 50–65%, reflects an increase in the true prevalence of the disorder. (*JEL* L11, J2, J3)

I. INTRODUCTION

Autism is a developmental disorder characterized by impairments in social interaction, communication, and restricted or repetitive behaviors (American Psychiatric Association 1994). The previously rare condition has experienced a dramatic increase among 8-year-old children with a prevalence of 0.5 in 1,000 children during the 1970s to 14.7 in 1,000 children in 2010 (Baio 2014).[1] Currently, autism is only second to mental retardation (MR) as the most commonly diagnosed developmental disability (Bhasin et al. 2006; Yeargin-Allsopp et al. 2003). Furthermore, the cost associated with caring for individuals with autism is not trivial. The annual costs of care for a child with autism are estimated to be 85%–550% higher than the cost for a typically developing child and the average

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Dave: Department of Economics, Bentley University & National Bureau of Economic Research (NBER), Waltham, MA 02452-4705. Phone 781-891-2268, Fax 917-426-7015, E-mail ddave@bentley.edu

Fernandez: Department of Economics, College of Business, University of Louisville, Louisville, KY 40292. Phone 502-852-4861, Fax 502-852-7672, E-mail jose.fernandez@louisville.edu

1. Self-reported parent surveys place the prevalence rate at 2% for school-age children in 2012 (Blumberg et al. 2013).

ABBREVIATIONS

ABA: Applied Behavioral Analysis
ACS: American Community Survey
ADD: Attention Deficit Disorder
ADHD: Attention Deficit Hyperactivity Disorder
BLS: Bureau of Labor Statistics
DD: Difference-In-Differences
DDD: Difference-In-Difference-In-Differences
DDS: Department of Developmental Services
MR: Mental Retardation
NCHS: National Center for Health Statistics
NIMH: National Institute of Mental Health
NS-CSHCN: National Survey of Children with Special Health Care Needs
OLS: Ordinary Least Squares
PDD-NOS: Pervasive Developmental Delay-Not Otherwise Specified
PUMA: Public Use Microdata Area
PUMS: Public Use Microdata Sample

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lifetime public expenditures are approximately \$4.7 million (Guevara et al. 2003; Jacobson and Mulick 2000). This increase in prevalence, compounded with the cost of care, has prompted many researchers to investigate various factors that could potentially explain the cause of such an increase.

The three leading factors are an increase in environmental toxins,[2] de novo[3] gene mutations caused by older parental age at birth, and a change in diagnosis determinants. The latter factor has led to much debate in the medical community as researchers cannot agree on the true incidence level of autism. The diagnosis of autism poses a difficult challenge to clinicians in that there are no biological markers and many of the observable characteristics are shared with other mental disorders such as MR and attention deficit disorder (ADD). For example, King and Bearman (2009) found that roughly 25% of the increased prevalence of autism is associated with a diagnostic change in determining MR. Bishop et al. (2008) studied adults with a history of developmental language disorder and found that one-third of adults previously diagnosed with this disorder would have been diagnosed with autism using contemporary techniques.

In this study, we use economic theory to help shed some light on the debate. If the incidence of autism is increasing independently of other mental disorders (such as MR), then the demand for auxiliary health providers (e.g., speech pathologist, behavioral therapist, occupational therapist, etc.) should increase, leading to higher wages and labor supply for these providers as well as an increase in the number of providers. However, if the increase in autism diagnosis is merely displacing other mental disorders, then the effects of the increase on demand will be mitigated or not present as individuals are only changing diagnostic labels but maintaining the same level of services demanded. We construct an econometric model to distinguish between these two effects.

Using data from the California Department of Developmental Services, we study how changes in the number of autism cases at each of the 21 regional development centers affected local wages, labor supply, and quantity of auxiliary health providers. We focus on this subset of health providers because, unlike physicians and psychologists who can diagnose autism, these workers cannot induce their own demand.[4] Using data from the regional development centers, we estimate that one-third of the increase in autism stems from displacing MR diagnoses, but not other mental disorders, which is consistent with previous studies (Coo et al. 2008; King and Bearman 2009). Using annual wages and provider counts from the American Community Survey (ACS) from 2005 to 2011 (referencing 2004–2010), we find that a 100% increase in the number of autism cases at a regional center, which is approximately the average increase experienced in CA over the sample period, raises the wages of auxiliary healthcare workers over non-autism healthcare occupations by 8%–11%; additionally, the number of providers increases by 9%–14% over the following 2 years.

II. BACKGROUND

Autism is a developmental disorder that limits an individual's ability to form social relations and appropriately respond to environmental stimuli. The prevalence of autism in the United States has increased rapidly over the last 30 years. In California, the number of autism cases increased by 1,148% between 1987 and 2007, which is remarkable considering that cerebral palsy increased by 73%, epilepsy by 66%, and MR by 95% over the same time period (Cavagnaro 2007). However, the co-morbidity rate between autism and MR has fallen from 79.6% in 1987 to 35.6% in 2007, which differs from national trends ranging now between 40% and 55% (American Psychiatric Association 2000; ASD Best Practice Guidelines 2002; Chakrabarti and Fombonne 2001).

A confounder in distinguishing between autism and mild MR arises when the child presents speech delay, rendering important IQ measurements useless. When initial testing does not present a clear diagnosis, physicians often label the child as having "developmental delay," which is the same categorization used for autistic children prior to a diagnosis. MR is disaggregated into severity levels by IQ: mild (70–50), moderate (49–35), severe (34–25), and profound (less than 25). According to the American Academy of Family Physicians, mild MR represents nearly

2. Waldman et al. (2008) find an association between increases in precipitation and increases in autism prevalence.

3. De novo mutations are deletions, insertions, and duplications of DNA in the germ cells (sperm or egg) that are not present in the parents' DNA.

4. See Fuchs (1978) for a theory of physician-induced demand.

75% of all MR cases. These individuals may have no unusual physical signs and may be able to perform practical tasks, which are two traits shared with most cases of autism. However, autism is not bounded by IQ restrictions, and an individual with mild MR is still capable of appropriate social interaction.

We highlight both the rise in reported autism cases as well as the trade-off between autism and MR as these relationships are at the center of much debate. Grinker (2007) argues that the true prevalence of autism is not rising. Rather, physicians are finally diagnosing autism correctly. The author cites five factors causing the rise in autism cases: (1) broader definition of autism; (2) a change in school policy allowing autistic students to receive special education in 1992; (3) the decreased stigma associated with an autism diagnosis reducing the number of under-reported cases; (4) states started to allow families with autistic children to apply for Medicaid funds regardless of family income leading more families to seek care and more physicians to "up-code" patients so they can receive funding (an advantage not readily available for a diagnosis of MR); and (5) relabeling, where due to the broadening of the autism diagnosis fewer cases are misdiagnosed into other mental disorders such as MR and attention deficit hyperactivity disorder (ADHD).

Mental disorders have a history of under-reporting and misdiagnosis. Elder (2010) uses regression discontinuity methods to compare ADHD diagnosis between students who are slightly above and below the birthday enrollment cutoff for kindergarten and finds that approximately 20% of children who use stimulants intended to treat ADHD are misdiagnosed. Epilepsy is found to have a misdiagnosis rate of 26.1% in adults (Smith et al. 1999) and 39% in children (Uldall et al. 2006).

A similar pattern is observed with autism. Autism was first recognized as a disorder associated with schizophrenia beginning in 1911 (Bleuler 1912). This association continued well through the 1960s. Autism is later categorized into four individual disorders comprising the autism spectrum: Rett syndrome, Asperger syndrome, Autistic disorder, and pervasive developmental delay-not otherwise specified (PDD-NOS).

PDD-NOS is the primary source of growth within the spectrum and could be the source of misdiagnoses. Tomanik et al. (2007) run an experiment where independent physicians are asked to review cases for autism. There are two groups of patients, 77 autistic patients and 52 non-autistic patients. The authors find that 21.2% of individuals who are not classified as autistic receive an autism diagnosis and 23.4% of autistic individuals are not diagnosed with autism. With respect to under-reporting, Liu et al. (2010) find the reduction in stigma associated with autism has led to a 16% increase in the number of reported cases between 2000 and 2005. Furthermore, autism diagnosis rates can differ based on demographic characteristics. Mandell et al. (2002) use administrative data for Medicaid patients in Philadelphia and find that African American children receive an autism spectrum disorder diagnosis nearly 2 years later than Caucasian children, on average.

The displacement effect of autism has been previously studied. As noted above, King and Bearman (2009) find a 25% displacement rate of autism on MR diagnoses. Coo et al. (2008) report that one-third of the diagnoses of autism from 1996 to 2004 in British Columbia, Canada resulted in a switch from a diagnostic category other than autism to autism. Nassar et al. (2009) also report diagnostic substitution. They note that as incidents of severe intellectual disability decreased by 10% in the state of Washington (USA), rates of autism increased by an average of 22%. Shattuck (2006) analyzes administrative data from the U.S. special education system for students between the ages of 6 and 11 years and compares how changes in the administrative prevalence of autism versus other mental disorders affect the demand for special education classes. The author finds that the average administrative prevalence of autism among children increased from 0.6 to 3.1 per 1,000 from 1994 to 2003, whereas the prevalence of MR and learning disabilities declined by 2.8 and 8.3 per 1,000, respectively, over the same time period. The increased administrative prevalence in autism is concluded to be offset by the decrease in prevalence in other mental disorder categories.

