Stimulants and drug shortages

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Abstract

We examine the impact of a national shortage of extended-release amphetamine salts, a first-line treatment for Attention-Deficit/Hyperactivity Disorder, that occurred in 2020. We combine all-payer health insurance claims data 2015-2022 with difference-in-differences methods, exploiting pre-shortage exposure measured by county-level prescription rates, to identify the impact of the shortage on extended-release amphetamine salts prescriptions and costs. During the shortage, prescriptions for extended-release amphetamine salts declined by 7% in more vs. less exposed counties.

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1 Introduction

Drug shortages, where demand for a drug exceeds supply, are common within the United States healthcare system (U.S. Department of Health and Human Services, 2024). According to the American Society of Health-System Pharmacists, in April 2025 there were 270 active drug shortages (American Society of Health-System Pharmacists, 2025) and the number of drug shortages has reached a ten-year high (American Medical Association, 2024). More than half of all drug shortages last over two years and the average shortage impacts approximately 500,000 Americans (Maxor, 2025). Further, the duration of drug shortages is also increasing over time (American Medical Association, 2024). Drugs in shortage cover a wide range of conditions and include central nervous system, antibiotic, chemotherapy, and other medications (American Society of Health-System Pharmacists, 2025).

Drug shortages can arise due to supply chain disruptions, weather events, government regulations, or simply increased demand as new patients are prescribed, and begin to use, the medication (American Society of Health-System Pharmacists, 2025; Currie and Malinovskaya, 2026). When a drug becomes scarce, patients may be unable to fill the prescriptions their clinicians write, interrupting patient care and leading to increased symptom burden. Drug shortages can raise both time and money costs for patients: patients spend more time searching for their medication and may pay higher out-of-pocket prices for the same drug when drugs are in shortage. As a result of a drug shortage, some patients skip or reduce doses, forgo care altogether, or switch to substitute treatments that may be less effective (U.S. Department of Health and Human Services, 2024). These changes can have negative impacts on patients' daily functioning, financial burden, and overall quality of life (Metzger et al., 2012; Vail et al., 2017; Dave et al., 2018).

We examine the impacts of recent shortages of drugs used to treat attention-deficit hyperactivity disorder (ADHD). There is limited work on how shortages impact patients, and in particular, there is scant economic work investigating the impacts of shortages on patients with mental health conditions. Mental healthcare is an interesting setting in which to study the impacts of drug shortages as medications are a core part of treatment for many mental health conditions and there is compelling evidence that mental health treatment improves symptom management and functioning (National Institute of Mental Health, 2024). Moreover, patients may view mental healthcare as more discretionary than physical healthcare (Frank and McGuire, 2000). For example, Ellis et al. (2017) show that the price elasticity

of demand is greater for mental health treatment than overall healthcare, and thus patients may respond differentially when mental health drugs become scarce. More specifically, when supply disruptions occur, patients may stretch doses, switch drugs, or face interruptions in treatment, and symptom control can worsen. Furthermore, the benefits of treatment are not uniform – some patients gain more from the same care than others (Hautmann et al., 2013; Parlatini et al., 2025), so drug shortages may widen existing gaps in patient outcomes.

In June 2020 the University of Utah Drug Information Service (2025), an independent organization that tracks drug shortages throughout the U.S., declared a national shortage for extended-release amphetamine salt drugs. These medications are stimulants and are among the first-line ADHD treatment options for most patients, particularly those over age six. Extended-release amphetamine salts include common medications such as Adderall XR and Mydayis, and their generic equivalents (Cortese et al., 2018). In 2022, mixed amphetamine salts (which include extended-release versions) were the 14th most commonly prescribed medication in the U.S. with over 34 million prescriptions (ClinCalc, 2025). The 2020 national shortage was declared resolved by the University of Utah Drug Information Service (2025) in August, 2021, though the resolution was only temporary as a second shortage occurred in April, 2022 and has not, at the time of writing, been declared resolved.

One potential cause of these shortages was manufacturing and supply chain problems due to the COVID-19 pandemic, which disrupted global pharmaceutical manufacturing and distribution (Socal et al., 2021). A second potential cause was increased patient demand, which may, in part, be driven by lax prescribing rules during the COVID-19 pandemic – including expansion of telehealth services and reductions in the requirement of in-person consultations with a healthcare professional prior to receiving a prescription for ADHD stimulants and other Schedule II controlled medications (Danielson, 2023; U.S. Department of Health and Human Services, 2022).[1] Finally, the Schedule II classification of extended-release amphetamine salt drugs could have exacerbated shortages attributable to increased demand for these medications. The Drug Enforcement Agency imposes limits on production of controlled substances in this schedule, which theoretically could undermine suppliers' ability to

[1]The Drug Enforcement Agency 'schedules' drugs based on their potential harm and medical use, where the Agency attempts to balance benefits to legitimate patients against potential harms associated with misuse. There are five schedules with Schedule I drugs having high potential for abuse and no accepted medical use (e.g.. heroin), and Schedule V having the lowest potential for abuse among all scheduled drugs and accepted medical use (e.g., cough preparations with codeine such as Robitussin AC). Other Schedule II drugs include opioids such as fentanyl and hydrocodone, and cocaine.

respond to demand changes. However, the extent to which the Drug Enforcement Agency's limits on ADHD drug production are a binding constraint on consumer access to these drugs is unclear (Sheykhsoltan et al., 2025).

We explore the implications of the recent ADHD drug shortages for patterns of ADHD treatment and spending. We also investigate heterogeneity in response to the shortage across types of patients. In particular, we place emphasis on patients who may be more or less able to engage in additional search as medications become scarce or have differential access to healthcare, baseline utilization of – or need for – the medication, or other factors that could increase or decrease vulnerability to drug shortages – i.e., age, sex, prior use of extended-release amphetamine salts, payer, and urbanicity. We also examine heterogeneity by community-level factors that can potentially shed light on the extent to which the shortage was driven by supply-side factors. More specifically, we estimate shortage effects separately for counties that 1) had differential access to pharmacies (where prescriptions for extended-release amphetamine salts can be filled) and clinicians able to prescribe extended-release amphetamine salts, and 2) experienced unexpectedly high levels of demand based on historical patterns, and counties located in states that do and do not grant financially protected time away from work for health related reasons to employees. We assess the effects of the shortage on the use of substitute treatments not experiencing scarcity – other stimulant and non-stimulant medications – and patient well-being which we proxy with ADHD-related (non-prescription medication) healthcare use – i.e., emergency department episodes, hospitalizations, and outpatient visits.

To study these questions, we use all-payer health insurance claims data over the period 2015 to 2022 from IQVIA – a global health data and analytics company. To establish the timeline of the extended-release amphetamine salt shortage, we obtain the initiation and resolution dates from the University of Utah Drug Information Service Drug Shortage Dataset, which is the most comprehensive source for drug shortages in the U.S. (Wosińska et al., 2015).

We find that prescriptions for extended-release amphetamine salts declined by approximately 7% in areas more vs. less exposed to the shortage – which we define as counties at the 75th vs. 25th percentile of the pre-shortage extended-release amphetamine salt prescription distribution – during the shortage with some heterogeneity across patients and communities. Heterogeneity analysis suggests that both demand- and supply-side factors contributed to the shortage. Descriptive analysis using Drug Enforcement Agency data on drug quotas and

shipments supports the hypothesis that both demand and supply changes were important contributors to the shortage. Our results do not appear to be driven by differential trends in counties more vs. less exposed to the shortage and are robust to a range of sensitivity checks. We also show that out-of-pocket prices rose during the shortage in more vs. less exposed counties, out-of-pocket price increases could have contributed to the decline in use alongside general difficulties in accessing scarce medications.

Beyond average effects, we find that the burden of the shortage fell unevenly across patient groups. In particular, we focus on young people as childhood and adolescence are periods of rapid development in which untreated or under-treated ADHD can have compounding consequences. Children experienced especially large declines in access to extended-release amphetamine salts – on the order of 19% to 20% in more vs. less exposed counties.

In secondary analyses, we explore the extent to which patients were able to substitute to alternative treatments and whether the shortage led to worsening patient health, which we proxy with ADHD-related healthcare. We show that some patients were able to shift to arguably close substitutes – other stimulant medications. We observe no evidence that patients substituted non-stimulant medications for extended-release amphetamine salts during the shortage. Further, we observe no evidence that patient health worsened during the shortage, instead we find some evidence that health may have improved, suggesting that the pre-shortage period may have been characterized by over-prescription of extended-release amphetamine salts. However, we interpret our analysis of health outcomes with some caution as the metrics we are able to study in claims data may be too blunt to fully capture changes in patient functioning associated with reduced access to ADHD medication during the shortage. Finally, after the resolution of the shortage, prescriptions for extended-release amphetamine salts returned to their pre-shortage level.

The paper is organized as follows. Background on ADHD and our contributions to the literature are described in Section 2. Section 3 outlines our data sources and Section 4 describes the empirical methods we use. Our main results and heterogeneity analyses are reported in Section 5. We report extensions to the main analyses and robustness checking in Section 6. Finally, Section 7 provides a discussion and conclusion.

2 Background and contributions

2.1 Background on attention-deficit/hyperactivity disorder (ADHD)

ADHD is a neurodevelopmental condition and typical symptoms include inattention, hyperactivity, and impulsivity (Mercugliano, 1999). This disorder is relatively common among children – with one in ten children having an ADHD diagnosis (Li et al., 2023). Moreover, rates of ADHD diagnosis have recently begun to increase among adults, with 6.0% of adults self-reporting a current ADHD diagnosis in 2023 (Danielson, 2023; Staley, 2024).

ADHD can be treated in several ways, but pharmaceutical care is considered the first-line treatment for most patients (Eiland and Gildon, 2024; Williams et al., 2023). More specifically, stimulant medications – including extended-release amphetamine salts impacted by the drug shortage we study – have higher efficacy than non-stimulant ADHD medications (Cortese et al., 2018), and stimulants represent the vast majority of dispensed ADHD medications in the U.S. (Chai et al., 2024). Stimulants moderate ADHD symptoms by reducing the re-uptake of dopamine and norepinephrine – catecholamines which are chemicals in the brain that act as neuromodulators that regulate how the brain processes information – thus increasing the concentration of these neurotransmitters in the brain (Perugi et al., 2022).

ADHD patients utilizing stimulant medications experience improved concentration and ability to focus, and less hyperactive and impulsive behaviors (Kolar et al., 2008). Despite their established effectiveness, concerns exist around both underuse and overuse of ADHD stimulant medications in child and adult populations. Overprescription concerns are heightened due to the potential for diversion and misuse of ADHD medications (Coker et al., 2016; National Institute on Drug Abuse, 2025). Indeed, a recent systematic review of peer-reviewed studies published between 2012 and 2023 demonstrates that over one in five patients reported misuse of their prescribed stimulant medication, and one in six reported diverting this medication (Forrest et al., 2025). Patients prescribed an amphetamine-based stimulant were at elevated risk for misuse (Forrest et al., 2025).

Since 2018, the use of ADHD drugs has increased, driven primarily by greater utilization among adults. Two recent clinical papers examined descriptive trends in ADHD filled medications. One compared the two years prior to the COVID-19 pandemic with the two years after the beginning of the pandemic, and found no change in stimulants for people under 20, but large increases for people 20 and older (Chai et al., 2024). Non-stimulant ADHD

drugs were used far less than stimulant drugs over this period. However, there was a larger relative increase in non-stimulant ADHD drugs compared to stimulants, and this increase was also driven by adults. A second study examined filled ADHD prescriptions in 2019 and 2023, and found similar results (Huskamp et al., 2025). These recent increases in use of ADHD drugs among adults likely stem from a combination of increased diagnoses of adult ADHD, and also potentially inappropriate prescribing behavior by telemedicine companies that faced relaxed requirements for prescribing during the COVID-19 pandemic (U.S. Department of Health and Human Services, 2022). The findings of both Chai et al. (2024) and Huskamp et al. (2025) suggest that the 2020 shortage lead to changes in use of extended-release amphetamine salts and associated treatment. We will use difference-in-differences and event-study methods to examine the extent to which these documented trends represent causal impacts of the shortage on patients.

2.2 Contributions

Our study contributes to several strands of economic literature. First, we connect with work investigating the causes and consequences of drug shortages in general (Conti and Wosińska, 2025; Currie and Malinovskaya, 2026). Our contribution to this line of research is to study a recent national shortage for first-line treatment ADHD medications that is believed to have been caused by both supply- and demand-side factors that originated during the COVID-19 pandemic. Patients may respond differently to mental health drug shortages than shortages for physical health medications if mental healthcare is viewed as more discretionary than other forms of care (Frank and McGuire, 2000; Ellis et al., 2017), thus separate study of mental healthcare is warranted. Second, we add new information on the extent to which patients substitute between alternative pharmacological treatments, and differences across patients in their willingness to invest in costly search as drugs become scarce (Whaley et al., 2017; McMichael et al., 2020).

Third, this work also examines whether differing population subgroups are disproportionately affected by shortages, which might point to heterogeneities that are important to document when estimating welfare effects, indeed, earlier studies reveal differences across groups in the impact of economic shocks (Cengiz et al., 2019; Diamond et al., 2019). Fourth, our work adds to the large body of economic research on the COVID-19 pandemic (Brodeur et al., 2021; Cronin and Evans, 2021; Chetty et al., 2024; Meier and Pinto, 2024; Abouk

et al., 2025). Here, we study the impacts of a drug shortage believed to be, at least in part, attributable to disruption associated with the pandemic. Finally, we add to the broader economic literature that examines the causes and consequences of mental health disorders – both in youth and adult populations – in the U.S. (Frank and Glied, 2023; Currie, 2025).

From a policy perspective, our findings suggest that governments, and other groups involved in the drug supply chain, may wish to consider strengthening the supply infrastructure of medications in the U.S. to minimize costs to patients and support stable access to healthcare. In 2024, the U.S. Department of Health and Human Services (2024) released a white paper on various policies that could mitigate drug shortages specifically and strengthen the supply chain more broadly. Similarly, in 2024, the American Medical Association (2024), one of the largest professional medical associations in the U.S., adopted policies designed to reduce drug shortages. In particular, the American Medical Association formalized support for 1) federal review and oversight of compounding pharmacies to advertise drugs actively in shortage, 2) combating artificial drug shortages, and 3) offering incentives to manufacturers seeking to invest in manufacturing processes. Our work hints that these, and other, efforts to bolster drug supply may have beneficial impacts on patients and beyond.

3 Data

3.1 Data sources

Claims data: We use all-payer prescription claims data from the IQVIA Longitudinal Prescription Database (LRx) 2015-2022. Use of all-payer claims data is beneficial for our study as we can investigate impacts of the shortage on patients with different insurance types. For example, patients with Medicaid – a public insurance program for people with lower incomes and disabilities – coverage may have different risk profiles than patients with commercial insurance, and may be less able to invest in costly search when medications become scarce due to, among other factors, lower income levels.

IQVIA LRx includes information from about 90% of U.S. retail pharmacy transactions, capturing approximately four billion dispensed prescriptions annually (The IQVIA Institute, 2024). The dataset contains individual-level prescription claims with detailed information on the National Drug Code (NDC) of the dispensed medication, fill date, quantity dispensed,

days' supply, patient demographics (i.e., age, sex, and urbanicity), and payer. Data are de-identified, but each claim is linked to provider identifiers and includes provider geographic information, which we use for assigning location.

Our IQVIA extract includes patients with a mental health- or substance use-related diagnosis from 2015 to 2022, in line with earlier work using these data to study patterns of mental healthcare use (Eisenberg et al., 2025).[2] The IQVIA data are very costly and selecting our sample in this manner – i.e., focusing on patients with mental health and/or substance use disorder diagnoses – made accessing these data financially feasible. However, a potential concern with this sample is that the drug shortage we study could change the probability that a person receives a mental health- or substance use-related diagnosis from a clinician. Given that the shortage should (directly) affect ADHD patients through their ability to obtain medication after receiving a prescription from a clinician, we do not suspect the shortage to impact diagnoses for any mental health or substance use condition. Moreover, patients receiving mental health or substance use treatment without any mental health or substance use diagnosis over an extended period of time is very uncommon (Toth et al., 2025). Clinicians face a financial incentive to record mental health and substance use diagnoses when providing treatment for these conditions. For example, public and commercial insurers require a mental health or substance use diagnosis for reimbursement of the associated services a patient receives. More specifically, diagnoses codes are used to show the 'medical necessity' of the healthcare received. Failure to include such diagnoses codes in reimbursement documentation can lead to a denial of the claim by the insurer, meaning that the clinician will not be reimbursed for services delivered (Chute, 2013). Finally, in Section 5.1.1, we report results for patients with and without a history of ADHD stimulant medications and find very similar effects across the two groups, suggesting that a change in the composition of patients attributable to the shortage does not drive our findings.