III. METHODS

The primary aim of this study is to assess whether, and to what extent, the increase in autism diagnoses impacts the demand for auxiliary healthcare workers. As these workers do not diagnose autism, in contrast to physicians and psychologists, they cannot induce their own demand.[5] Any shift in autism diagnoses in the area therefore represents an exogenous shift in the demand for their services. In the short term, this potential increase in demand would be reflected in the form of higher wages and salary among these workers, likely because of increased work effort and/or a higher price for their services. This may also induce a higher entry of such providers over time into the market area experiencing the increase in diagnoses, demand, and wages. However, to the extent that the increase in autism cases is displacing diagnoses of other mental disorders, notably mild or moderate MR, the increase in the demand for auxiliary healthcare workers would be mitigated as one diagnosis is simply replacing another.

First, we therefore study the association between autism diagnoses and MR over the sample period to assess whether, and the extent to which, the increase in autism cases may be displacing MR diagnoses in CA.

$$\text{(1)}\quad \mathrm{MR}_{jt} = \delta_0 + \Lambda\ (\mathrm{Autism})_{jt} + \delta_1\,(\mathrm{Total\ clients})_{jt} + \delta_2\,(\mathrm{Center\ demographics})_{jt} + A_j\Omega + Z_t\Phi + \nu_{jt}$$

The parameter Λ, in Equation (1), represents the association between *Autism* and MR, which we measure alternately as percentage of total clients and as the number of total cases in regional center j in year t. A negative Λ would suggest that increases in autism cases are displacing MR cases. Alternate specifications control for center demographics, center-specific indicators (A_j) to account for time-invariant factors that may differ across the regions, and year indicators (Z_t) to account for general trends in the state that may be affecting diagnoses, healthcare coverage, and other unobserved factors. The disturbance term is represented by ν, and we adjust standard errors for arbitrary correlation in this error term within centers over time.

Next, we turn to our main analyses, which examine the impact of the increase in autism diagnoses on the wages of auxiliary healthcare providers in the short term and, in alternate specifications, their labor supply at the intensive margin (annual hours worked), and the number of providers over the medium term. We use a quasi-experimental research design—akin to a pre- and post-comparison with treatment and control groups—in conjunction with multivariate regression methods. The following specification relates changes in wages to autism diagnoses:

$$\text{(2)}\quad \mathrm{Ln\ Wages}_{ijt} = \alpha_0 + \pi\left(\mathrm{Ln\ Autism}_{jt}\right) + \mathrm{X}_{jt}\beta + \mathrm{O}_i\Psi + \mathrm{A}_j\Omega + \mathrm{Z}_t\Phi + \epsilon_{ijt}.$$

Equation (2) posits that log wages (*Ln Wages*), for the ith auxiliary healthcare occupation in center j during year t, is a function of the number of autism diagnoses (*Ln Autism*). The parameter of interest is π, which captures the effects of autism diagnoses on the average wages of those healthcare providers whose services are complementary to the treatment of autism. The parameter ϵ represents an error term at the level of the occupation, center, and year. We use a log transformation of wages and autism diagnoses, separately controlling for the county-specific population base and the total number of cases in each center, and allowing these coefficients to remain unrestricted. The log adjusts for the skewness of the wage and diagnoses distributions, facilitates interpretation (in terms of elasticity), and makes the effect magnitudes comparable across outcomes.[6] We estimate models for wages and hours worked using ordinary least squares (OLS). For the number of providers, we use a Poisson regression model for two reasons. First, the discrete nature of the outcome variable as a count of service providers makes the Poisson probability distribution especially suitable. Second, the Poisson framework does not suffer from the "incidental parameters" problem and can accommodate fixed effects well (Cameron and Trivedi 1998). We adjust standard errors on the conservative side to account for arbitrary correlation within centers, across occupations, and over time.

A challenge in any such analysis relates to disentangling the effects of autism diagnoses from other unobserved factors that may also affect the outcome. We account for such confounding factors in various ways. First, in alternate

5. Parents seek out some of these alternative health workers for other symptoms such as delayed speech. The parents take the child to a speech pathologist, and the speech pathologist may recommend that the child be tested for autism. Thus, it might appear that the demand is induced, but if anything this would bias the results towards zero because the child would not yet be counted as an autism case. Therefore, this would be an increase in demand for the services of a speech pathologist in the absence of an increase in autism within the data.

6. Elasticity estimates are not sensitive to alternate functional forms: (1) non-logged wages, (2) non-logged autism diagnoses, and (3) rate of autism diagnoses relative to various population bases.

specifications, we control for a vector of time-varying center-specific (and county-specific) characteristics (X) including the total number of clients served within the center's geographic area, the racial and ethnic composition of the center's clients and at-need population, total population of the counties reporting to the center, and the demographic (age, race, and ethnicity) composition of the served population. It is important to control for the racial/ethnic constitution of the county population and the clients served by the center as research indicates substantial disparities in autism diagnoses and the age of diagnosis across Black and White families (e.g., Mandell et al. 2002, 2009).[7]

Year fixed effects (Z) account for unobserved trends specific to the state of California, including changes in public and private insurance coverage, overall economic conditions, shifts in diagnosis criteria, and state-level policies enacted over the sample period.[8] Alternate specifications include center-specific fixed effects (A), which account for all unobserved time-invariant local factors that may be differentially affecting autism diagnoses, clients served, and treatment patterns across centers, and include occupation fixed effects (O), which account for unobserved time-invariant characteristics specific to each occupation (such as working conditions, nonmonetary attributes, and stable labor demand) that may affect wages in these occupations.

Despite these controls, the possibility remains that there may be residual unobserved time-variant factors which potentially impact wages. We address this problem by considering a comparison group of occupations that should not be directly affected by a shift in autistic disorder diagnoses. Thus, any correlation between autism diagnoses and wages for these "control" occupations reflects unobserved center-specific trends. This correlation can be differenced out from the effect (π) identified in Equation (2) to arrive at a cleaner estimate of the effects of autism diagnoses on the wages of impacted providers.

This difference-in-differences (DD) effect can be obtained directly from estimating the following specification:

$$(3) \qquad \text{Ln Wages}_{ijt} = \alpha_0 + \alpha_1 \left(\text{Target}_{ijt}\right) + \alpha_2 \left(\text{Ln Autism}_{jt}\right) + \pi^* \left(\text{Ln Autism}_{jt} \times \text{Target}_{ijt}\right) + X_{jt}\beta + O_i\Psi + A_j\Omega + Z_t\Phi + \epsilon_{ijt}.$$

In Equation (3), *Target* represents a dichotomous indicator equal to one for those healthcare occupations whose services are demanded by families with autistic children, and zero for occupations in the comparison group (providers whose services are not directly impacted by autism diagnoses). The DD estimate of the effect of autism diagnoses is the coefficient (π^*) of the interaction term between *Ln Autism* and the *Target* indicator. This effect is identified by comparing changes in wages associated with autism diagnoses for the target occupations in relation to changes for the control occupations, accounting for all other observable factors and the fixed effects.

The choice of the target group of auxiliary healthcare occupations, whose services are used by families with autistic children, is straightforward. As noted earlier, nonmedical interventions include behavioral, educational, sensory, and communication therapy, typically requiring the services of healthcare providers such as a speech pathologist, behavioral therapist, or occupational therapist.[9] These occupations are supported by the Committee on Children with Disabilities of the American Academy of Pediatrics (2001; Myers and Johnson 2007) and the American Academy of Family Physicians (Daily et al. 2000) as accepted therapy for both autism and MR. Data from the 2009–2010 National Survey of Children with Special Health Care Needs show that almost 75% of children diagnosed with autism use the services of physical, speech and language, and occupational therapists. We therefore expect the demand for services for the following providers to be potentially and directly impacted by a shift in autism diagnoses: (1) audiologist, (2) occupational therapist, (3) physical therapist, (4) recreational therapist, (5) respiratory therapist, (6) speech-language pathologist,

7. Mandell et al. (2002) show that among Medicaid-eligible children, White children on average receive an autistic disorder diagnosis at 6.3 years compared with 7.9 years for Black children.

8. Insurance status is unavailable in the ACS data prior to 2008. We construct center-specific rates of public coverage, private coverage, and uninsured for 2008–2011. Including these center-specific measures of insurance status in models estimated over 2008–2011 does not materially change the point estimates, although standard errors are inflated in these models due to the reduced sample size.

9. See for instance: http://www.autism-society.org/living-with-autism/treatment-options/ and http://www.webmd.com/brain/autism/autism-treatment-overview.
To see medical treatments used by autistic parents, see http://www.autism.com/pdf/providers/ParentRatings2009.pdf

TABLE 1
Descriptive Statistics: 21 California Regional Centers

Time Period	2002	2004	2010	2011	2004–2010
Total clients	7,799.6	8,403.1	10,123.8	10,376.1	9,228.8
Total autism cases	970.4	1,265.4	2,359.9	2,566.0	1,786.0
Total mild MR cases	3,067.0	3,290.4	3,694.2	3,740.3	3,479.1
Total mild or moderate MR cases	4,499.4	4,783.8	5,276.9	5,370.2	5,017.9
% Clients White	0.4603	0.4527	0.4082	0.3998	0.4306
% Clients Black	0.1029	0.1043	0.0986	0.0976	0.1012
% Clients Hispanic	0.2805	0.2951	0.3263	0.3322	0.3103
Total population		2,595,893	2,669,724	2,759,920	2,587,315
% Population Black		0.0607	0.0620	0.0627	0.0605
% Population Other Race (non-White & non-Black)		0.1479	0.1726	0.1755	0.1534
% Population Hispanic		0.2986	0.3294	0.3353	0.3097
% Population ages ≤13		0.1944	0.1813	0.1800	0.1901
Annual wages (autism occupations)		42,776.4	59,897.4		49,775.7
Annual earnings (autism occupations)		49,504.5	62,893.6		55,032.3
Annual wages (other healthcare practitioner/technical occupations)		56,737.9	71,292.7		65,408.9
Annual earnings (other healthcare practitioner/technical occupations)		66,909.8	77,847.9		73,192.1
Annual wages (all non-autism healthcare occupations)		44,103.3	54,619.9		50,517.5
Annual earnings (all non-autism healthcare occupations)		51,296.4	59,284.3		56,097.7
Annual wages (non-healthcare occupations)		34,208.8	35,242.6		35,506.1
Annual earnings (non-healthcare occupations)		38,259.7	38,282.7		39,160.1

Notes: Means are reported across 21 regional centers in California for the noted periods. Information on average wages and earnings are from the American Community Surveys (2005–2011) referring to years 2004–2010; means are weighted by occupation counts. Information on population demographics are from the U.S. Census Bureau (2005–2011).

and (7) other therapist.[10] Additionally, these same therapists serve individuals with MR.[11]

We use two alternate control groups to account for unobserved trends in wages within centers over time: (1) all other healthcare practitioner and healthcare technical occupations (occupation codes 3000–3540); and (2) all other healthcare practitioner, healthcare technical, and healthcare support occupations (occupation codes 3000–3650).[12] The former control group includes occupations that provide direct healthcare services to the patient. As auxiliary healthcare providers of services to autistic children are classified by the Bureau of Labor Statistics (BLS) in this grouping, this control group may represent those occupations that are most similar to those in the target group but not directly impacted by an increase in autism diagnoses. The latter control group comprises all healthcare-related occupations and also includes support occupations such as aides, assistants, and other support workers. These control groups will account for trends specific to healthcare occupations within each center and county. However, to the extent that demand and wages for some of these other health practitioner (physicians) and health support occupations (e.g., aides and nurses) may also be impacted by an increase in autism diagnoses, effects may be potentially understated. We therefore draw conclusions based on the range of estimates from both sets of control occupations and interpret these estimates as potentially conservative effects.[13]

Unconditional means from Table 1 suggest that wages in occupations whose services are complementary to autism diagnoses increased by 40% between 2004 and 2010. This compares with wages for other healthcare practice occupations, which increased 26%, while those among all healthcare occupations increased 24%. Thus, wages among autism service

10. Occupations in the ACS are identified by the 2002 Census codes. We therefore include codes 3140 (audiologists), 3150 (occupational therapists), 3160 (physical therapists), 3210 (recreational therapists), 3220 (respiratory therapists), 3230 (speech-language pathologists), and 3240 (other therapists) in the target group. Estimates are robust to excluding other therapists (code 3240).

11. (http://children.webmd.com/intellectual-disability-mental-retardation?page=2

12. Specifically, we define control healthcare practitioner and support occupations based on 2002 Census codes 3000 to 3650, excluding those defined above for the target group.

13. In supplementary analyses, as a robustness check, we also considered all other occupations (healthcare and non-healthcare) as a global control group. Expectedly, these estimates were of a larger magnitude as healthcare occupations (including the auxiliary service providers for autistic children) generally enjoy stronger wage growth relative to other jobs, and effects are likely overstated, partly reflecting just an overall positive trend in the wages of healthcare occupations.

providers have increased relative to those among similar healthcare practice providers as well as all other healthcare providers and support workers, coinciding with an increase in the number of autism diagnoses over our sample period, and this increase in wages is statistically significant.

We extend the model specified in Equation (2) in order to test for a "dose-response" relation and to assess the plausibility of the estimates by exploiting the suggestive displacement of other mental disorders for autism diagnoses. That is, we expect a stronger *response* on wages for those centers where the increase in autism represents a larger increase in demand (larger *dose*) for the services of the auxiliary healthcare workers. If the increase in the diagnoses of autistic disorders is partly displacing other mental disorders, then the effects of the increase on demand and wages would be mitigated. If one diagnosis is merely displacing another, then there is no effective increase in the demand for the services of the auxiliary healthcare workers as their services are demanded by both individuals with autism as well as those with other mild or moderate mental disorders. Hence, if one diagnosis is merely displacing another, then there should be no observed increase in their wages, conditional on trends. We therefore test whether the demand effects are larger in those areas where this displacement is low, in which case the increase in autism diagnoses is occurring independently of other mental disorders and would lead to a net increase in demand for the healthcare providers.

Specifically, we estimate a version of Equation (1) for each of the 21 regional centers, as part of a two-step procedure, to quantify the effects of higher autism diagnoses on the diagnoses of mild MR.

$$\text{(4)} \quad \text{Mild MR}_t = \delta_0 + \Lambda\,(\text{Autism})_t + \delta_1\,(\text{Total clients})_t + \delta_2\,(\text{Center demographics})_t + \delta_3\text{Trend} + \delta_4\text{Trend}^2 + \nu_t$$

The parameter Λ, which is estimated separately for each center, represents the association between *Autism* and *Mild* MR, both measured as the number of total cases.[14] We multiply Λ, for each center, by -1 to obtain the magnitude of the displacement. Thus, if the displacement is 0.5, this signifies that for every two additional diagnoses of autism, one of these cases is displacing a diagnosis of mild MR in that center, on average. While Equation (4) controls for linear and quadratic trends and demographic shifts within each center, we note that these rates should not be interpreted as causal because they may reflect residual unobserved trends. Nevertheless, we expect to find weaker effects on the demand for services in those centers where the displacement rate is high.

In the second step, we modify the baseline DD model (Equation (3)) to allow an interaction between the effect of autism diagnoses and the center-specific displacement rate[15]:

$$\text{(5)} \quad \text{Ln Wages}_{ijt} = \alpha_0 + \alpha_1\left(\text{Target}_{ijt}\right) + \alpha_2\left(\text{Ln Autism}_{jt}\right) + \lambda_1\left(\text{Ln Autism}_{jt} \times \text{Target}_{ijt}\right) + \lambda_2\left(\text{Ln Autism}_{jt} \times \text{Target}_{ijt} \times \text{Displacement}_j\right) + X_{jt}\beta + O_i\Psi + A_j\Omega + Z_t\Phi + \epsilon_{ijt}$$

The parameter λ_1 represents the effect of autism diagnoses on wages, *among those centers which had no displacement of MR cases for autism*; hence, we expect λ_1 to be larger than the estimated DD effect π^* in Equation (3) which represented a weighted average effect that conflates effects for centers that have high and low displacement rates. The parameter λ_2 represents the effect of higher levels of displacement on the link between autism and wages. We expect λ_2 to be negative, because centers that have high rates of displacement would see lower demand and hence lower wages, relative to centers that have no displacement. This specification tests the proposition that higher autism diagnoses should only represent an effective increase in the demand for the services of the auxiliary healthcare workers if these diagnoses represent a "true" increase rather than a substitution from MR diagnoses. Standard errors for Equation (5) are bootstrapped to account for the sampling variance in the estimate of the displacement rate.[16]

14. Estimates are not sensitive to alternate functions forms: (1) percent of total cases and (2) log of total cases.

15. This becomes a difference-in-difference-in-differences (DDD) model, which we estimate as a fully flexible specification by also allowing interactions between *Displacement* and *Ln Autism*, and between *Displacement* and *Target*.

16. Specifically, we report cluster bootstrapped standard errors based on 200 replications at the center-year cluster level. Center-level clusters provide too few clusters for the bootstrap. We note, however, that non-bootstrapped standard errors clustered at the center-level or at the center-year level in our DD models yield highly similar variance estimates and inferences.

FIGURE 1
Map of Regional Centers in California

Source: California Department of Developmental Services.

IV. DATA

The autism data are collected from the California Department of Developmental Services (DDS). The California DDS is the central administrating body tasked with diagnosing and reporting mental health cases in the 58 counties of the state. The 58 counties are serviced by 21 regional centers. The service areas of these regional centers are shown in Figure 1. The data for this study are collected from the quarterly Client Evaluation Reports, which are available for each county or each regional center for the years 2002–2011.[17] We use the December issue of the Client Evaluation Reports, which includes the following client characteristics: number of total clients, number of autism cases, number of MR cases (by severity), number of cases with physical handicap, primary language, gender, race, and age distribution.