Drug shortages: To identify periods of drug shortage, we obtain national drug shortage data from the University of Utah Drug Information Service (UUDIS). Drug shortages are widespread: at any moment, hundreds are active in the U.S. (American Society of Health-System Pharmacists, 2025). UUDIS defines a drug shortage as '*a supply issue that affects how the pharmacy prepares or dispenses a drug product or influences patient care when prescribers must use an alternative agent*' (Wosińska et al., 2015). Voluntary reports on shortages are collected on a rolling basis via the ASHP website through a public intake form. Trained

[2] A full list of all ICD codes used to select our IQVIA extract is available from the corresponding author.

clinical pharmacists at the UUDIS review and verify each reported shortage using independent confirmation through contacting all potential manufacturers. This rigorous verification process ensures the recorded shortages reflect true supply issues nationally for all NDCs listed (Wosińska et al., 2015). A shortage is considered resolved when all suppliers have all presentations available or have discontinued their products. For the medications we study, no products were discontinued, instead, suppliers were able to provide all drug presentations at shortage resolution. Information may also be obtained from the Food and Drug Administration's (FDA) drug shortage website if the FDA considers certain shortages resolved.

The UUDIS definition of a drug shortage differs from the FDA definition, with the FDA's definition focusing on whether the total supply of a drug from all manufacturers in the U.S. is able to meet historical demand (Wosińska et al., 2015). The FDA definition is: '*A situation in which the total supply of all versions of an FDA-regulated drug is inadequate to meet the current or projected demand at the patient level.*' We choose to rely on the UUDIS dates because the patient-focused definition better matches our goal of measuring care disruptions experienced by real-world patients than the FDA's national drug supply perspective.

UUDIS lists two shortages of extended-release amphetamine salts in our study period: 1) June 2020 to August 2021 and 2) April 2022 through the end of 2022 and beyond. We concentrate on the 2020 to 2021 episode, as our IQVIA data include both the period before the shortage and the period after the resolution; the 2022 shortage continued beyond our study period (2015-2022), though we will report results that incorporate the second drug shortage.[3] Notably, immediate-release amphetamine salts experienced a shortage during our study period as defined by UUDIS (February 2019 through March 2022), thus we exclude prescriptions for this medication from our analysis. No other stimulant medication used to treat ADHD was in a UUDIS-defined shortage over our study period. We note that UUDIS listed extended-release methylphenidate (an alternative stimulant medication used to treat ADHD) in shortage as of November, 2022. However, this date falls outside our primary analysis sample (described in Section 3.2) and thus this shortage should not influence our findings.

UUDIS pharmacists attempt to determine the cause(s) of drug shortages and this information is listed in the database. Categories of shortage causes include: increased demand, supply problem, business decision, facility closure, manufacturing delay or problem, Drug

[3]For comparison, the FDA reports only one shortage: October 12, 2022, through August 1, 2023 (Food and Drug Administration, 2025).

Enforcement Agency amphetamine quota on amphetamine domestic production binding, and so forth. There is also a category of unknown, which is UUDIS-listed cause for the extended-release amphetamine salts shortage that we study.

3.2 Sample construction

From the UUDIS shortage database, we identify extended-release amphetamine salts – a commonly prescribed stimulant medication for ADHD – as the primary drug of interest. According to the reported shortage dates, this drug experienced a formally recognized shortage period during our study window. The shortage start date for this medication fell within the observation period, and we confirm that the time window allowed for at least one to two years of data both prior to and following the reported shortage, so that there is sufficient time to observe both pre-shortage and post-shortage use and out-of-pocket price patterns.

We construct a county-quarter level panel dataset of dispensed prescription medications for extended-release amphetamine salts. Because the IQVIA LRx data do not include patient residence information at the county level, we assign each claim to a county based on the county associated with the linked provider, using provider location of business as a proxy for patient location of residence. This method assumes that prescriptions are generally filled near the patient's location (i.e., within the same county). We restrict the primary analytic sample to the beginning of 2018 to the third quarter of 2021 when the shortage was declared resolved (University of Utah Drug Information Service, 2025). Though we will report results that use data through December 2022 (the last year of our data) to provide insight on i) changes in prescriptions following the 2020 shortage resolution, and ii) the evolution of the 2022 extended-release amphetamine salts shortage. Moreover, as we will discuss in Section 3.4, we use data over the period 2015 to 2017 to construct our primary measure of exposure to the 2020 extended-release amphetamine salts shortage. A complete list of the NDCs we use to identify extended-release amphetamine salts is provided in Table A1.

3.3 Outcome measures

We define two primary outcomes to assess how the shortage changed use, measured at the county-by-quarter level. The first is the number of extended-release amphetamine salt prescriptions filled in each county-quarter per 1,000 county residents, which captures how

often patients obtain the drug. The second is the total days of pharmacotherapy dispensed during the same period per 1,000 county residents,[4] calculated by adding up the days' supply for every fill in the county. This supply-day measure reflects the amount of medication that actually reaches patients and is sensitive to shifts such as partial fills or tighter quantity limits potentially imposed during a shortage. We use these outcomes to estimate changes in access to extended-release amphetamine salts following the national supply shortage, accounting for baseline trends and variation in prior use intensity. We also examine out-of-pocket costs for extended-release amphetamine salts, both total costs and average cost per claim, faced by patients. If out-of-pocket prices rise during shortages, then through basic demand theory, we might expect that the quantity of medications will decline.

In secondary analyses that complement our primary analysis of extended-release amphetamine use patterns, we explore whether 1) patients utilized substitute medications used to treat ADHD when extended-release amphetamine salts became scarce, and 2) the 2020 shortage influenced health outcomes among ADHD patients. We first consider other stimulant drugs: 1) amphetamine-based stimulants (Isdexamfetamine, Dextroamphetamine, Evekeo, Adzenysm, Dyanavel, etc., and their generic equivalents) and 2) methylphenidate-based stimulants (Ritalin, Concerta, Metadate, Focalin, Daytrana, Quillivant, etc., and their generic equivalents). We also examine non-stimulant drugs used to treat ADHD: Strattera, Intuniv, Kapvay, and Qelbree, and their generic equivalents. Table A2 reports examples of the NDC codes we use to identify these medications, a full list is available on request from the corresponding author. Second, we examine proxies for patient well-being as measured by emergency department episodes, hospitalizations, and outpatient visits related to ADHD. We use the IQVIA Medical Claims (Dx) Database to construct these measures. These data include pre-adjudicated professional claims generated by office-based physicians and specialists and collected by IQVIA through practice management software and claims clearinghouses, or 'switches.' 96% of licensed physicians, documented by the American Medical Association, are captured in the Dx data. Parallel to our analysis of prescription claims, we use the location of service to assign geography. These metrics are, at most, crude proxies for poorly managed ADHD. For example, the majority of such cases do not require hospital or emergency department care (Chan et al., 2002).

[4]This variable is calculated by IQVIA and captures the estimated number of days that the prescription will last the patient.

3.4 Exposure to the 2020 national drug shortage

How best to measure exposure to the extended-release amphetamine salts shortage is not immediately clear, thus we will use several metrics that capture different dimensions of exposure. In our main analyses, we calculate the average monthly proportion of individuals receiving the extended-release amphetamine salts in each county in the 2015-2017 period – several years prior to the onset the drug shortage we study – using the IQVIA data to measure exposure to the shortage. The logic of this exposure measure is that counties with higher baseline use of extended-release amphetamine salts were more exposed to the 2020 shortage than counties with lower baseline rates. We select this time period to avoid contamination from any early signs of the emerging drug shortage that may have affected treatment patterns during the more proximate pre-treatment years.

A concern with our exposure measure is that, as described in Section 1, the shortage may be attributable to increases in demand for extended-release amphetamine salts that emerged in the lead-up to the shortage and driven by additional patients and/or changes in regulations around prescribing, and pre-shortage prescribing levels may not capture these origins. More specifically, an exposure measure based on 2015-2017 prescription rates arguably captures patients who used extended-release amphetamine salts prior to changes in demand and supply in the lead-up to the 2020 shortage, and may capture more 'legitimate' patients. Thus, we will report results using alternative definitions that reflect different features of the shortage. First, we will measure exposure based on the prescription rate in two time periods that are more proximate to the shortage: 1) 2018-2019, and 2) Q1 2020 (immediately prior to the shortage). These measures may better capture demand for extended-release amphetamine salts immediately prior to the shortage. Second, we construct the county-level change in extended-release amphetamine salts between the first quarter of 2015 and the first quarter of 2020. The change, measured in the lead-up to the shortage, potentially allows us to assess whether areas that experienced higher growth in demand for extended-release amphetamine salts where differentially exposed to the shortage than areas with more stable demand. Finally, we measure deviations from predicted use rates in 2019. To construct this measure, we estimate the change in extended-release amphetamine salts over the period 2015 to 2018 and predict the value for 2019, assuming linear growth. We then use the deviation between actual and predicted 2019 values to measure exposure, this variable can potentially shed light on the role of supply, that is suppliers may ship medications based on historical demand for medications, and if there are unexpected shifts in demand, then some areas may be subject to excess demand as a result. Using these alternative measures of exposure can

potentially shed light on mechanisms that lead to the shortage. In Table A3, we report the pair-wise correlations between these measured. Correlations are all positive and range from a low of 0.43 to a high of 0.97, suggesting that the exposure metrics we consider capture common underlying factors related to the shortage.

Covariates: We include county-level demographic information from population counts in the Surveillance, Epidemiology, and End Results (2022) program in regression specifications. We construct measures of county-level age (proportions less than five years, six to 18 years, 19 to 39 years, 40 to 64 years, and 65 years and older, with less than five years as the omitted group), sex (proportions female and male, with female as the omitted group), race (proportions White, Black, and other race, with White as the omitted group), and ethnicity (proportions Hispanic and non-Hispanic, with non-Hispanic as the omitted group) groups.

3.5 Summary statistics and trends

Summary statistics are reported in Table A4 for the full sample, and Table A5 depicts the summary statistics for counties at or above the median exposure rate and counties below this rate. The mean exposure rate in counties at/above the median is 0.16% and the rate is 0.03% in other counties. Rates of claims for extended-release amphetamine salts are higher in counties at/above the median exposure rate than in counties at lower levels of exposure. For example, the number of claims per 1,000 are 1,323 and 109 in counties at/above the median exposure and below the median value, respectively. While not identical, higher and lower exposure counties have similar demographics, though counties with higher exposure have larger average population than counties with lower exposure – 159,354 vs. 51,035.

Figure 1 depicts trends in our two main extended-release amphetamine salts outcomes. We divide counties into two groups based on pre-shortage extended-release amphetamine salts prescription use, in particular, we stratify based on the sample median value, and plot trends for each group separately. The trend lines suggest there is a decline in the above-median group that coincides with the UUDIS-defined shortage start time.

4 Methods

4.1 Main specification

To estimate the impact of the drug shortage on the treatment utilization of extended-release amphetamine salts and related outcomes, we implement a generalized difference-in-differences approach. This approach compares counties that are exposed to different 'doses' of the 2020 national drug shortage based on our pre-shortage baseline use of extended-release amphetamine salts. Specifically, the regression we estimate is reported in Equation 1:

$$Y_{c,s,t} = \beta_0 + \beta_1 * Post_t * exposure_c + V_{c,s,t} * \beta_2 + \delta_c + \theta_{s,t} + \epsilon_{c,s,t} \quad (1)$$

Where $Y_{c,s,t}$ is one of our outcome measures in each county c of state s at each quarter t. $Post_t$ is the post-shortage indicator and $exposure_c$ is the underlying treatment needs of people residing in each county, measured by the average monthly proportion of individuals with an extended-release amphetamine salts prescription in each county 2015-2017 in our primary specification or one of the alternative exposure measures described in Section 3.4 (e.g., growth rates in the pre-shortage period). $V_{c,s,t}$ is a vector of county-level time-varying demographic measures (i.e., age, sex, race, and ethnicity shares). δ_c and $\theta_{s,t}$ are county and state-by-quarter-year fixed effects, respectively. Thus, our regression will account for time-varying county-level demographics included in $V_{c,s,t}$, all fixed county-level characteristics (e.g., underlying need for ADHD medications), and all state-by-time characteristics (e.g., state policies adopted during the COVID-19 pandemic period such as stay-at-home and state-of-emergency orders and changes in telemedicine regulations).

The regression is estimated with ordinary least squares (OLS) with the prescription rate as the outcome variable, though we will show in Section 6 that our results are robust to 1) taking the logarithm of the rate, 2) using the prescription count (controlling for the county population), and 3) using a Poisson specification (with the county population as the exposure variable). Data are weighted by the county-year population, though we report unweighted results in Section 6. The shortage was officially declared on June 17th, 2020, we code the shortage as beginning in Q2 2020, thus our first quarter is partially treated but this approach to coding the beginning of the shortage allows us to have a clean pre-treatment period. Standard errors are clustered by county as treatment intensity varies at this level (Bertrand et al., 2004). Our treatment (the 2020 drug shortage) affects the entire nation at one point in time, thus our analysis is not vulnerable to bias related to staggered treatment adoption as out-

lined by, among others, Callaway and Sant'Anna (2021) and Goodman-Bacon (2021).

Regression coefficient estimates generated in Equation 1 reveal the effect of a county with 100% exposure to a county with 0% exposure to the national ADHD drug shortage in 2020, which is arguably a very large dose, particularly given that no county has 100% exposure. We thus scale coefficient estimates to compare the effect of the shortage on the county at the 75th percentile to the 25th percentile of the exposure distribution. These counties have 0.03% and 0.14% exposure to the shortage, respectively. This design has been used within the economic literature to study shocks that impact all observations in a geographic area at the same time (Finkelstein, 2007; Miller, 2012; Alpert et al., 2018; Argys et al., 2020; Park and Powell, 2021; Andersen et al., 2023; Cohle and Ortega, 2023; Hackmann et al., 2025).

5 Results

5.1 Main results

Figure 2 presents the event-study plots for our two primary outcome measures over the study period. We use the event-study to provide suggestive evidence on the extent to which our data can satisfy the parallel trends assumption that is required for difference-in-difference methods to recover causal estimates. In particular, we must assume that counties with higher and lower exposure to the 2020 drug shortage would have followed similar trends in extended-release amphetamine salts dispensed prescriptions absent the shortage. We decompose our static difference-in-differences variable ($Post_t \times exposure_c$) into a series of interactions between pre-shortage county-level exposure and time to the drug shortage. More specifically, we construct two-quarter 'bins' and interact each with our primary exposure measure (extended-release amphetamine salts prescription rates over the period 2015-2017). Thus the first treated time-to-event bin includes 2020 Q1-Q2. Examination of the 2020 shortage leads allows us to assess the plausibility of the parallel trends assumption, while examination of the shortage lags allows for an exploration of dynamics.

In our preferred event-study, we choose to omit the first bin of the study period (2018 Q1-Q2) rather than the more standard -1 (i.e., 2019 Q3-Q4 or the six-month period prior to the event) as we are concerned that the periods immediately prior to the UUDIS-defined drug shortage could be contaminated by the emergence of the shortage. As described earlier

in Section 3.1, the actual drug shortage start date defined by UUDIS is potentially a lagging indicator for the 'true' effective date. However, we also report results omitting two periods in advance of the shortage (i.e., 2019 Q1-Q2) and we report results excluding time-varying covariates, results are very similar across the different specifications.

Figure 2 reports results from the three alternative event-studies. Overall, the findings reveal no evidence of differential pre-trends between counties with higher and lower exposure to the shortage. One exception to this pattern is there there is a slight increase in prescriptions in 2018 Q3-Q4. This increase could reflect the emergence of the shortage, but appears to dissipate closer to the shortage date. Given this coefficient estimate, we next apply partial identification methods proposed by Rambachan and Roth (2023) to assess the extent to which our difference-in-differences findings are robust to potential violation of the parallel trends assumption.[5] This method produces confidence intervals that are robust to violations of parallel trends equal to $\bar{M}$ times the size of the largest parallel trends violation observed in the pre-period. We compute robust confidence intervals for potential values of $\bar{M}$ in multiples of 0.5, and then report the smallest value of $\bar{M}$ that would yield a robust confidence interval that includes zero. Findings from this analysis, based on the claims count outcome (results based on the supply day measure are similar and available on request), are reported in Figure A3. These findings suggest that our difference-in-differences coefficient estimates, reported later in this section, for the effect of the drug shortage are robust to violations of the parallel trends assumption of up to 1.0 times the largest observed pre-trend.