Next, we identify the target group of auxiliary healthcare providers by nonmedical treatment therapy used. The National Institute of Mental Health (NIMH) provides separate guidance manuals for autism and MR.[18] Both manuals encourage the use of behavioral therapy (i.e., applied behavioral analysis [ABA]), psychotherapy (i.e., the developmental, individual difference, relationship-based model), as well as speech and language therapy for autism and MR.[19] From these treatments, we identified the following providers: audiologists, occupational therapists, physical therapists, and speech-language pathologists. We expand this list of providers to include recreational and respiratory therapists. The Bureau of Labor and Statistics defines recreational therapists as individuals who plan, direct, and coordinate recreation programs for people with disabilities or illnesses. We include respiratory therapists as some individuals with poor brain activity report using hyperbaric oxygen therapy.[20]

Information on annual provider income from wages and salary and their total earnings is matched to these 21 regional centers for each year. Specifically, we use data from the 2005–2011 ACS Public Use Microdata Sample (PUMS) to compute occupation-specific wages and earnings in California. The ACS is administered monthly by the U.S. Bureau of Census. It is nationally representative, and annual estimates are also representative of geographic units with a population of at least 65,000 individuals; representative estimates of smaller areas may be obtained by combining multiple years from the ACS-PUMS (3-and 5-year estimates). The PUMS comprises approximately a 1% random sample of the total number of housing units in the nation. It thus contains information on about 1.34 million housing units and 3 million person records in total, and yields about 368,809 persons sampled in California in 2011.

The smallest geographic unit identified in the ACS-PUMS is the Census-defined Public Use Microdata Area (PUMA). PUMAs are statistical geographic areas nested within states, which have a population of at least 100,000 individuals.[21] The 21 regional centers that report the provision of services for developmental disabilities in California are matched to the PUMAs, based on the counties that each center serves, for 2005–2011[22] (we are unable to use ACS information prior to 2005 as local-area identifiers within each state are not available in the PUMS).

Each individual respondent reports their average annual total income from wages and salary, which represents earned income from employment within an establishment, as well as their average annual total personal earnings, which reflects all earned income and additionally includes income from self-employment.[23] Respondents also report on their hours worked in the past year and their occupation (4-digit occupation code based on the 2002 Census). We compute mean annual wages, annual earnings, and annual hours worked, and the total number of individuals working within each occupation, for each regional center and year.[24] As annual wages and hours worked reference the past year, we match the ACS information at time period t (referencing period $t-1$) with the DDS information at time period $t-1$, to assess the contemporaneous effects on wages of the demand shock stemming from the increase in autism diagnoses.

In supplementary analyses, we also assess lagged effects on wage income and labor supply

17. These reports are available from the California DDS at http://www.dds.ca.gov/FactsStats/Diagnostic_Main.cfm.

18. The NIMH "A Parent's Guide to Autism Spectrum Disorder" http://www.nimh.nih.gov/health/publications/a-parents-guide-to-autism-spectrum-disorder/parent-guide-to-autism.pdf and the NIMH "Mental Retardation: A Manual for Psychologists" http://www.nimhindia.org/A%20Manual%20for%20Psychologists.pdf.

19. Eldevik et al. (2006) demonstrates the effectiveness of ABA therapy to improve intellectual functionality among autistic and mentally retarded children.

20. Medscape.com also provides a list of proposed treatments for autism and mental retardation. See (http://emedicine.medscape.com/article/912781-treatment#showall) for autism treatments and (http://emedicine.medscape.com/article/1180709-treatment#showall)

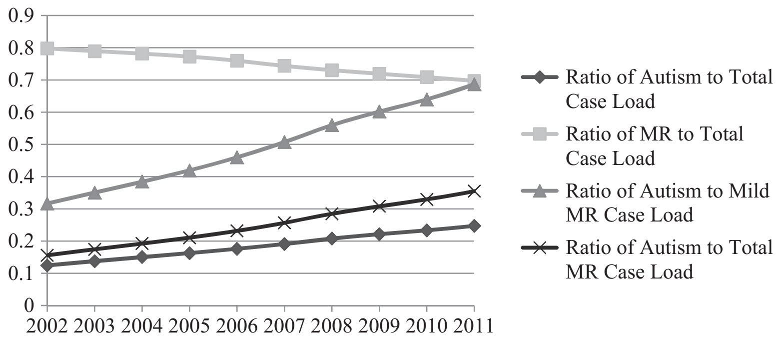
21. There are 233 PUMAs defined for California. See the Census ACS webpage (http://www.census.gov/acs/www/) for information on these geographic areas and the sampling schemes of the ACS and the ACS-PUMS.

22. There are seven regional centers that service Los Angeles County. Aggregating these centers into a single regional center servicing LA does not alter results (reported in Table 9).

23. For instance, a therapist may work for an employer (school, hospital, or practice) and supplement their income by billing via a sole proprietorship.

24. We compute annual hours worked as the product of number of weeks worked and usual hours worked per week.

FIGURE 2
Ratio of Autism to Mental Retardation (MR)



Source: Data from the California Department of Developmental Services are used.

in the subsequent period by matching ACS wage income and hours worked information at time period t (referencing period $t-1$) with the DDS information at time period $t-2$. As provider counts reference the year of interview, we match ACS information on the number of providers in each occupation at time period t with DDS information at time periods $t-1$ and $t-2$ to assess 1- and 2-year lagged effects on provider entry. In addition, we append population figures and the demographic (age, race, and ethnicity) composition of the population for each center and year, derived from the U.S. Census Bureau.

Table 1 presents the means for key variables across various periods spanning our analysis sample. Over 2004–2010, the average regional center reported 9,229 clients served for mental health disorders, 19.4% of whom were diagnosed with an autistic disorder and 54.4% were diagnosed with mild or moderate MR. Most of the clients served are minorities, with Whites representing only about 47.6% of the cases in the average center.

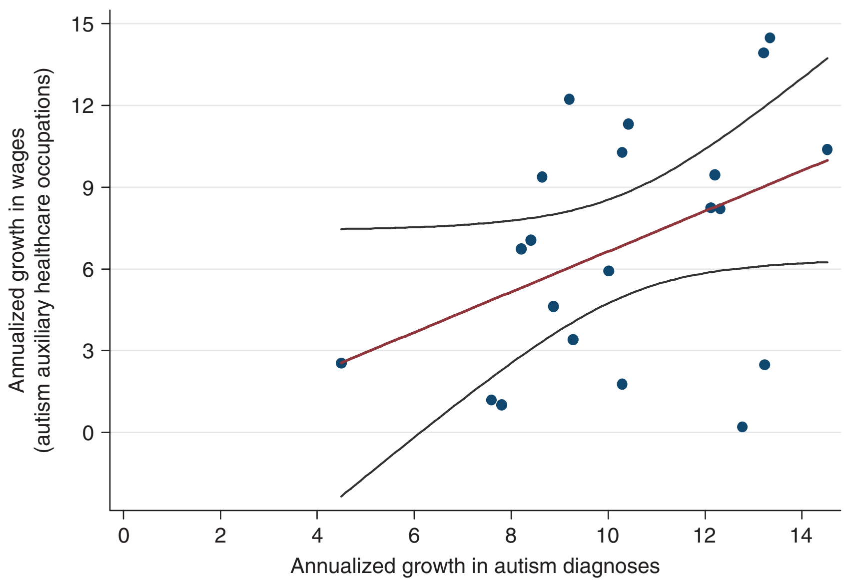
As illustrated in Figure 2, the percentage of autism cases has increased from 12% to 25% between 2002 and 2011. However, the percentage of total MR cases has decreased from 80% to 70% and the percentage of mild and moderate MR cases decreased from 58% to 52%. Moreover, the total number of both autism and MR cases has grown over this time period, but the ratio of autism cases to MR cases has increased from 0.16 to 0.35, and specifically the ratio of autism to mild MR cases has increased from 0.32 to 0.69.

There is substantial variation in autism growth within centers (ranging from an average of 4% to over 14% on an annualized basis). This within-center variation is significantly positively correlated, even without controlling for other factors, with increases in the growth rate of annual wages for auxiliary healthcare workers (Figure 3); and the differential growth rate of annual wages for auxiliary healthcare workers compared with the control group of other healthcare practitioner occupations (Figure 4). We exploit this source of year-to-year within-center variation in the DD models, adding two alternate control groups and adding a further source of variation based on the center-specific displacement rates in the DDD models, after accounting for various center-specific demographic factors along with occupation, center, and time fixed effects—all of which further help to reduce the sampling variance and maximize precision.

V. RESULTS

Table 2 shows the association between autism diagnoses and MR cases over the sample period. Model 1 indicates that a 1% increase in autism cases is associated with a statistically significant 0.40% decrease in mild MR cases, suggestive of a displacement of MR diagnoses for autistic disorder diagnoses. This displacement rate is robust to nonparametric (inclusion of year indicators) controls for trends in California (Model 2) and decreases slightly in magnitude to −0.34% with the addition of center-level fixed effects in Model 3. Thus, the negative association between autism and MR diagnoses is present both across centers (cross-sectionally) and within centers over time. Model 4 suggests a similar

FIGURE 3
Growth in Autism and Annual Wages for Auxiliary Healthcare Workers (2004–2010)



Notes: Data for 21 regional centers in CA. Fit from linear regression and 95% confidence interval shown. *p* value for slope coefficient is 0.06.

displacement rate (−0.38%) when moderate MR cases are considered in addition to the mild cases.