We do not observe elevated prescriptions in the quarters immediately preceding the shortage effective dates (i.e., 2019 Q3-Q4). This pattern of null findings suggests that increased demand for ADHD stimulant medications may not be the sole driver of the 2020 shortage. Instead, changes in demand for extended-release amphetamine salts alongside other factors – for example, disruptions in the supply of these drugs due to the COVID-19 pandemic – might have contributed to the shortage.

In the post-period, we observe declines in extended release amphetamine salt prescriptions in counties more exposed to the shortage that appear in the first six months of the shortage. Estimated effects for more distal lag variables (seven to 12 months and 13 to 18 months post-shortage) are larger than coefficient estimates for earlier periods, though

[5] We use the `HonestDID` package to implement this procedure (Caceres Bravo et al., 2022; Rambachan and Roth, 2023).

our estimated 95% confidence intervals in some cases overlap and thus we are reluctant to over-interpret time dynamics. The results are broadly robust across the three event-study specifications, which further supports the validity of our design.

Table 1 presents difference-in-differences coefficient estimates which provide a summary measure of the drug shortage, averaged over the post-period. As described in Section 3.4, we scale our coefficient estimates to reflect the impact of the 2020 drug shortage comparing the county at the 75th percentile of the baseline exposure distribution to the county at the 25th percentile. Panel A of Table 1 reports results using our primary measure of shortage severity (i.e., the prescription rate measured over the period 2015 to 2017) and Panels B through E report results using alternative measures of exposure to the shortage.

With the scaling described in the last paragraph and using our primary measure of exposure, we find that the shortage lead to a 7.5% and 7.3% reduction in the number of claims and supply days for the county at the 75th percentile vs the county at the 25th percentile of pre-shortage exposure, respectively. Results – reported in Panels B through E of Table 1 – are similar using our alternative measures of exposure to the shortage. The similarly across alternative exposure measures suggests that counties with high baseline levels of, deviations in projections vs actual of, and growth rates in extended-release amphetamine salt prescriptions were influenced by the shortage similarly.

One interpretation of these, qualitatively similar, findings across alternative approaches to measuring exposure to the shortage is that counties with relatively high baseline levels of extended-release amphetamine salts, growth rates, and deviations from historical trends were negatively impacted by the shortage, thus the impact of the shortage was not concentrated only in counties were the rates of medication use increased in the lead-up to the shortage and instead was more broadly experienced. Moreover, these similar findings further support the hypothesis that both demand- and supply-side factors lead to the shortage.

In Table 2 and Figure A4, we report difference-in-differences and event-study coefficient estimates for quarterly extended-release amphetamine salts prescription out-of-pocket payments, measured as i) the total out-of-pocket costs and ii) the average out-of-pocket costs. As expected given the declines we observe in prescription rates in Table 1, total costs declined by 14.1% in the county at the 75th percentile vs. the 25th percentile of the exposure distribution. Notably, the relative effect size is nearly double what we observe for prescrip-

tions (Table 1), however, the the 95% confidence interval includes values much closer to the changes we observe for prescription rates. Further, we see that out-of-pocket costs increased by 5.0% during the shortage in the county at the 75th percentile vs. the county at the 25th percentile. Event-studies do not reveal any evidence prior to the shortage in more and less exposed counties for the total cost measure, but we do observe evidence of difference in pre-trends for the out-of-pocket cost variable (in particular, the pattern suggest some seasonality that is not captured by our time fixed effects), thus we interpret the difference-in-differences coefficient estimate for this measure with caution.

5.1.1 Heterogeneity

In this section, we implement two complementary sets of heterogeneity analyses. First, we investigate heterogeneity across patients. Here we focus on groups of patients that may have different ability to engage in costly search efforts when their medications become scarce, have less attachment to the scarce medications (e.g., ADHD conditions that are less well managed by extended-release amphetamine salts vs other treatments), and so forth. Second, we explore whether patients in counties with different characteristics (e.g., located in states with better access to extended-release amphetamine salts through greater supply of clinicians and pharmacies able to prescribe and dispense these medications) where differentially exposed to the shortage. While our reduced form methods capture the next effect of the shortage on outcomes, examining heterogeneous effects in this manner may shed some light on the extent to which demand- and supply-side factors could have contributed to the shortage.

In our analysis of heterogeneity, we use our overall measure of exposure to the 2020 shortage. That is we do not construct separate exposure measures for particular groups of patients (e.g., patients who are male and patients who are female). Our rationale is that the objective of our study is to test whether shortages influence patients, thus whether the baseline rate of extended-release amphetamine salts prescriptions is greater among – for example – women than men in a county should not influence shortage effects.

Patient heterogeneity: We examine heterogeneity in the impact of the shortage by age group (Table A6), sex (Table A7), payer group (Table A8), and existing vs. new patient status (Table A9). We compare age groups that are categorized as zero to 18 years, 19 to 64 years, and 65 years and older. Payers are categorized into the following groups: 1) commercial insurance, 2) Medicare, 3) Medicaid and the Children's Health Insurance Program

('Medicaid'), and 4) self-pay/cash and other where other includes Veterans' Affairs, Workers Compensation, other state and federal plans, and other plans. Finally, we define new patients as those who do not have an extended-release amphetamine salts prescription in the year prior to the focal prescription. These subgroup analyses allow us to assess whether the effects of the drug shortage varied across demographic and insurance categories that may reflect differences in access to healthcare, baseline medication use, ability to engage in additional search efforts when drugs are scarce, or other vulnerability to supply disruptions.

Across all subgroups, we find statistically significant reductions in utilization following the beginning of the drug shortage. Moreover, 95% confidence intervals often overlap, and thus we are reluctant to over-interpret differences across samples. However, declines are particularly large among children (19% to 20%), men (11% to 12%), those covered by Medicare (14% to 20%), and those who use cash/self-pay (35% to 50%).

Community heterogeneity: We report community-level heterogeneity analysis by state paid sick leave mandate status which confers financially protected time for health-related activities to employees (Table A10); scope of practice law that allows nurse practioners 'full practice authority' which includes the ability to prescribe medications such as extended-release amphetamine salts (Table A11); urbanicity (Table A12); at or above vs below the median exposure to the shortage (Table A13); and at or above below median pharmacy, mental healthcare physicians, and general physician offices (Table A14). We use policy data on paid sick leave mandates prepared by the National Partnership of Women & Families (2023). These mandates provide employees with, on average, seven days of financially protected time off each year that can be used for health-related reasons and have been shown to influence mental healthcare use (Maclean et al., 2024; Eisenberg et al., 2025). Thus, patients residing in states with such mandates in place may face lower time costs to searching for medications during periods of scarcity. Scope of practice laws are based on a coding system proposed by McMichael and Markowitz (2023). We use information from the U.S. Department of Agriculture (2025) to classify counties as metropolitan and non-metropolitan and data from the U.S. Census Bureau (2024) County Business Patterns to measure the number of retail pharmacies (NAICS code = 456110), mental health physician offices (NAICS code = 621112), and general physician offices (NAICS code = 621111).[6] We

[6]Beginning in 2017, the U.S. Census Bureau suppresses cell (county-NAICS code in our setting) with fewer than three establishments. We assign suppressed cells a value of three, which is below the median value, thus the suppression does not impact our classification of counties.

measure state policies as of 2019, and the number of pharmacies and healthcare professional offices per county in 2019, thus measurements precede the shortage.

Two broad patterns emerge from our analysis of community-level heterogeneity in the effect of the 2020 shortage. First, all types of counties that we consider in this analysis experienced a decline in the rate of extended-release amphetamine salts during the shortage, the coefficient estimates are uniformly negative and statistically different from zero at conventional levels. Second, counties located in states without a paid sick leave mandate or scope of practice law, in non-metropolitan areas, and with below median number of pharmacies and number of healthcare professionals able to prescribe extended-release amphetamine salts experienced larger declines in prescriptions than other counties. For example, in counties with the number of mental health physicians offices at or above the 2019 median value, the decline in extended-release amphetamine salts was 6.0% to 6.3% in more vs. less exposed counties, while the comparable decline in counties with below the 2019 median number of mental health physicians was 12.2% to 12.5%. Overall, these findings suggest that factors beyond the patient shape access to healthcare.

Discussion of heterogeneity: We investigate heterogeneous responses to the drug shortage as we are interested in understanding distributional impacts of restrictions in access to first-line medications used to treat ADHD and to shed light on the forces that may have lead to the shortage. In terms of the distribution of effects, all groups experienced a decline in extended-release amphetamine salts during the shortage, but declines were particularly large among children, patients covered by Medicare, and patients who self-paid. Given that childhood is a key developmental period (e.g., accumulation of human capital, social skill acquisition), constrained access to effective treatment for ADHD could have persistent impacts on children. Patients covered by Medicare and who self-paid may face additional burdens (e.g., comorbidities and lower income), and an inability to access treatment could exacerbate mental health disparities.

Our analysis of community-level heterogeneity can potentially offer some insight on the extent to which the shortage was driven by demand- or supply-side factors. Generally, we find larger effects in counties characterized by lower baseline access to both healthcare professionals who can prescribe extended-release amphetamine salts and retail pharmacies where patients can fill prescriptions for these medications. These findings hint that supply-side factors, at least partially, contributed to the emergence of the shortage.

6 Extensions and robustness checking

In this section, we first investigate the extent to which patients may substitute extended-release amphetamine salts with alternative medications. Second, we use IQVIA data through the end of 2022 (the most recent year of data available to us) to examine the extent to which extended-release amphetamine salts prescriptions rebounded following the resolution of the 2020 drug shortage, and explore the evolution of the 2022 shortage. Third, we investigate the implications of the 2020 drug shortage on proxies for patient health. Fourth, we use administrative data from the Drug Enforcement Agency to dig deeper on the importance of demand- and supply-side determinants of the shortage. Finally, we conduct robustness checking to assess the stability of our main findings.

6.1 Substitution

Patients may turn to substitute pharmacotherapy treatments when extended-release amphetamine salts become scarce. Such substitution could imply a welfare cost to patients as, through revealed preferences, these patients were prompted to switch medications through an exogenous shock rather than through endogenous sorting to the preferred treatment. Further suggesting that shifts in mental healthcare treatment patterns could imply reductions in welfare for patients, interviews with clinicians who prescribe stimulant medications for ADHD report that even small changes in the drug – for example, shifting from one supplier to another of the same medication – can lead to patient-reported declines in medication effectiveness and increases in side effect burden (Yasinski, 2025).

Table 3 reports our findings for other stimulant (Panel A) and non-stimulant (Panel B) prescriptions. Some patients were able to substitute to other stimulant medications during the 2020 shortage: comparing the county and the 75th percentile to the 25th percentile of exposure, claims and supply days increased by 2.7% and 2.6%, respectively. We observe no evidence that non-stimulant prescription use changed during the shortage. Figures A5 and A6 report event-studies for these outcomes, and there is no evidence that more and less exposed counties followed divergent trends prior to the shortage.

6.2 Extended time horizon

Here we extend our study period through December 2022 to study the extent to which extended-release amphetamine salts prescriptions rebounded following the resolution of the 2020 supply drug shortage (i.e., August 2021) and to observe trends before and after the 2022 shortage commenced (i.e., April 2022). To these ends, we estimate the three event-studies described in Section 5.1 using data through December 2022 (Figure A7).

In the sixth quarter post-shortage, which corresponds to the 4th quarter of 2021, both the claim count and the supply day count of the extended-release amphetamine salts prescriptions display a re-bound in utilization. Moreover, in the periods following the resolution of the 2020 shortage, the rate of dispensed extended release amphetamine sales rose to pre-shortage levels. These findings suggest that, as the shortage ended and access to medications increased, patients with ADHD – quite quickly, within one year – resumed their pre-shortage patterns of extended-release amphetamine salt use.

6.3 Patient health

We have shown that extended-release amphetamine salts prescription outcomes declined during the national drug shortage. We next investigate whether this reduction in access impacted patient health. To do so, we measure emergency department visits, hospitalizations, and outpatient visits related to ADHD in the IQVIA data. We use diagnosis codes (F90) to identify ADHD claims and place of service descriptions (Table A15) to isolate emergency department, hospitalization, and outpatient claims. Patients with poorly managed ADHD, as may occur when medications are scarce, could be at elevated risk for an emergency department visit, either due to a mental health crisis or potentially through accidents that may occur as a result of ADHD symptoms (e.g., impulsiveness).

Difference-in-differences coefficient estimates are reported in Table A16 and event-study findings are depicted in Figure A8. We a decline in ADHD-related emergency department visits and outpatient visits – 12.3% and 16.3% in the county with exposure at the 75th vs. 25th percentile, respectively. The coefficient estimate for hospitalization is small and statistically indistinguishable from zero. Thus, our analysis into patient health provides no evidence that the shortage lead to a worsening in mental health. One possible interpretation, though we cannot confirm with these data, is that our results suggest an improvement

in health and this finding is consistent with over-prescribing in the pre-intervention period. We note that the decline in outpatient visits could be, at least, partially attributable to inability to patients, who know that they cannot access extended-release amphetamine sales during the shortage, electing not to schedule outpatient visits where these medications can be prescribed. Notably, as described in Section 4, these metrics are likely crude proxies for poorly managed ADHD (Chan et al., 2002).

6.4 Using administrative data to explore the importance of demand- and supply-side drivers of the 2020 shortage

We use Drug Enforcement Agency administrative data on the federally-set amphetamine production quota in each year 2018 to 2021 (U.S. Drug Enforcement Administration, Diversion Control Division, 2024) and compare these values with total shipments of amphetamines within the U.S. in the corresponding years (U.S. Drug Enforcement Administration, Diversion Control Division, 2023) to assess whether the quota was binding in any year we examine. We take the sum of shipments in all 50 states and DC in each year 2018-2021, and compare with the quota listed in Drug Enforcement Agency reports.

In all years of our study, amphetamine shipments fell far short of the quota, which is in line with other studies examining stimulant shortages (Currie and Malinovskaya, 2026). More specifically, the annual quota (in kilograms) on amphetamine domestic production in 2018, 2019, 2020, and 2021 was 39,856; 42,400; 44,330; and 42,400; respectively. In these years, the total shipments of amphetamines (in kilograms) were 21,888; 23,002; 23,901; and 25,275. While these data are imperfect – for example, we can only examine total amphetamine quotas and shipments, and we cannot isolate extended release versions of amphetamine salts – these findings imply that federal regulations on the production of amphetamines were not likely the sole driver of the 2020 shortage that we study.

6.5 Robustness checking

We next report our main results (i.e., Panel A in Table 1) using alternative specifications. First, we report unweighted results (Table A17). Second, we replace state-by-time fixed effects with time fixed effects (Table A18). Third, take the logarithm of the prescription rate outcomes, use the counts of the two prescription variables while controlling for the county

population, and we use a Poisson regression with the county population as the exposure variable (Table A19). Many counties had no prescriptions and are excluded from the sample when we take the log of the prescription rate variables.[7] Results are similar in these alternative specifications, though the coefficient estimates are somewhat smaller in magnitude when we use a Poisson and unweighted OLS regression.

Finally, we conduct a structural break test to examine whether the 'effective date' we use for the beginning of the 2020 drug shortage captures a meaningful change in extended-release amphetamine prescriptions. We measure the shortage period based on data reported by UUDIS. This information potentially captures true shortage effective dates with a lag – i.e., there could be some difference between the actual effective period and the period we classify as the shortage period. Given this potential difference, we assess whether the UUDIS shortage date represents a meaningful break in extended-release amphetamine salts prescription. To do so, we conduct a formal statistical test for a structural break test (Cronin and Evans, 2021; Andersen et al., 2023). Specifically, we estimate a linear time trend model with a potential structural break and conduct 'rolling' F-tests for structural change. The logic of this approach is to observe whether the relationship between the dependent variable and an independent variable changes systematically at a specific point in time.

To this end, we aggregate the total supply days to the national level in each year-month and calculate the total supply days per thousand population for each month during the study period, which serves as the outcome of interest y_t. This approach generates a time series with potential structural breaks at each candidate month m. We construct $counter_t$ as a linear time trend, set to one in January 2018, two in February 2018, and so forth. We also include time squared and cubic terms to adjust for nonlinear trends. Additionally, we create dummy variables $MOY(j)_t$ to indicate the month of the year (j = one to eleven, omitting twelve) to account for seasonal effects. Finally, we define a dummy variable D_t^m, which equals one if $t \geq m$ and zero otherwise, to capture whether a given month occurs after the candidate breakpoint m. The structural break test is outlined in Equation 2:

$$y_t = \alpha + \sum_{k=1}^{3} counter_t^k (1 - D_t^m) * \pi_{bk} + \sum_{k=1}^{3} counter_t^k D_t^m * \pi_{ak} \tag{2}$$

[7] We do not add a positive value to all observations as Chen and Roth (2024) show that this practice can complicate interpretation of regression coefficient estimates.

$$+\sum_{j=1}^{11}[MOY(j)_t(1-D_t^m)*\psi_{bj}+MOY(j)_tD_t^m*\psi_{aj}]+\epsilon_t$$

The breakpoint varies from the first month to the last month of the study period. Our goal is to identify the breakpoint associated with the maximum F-statistic from the joint hypothesis test of coefficient equality before and after the breakpoint, $H_0 : \pi_{ak} = \pi_{bk}, \psi_{aj} = \psi_{bj}$ for all $k = 1, 2, 3$ and all $j = 1, 2, ..., 11$. If the null hypothesis is rejected, this result implies the model relationship changed at that month. Therefore, the F-statistic serves as a measure of the strength of a potential break each month, and the maximum F-statistic identifies when the break is most likely to happen. We conduct the structural break test at the monthly level (vs. quarterly in our main analyses) to ensure that we do not obscure break points.

The estimated F-statistics from the structural break test are plotted in Figure A9. The maximum F-statistic occurs between the first and second quarters of 2020, demonstrating a break in extended-release amphetamine salts prescription supply days during that period. We also estimate the structural break text separately for the four regions of the U.S. (Figure A10) and by urban-rural status (Figure A11). Results suggest that counties in different regions and at different levels of urbancity appear to experience the shortage at roughly the same time. Thus, the results of the structural break analysis align with the shortage start time according to the UUDIS. Moreover, this finding is also in line with the argument that shortage notification dates likely capture the true start date of the shortage with a lag, which is expected as shortage emerge through changes in supply- and demand-side factors that eventually filter down to prescribers and patients.

7 Discussion and conclusion

Drug shortages are common in U.S. healthcare, with more than 300 under way at the time of this writing, and they arise from both supply problems and demand surges (Conti and Wosińska, 2025). Such shortages curtail access to recommended drugs and can harm patients. When a medicine is hard to find, patients can respond in several ways: they may engage in extended search time, ration the supply of the drug they have, switch to another therapy, or stop treatment altogether. These responses differ across the population; for example, patients with higher income can potentially devote more time or money to searching, so the burden of shortages may fall hardest on people with fewer resources.

We use all-payer claims data to study the impact of a 2020 national shortage of extended-release amphetamine salts, common and effective stimulant medications used to treat Attention-Deficit/Hyperactivity Disorder (ADHD), on patients. We have several findings.

First, once the shortage took hold, patients had a harder time obtaining these medications and faced higher out-of-pocket prices. Second, though all groups we consider were influenced by the shortage, there was some heterogeneity across demographic groups of patients in terms of the magnitude of the burden of the extended-release amphetamine salts shortage. Specifically, we find that children, men, patients enrolled in Medicare, and patients who self-paid, and who resided in counties with less access to healthcare experienced larger declines in dispensed medications during the period of shortage. Third, we demonstrate differences across communities in shortage effects across metrics that may proxy for extended-release amphetamine salts supply. While all types of communities we examine experienced a decline in prescription rates during the shortage, declines were disproportionally large in counties with more limited access to prescriptions as measured by pharmacies and healthcare professionals who can prescribe extended-release amphetamine salts. Fourth, some patients shifted to substitute treatments – other stimulant medications used to treat ADHD, though not non-stimulant drugs – when their preferred medication becomes scarce. These findings suggest that patients view alternative stimulant medications as closer substitutes than stimulants and non-stimulants. Fifth, we find no evidence that patient health worsened during the shortage, if anything our findings suggest that health – a measured by healthcare utilization – may have improved, and this finding hints that over-prescribing may have occurred prior to the shortage. However, our health measures have many limitations and thus these findings are, at most, suggestive. Finally, following the shortage resolution, extended-release amphetamine salt prescribing patterns returned to their pre-shortage levels.

Notably, our findings are qualitatively similar to two descriptive clinical studies that explore time trends in ADHD medication use over the period of extended-release amphetamine salts shortage (Chai et al., 2024; Huskamp et al., 2025). All three studies point towards the shortage increasing the use of other stimulant medications, but our work suggests less evidence that patients shifted towards non-stimulant ADHD medications than do the findings of Chai et al. (2024) and Huskamp et al. (2025). While we cannot fully explain why findings might diverge, we suspect that different empirical approaches – that is we use causal difference-in-differences methods while Chai et al. (2024) and Huskamp et al. (2025) focus on documenting trends over time.

The fact that we find evidence that some patients may switch to alternative stimulant, but not non-stimulant, ADHD medications when extended-release amphetamine salts become scarce potentially merits some additional discussion. First, changing stimulant medications is not uncommon among patients with ADHD, switching is particularly common among new patients, that is patients have recently initiated medication treatment for the condition (Biederman et al., 2021b,a). For example, Biederman et al. (2021a) show that, in a sample of adult patients receiving their first medication treatment for ADHD, one in four had to switch to a different medication within the first two months of intuition. Thus, our finding that patients will substitute to other stimulants when extended-release amphetamine salts become scarce is in line with clinical patterns. Moreover, we include extended-release amphetamine salts in our classification of stimulant medications, suggesting that some patients may have substituted from an extended-release to immediate release of the same drug. Second, non-stimulant medications are typically viewed as 'second-line' treatment for ADHD while stimulant medications are viewed as 'first-line' care (Isfandnia et al., 2024). Thus, when extended-release amphetamine salts become scarce, clinicians may be more likely to switch affected patients to other stimulant medications.

Finally, despite curtailed access to a first-line treatment for ADHD (Cortese et al., 2018), we observe no evidence that patient health declined during the 2020 extended-release amphetamine salt drug shortage. These null findings may stem from several factors. First, the declines in extended-release amphetamine salts we document (approximately 7%) may be too small to drive changes in health outcomes, moreover, some patients substituted to other stimulants during the shortage which may have minimized declines in patient functioning. Common symptoms associated with a termination of extended-release amphetamine salts include fatigue, body aches, mood changes, depression, and sleeping difficulties, but most withdrawal symptoms over the course of a few days or weeks (Nall and Biggers, 2018). Thus, the most long-lasting effect for patients may be worsening management of ADHD symptoms and associated health consequences (e.g., lower life expectancy), these effects would not emerge during our study period. Related to this point, hospitalizations, emergency department visits, and office visits may be too blunt of a measure of the types of health change ADHD patients experience when they are less able to access medication treatment, in particular over the short-run. An interesting avenue for future work would be to consider outcomes that may be more responsive to reductions in access to ADHD treatment such as school outcomes for children, labor market engagement for adults, and behavioral outcomes such as

substance use, personal relationships, diet and body weight, sleep, and so forth. Second, the shortage may have been too short in duration to lead to changes in patient well-being. Third, the shortage was relatively short – most shortages last at least two years (Maxor, 2025) – and thus the duration of the shortage may not have been sufficiently long to observe changes in patient health, at least using the metrics that we have available in claims data. Further work, using alternative sources of data, could explore whether other aspects of patient well-being varied during the shortage period.

The disproportionate impact of the shortage on children warrants particular attention. Our findings suggest that children experienced roughly twice the decline in extended-release amphetamine salts prescriptions as the overall population. The effects of untreated or undertreated ADHS in children can accumulate over time. Moreover, children have limited agency to seek out alternative medications or pharmacies on their own, making them especially dependent on the adults and systems around them to manage treatment disruptions.

Thinking through the welfare implications of our findings is important. We observe no evidence of a in a decline in health outcomes (based on healthcare utilization) among patients with ADHD during the 2020 shortage, if anything our findings may suggest an improvement in health. With the caveat that our patient health measures are less than ideal, one interpretation of our findings is that – though some patients were not able to access their preferred medication during the shortage – the shortage did not have substantial implications for patient welfare. However, when we consider periods of time after the shortage was determined resolved, we observe a rebound effect, that is, patients returned to their pre-shortage level of medication use when extended-release amphetamine salts were more available. These findings are somewhat inconclusive in terms of changes in patient welfare, on the one hand we do not observe worsening health but, when access to extended-release amphetamine salts was restored, patients returned to their prior use patterns.

Our study has some limitations. First, though we rely on the most comprehensive database of drug shortages in the U.S., the exact dates of the shortage are challenging to identify. Second, the 2020 extended-release amphetamine salts drug shortage occurred during the COVID-19 period, which may limit the generalizability of our findings. Third, as mentioned above, our measures of patient health (outpatient visits, hospitalizations, and emergency department episodes) are imperfect proxies for patient health and likely miss many important aspects of well-being. Fourth, while prescription-based measures are com-

monly used with economics, they do not capture patient use and instead are a proxy.

Overall, we offer new evidence on the impacts of drug shortages generally and on patients with ADHD specifically. Our findings suggest that shortages impose costs on patients as they stretch or skip doses, or go without care. Government efforts to minimize shortages (e.g., relaxing federally imposed restrictions in response to shortages and strengthening national supply chains) may have benefits for the economy and for patients.

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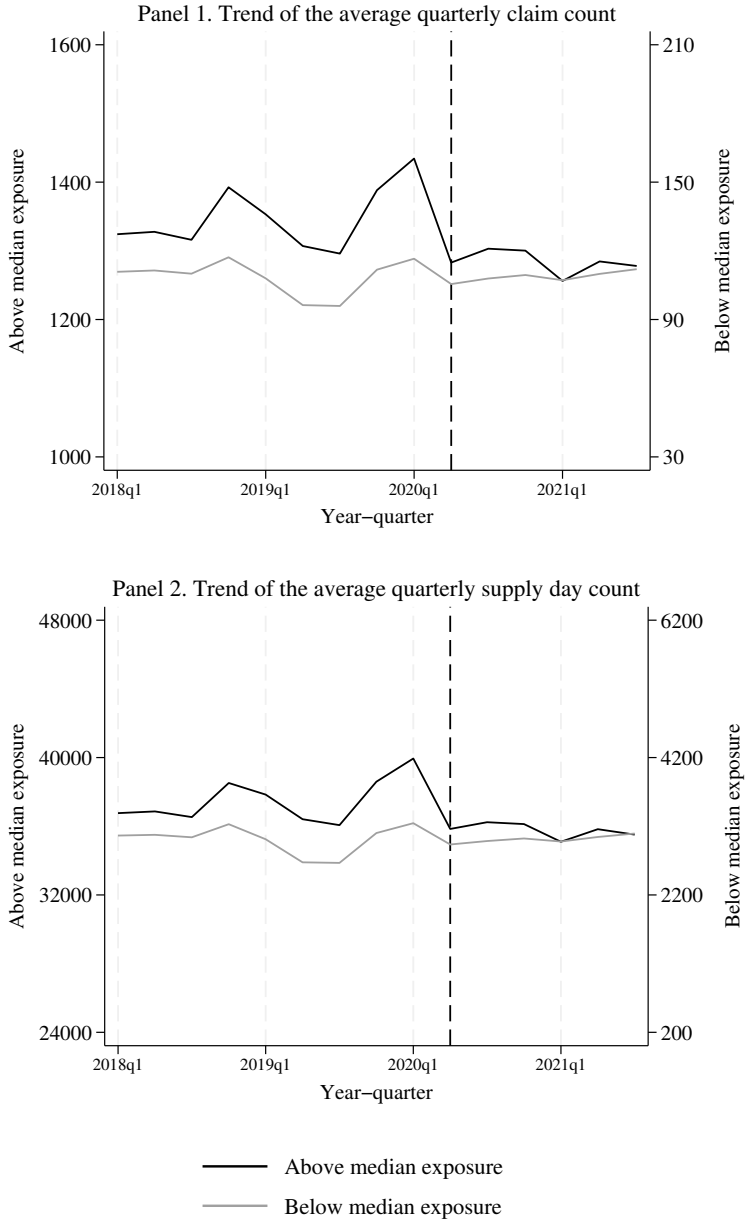
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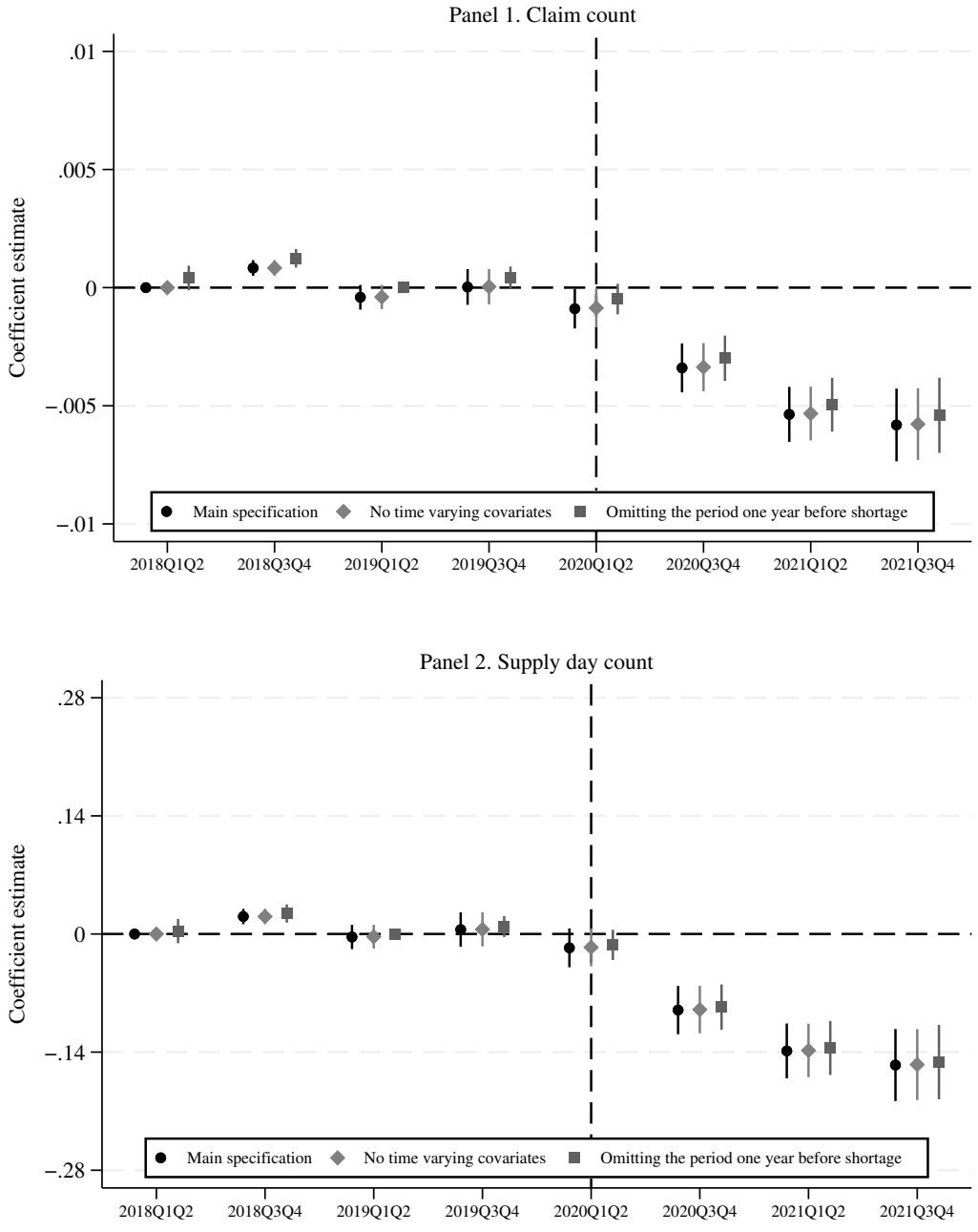
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Figure 1: Quarterly trends in extended-release amphetamine salts prescription outcomes: IQVIA Q1 2018 to Q3 2021



Notes: This figure reports trends in extended-release amphetamine salts prescription outcomes for counties at or below the median exposure to the drug shortage. The data source is IQVIA Q1 2018 to Q3 2021. The outcomes are claims count or supply day count per 1,000 in each county. Exposure is measured as the average monthly proportion of individuals with an extended-release amphetamine salts prescription Q1 2015 to Q4 2017 in each county. The unit of observation is a group-year-quarter, where the group is either above or below the median pre-shortage exposure. The vertical dashed line indicates the initiation of the drug shortage, which is the second quarter of 2020.

Figure 2: The effect of a drug shortage on extended-release amphetamine salts prescription outcomes using an event-study: IQVIA Q1 2018 to Q3 2021



Notes: This figure reports results from a regression of extended-release amphetamine salts prescription outcomes on interactions between county-level exposure and quarters relative to the national extended-release amphetamine salts drug shortage. The data source is IQVIA Q1 2018 to Q3 2021. The outcomes are claims count or supply day count per 1,000 in each county. Exposure is measured as the average monthly proportion of individuals with an extended-release amphetamine salts prescription Q1 2015 to Q4 2017 in each county. The unit of observation is a county in a quarter of a year. The regression is estimated with an OLS model and includes county-level time-varying covariates, county fixed effects, and state-by-time (state-year-quarter) fixed effects. The county-level population is the weight and the exposure variable. 2019 Q1-Q2 is the omitted category unless otherwise noted. The total number of observations is 47,055 though observations are dropped if they are singletons or separated by a fixed effect. Shapes represent coefficient estimates and vertical lines represent 95% confidence intervals that account for within-county clustering.