Displacement is also evident in levels (Models 5–8).[25] These specifications suggest that about one of every three additional autism cases is a shift from mild or moderate MR to an autism diagnosis.

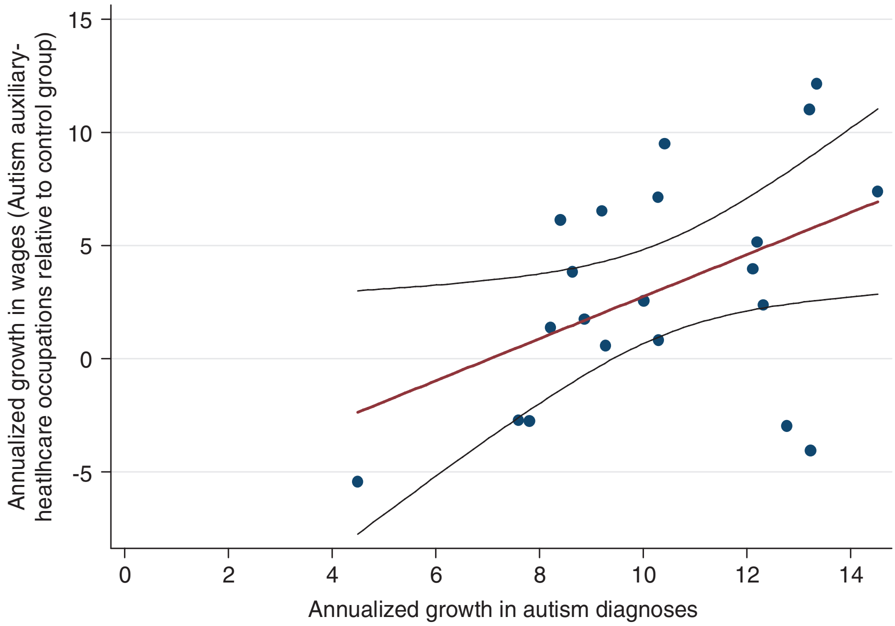
Models 9 and 10 present a placebo test and confirm that with respect to cerebral palsy and epilepsy there is no significant or substantial displacement coinciding with an increase in autism diagnoses. Individuals with these conditions also use occupational and behavioral therapists, but unlike MR, these conditions are easier to diagnose. Furthermore, as these conditions are also served by the developmental centers, it is possible that autism is potentially crowding out other conditions besides MR or there is an unobserved effort by administrators to increase autism diagnosis. However, we find no discernible displacement effect between these conditions and autism cases at the center level.

Table 3 presents the effects of an increase in the autism caseload on annual wages, based on the DD framework specified in Equation (3). Models 1–4 use non-autism healthcare practitioner occupations as a control group, whereas Models 5–8 use an alternate control group that includes all non-autism healthcare occupations (practitioner and support occupations). Model 1 suggests that a 100% increase in autism diagnoses, which is approximately the increase that occurred over the sample period, raises wages among the target occupations (auxiliary healthcare providers of services to autistic clients) by 10.8%, relative to all other healthcare practice occupations. This effect remains robust and statistically significant with the inclusion of center-level fixed effects (Model 2) and center- and county-level demographics (Model 3). The effect magnitude decreases slightly to 8.2%, although it still remains statistically significant, when the full set of occupation-specific fixed effects is added to the regression (Model 4). The coefficient of

25. While the population-weighted mean found in Table 2 from the individual center displacement rates is about 0.3–0.4, there is a wide range across centers suggesting that some regional centers had essentially no displacement (e.g., Central Valley, Golden Gate, Valley Mountain, and Tri Counties) and others had very high or close to full displacement (Far Northern, Inland, Kern, Orange County, and Kern). Some of these differences may be due to variation in provider practice and diagnosis criteria as actually applied, public and private coverage, and other region-specific observable and unobservable factors. It is validating that the displacement rates of 0.3–0.4 suggested by the pooled regression model (reported in Table 2) accord with the average displacement rate from the individual center regressions (estimated from Equation (4)).

FIGURE 4

Growth in Autism and Annual Wages for Auxiliary Healthcare Workers Relative to Wages for Control Group of Other Healthcare Practitioner Occupations (2004–2010)



Notes: Data for 21 regional centers in CA. Fit from linear regression and 95% confidence interval shown. *p* value for slope coefficient is 0.03.

Ln Autism is generally insignificant although not necessarily insubstantial in magnitude; this suggests that the control group is indeed picking up remaining (noisy) trends in healthcare wages within centers coinciding with the increase in autism diagnoses. The DD estimates purge these residual trends by differencing the effects for the control group. The coefficients of the Target indicator are expectedly negative, consistent with the patterns suggested by the unconditional means (Table 1) that providers of healthcare services to autistic clients in general have lower wages relative to other healthcare practitioners.

Models 5–8 indicate that the effect magnitudes of the DD estimates are highly similar when the control group is broadened to include healthcare support workers. Specifically, these estimates suggest that a 100% increase in autism diagnoses is associated with a 7.1%–10.2% increase in the annual wages of the auxiliary healthcare providers (relative to all other healthcare occupations).

The DD effects are understated as part of the increase in autism diagnoses represents a displacement of MR cases, in which case the increase in the demand for the services of the target healthcare occupations is also mitigated. Table 2 suggests displacement rates of about one-third to one-half, in which case the DD effects reported above are also understated by a similar factor. If some of the increase in autism cases is merely displacing MR cases, and if an effective increase in autism cases causally raises the demand for services of certain healthcare providers, then we expect that accounting for the level of displacement or directly controlling for MR cases should raise the magnitude of the wage effects. The models reported in Table 4 implement this plausibility check.

Models 1–3 present estimates of Equation (5), which interact the displacement rate with the DD effect to assess whether the impact on wages is larger in those centers where displacement of MR for autism is lower. The coefficient of the interaction between *Ln Total Autism* and *Target* increases in magnitude to 17% (Model 1); it can be interpreted as the impact of an effective 100% increase in autism diagnoses, independent of MR cases, on annual wages. The effect is robust to the inclusion of area and center demographics

TABLE 2

Displacement of Mental Retardation (MR) Diagnoses for Autism Diagnoses: 21 California Regional Centers 2002–2011

Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Outcome		**Mild MR (% Clients)**		**Mild or Moderate (% Clients)**		**Total Mild MR Cases**		**Total Mild or Moderate MR Cases**	**Total Cerebral Palsy Cases**	**Total Epilepsy Cases**
Autism	−0.40264**	−0.40247**	−0.33529***	−0.38060**	—	—	—	—	—	—
(% of clients)	(0.14454)	(0.14712)	(0.08693)	(0.14167)						
Total autism cases	—	—	—	—	−0.26503**	−0.26488**	−0.25238**	−0.18031	−0.04404	−0.08555
					(0.10402)	(0.10581)	(0.09653)	(0.16275)	(0.06559)	(0.05369)
Controls for trends	Linear + Quadratic	Year indicators	Year indicators	Year indicators	Linear + Quadratic	Year indicators	Year indicators	Year indicators	Year indicators	Year indicators
Center indicators and client demographics	No	No	Yes	Yes	No	No	Yes	Yes	Yes	Yes
R^2	0.23625	0.23660	0.99173	0.98628	0.89712	0.89717	0.99809	0.99815	0.99930	0.99922
Observations	210	210	210	210	210	210	210	210	126	126

Notes: Coefficient estimates from OLS models are presented. Standard errors are adjusted for arbitrary correlation within center cells. Models 9 and 10 are based on data from 2002 to 2007. All models also control for the total number of clients served at the center.

Asterisks denote statistical significance as follows: $^{***}p \leq .01$; $^{**}.01 < p \leq .05$; $^{*}.05 < p \leq .10$.

(Model 2) and declines somewhat in magnitude to 12.7% with the inclusion of occupation fixed effects (Model 3). It is validating that these effects (12.7%–17%) are larger, as hypothesized, relative to the effects in Table 3 that do not account for displacement (8.1%–11%). Furthermore, the coefficient of the triple interaction term is negative and significant (−0.064 to −0.086), suggesting that the effect on wages varies inversely with displacement; in those centers where the increase in autism cases is mostly reflecting a shift from MR to autism, we would not expect large increases in the demand for services.

Model 4 explicitly controls for mild or moderate MR diagnoses at the center-year level. As expected, the DD effect of a 100% increase in autism cases (which now represents a pure demand shock for related auxiliary healthcare providers) increases in magnitude, suggesting a 16.1% higher annual income from wages and salary. It is validating that this estimate of the wage increase from a "pure" 100% increase in autism diagnoses is consistent with the effects emerging from the DDD models (12.7%–17.1%) noted above. It is further validating that the inflation of the effect magnitudes in Models 1–4 in Table 4 relative to similar models in Table 3 (that do not account for displacement) is consistent with the displacement ratios estimated in Table 2. That is, the effect magnitudes with respect to a pure 100% increase in autism diagnoses are about 40% larger, corresponding to a displacement rate of autism for mild or moderate MR of about 30%–40%. Models 5–8 suggest very similar patterns and effect sizes based on the alternative control group of all healthcare occupations.