Table 1: The effect of a national drug shortage on extended-release amphetamine salts prescription outcomes using difference-in-differences methods: IQVIA Q1 2018 to Q3 2021

Outcome variable →	Claims	Supply days
Panel A: Primary exposure measure		
$Post_t \times exposure_c$	-4.75***	-127,479.80***
	(0.48)	(13,245.21)
Scaled β (75th – 25th percentile)†	-0.52	-14,022.78
Mean value of outcome pre-shortage	6.95	193,230.12
Percent change††	-7.48%	-7.26%
Panel B: 2018-2019 exposure level		
$Post_t \times exposure_c$	-2.92***	-77,866.52***
	(0.32)	(8,776.43)
Scaled β (75th – 25th percentile)†	-0.53	-14,015.97
Mean value of outcome pre-shortage	6.95	193,230.12
Percent change††	-7.63%	-7.25%
Panel C: 2020 (pre-shortage) exposure level		
$Post_t \times exposure_c$	-1.99***	-52,616.97***
	(0.33)	(9,184.53)
Scaled β (75th – 25th percentile)†	-0.36	-9,471.05
Mean value of outcome pre-shortage	6.95	193,230.12
Percent change††	-5.18%	-4.90%
Panel D: 2020 Q1 - 2015 Q1 exposure growth		
$Post_t \times exposure_c$	-1.85***	-48,133.79***
	(0.51)	(14,059.31)
Scaled β (75th – 25th percentile)†	-0.22	-5,776.05
Mean value of outcome pre-shortage	6.95	193,230.12
Percent change††	-3.17%	-2.99%
Panel E: 2019 deviations exposure		
$Post_t \times exposure_c$	-10.80***	-292,180.50***
	(0.95)	(26,242.41)
Scaled β (75th – 25th percentile)†	-0.54	-14,609.02
Mean value of outcome pre-shortage	6.95	193,230.12
Percent change††	-7.77%	-7.56%

Notes: This table reports results from a regression of extended-release amphetamine salts prescription outcomes on an interaction between county-level exposure and an indicator for the post-shortage period. The data source is IQVIA Q1 2018 to Q3 2021. The outcomes are claims count or supply day count per 1,000 in each county. Exposure is measured as the average monthly proportion of individuals with an extended-release amphetamine salts prescription Q1 2015 to Q4 2017 in each county. The unit of observation is a county in a quarter of a year. The regression is estimated with OLS and includes county-level time-varying covariates, county fixed effects, and state-by-time (state-year-quarter) fixed effects. The county-level population is the weight. The total number of observations is 47,055 though observations are dropped if they are singletons or separated by a fixed effects.

***, **, * = statistically different from zero at the 1%, 5%, and 10% levels.

†The coefficient estimate ($\hat{\beta}$) is scaled to reflect the difference between the county at the 75th and 25th percentile of the pre-shortage exposure measure.

††Percent change = scaled $\beta \div$ mean value of outcome pre-shortage $\times$ 100%.

Table 2: The effect of a drug shortage on the out-of-pocket cost for extended-release amphetamine salts prescription using difference-in-differences methods: IQVIA Q1 2018 to Q3 2021

Outcome variable →	Total cost	Average cost per claim
$Post_t \times exposure_c$	-234.22***	0.09**
	(18.76)	(0.05)
Scaled β (75th – 25th percentile)†	-25.76	0.01
Mean value of outcome pre-shortage	182.96	0.20
Percent change††	-14.08%	5.00%

Notes: This table reports results from a regression of the out-of-pocket costs of extended-release amphetamine salts prescription on an interaction between county-level exposure and an indicator for the post-shortage period. The data source is IQVIA Q1 2018 to Q3 2021. The outcomes are claims count or supply day count per 1,000 in each county. Exposure is measured as the average monthly proportion of individuals with an extended-release amphetamine salts prescription Q1 2015 to Q4 2017 in each county. The unit of observation is a county in a quarter of a year. The regression is estimated with OLS and includes county-level time-varying covariates, county fixed effects, and state-by-time (state-year-quarter) fixed effects. The county-level population is the weight. The total number of observations is 47,055 though observations are dropped if they are singletons or separated by a fixed effects. The costs are inflation-adjusted with 2022 quarter four as the base period.
***, **, * = statistically different from zero at the 1%, 5%, and 10% levels.
†The coefficient estimate ($\hat{\beta}$) is scaled to reflect the difference between the county at the 75th and 25th percentile of the pre-shortage exposure measures.
††Percent change = scaled $\beta \div$ mean value of outcome pre-shortage $\times$ 100%.

Table 3: The effect of a national drug shortage on other stimulant and non-stimulant drug prescription outcomes using difference-in-differences methods: IQVIA Q1 2018 to Q3 2021

Outcome variable →	Claims	Supply days
Other stimulant medications		
$Post_t \times exposure_c$	5.88***	146.09***
	(1.59)	(40.17)
Scaled β (75th – 25th percentile)†	0.65	16.07
Mean value of outcome pre-shortage	24.21	620.12
Percent change††	2.68%	2.59%
Non-stimulant medications		
$Post_t \times exposure_c$	-0.50	-7.98
	(0.46)	(11.04)
Scaled β (75th – 25th percentile)†	-0.05	-0.88
Mean value of outcome pre-shortage	10.41	262.22
Percent change††	0.48%	-0.34%

Notes: This table reports results from a regression of other and non-stimulant drug prescription outcomes on an interaction between county-level exposure and an indicator for the post-shortage period. The data source is IQVIA Q1 2018 to Q3 2021. The outcomes are claims count or supply day count per 1,000 in each county. Exposure is measured as the average monthly proportion of individuals with an extended-release amphetamine salts prescription Q1 2015 to Q4 2017 in each county. The unit of observation is a county in a quarter of a year. The regression is estimated with OLS and includes county-level time-varying covariates, county fixed effects, and state-by-time (state-year-quarter) fixed effects. The county-level population is the weight. The total number of observations is 47,055 though observations are dropped if they are singletons or separated by a fixed effects.

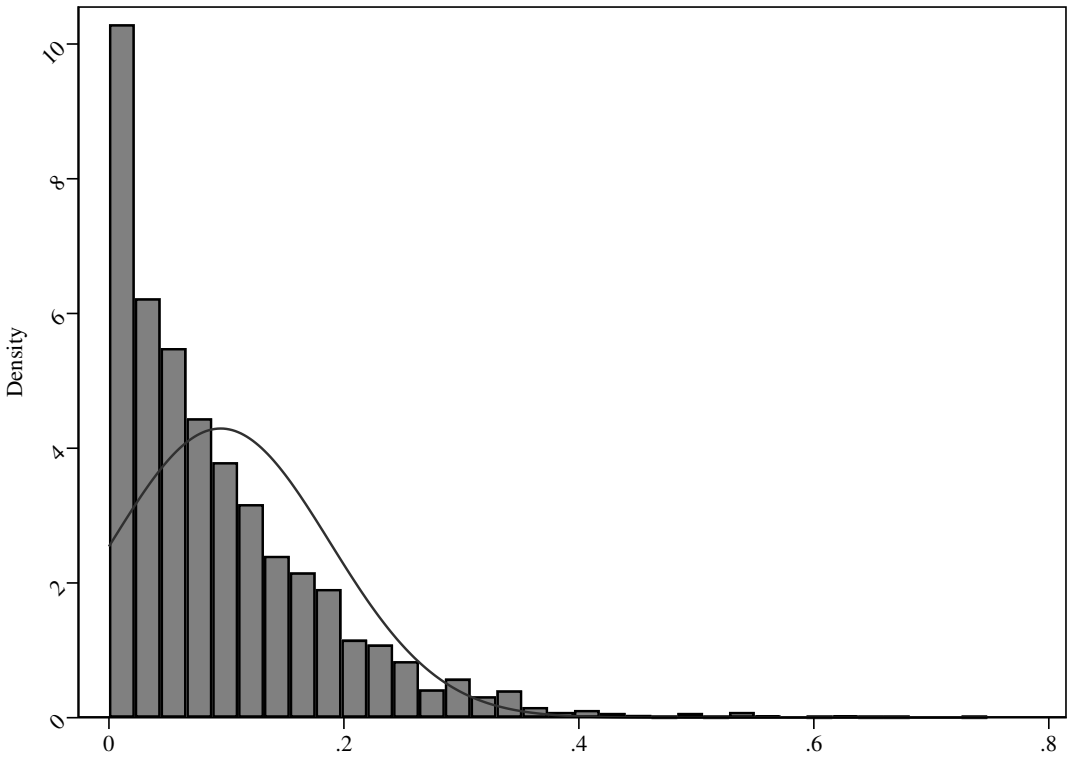
***, **, * = statistically different from zero at the 1%, 5%, and 10% levels.

†The coefficient estimate ($\hat{\beta}$) is scaled to reflect the difference between the county at the 75th and 25th percentile of the pre-shortage exposure measure.

††Percent change = scaled $\beta \div$ mean value of outcome pre-shortage $\times$ 100%.

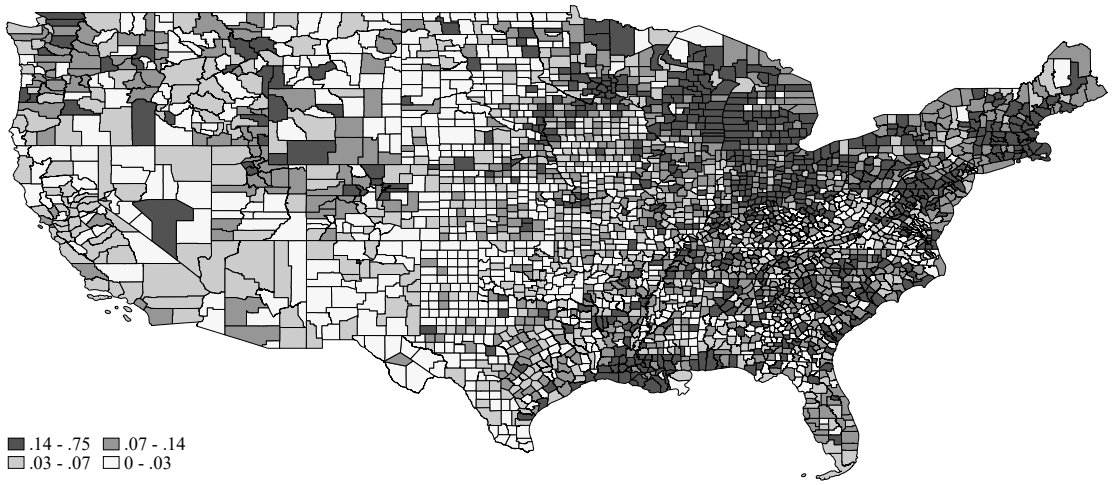
Appendix

Figure A1: Histogram of exposure to the extended-release amphetamine salts prescription outcomes drug shortage: IQVIA Q1 2015 to Q4 2017



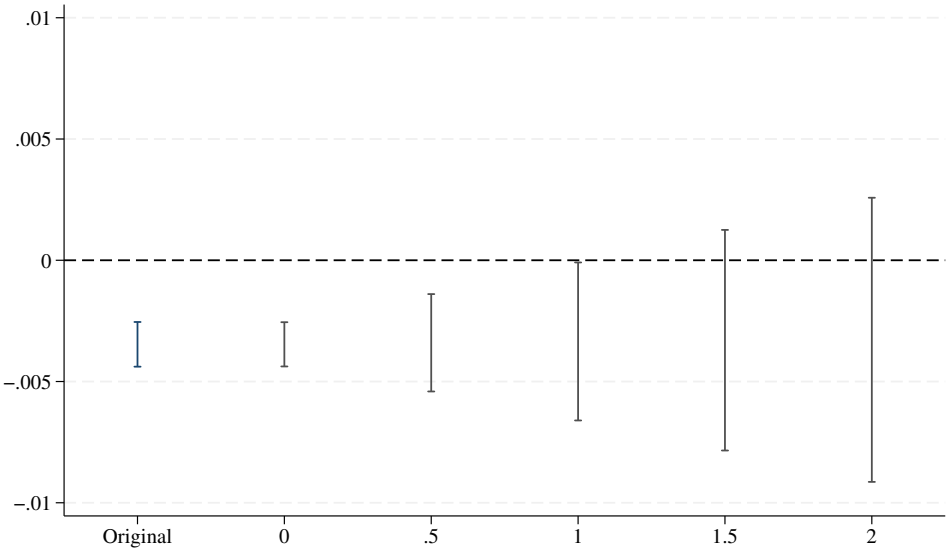
Notes: This figure reports a histogram of exposure to the extended-release amphetamine salts drug shortage. The data source is IQVIA Q1 2015 to Q4 2017. Exposure is measured as the average quarterly proportion of individuals with an extended-release amphetamine salts prescription Q1 2015 to Q4 2017 in each county. Data are at the county level and are unweighted.

Figure A2: Geographic distribution of exposure to the extended-release amphetamine salts prescription outcomes drug shortage: IQVIA Q1 2015 to Q4 2017



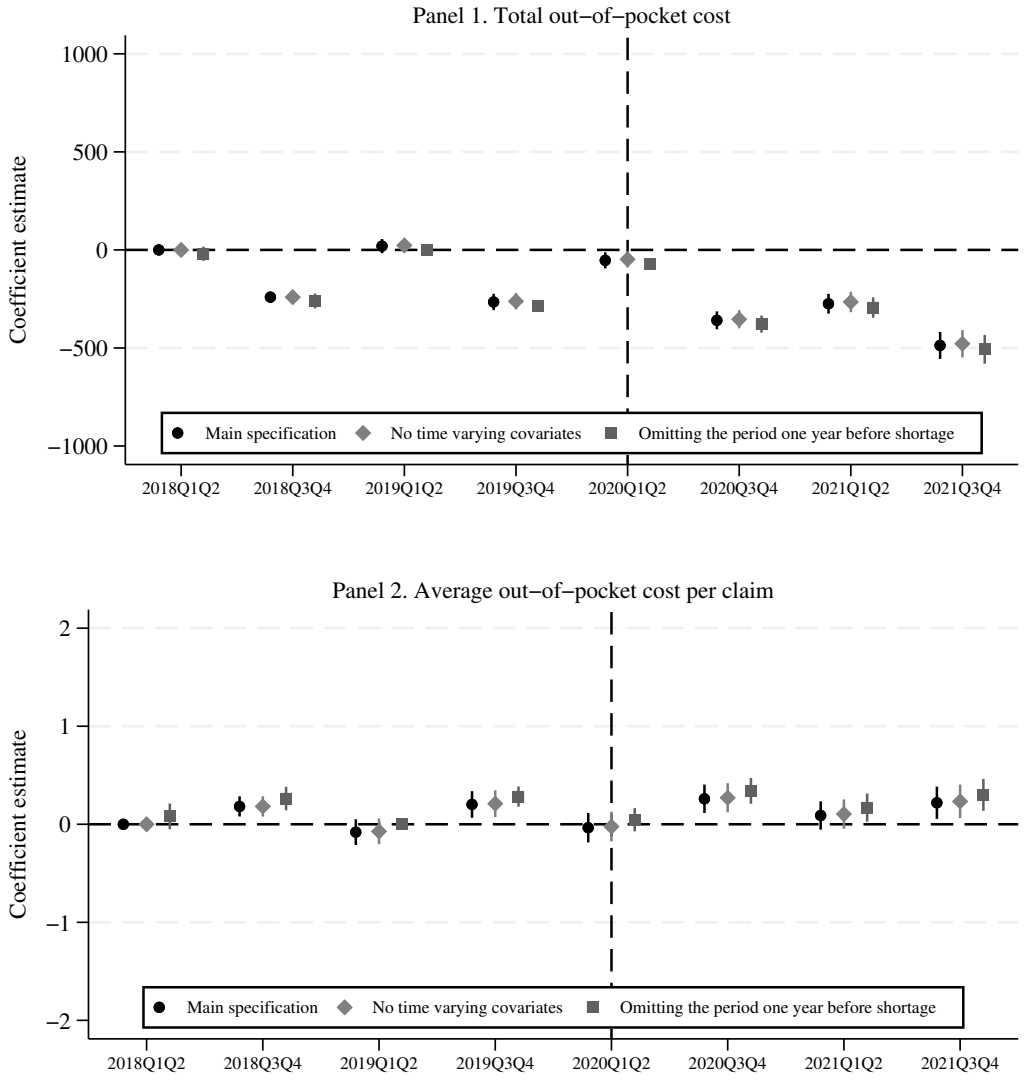
Notes: This figure reports a the geographic variation across U.S. counties in exposure to the extended-release amphetamine salts drug shortage. The data source is IQVIA Q1 2015 to Q4 2017. Exposure is measured as the average monthly proportion of individuals with an extended-release amphetamine salts prescription Q1 2015 to Q4 2017 in each county. Data are at the county level and are unweighted. Alaska and Hawaii are suppressed for readability.

Figure A3: Testing the robustness of difference-in-differences results to violations of the parallel trends assumption: IQVIA Q1 2018 to Q3 2021



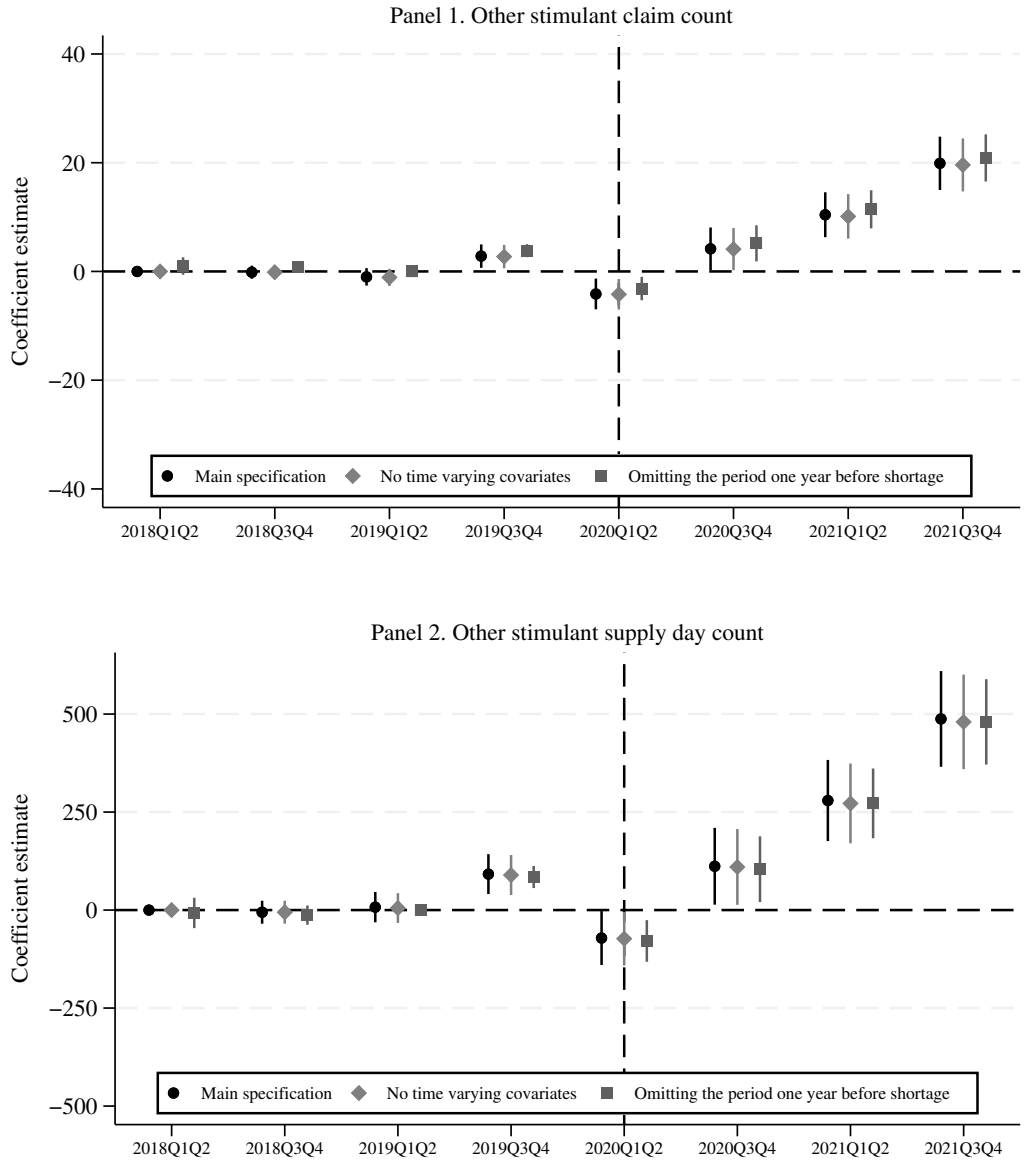
Notes: This figure reports results from the partial identification approach to testing robustness to violations of the parallel trends assumption proposed by Rambachan and Roth (2023). The data source is IQVIA Q1 2018 to Q3 2021. The outcome is the claim count per 1,000 in each county. Exposure is measured as the average monthly proportion of individuals with an extended-release amphetamine salts prescription Q1 2015 to Q4 2017 in each county. The unit of observation is a county in a quarter of a year. The regression is estimated with an OLS model and includes county-level time-varying covariates, county fixed effects, and state-by-time (state-year-quarter) fixed effects. The county-level population is the weight and the exposure variable. The total number of observations is 47,055 though observations are dropped if they are singletons or separated by a fixed effect. Vertical lines represent robust confidence intervals.

Figure A4: The effect of a drug shortage on extended-release amphetamine salts prescription out-of-pocket costs using an event-study: IQVIA Q1 2018 to Q3 2021



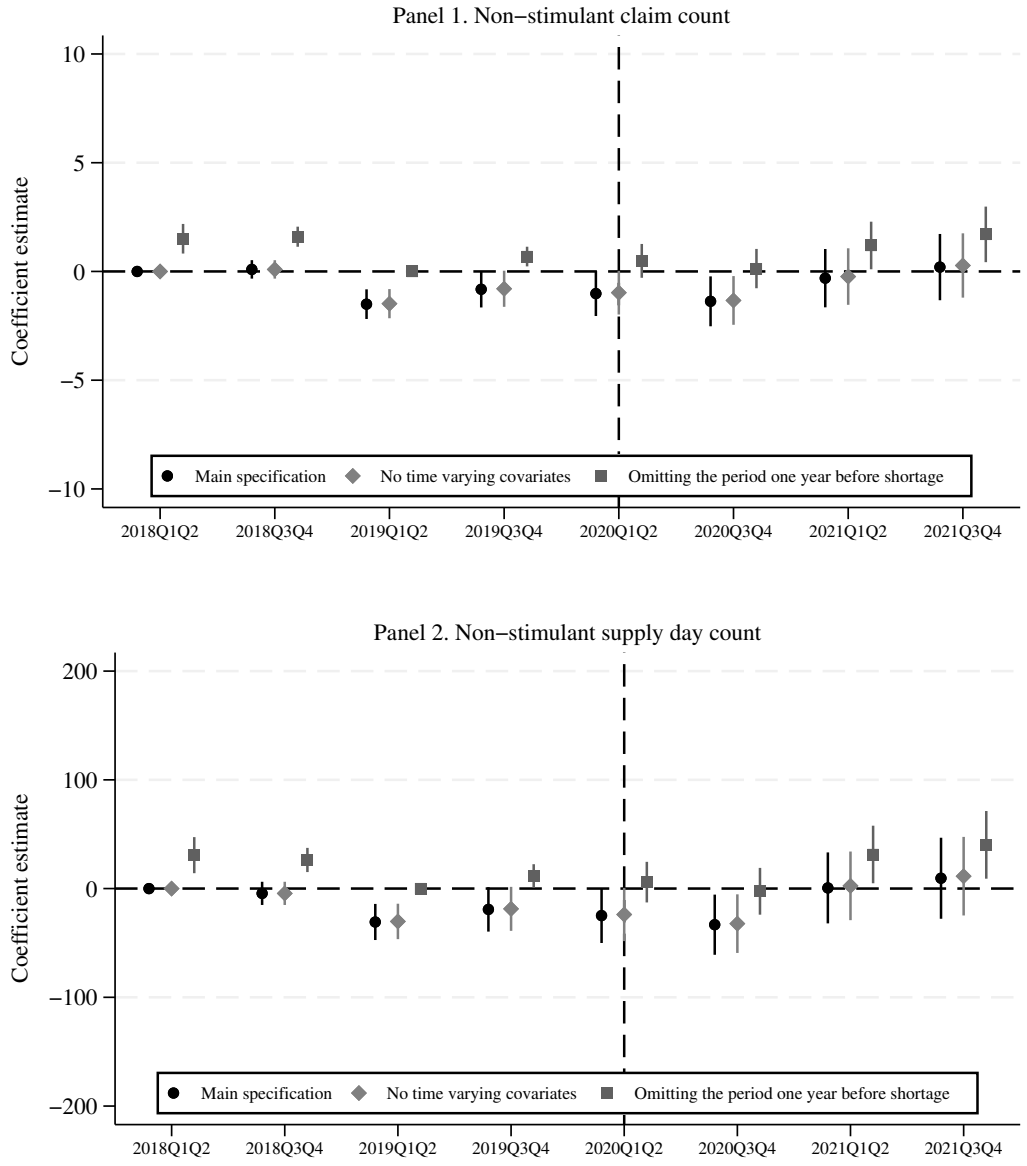
Notes: This figure reports results from a regression of extended-release amphetamine salts prescription outcomes on interactions between county-level exposure and quarters relative to the national extended-release amphetamine salts drug shortage. The data source is IQVIA Q1 2018 to Q3 2021. The outcomes are claims count or supply day count per 1,000 in each county. Exposure is measured as the average monthly proportion of individuals with an extended-release amphetamine salts prescription Q1 2015 to Q4 2017 in each county. The unit of observation is a county in a quarter of a year. The regression is estimated with an OLS model and includes county-level time-varying covariates, county fixed effects, and state-by-time (state-year-quarter) fixed effects. The county-level population is the weight and the exposure variable. 2018 Q1-Q2 is the omitted category unless otherwise noted. The total number of observations is 47,055 though observations are dropped if they are singletons or separated by a fixed effect. Shapes represent coefficient estimates and vertical lines represent 95% confidence intervals that account for within-county clustering.

Figure A5: The effect of a drug shortage on other stimulants using an event-study: IQVIA Q1 2018 to Q3 2021



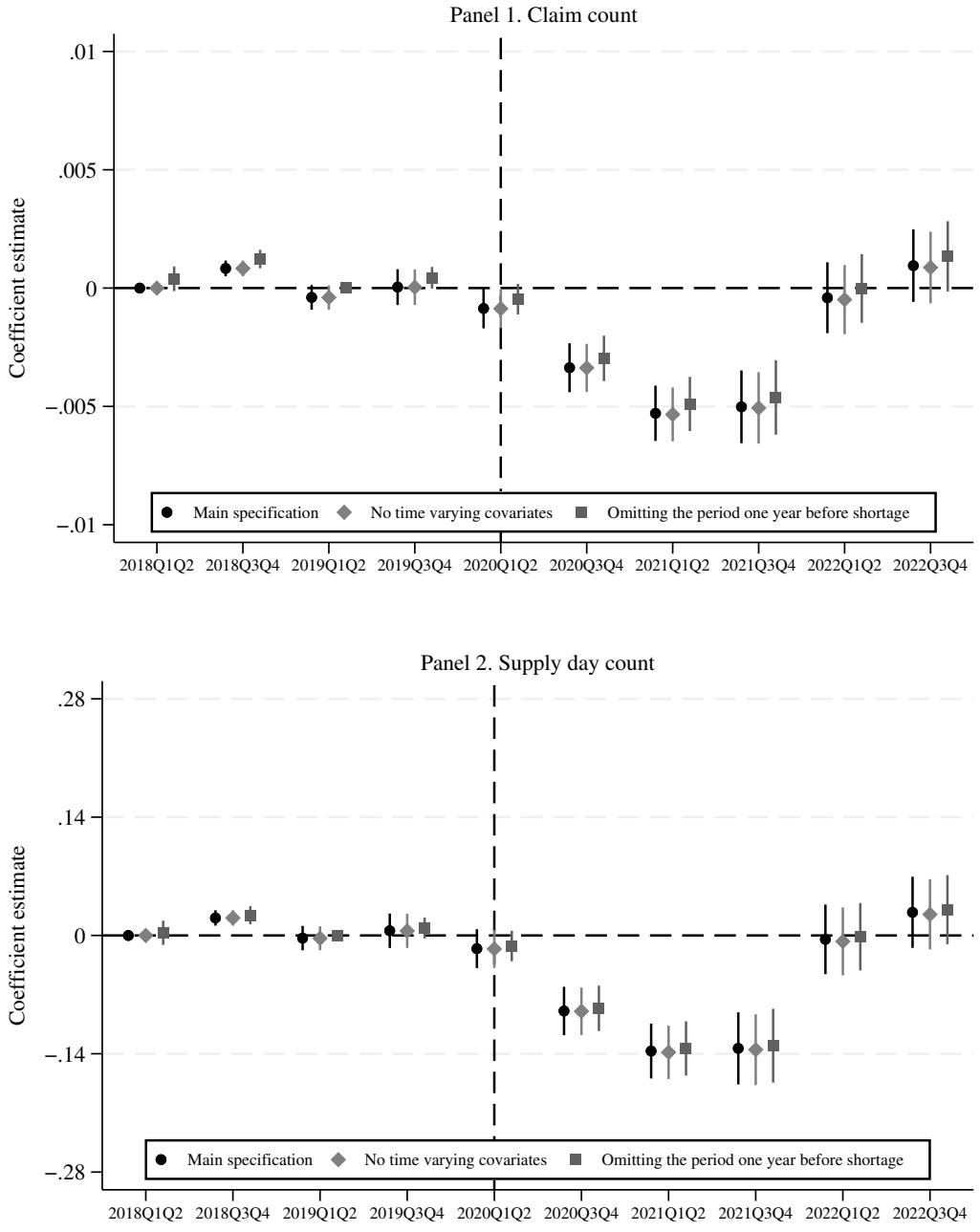
Notes: This figure reports results from a regression of other stimulant prescription outcomes on interactions between county-level exposure and quarters relative to the national extended-release amphetamine salts drug shortage. The data source is IQVIA Q1 2018 to Q3 2021. The outcomes are claims count or supply day count per 1,000 in each county. Exposure is measured as the average monthly proportion of individuals with an extended-release amphetamine salts prescription Q1 2015 to Q4 2017 in each county. The unit of observation is a county in a quarter of a year. The regression is estimated with an OLS model and includes county-level time-varying covariates, county fixed effects, and state-by-time (state-year-quarter) fixed effects. The county-level population is the weight and the exposure variable. 2018 Q1-Q2 is the omitted category unless otherwise noted. The total number of observations is 47,055 though observations are dropped if they are singletons or separated by a fixed effect. Shapes represent coefficient estimates and vertical lines represent 95% confidence intervals that account for within-county clustering.