Table 5 presents supplementary DD and DDD models similar to Equations (3) and (5), which inform whether an increase in autism prevalence affects the supply of auxiliary healthcare providers in the subsequent period. Specifications (2) and (6), using alternate control groups, indicate that a 100% increase in the prevalence of autism raises the number of auxiliary healthcare workers in the area in the next year by a statistically significant 8.9%–10.9%, relative to the supply of other healthcare providers and support workers.

To the extent that the increase in autism diagnoses is supplanting alternate diagnoses of MR, these effects underestimate the impact of an effective 100% increase in autism cases. Specifications (3) and (7) estimate the DDD model shown in Equation (5) for alternate

TABLE 3

Ln Annual Wages Difference-in-Differences (DD) Estimates American Community Surveys 2005–2011: 21 California Regional Centers

Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Control Group	Non-Autism Healthcare Practitioner and Technical Occupations				Non-Autism All Healthcare Occupations			
Ln total autism	0.04962	0.12562	−0.05549	0.01649	0.07283*	0.03893	−0.20856	−0.14517
	(0.03458)	(0.14506)	(0.25729)	(0.26153)	(0.03686)	(0.12864)	(0.16589)	(0.17974)
Ln total autism* Target	**0.10784***	**0.11042***	**0.10807***	**0.08162***	**0.09801**	**0.10188***	**0.10019***	**0.07132**
	(0.03753)	**(0.03721)**	**(0.03649)**	**(0.02840)**	**(0.03548)**	**(0.03568)**	**(0.03480)**	**(0.02814)**
Target (autism occupations)	−0.78875**	−0.81160***	−0.79400***	—	−0.50971*	−0.54210*	−0.52894*	—
	(0.27905)	(0.27696)	(0.27137)		(0.26515)	(0.26722)	(0.26036)	
Year indicators	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Center indicators	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Area demographics	No	No	Yes	Yes	No	No	Yes	Yes
Center demographics	No	No	Yes	Yes	No	No	Yes	Yes
Occupation indicators	No	No	No	Yes	No	No	No	Yes
R^2	0.90397	0.90506	0.90531	0.93844	0.87469	0.87596	0.87623	0.93541
Observations	3,630	3,630	3,630	3,630	4,535	4,535	4,535	4,535

Notes: Coefficient estimates from OLS models are presented. Standard errors are adjusted for arbitrary correlation within center cells. Area demographics include total county population; percent of the population that is Black; percent other race; percent Hispanic; and percent ages <13, 15–44, 45–64, >65 years. Center demographics include total number of clients served, percent of the total clients who are White, percent Black, and percent Hispanic. Estimated DD effects are presented in bold.

Asterisks denote statistical significance as follows: ***$p \leq .01$; **$.01 < p \leq .05$; *$.05 < \leq .10$.

TABLE 4

Ln Annual Wages DDD Estimates Differential Effects by Displacement American Community Surveys 2005–2011: 21 California Regional Centers

Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Control Group	Non-Autism Healthcare Practitioner and Technical Occupations				Non-Autism All Healthcare Occupations			
Ln total autism	0.12771	−0.06015	0.03039	−0.06241	0.04617	−0.21192	−0.13880	−0.22081
	(0.17179)	(0.41487)	(0.40254)	(0.26571)	(0.14978)	(0.31590)	(0.31789)	(0.17001)
Ln total autism × Target	**0.17044***	**0.16778***	**0.12713**	**0.16099***	**0.16648**	**0.16419**	**0.11747***	**0.15181**
	(0.06150)	**(0.06096)**	**(0.05937)**	**(0.05558)**	**(0.06703)**	**(0.06683)**	**(0.06491)**	**(0.05616)**
Ln total autism × Target × Displacement	**−0.08591***	**−0.08567***	**−0.06401***	—	**−0.09206***	**−0.09148***	**−0.06472**	—
	(0.03258)	**(0.03236)**	**(0.03270)**		**(0.03302)**	**(0.03279)**	**(0.03232)**	
Target (autism occupations)	−1.24608***	−1.22627***	−1.37265***	−0.21048	−1.00918**	−0.99167**	−0.59070	0.03711
	(0.45757)	(0.45378)	(0.41622)	(0.31432)	(0.49954)	(0.49817)	(0.45626)	(0.32967)
Year indicators	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Center indicators	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Area demographics	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Center demographics	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Occupation indicators	No	No	Yes	No	No	No	Yes	No
Mental retardation (MR) and mild/moderate MR × Target	No	No	No	Yes	No	No	No	Yes
R^2	0.90522	0.90546	0.93853	0.90537	0.87612	0.87638	0.93549	0.87628
Observations	3,630	3,630	3,630	3,630	4,535	4,535	4,535	4,535

Notes: Coefficient estimates from OLS models are presented. For Models 1–3 and 5–7, bootstrapped standard errors clustered within center-year cells based on 200 replications are reported. For Models 4 and 8, standard errors are adjusted for arbitrary correlation within center cells. Area demographics include total county population; percent of the population that is Black; percent other race; percent Hispanic; and percent ages <13, 15–44, 45–64, >65 years. Center demographics include total number of clients served, percent of the total clients who are White, percent Black, and percent Hispanic. In Models 1–3 and 5–7, displacement represents the percent displacement of mild MR cases for autism diagnoses, obtained from estimating Model 5 in Table 1 separately for each center and controlling for center demographics. These models also control for interactions between displacement and Ln total autism, and displacement and autism occupations. Estimated DD and DDD effects are presented in bold.

Asterisks denote statistical significance as follows: ***$p \leq .01$; **$.01 < p \leq .05$; *$.05 < p \leq .10$.

control groups, including the explicit interactions with the center-specific displacement rate. The coefficient of the interaction between *Ln Total Autism* and *Target* suggests that, among centers that do not experience any displacement of MR for autism and for whom the increase in autism diagnoses reflects a real increase in the demand for services, the elasticity of provider supply with respect to autism cases is 0.09–0.13. The latter effect magnitude is about 20% larger

TABLE 5
Provider Counts (1-Year Lag) Poisson Regression American Community Surveys 2005–2011: 21 California Regional Centers

Model	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Control Group	**Non-Autism Healthcare Practitioner and Technical Occupations**				**Non-Autism All Healthcare Occupations**			
Ln total autism	−0.08940 (0.11183)	−0.08896 (0.10020)	−0.15050 (0.21288)	−0.08831 (0.09659)	−0.19599* (0.10337)	−0.17378** (0.08434)	−0.19718 (0.17682)	−0.17778** (0.08799)
Ln total autism × Target	**0.04825 (0.03183)**	**0.08903*** (0.03316)**	**0.09257** (0.03874)**	**0.10418** (0.04708)**	**0.11675*** (0.04206)**	**0.10864*** (0.03999)**	**0.12555*** (0.03624)**	**0.13226** (0.05692)**
Ln total autism × Target × Displacement	—	—	**−0.06380 (0.07205)**	—	—	—	**−0.09171 (0.06746)**	—
Target (autism occupations)	−1.54562*** (0.24036)	—	—	—	−2.18229*** (0.31672)	—	—	—
Year indicators	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Center indicators	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Area demographics	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Center demographics	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Occupation indicators	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Mental retardation (MR) and Mild/moderate MR × Target	No	No	No	Yes	No	No	No	Yes
Observations	4,147	4,147	4,147	4,147	5,233	5,233	5,233	5,233

Notes: See Tables 3 and 4.

relative to the effects that do not account for displacement (Model 6), consistent with the 25%–35% displacement rates noted in Table 2. It further adds to the plausibility of this estimate that the coefficient of the triple interaction is negative (−0.064 to −0.092), suggestive of a dose-response relation—although they are imprecisely estimated. The effect of autism diagnoses on the supply of auxiliary healthcare workers is diminished with larger displacement rates; for those centers where the increase in autism is crowding out MR diagnoses, this increase would not be expected to raise substantially the demand for services of workers in the target occupations. Models 4 and 8 explicitly control for mild or moderate MR cases to isolate the full effect in a different way. After accounting for MR cases, the estimates indicate a robust 10.4%–13.2% increase in auxiliary healthcare workers in the target group, relative to the control group.

Table 6 presents estimates for the current and lagged effects on annual wages, labor supply at the intensive margin as measured by annual hours worked, and provider counts to shed more light on the adjustment mechanisms in the labor market for these workers. We do not expect the supply of *new* auxiliary healthcare workers to adjust substantially over a short span of a few years given that the requirements for these auxiliary healthcare occupations typically comprise a specialized Master's degree and practical training spanning 2–3 years. Any increase in supply in the medium term is likely to come from mobility of providers from surrounding areas; this may include full relocation, working in offices/hospitals in more than one area, and/or home visits by auxiliary healthcare providers to surrounding areas experiencing an increase in demand. It should be noted that the regional centers servicing CA are fairly large and represent a collection of counties. Hence, we do not expect strong cross-center mobility over the very short term given that doing so would necessitate traveling through several counties. Thus, for the very short term, provider supply is expected to be fairly inelastic and thus any adjustment in the labor market for these providers would occur through wages.

Estimates in Table 6 suggest that the largest contemporaneous response to an increase in autism occurs through wages (Model 1). There is also a slight lagged effect on wages as well, as evidenced by the larger 1-year lagged elasticity (0.103) relative to the contemporaneous elasticity (0.082). Part of this increase in annual wages occurs through an increase in labor supply at the intensive margin, that is an increase in hours worked. This effect on labor supply is somewhat larger in the following year. Models 3 and 4 suggest that a 100% increase in autism cases leads to a 5.4% and 7.1% increase in hours

TABLE 6
Adjustment of Annual Wages, Hours Worked, Provider Counts American Community Surveys 2005–2011: 21 California Regional Centers

Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Control Group	Non-Autism Healthcare Practitioner & Technical Occupations						
Outcome	Ln Annual Wages	Ln Annual Wages	Ln Annual Hours	Ln Annual Hours	Provider Count	Provider Count	Provider Count
Estimation	OLS				Poisson		
Effect	Current	1-year lag	Current	1-year lag	Current	1-year lag	2-year lag
Ln total autism × Target	**0.08162*****	**0.10279*****	**0.05356*****	**0.07070****	**0.00843**	**0.08903*****	**0.13983****
	(0.02840)	**(0.03218)**	**(0.01814)**	**(0.02614)**	**(0.02784)**	**(0.03316)**	**(0.05794)**
Year indicators	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Center indicators	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Area demographics	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Center demographics	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Occupation indicators	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.93844	0.93533	0.94918	0.94153	—	—	—
Observations	3,630	3,123	3,590	3,086	4,142	4,147	3,572

Notes: See Tables 3 and 4.

worked in the current year and the subsequent year, respectively. Thus, about two-thirds of the increase in annual wages is due to an increase in work effort, and the remainder representing an increase in the price of these services.

There is essentially no effect on provider supply in the very short run, which is validating given that the supply of new providers to the region is expected to be inelastic in the short term. There is a positive and significant elasticity for provider supply (0.089) in the following year, and this effect increases to 0.140 after 2 years following the increase in autism diagnoses. The average center had about 25 autism-supporting auxiliary healthcare providers per 100,000 population in 2005. These estimates suggest that a 100% increase in autism cases would increase provider supply in a region by about 2–4 extra providers (per 100,000 population) over the next 2 years. The pattern of results in Table 6 is suggestive of an adjustment mechanism favoring higher wages and labor supply at the intensive margin (hours worked) in the short and medium term, and higher provider supply (potentially through mobility from surrounding areas) over the medium to longer term.[26]

VI. COMPETING HYPOTHESES AND ROBUSTNESS CHECKS

A potential caveat to our estimates is the effect of "labeling" on the demand for services. An underlying assumption of our identification strategy is that the price of an autism hour of therapy is equivalent to that for a mentally retarded patient. However, there may be differences in intensity of use between the two diagnoses or differences in willingness to pay due to the labeling of autism instead of an alternative mental disorder. If this is indeed the case, then we should expect a significant difference in the elasticity of wages for autism-related occupations with respect to a 1% increase in either autism or mild MR cases. We find the elasticities of 0.20 for autism and 0.10 for mild-to-moderate MR cases, but we cannot reject the null hypothesis of equal elasticities. While this suggests somewhat higher intensity of use among autism cases than mild-to-moderate MR, these effects are not sufficiently large to be the primary driver of our results.

Next, we consider sources of external validity to the "labeling" hypothesis. The first external source is from the 2005–2006 and 2009–2010 waves of the National Survey of Children with Special Health Care Needs (NS-CSHCN), a nationally representative study of all noninstitutionalized children with special health care needs

26. There could also be a response to an increase in the demand for the services of these healthcare workers through mobility at the level of the parents/patient. That is, parents of autistic children may seek out auxiliary healthcare workers in surrounding areas if they are unable to obtain timely services in their own area due to an increase in demand. This points to some spatial spillovers such that an increase in autism diagnoses may spill over to higher demand for auxiliary workers and their wages in surrounding areas. We note that the regional centers servicing CA are fairly large, with an average population of 2.7 million (2.1 million, excluding LA). Hence, our estimates already capture any mobility of patients and providers across counties within each center.

TABLE 7

Ln Annual Wages: Sensitivity of DD Estimates to Excluding Each Auxiliary Healthcare Occupation in Turn American Community Surveys 2005–2011

Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Occupation Excluded	Audiologists	Occupational Therapists	Physical Therapists	Recreational Therapists	Respiratory Therapists	Speech-Language Pathologists	All Other Therapists
Control Group	Non-Autism Healthcare Practitioner and Technical Occupations						
Ln total autism × Target	**0.11677*****	**0.09455****	**0.09438****	**0.08359****	**0.13066*****	**0.13028*****	**0.10611****
	(0.03955)	**(0.03480)**	**(0.03767)**	**(0.03423)**	**(0.04304)**	**(0.04001)**	**(0.04070)**
R^2	0.90539	0.90622	0.90502	0.90753	0.90526	0.90606	0.90730
Observations	3,575	3,504	3,483	3,570	3,489	3,488	3,531
Control Group	Non-Autism All Healthcare Occupations						
Ln total autism × Target	**0.10738****	**0.08693****	**0.08531****	**0.07610****	**0.12286*****	**0.12309*****	**0.09889****
	(0.03962)	**(0.03450)**	**(0.03775)**	**(0.03004)**	**(0.04137)**	**(0.03810)**	**(0.03706)**
R^2	0.87576	0.87672	0.87536	0.87753	0.87568	0.87656	0.87770
Observations	4,480	4,409	4,388	4,475	4,394	4,393	4,436

Notes: See Tables 3 and 4.

between the ages of 0 and 17 in the United States conducted by the National Center for Health Statistics (NCHS). We calculate the percentage of individuals with autism and mild or moderate MR that use these auxiliary healthcare providers for each wave. In the 2005–2006 wave, 70.1% of autistic children and 71.4% of mild or moderate MR children used these services. Likewise, in the 2009–2010 wave, 71.7% of autistic children and 71.6% of mild or moderate MR children used these services. The differences in percentages by disability are neither significant within nor across waves.

The second external source is the Special Education Expenditure Project report: Total Expenditures for Students with Disabilities, 1999–2000, by the U.S. Department of Education (Chambers, Shkolnik, and Perez 2003). The report documents federal expenditure per pupil by disability type. The average expenditure for MR is $15,040 and that for autism is $18,790, but the 95% confidence intervals surrounding these means overlap. Therefore, we cannot reject the null hypothesis of equal mean expenditure per pupil for these two diagnoses at the 5% level of significance. In this same report, expenditures are disaggregated by the type of auxiliary healthcare provider. Again, we cannot reject the null hypothesis of equal expenditures with respect to occupational therapists and other related services (e.g., school psychologists, social workers, school nurses, audiologists, vision specialists, other therapists, and personal health aides). However, there is a significant difference associated with speech-language pathologists. We have estimated the primary model dropping speech pathologists and find that the effects are fully robust both in terms of magnitude and significance to excluding speech-language pathologists from the analyses. We report similar results of excluding other auxiliary healthcare providers in Table 7.

Along these lines, we may be concerned that although these auxiliary healthcare workers cannot induce their own demand they may work for physicians or units that can.[27] Based on the BLS Occupational Outlook Handbook (2012–2013 edition), about 37% of physical therapists, 29% of recreational therapists, 27% of occupational therapists, 17% of recreational therapists, and 13% of speech-language pathologists worked in hospitals or large medical practices. The remainder worked in offices and clinics of physical, occupational and speech therapists and audiologists, home healthcare services, nursing care facilities, schools, community care facilities, and individual and family services. Hence, while spillovers from induced demand by primary providers to auxiliary healthcare providers is a possibility, the majority of these auxiliary healthcare providers do not work in hospitals or medical practices where one might expect such spillovers to be the strongest.

The fraction working in hospitals and medical practices is highest for respiratory therapists

27. We thank an anonymous reviewer for raising this point regarding spillover-induced demand.

TABLE 8
Ln Annual Wages and Provider Count Falsification: Pseudo Occupations American Community Surveys 2005–2011

Model	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Outcome	**Ln Wages (OLS)**			**Provider Count (1-Year Lag) (Poisson)**		
Control Group	**Non-Autism Healthcare Practitioner and Technical Occupations**					
Ln total autism	0.12210	−0.01644	−0.01175	0.00741	−0.41967**	−0.14335
	(0.15324)	(0.26983)	(0.27795)	(0.12372)	(0.18884)	(0.11209)
Ln total autism × Pseudo target	**0.01004**	**0.01007**	**0.01560**	**−0.01770**	**−0.01786**	**0.00110**
	(0.02225)	**(0.02257)**	**(0.01898)**	**(0.02066)**	**(0.02087)**	**(0.02547)**
Pseudo target	0.10369	0.10330	—	−1.01131***	−1.01022***	—
	(0.16599)	(0.16820)		(0.17156)	(0.17342)	
Year indicators	Yes	Yes	Yes	Yes	Yes	Yes
Center indicators	Yes	Yes	Yes	Yes	Yes	Yes
Area demographics	No	Yes	Yes	No	Yes	Yes
Center demographics	No	Yes	Yes	No	Yes	Yes
Occupation indicators	No	No	Yes	No	No	Yes
R^2	0.91013	0.91034	0.94553	—	—	—
Observations	3,012	3,012	3,012	3,223	3,223	3,223

Notes: See Tables 3 and 5. Pseudo target represents the following non-autism healthcare practitioner occupation codes: 3,000 (chiropractors); 3,010 (dentists); 3,030 (dieticians and nutritionists); 3,040 (optometrists); 3,050 (pharmacists); 3,200 (radiation therapists); and 3,310 (dental hygienists). Autism occupations are excluded from all models.