Figure A6: The effect of a drug shortage on non-stimulants using an event-study: IQVIA Q1 2018 to Q3 2021



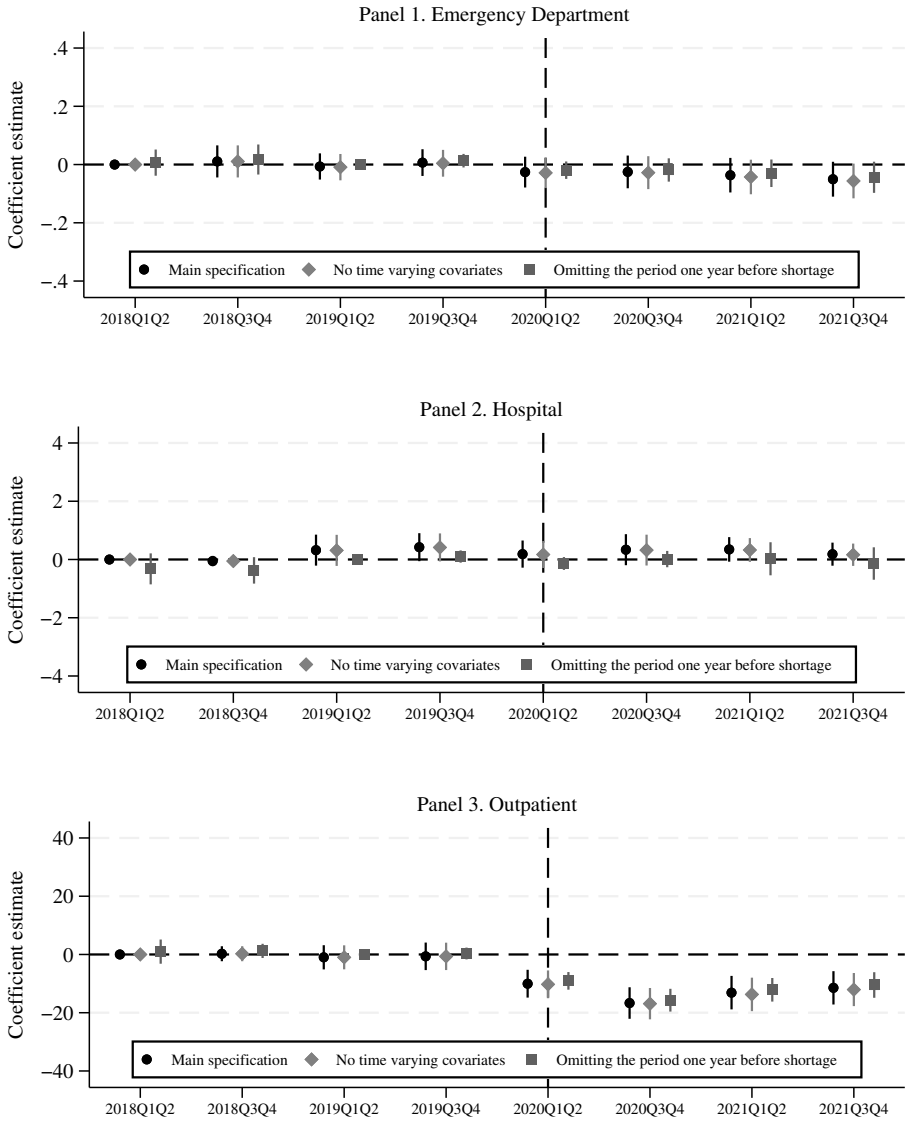
Notes: This figure reports results from a regression of non-stimulant prescription outcomes on interactions between county-level exposure and quarters relative to the national extended-release amphetamine salts drug shortage. The data source is IQVIA Q1 2018 to Q3 2021. The outcomes are claims count or supply day count per 1,000 in each county. Exposure is measured as the average monthly proportion of individuals with an extended-release amphetamine salts prescription Q1 2015 to Q4 2017 in each county. The unit of observation is a county in a quarter of a year. The regression is estimated with an OLS model and includes county-level time-varying covariates, county fixed effects, and state-by-time (state-year-quarter) fixed effects. The county-level population is the weight and the exposure variable. 2018 Q1-Q2 is the omitted category unless otherwise noted. The total number of observations is 47,055 though observations are dropped if they are singletons or separated by a fixed effect. Shapes represent coefficient estimates and vertical lines represent 95% confidence intervals that account for within-county clustering.

Figure A7: The effect of a drug shortage on extended-release amphetamine salts prescription outcomes using an event-study and an extended time-period: IQVIA Q1 2018 to Q4 2022



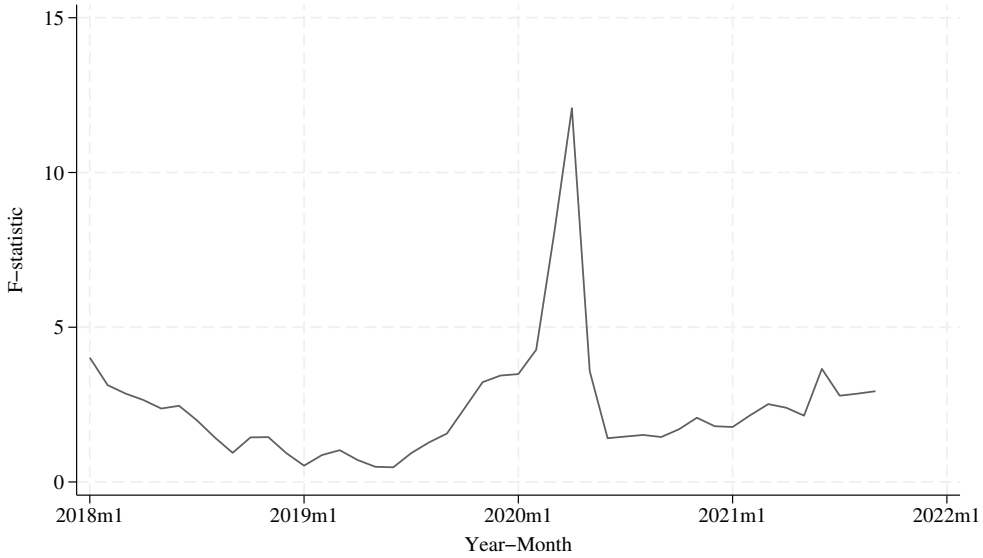
Notes: This figure reports results from a regression of extended-release amphetamine salts prescription outcomes on interactions between county-level exposure and quarters relative to the national extended-release amphetamine salts drug shortage. The data source is IQVIA Q1 2018 to Q4 2022. The outcomes are claims count or supply day count per 1,000 in each county. Exposure is measured as the average monthly proportion of individuals with an extended-release amphetamine salts prescription Q1 2015 to Q4 2017 in each county. The unit of observation is a county in a quarter of a year. The regression is estimated with a Poisson model and includes county-level time-varying covariates, county-fixed effects, and state-by-time (state-year-quarter) fixed effects. Coefficient estimates are converted to average marginal effects. The county-level population is the weight and exposure variable. 2019 Q1-Q2 is the omitted category unless otherwise noted. Shapes represent coefficient estimates and vertical lines represent 95% confidence intervals that account for within-county clustering. Different from Figure 2, the time period in this figure extends beyond the main study period to include the time after the 2020 shortage was declared resolved.

Figure A8: The effect of a drug shortage on services using an event-study: IQVIA Q1 2018 to Q3 2021



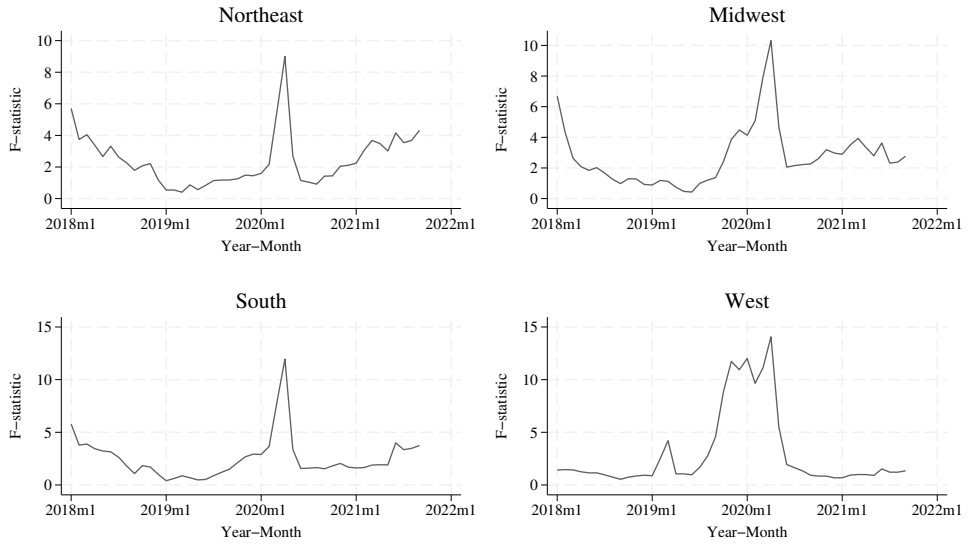
Notes: This figure reports results from a regression of ADHD-related health outcomes on interactions between county-level exposure and quarters relative to the national extended-release amphetamine salts drug shortage. The data source is IQVIA Q1 2018 to Q3 2021. The outcomes are claims count or supply day count per 1,000 in each county. Exposure is measured as the average monthly proportion of individuals with an extended-release amphetamine salts prescription Q1 2015 to Q4 2017 in each county. The unit of observation is a county in a quarter of a year. The regression is estimated with an OLS model and includes county-level time-varying covariates, county fixed effects, and state-by-time (state-year-quarter) fixed effects. The county-level population is the weight and the exposure variable. 2018 Q1-Q2 is the omitted category unless otherwise noted. The total number of observations is 47,055 though observations are dropped if they are singletons or separated by a fixed effect. Shapes represent coefficient estimates and vertical lines represent 95% confidence intervals that account for within-county clustering.:

Figure A9: Structural break test for extended-release amphetamine salts prescription outcomes: IQVIA Q1 2018 to Q3 2021



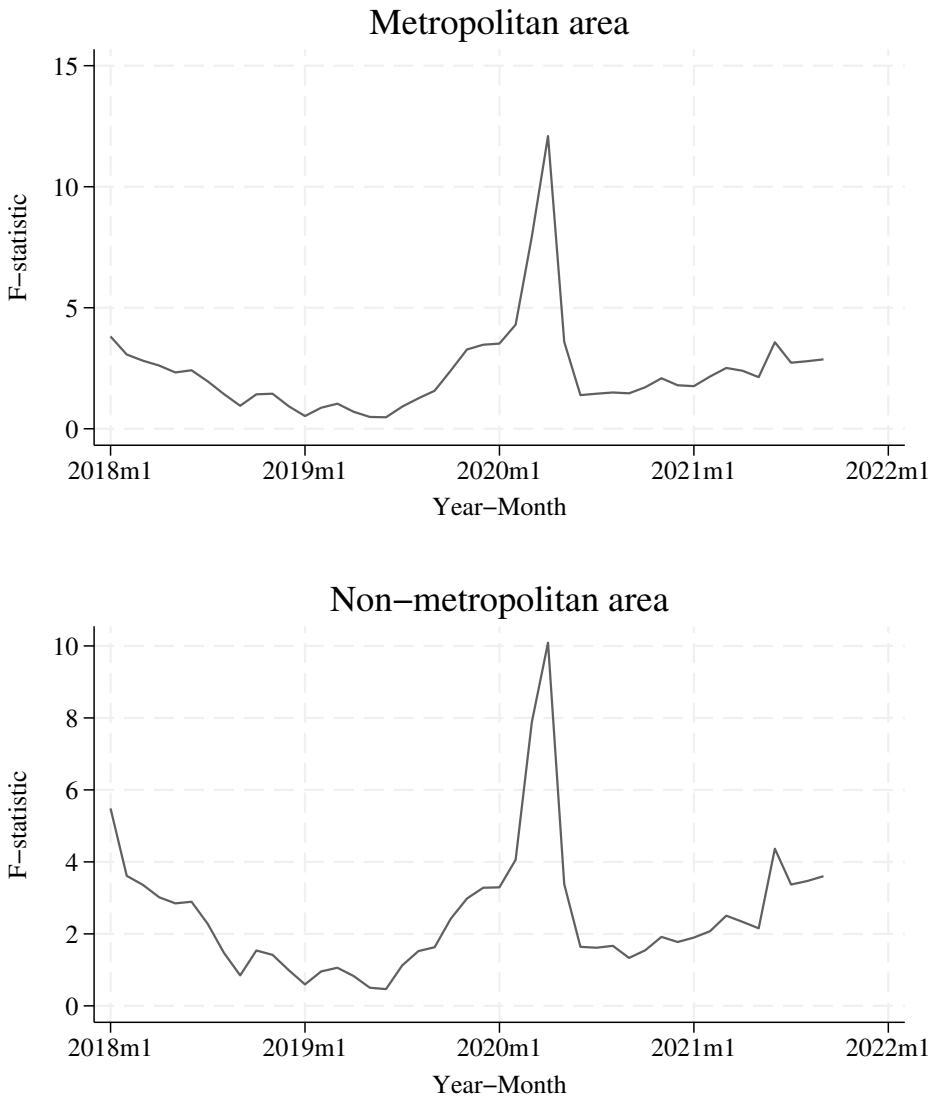
Notes: This figure reports the results of testing for a structural break each month in the study period. F-statistics are plotted. See Section 5 for details. Data source is IQVIA 2018-2022. Data are at the year-month level and are unweighted.

Figure A10: Structural break test for extended-release amphetamine salts prescription outcomes by U.S. regions: IQVIA Q1 2018 to Q3 2021



Notes: This figure reports the results of testing for a structural break each month in the study period. F-statistics are plotted. See Section 5 for details. Data source is IQVIA 2018-2022. Data are at the year-month level and are unweighted. States in the Northeast region include: Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont. States in the Midwest region include: Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin. States in the South region include: Alabama, Arkansas, Delaware, District of Columbia, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, and West Virginia. States in the West region include: Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming.

Figure A11: Structural break test for extended-release amphetamine salts prescription outcomes by county urbanicity: IQVIA Q1 2018 to Q3 2021



Notes: This figure reports the results of testing for a structural break each month in the study period. F-statistics are plotted. See Section 5 for details. Data source is IQVIA 2018-2022. Data are at the year-month level and are unweighted.

Table A1: List of National Drug Codes used to identify extended-release amphetamine salts

Drug type	National Drug Codes
Extended-release amphetamine salts	00115148601, 00115148701, 00115148801, 00115148901, 00115149001, 00115149101, 00228305911, 00228306011, 00228306111, 00228306211, 00228306311, 00228306411, 00406895101, 00406895301, 00406895501, 00527079037, 00527079137, 00527079337, 00527079537, 00527148837, 00527551437, 00781232901, 00781233501, 00781234301, 00781235201, 00781236801, 00781237101, 24478010201, 24478010601, 24478010801, 24478010901, 24478011001, 31722018501, 31722018601, 31722018701, 31722018801, 31722018901, 31722019501, 42858005501, 42858021501, 42858032501, 42858061010, 42858072001, 42858093001, 49884083901, 49884084001, 49884084101, 49884084201, 49884084301, 49884084401, 54092038101, 54092038301, 54092038501, 54092038701, 54092038901, 54092039101, 54092046801, 54092047101, 54092047401, 54092047701, 57664033688, 57664033788, 57664033888, 57664033988, 57664034088, 57664034188, 66993059402, 66993059502, 66993059602, 66993059702, 66993059802, 66993059902, 70165000530, 70165001030, 70165001530, 70165002030, 70165002530, 70165003030

Notes: This table reports National Drug Codes we use to identify extended-release amphetamine salt prescriptions. The data source is IQVIA 2018-2022.

Table A2: List of National Drug Codes used to identify other stimulant and non-stimulant medications used to treat attention-deficit/hyperactivity disorder

Medications class ↓	National Drug Codes (examples)
Other stimulants	00078038005, 63629946701, 70010000401
	00007351156, 64720013110, 70165000530
	00406511101, 67651005301, 72162221601
	50458058501, 50458058601, 50458058701
	68968555230, 68968555330, 68968555430
	43386057001,43386057101,43386057201
	00078043905, 00078044005, 00078044105
	65038028699, 65038042999, 65038056199
Medications class ↓	National Drug Codes (examples)
Non-stimulants	00002322701, 00005318023, 00031890363
	00182176829, 00781226531, 16714083901
	17772013307, 21695037100, 27241024301
	31722071430, 33358009360, 38779056102
	43547056710, 53506072230, 54092051302
	54274020950, 54569047807, 60346078790
	62332005471, 62584065701, 63370005225
	71205058812, 82393020905, 99114153323

Notes: This table reports National Drug Codes we use to identify stimulant and non-stimulant prescription medications. The data source is IQVIA 2018-2022.

Table A3: Correlation of alternative measures of exposure to the shortage: IQVIA Q1 2015 to Q2 2020

Exposure	Primary exposure	2018-2019 exposure level	2020 (pre-shortage) exposure level	2020Q1 vs 2015Q1 growth rate	2019 deviations exposure
Primary exposure	1				
2018-2019 exposure level	0.94	1			
2020 (pre-shortage) exposure level	0.90	0.97	1		
2020Q1 vs 2015Q1 growth rate	0.67	0.85	0.91	1	
2019 deviations exposure	0.61	0.62	0.50	0.43	1

Notes: This table reports correlations between alternative measures of exposure to the 2020 shortage that are weighted by the county population. The data source is IQVIA Q1 2015 to Q2 2020. The unit of observation is a county in a period (year-quarter).