(81%). We therefore assess whether our estimates are driven by potential spillovers in induced demand for these auxiliary healthcare workers who are most likely to work in medical practices/hospital settings. Table 7 reports estimates excluding respiratory therapists and physical therapists in turn, who are far more likely to work in medical facilities that may also diagnose autism. The estimate magnitudes are not substantially affected by this exclusion; the wage elasticities range from 0.08 to 0.13 compared with 0.07 to 0.11 for the full sample.[28]

One concern, which cannot be directly tested, is that there may be residual confounding trends that differentially affect the target and control groups leading to biased DD estimates. Table 8 indirectly assesses this possibility by implementing a placebo test based on a pseudo target group comprising healthcare occupations whose services (and hence wages or provider supply) should not be directly affected by an increase in autism cases. In order to define this pseudo target group, we chose the first seven occupations within the BLS classification of healthcare practitioner and technical occupations that service human patients and are not complementary to autism diagnoses. Specifically, the pseudo target group comprises the following seven occupations in sequence in the BLS classification: chiropractors, dentists, dieticians and nutritionists, optometrists, pharmacists, radiation therapists, and dental hygienists. The control group represents all other healthcare practice occupations (excluding the autism-related providers). If our DD estimates are effectively purging residual center-specific trends, then we would not expect an increase in autism cases to affect the wages or supply of providers in these pseudo occupational categories (relative to the control group). Indeed, Table 8 confirms that there are no significant or substantial effects on either wages or provider supply for occupations in this pseudo target group. This falsification check is further validating in that it also adds a degree of confidence to the use of our control groups as a counterfactual for the target autism-related occupations.

Next, the identification strategy relies on year-to-year variation in growth rates to estimate the parameters. If the year-to-year growth rates are highly correlated, then we cannot treat each observation as independent. We address this issue in two ways. First, we have adjusted all reported standard errors to account for arbitrary correlation across years within each center. If the year-to-year fluctuations in growth rates are mostly noise, then this would reduce the precision of our estimates. Second, we re-estimate the models

28. If respiratory therapists and physical therapists are excluded jointly then the elasticity range is 0.064–0.122 and remains significant at the 10% level in all but one specification.

only considering 2004 and 2010 and exploiting the long-span variation in autism growth rates (Figures 3 and 4). This step removes concerns of arbitrary correlations across years driving the significant results although it somewhat weakens the statistical power of our estimates as we have fewer observations. Although the estimates are less precise, we still find wage effects between 6.6% and 12% without displacement, and 9% and 14% with displacement where most estimates are significant at the 10% level or better.

Lastly, the estimates may potentially suffer from cross-county border effects. As illustrated in Figure 1, each regional center is responsible for several counties, thereby, requiring auxiliary healthcare workers to travel through potentially several counties before affecting wages in the service area of a different regional center. The primary exception is Los Angeles County. Table 9 presents estimates for a sample of 15 regional centers where the seven centers that service Los Angeles County are aggregated together. We also estimate all models for annual personal earnings as reported in the ACS (not shown). All of these estimates remain robust and highly similar, both in terms of magnitudes and statistical significance, to those discussed above.[29]

VII. DISCUSSION

As the prevalence of autism has expanded dramatically over the past three decades, a central debate relates to the various factors that could potentially explain this increase. This study directly assesses whether the increase in autism diagnoses in regional developmental disability service centers in California is associated with a displacement of MR diagnoses. We also test this proposition indirectly by examining the impact of the higher number of autism cases on the demand for auxiliary healthcare workers—occupations whose services are complementary to the diagnoses of autism—within a DD multivariate regression framework.

If the incidence of autism is increasing independently of other mental disorders, then the demand for auxiliary health providers (i.e., speech pathologist, behavioral therapist, occupational therapist, etc.) should also increase, leading to higher wages for these providers in the short term and possibly a higher supply of these providers over time. If, however, the increase in autism diagnosis is merely displacing other mental disorders, then the effects of the increase on demand will be moderated or not present.

We find robust evidence that the higher prevalence of autism in California has raised wages and earnings among those target occupations whose services would be potentially impacted, conditional on confounding trends. The elasticity of wages and earnings with respect to autism diagnoses controlling for displacement effects is estimated to be between 0.13 and 0.16. About two-thirds of the resulting increase in wages is due to an increase in work effort as measured by annual hours worked.

The wage elasticity diminishes in magnitude with a higher displacement rate of MR for autism diagnoses, consistent with mitigated demand. We find that the average displacement rate is on the order of one-third, suggesting that one of every three new autism diagnoses is merely supplanting MR diagnoses and does not represent a true increase in autistic disorders. The estimated displacement effect is similar in magnitude to those found using administrated data of one-fourth for autism versus MR (King and Bearman 2009) and one-third (Coo et al. 2008) for autism versus non-autism mental disorders. The total number of autism diagnoses in California increased by 86%. This suggests a 57.3% increase (assuming a displacement of one-third) in effectively "new" autism diagnoses. Combined with the above elasticity estimates, this increase in prevalence would raise the wages and earnings among auxiliary healthcare providers who provide behavioral intervention services for children with autistic disorders by 7.4%–9.2%. Actual wages for these workers increased by 40% (as shown in Table 1) over the sample period. Our estimates therefore suggest that about 19%–23% of this observed increase (7.4–9.2 percentage points out of the 40% observed increase in wages) was due to increased demand stemming from the increase in autism cases. The remainder of the increase is then due to general economic conditions and factors affecting all workers in the healthcare practice and technical occupations.

The short span of the data set precludes a comprehensive analysis of the effects on the number of providers in the long run. Nonetheless, we find suggestive evidence that expanded prevalence of autistic disorders does raise the number

29. We also use the number of autism cases in surrounding regional centers as a method to control for spatial effects and find similar results. Additionally, the number of autism cases in surrounding regional centers is not found to have a statistically significant effect on own wage elasticity at conventional levels.

TABLE 9
Ln Annual Wages American Community Surveys 2005–2011: 15 California Regional Centers (Aggregated Centers in Los Angeles County)

Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Control Group	Non-Autism Healthcare Practitioner and Technical Occupations				Non-Autism All Healthcare Occupations			
Ln total autism	−0.18686 (0.30589)	−0.10847 (0.29951)	−0.22723 (0.51682)	−0.21509 (0.28619)	−0.36153* (0.20394)	−0.25550 (0.20242)	−0.38154 (0.40327)	−0.38626* (0.18537)
Ln total autism × Target	**0.07278*** (0.02438)**	**0.06294*** (0.01799)**	**0.13465** (0.06649)**	**0.13951 (0.08302)**	**0.06304** (0.02446)**	**0.05457** (0.01871)**	**0.13582* (0.07283)**	**0.14142 (0.08847)**
Ln total autism × Target × Displacement	—	—	**−0.08349** (0.03281)**	—	—	—	**−0.08914** (0.03474)**	—
Target (autism occupations)	−0.55956** (0.19121)	—	−1.00565** (0.48927)	−0.17869 (0.30506)	−0.27606 (0.19117)	—	−0.79927 (0.53760)	0.17179 (0.35507)
Year indicators	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Center indicators	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Area demographics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Center demographics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Occupation indicators	No	Yes	No	No	No	Yes	No	No
Mental retardation (MR) and mild/moderate MR × Target	No	No	No	Yes	No	No	No	Yes
R^2	0.90672	0.94339	0.90894	0.90676	0.87493	0.94102	0.87781	0.87497
Observations	2,692	2,692	2,692	2,692	3,352	3,352	3,352	3,352

Notes: See Tables 3 and 4.

of auxiliary healthcare workers over the subsequent 2 years, with elasticity estimates ranging from 0.09 to 0.14.[30] As with wages, we would expect this effect to be mitigated if the increase in autism is substituting for MR cases, which is indeed what the estimates suggest.

These results further confirm that provider income and their hours worked are responsive to an increase in the demand for their services. We note that these wage effects are not reflective of a direct "supplier-induced demand" as these healthcare workers do not themselves diagnose autism and thus cannot induce their own demand. Thus, at least part of the increase in the autism caseload represents an effective increase in their demand given that we observe an increase in their wages. This further suggests that at least part of the increase in autism diagnoses, about one-half to two-thirds based on the direct and indirect estimates of displacement, reflects an increase in the true prevalence of the disorder.

30. Based on our estimates, we can back-out an implied labor supply-wage elasticity for auxiliary healthcare workers as the ratio of the labor-supply/autism elasticity to the wage/autism elasticity. We used two measures of labor supply capturing the intensive and extensive margins, respectively: (1) annual hours worked (contemporaneous) and (2) provider counts (1-year lag). Our estimates imply a labor supply-wage elasticity for auxiliary healthcare workers of about 0.55–0.70 at these margins. To place these estimate in context, the labor supply elasticity with respect to wages has been estimated to be 0.33 for physicians and 0.61 for solo proprietor physicians in the literature (e.g., Showalter and Thurston 1997).

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