Table A4: Summary statistics: IQVIA Q1 2018 to Q3 2021

Variable ↓	N	Mean	Std. Dev.	Min	Median	Max
Exposure variable						
Extended-release amphetamine salts prescription 2015-17 (%)†	3,137	0.0953	0.0929	0	0.0698	0.7476
Outcome variables						
Claim count	47,055	6,053	7,528	0	3,295	35,809
Supply day count	47,055	168,329	208,984	0	91,865	999,902
Covariates						
0-5 years (proportion)	47,055	0.0703	0.0102	0.0066	0.0697	0.1539
6-18 years (proportion)	47,055	0.1656	0.0211	0.0181	0.1637	0.3684
19-39 years (proportion)	47,055	0.2853	0.0417	0.1129	0.2829	0.5691
40-64 years (proportion)	47,055	0.3159	0.0239	0.1131	0.3181	0.5157
65+ years (proportion)	47,055	0.1629	0.0406	0.0460	0.1566	0.5848
Female (proportion)	47,055	0.5040	0.0124	0.2530	0.5042	0.5765
Male (proportion)	47,055	0.4960	0.0124	0.4235	0.4958	0.7470
White (proportion)	47,055	0.7742	0.1503	0.0873	0.7985	0.9946
Black (proportion)	47,055	0.1431	0.1312	0.0005	0.0971	0.8690
Other race (proportion)	47,055	0.0827	0.0882	0.0000	0.0565	0.9029
Hispanic (proportion)	47,055	0.1853	0.1712	0.0064	0.1195	0.9634
Non-Hispanic (proportion)	47,055	0.9006	0.1391	0.0366	0.9534	0.9936
Population	47,055	105,315	334,881	57	25,795	10,098,033

Notes: This table reports summary statistics that are weighted by the county population. The data source is IQVIA Q1 2018 to Q3 2021. Exposure is measured as the average monthly proportion of individuals with an extended-release amphetamine salts prescription Q1 2015 to Q4 2017 in each county. The unit of observation is a county in a period (year-quarter). †Exposure is time-invariant and thus the sample size is smaller than the full sample.

Table A5: Summary statistics in counties with different levels of exposure to the shortage: IQVIA Q1 2018 to Q3 2021

Sample →	At or above median exposure	Below median exposure
Exposure variable		
Extended-release amphetamine salts prescription 2015-17 (%)†	0.1623	0.0279
Outcome variables		
Claim count per 1,000	1,323	109
Supply day count per 1,000	36,812	3,011
Covariates		
0-5 years (proportion)	0.0681	0.0683
6-18 years (proportion)	0.1642	0.1645
19-39 years (proportion)	0.2640	0.2416
40-64 years (proportion)	0.3189	0.3200
65+ years (proportion)	0.1847	0.2060
Female (proportion)	0.5001	0.4903
Male (proportion)	0.4999	0.5097
White (proportion)	0.8524	0.8569
Black (proportion)	0.1117	0.0892
Other race (proportion)	0.0360	0.0539
Hispanic (proportion)	0.0800	0.1189
Non-Hispanic (proportion)	0.9200	0.8811
Population	159,354	51,035
N	23,580	23,475

Notes: This table reports summary statistics that are weighted by the county population. The data source is IQVIA Q1 2018 to Q3 2021. Exposure is measured as the average monthly proportion of individuals with an extended-release amphetamine salts prescription Q1 2015 to Q4 2017 in each county. The unit of observation is a county in a period (year-quarter). †Exposure is time-invariant and thus the sample size is smaller than the full sample.

Table A6: Heterogeneity by patient age in the effect of a supply shortage on extended-release amphetamine salts prescription outcomes using difference-in-differences methods: IQVIA Q1 2018 to Q3 2021)

Outcome variable →	Claims	Supply days
Sample: Age 0-18	-4.12***	-465,057.00***
	(0.2069)	(23,474.60)
Scaled β (75th – 25th percentile)†	0.4651	-52,485.28
Mean value of outcome pre-shortage	2.28	270,533.80
Percent change††	-20.42%	-19.40%
Sample: Age 19-64	-0.5885*	-14,411.52
	(0.3406)	(15,936.48)
Scaled β (75th – 25th percentile)†	-0.0664	-1,626.45
Mean value of outcome pre-shortage	4.50	206,143.27
Percent change††	-1.48%	-0.79%
Sample: Age 65+	-0.0448**	-18,944.28***
	(0.0196)	(3,385.45)
Scaled β (75th – 25th percentile)†	-0.0051	-2,138.01
Mean value of outcome pre-shortage	0.1744	31,696.78
Percent change††	-2.90%	-6.75%

Notes: This table reports results from a regression of extended-release amphetamine salts prescription outcomes on an interaction between county-level exposure and an indicator for the post-shortage period separately by patient age. The data source is IQVIA Q1 2018 to Q3 2021. The outcomes are claims count or supply day count per 1,000 in each county. Exposure is measured as the average monthly proportion of individuals with an extended-release amphetamine salts prescription Q1 2015 to Q4 2017 in each county. The unit of observation is a county in a quarter of a year. The regression is estimated with OLS and includes county-level time-varying covariates, county fixed effects, and state-by-time (state-year-quarter) fixed effects. The county-level population is the weight. The total number of observations is 47,055 though observations are dropped if they are singletons or separated by a fixed effects.
***, **, * = statistically different from zero at the 1%, 5%, and 10% levels.
†The coefficient estimate ($\hat{\beta}$) is scaled to reflect the difference between the county at the 75th and 25th percentile of the pre-shortage exposure measure.
††Percent change = scaled $\beta \div$ mean value of outcome pre-shortage $\times$ 100%.

Table A7: Heterogeneity by patient sex in the effect of a national drug shortage on extended-release amphetamine salts prescription outcomes using difference-in-differences methods: IQVIA Q1 2018 to Q3 2021

Outcome variable →	Claims	Supply days
Sample: Women	-1.31***	-1.32***
	(0.25)	(0.23)
Scaled β (75th – 25th percentile)†	-0.14	-0.15
Mean value of outcome pre-shortage	3.42	1.21
Percent change††	-4.09%	-12.40%
Sample: Men	-3.45***	-1.46***
	(0.25)	(0.26)
Scaled β (75th – 25th percentile)†	-0.38	-0.16
Mean value of outcome pre-shortage	3.53	1.31
Percent change††	-10.76%	-12.21%

Notes: This table reports results from a regression of extended-release amphetamine salts prescription outcomes on an interaction between county-level exposure and an indicator for the post-shortage period separately by patient age. The data source is IQVIA Q1 2018 to Q3 2021. The outcomes are claims count or supply day count per 1,000 in each county. Exposure is measured as the average monthly proportion of individuals with an extended-release amphetamine salts prescription Q1 2015 to Q4 2017 in each county. The unit of observation is a county in a quarter of a year. The regression is estimated with OLS and includes county-level time-varying covariates, county fixed effects, and state-by-time (state-year-quarter) fixed effects. The county-level population is the weight. The total number of observations is 47,055 though observations are dropped if they are singletons or separated by a fixed effects.
***, **, * = statistically different from zero at the 1%, 5%, and 10% levels.
†The coefficient estimate ($\hat{\beta}$) is scaled to reflect the difference between the county at the 75th and 25th percentile of the pre-shortage exposure measure.
††Percent change = scaled $\beta \div$ mean value of outcome pre-shortage $\times$ 100%.

Table A8: Heterogeneity by payer in the effect of a national drug shortage on extended-release amphetamine salts prescription outcomes using difference-in-differences methods: IQVIA Q1 2018 to Q3 2021

Outcome variable →	Claims	Supply days
Sample: Commercial	-1.60***	-0.50***
	(0.24)	(0.11)
Scaled β (75th – 25th percentile)†	-0.18	-0.05
Mean value of outcome pre-shortage	3.40	0.57
Percent change††	-5.29%	-8.77%
Sample: Medicare	-0.40***	-0.06***
	(0.07)	(0.02)
Scaled β (75th – 25th percentile)†	-0.04	-0.01
Mean value of outcome pre-shortage	0.29	0.05
Percent change††	-13.79%	-20.00%
Sample: Medicaid	-1.74***	-0.49***
	(0.21)	(0.12)
Scaled β (75th – 25th percentile)†	-0.19	-0.05
Mean value of outcome pre-shortage	1.76	0.41
Percent change††	-10.80%	-12.20%
Sample: Self-pay/cash	-0.15***	-0.06***
	(0.02)	(0.01)
Scaled β (75th – 25th percentile)†	-0.02	-0.01
Mean value of outcome pre-shortage	0.08	0.02
Percent change††	-25.00%	-50.00%
Sample: Other	-0.87***	-0.27***
	(0.14)	(0.06)
Scaled β (75th – 25th percentile)†	-0.10	-0.03
Mean value of outcome pre-shortage	1.43	0.21
Percent change††	-6.99%	-14.29%

Notes: This table reports results from a regression of extended-release amphetamine salts prescription outcomes on an interaction between county-level exposure and an indicator for the post-shortage period separately by payer type. The data source is IQVIA Q1 2018 to Q3 2021.The outcomes are claims count or supply day count per 1,000 in each county. Exposure is measured as the average monthly proportion of individuals with an extended-release amphetamine salts prescription Q1 2015 to Q4 2017 in each county. The unit of observation is a county in a quarter of a year. The regression is estimated with OLS and includes county-level time-varying covariates, county fixed effects, and state-by-time (state-year-quarter) fixed effects. The county-level population is the weight. The total number of observations is 47,055 though observations are dropped if they are singletons or separated by a fixed effects.
***, **, * = statistically different from zero at the 1%, 5%, and 10% levels.
†The coefficient estimate ($\hat{\beta}$) is scaled to reflect the difference between the county at the 75th and 25th percentile of the pre-shortage exposure measure.
††Percent change = scaled $\beta \div$ mean value of outcome pre-shortage $\times$ 100%.

Table A9: Heterogeneity by new vs. existing patients in the effect of a national drug shortage on extended-release amphetamine salts prescription outcomes using difference-in-differences methods: IQVIA Q1 2018 to Q3 2021

Outcome variable →	Claims	Supply days
Sample: Existing patients	-4.51***	-120.75***
	(0.45)	(12.63)
Scaled β (75th – 25th percentile)†	-0.50	-13.28
Mean value of outcome pre-shortage	6.49	180.62
Percent change††	-7.70%	-7.35%
Sample: New patients	-0.24***	-7.44***
	(0.04)	(0.99)
Scaled β (75th – 25th percentile)†	-0.03	-0.82
Mean value of outcome pre-shortage	0.46	13.38
Percent change††	-6.52%	-6.13%

Notes: This table reports results from a regression of extended-release amphetamine salts prescription outcomes on an interaction between county-level exposure and an indicator for the post-shortage period separately by new vs. existing patients. The data source is IQVIA Q1 2018 to Q3 2021. The outcomes are claims count or supply day count per 1,000 in each county. Exposure is measured as the average monthly proportion of individuals with an extended-release amphetamine salts prescription Q1 2015 to Q4 2017 in each county. The unit of observation is a county in a quarter of a year. The regression is estimated with OLS and includes county-level time-varying covariates, county fixed effects, and state-by-time (state-year-quarter) fixed effects. The county-level population is the weight. The total number of observations is 47,055 though observations are dropped if they are singletons or separated by a fixed effects.
***, **, * = statistically different from zero at the 1%, 5%, and 10% levels.
†The coefficient estimate ($\hat{\beta}$) is scaled to reflect the difference between the county at the 75th and 25th percentile of the pre-shortage exposure measure.
††Percent change = scaled $\beta \div$ mean value of outcome pre-shortage $\times$ 100%.

Table A10: Heterogeneity by paid sick leave mandate in the effect of a national drug shortage on extended-release amphetamine salts prescription outcomes using difference-in-differences methods: IQVIA Q1 2018 to Q3 2021

Outcome variable →	Claims	Supply days
Sample: States with a paid sick leave mandate	-2.36***	-58520.12***
	(0.65)	(17,711.43)
Scaled β (75th – 25th percentile)†	-0.26	-6,437.21
Mean value of outcome pre-shortage	5.64	154,441.90
Percent change††	-4.61%	-4.17%
Sample: States without a paid sick leave mandate	-5.22***	-141,306.73***
	(0.52)	(14,545.50)
Scaled β (75th – 25th percentile)†	-0.57	-15,543.74
Mean value of outcome pre-shortage	7.40	206,395.22
Percent change††	-7.70%	-7.53%

Notes: This table reports results from a regression of extended-release amphetamine salts prescription outcomes on an interaction between county-level exposure and an indicator for the post-shortage period separately by states that do an do not have a paid sick leave mandate in place. The data source is IQVIA Q1 2018 to Q3 2021. The outcomes are claims count or supply day count per 1,000 in each county. Exposure is measured as the average monthly proportion of individuals with an extended-release amphetamine salts prescription Q1 2015 to Q4 2017 in each county. The unit of observation is a county in a quarter of a year. The regression is estimated with OLS and includes county-level time-varying covariates, county fixed effects, and state-by-time (state-year-quarter) fixed effects. The county-level population is the weight. The total number of observations is 47,055 though observations are dropped if they are singletons or separated by a fixed effects.
***, **, * = statistically different from zero at the 1%, 5%, and 10% levels.
†The coefficient estimate ($\hat{\beta}$) is scaled to reflect the difference between the county at the 75th and 25th percentile of the pre-shortage exposure measure.
††Percent change = scaled $\beta \div$ mean value of outcome pre-shortage $\times$ 100%.

Table A11: Heterogeneity by states that do and do not have a law that extends nurse practioner scope of practice in the effect of a national drug shortage on extended-release amphetamine salts prescription outcomes using difference-in-differences methods: IQVIA Q1 2018 to Q3 2021

Outcome variable →	Claims	Supply days
Sample: States with a scope of practice law	-2.20***	-53,418.92***
	(0.70)	(19,541.84)
Scaled β (75th – 25th percentile)†	-0.24	-5,876.08
Mean value of outcome pre-shortage	7.28	199,488.58
Percent change††	-3.30%	-2.95%
Sample: States without a scope of practice law	-6.08***	-165,888.04***
	(0.59)	(16,257.85)
Scaled β (75th – 25th percentile)†	-0.67	-18,247.68
Mean value of outcome pre-shortage	6.81	190,440.37
Percent change††	-9.84%	-9.58%

Notes: This table reports results from a regression of extended-release amphetamine salts prescription outcomes on an interaction between county-level exposure and an indicator for the post-shortage period separately by states that have a law that extends nurse practioner scope of practice. The data source is IQVIA Q1 2018 to Q3 2021. The outcomes are claims count or supply day count per 1,000 in each county. Exposure is measured as the average monthly proportion of individuals with an extended-release amphetamine salts prescription Q1 2015 to Q4 2017 in each county. The unit of observation is a county in a quarter of a year. The regression is estimated with OLS and includes county-level time-varying covariates, county fixed effects, and state-by-time (state-year-quarter) fixed effects. The county-level population is the weight. The total number of observations is 47,055 though observations are dropped if they are singletons or separated by a fixed effects.
***, **, * = statistically different from zero at the 1%, 5%, and 10% levels.
†The coefficient estimate ($\hat{\beta}$) is scaled to reflect the difference between the county at the 75th and 25th percentile of the pre-shortage exposure measure.
††Percent change = scaled $\beta \div$ mean value of outcome pre-shortage $\times$ 100%.

Table A12: Heterogeneity by county metropolitan status in the effect of a national drug shortage on extended-release amphetamine salts prescription outcomes using difference-in-differences methods: IQVIA Q1 2018 to Q3 2021

Outcome variable →	Claims	Supply days
Sample: Metropolitan counties	-4.60***	-0.66***
	(0.55)	(0.17)
Scaled β (75th – 25th percentile)†	-0.51	-0.07
Mean value of outcome pre-shortage	7.24	0.77
Percent change††	-7.04%	-9.09%
Sample: Non-metropolitan counties	-6.34***	-6.56***
	(1.08)	(1.09)
Scaled β (75th – 25th percentile)†	-0.70	-0.72
Mean value of outcome pre-shortage	5.11	4.37
Percent change††	-13.70%	-16.48%

Notes: This table reports results from a regression of extended-release amphetamine salts prescription outcomes on an interaction between county-level exposure and an indicator for the post-shortage period separately by urbanicity. The data source is IQVIA Q1 2018 to Q3 2021. The outcomes are claims count or supply day count per 1,000 in each county. Exposure is measured as the average monthly proportion of individuals with an extended-release amphetamine salts prescription Q1 2015 to Q4 2017 in each county. The unit of observation is a county in a quarter of a year. The regression is estimated with OLS and includes county-level time-varying covariates, county fixed effects, and state-by-time (state-year-quarter) fixed effects. The county-level population is the weight. The total number of observations is 47,055 though observations are dropped if they are singletons or separated by a fixed effects.
***, **, * = statistically different from zero at the 1%, 5%, and 10% levels.
†The coefficient estimate ($\hat{\beta}$) is scaled to reflect the difference between the county at the 75th and 25th percentile of the pre-shortage exposure measure.
††Percent change = scaled $\beta \div$ mean value of outcome pre-shortage $\times$ 100%.

Table A13: Heterogeneity by at or above/below median exposure in the effect of a national drug shortage on extended-release amphetamine salts prescription outcomes using difference-in-differences methods: IQVIA Q1 2018 to Q3 2021

Outcome variable →	Claims	Supply days
Sample: States with at or above median exposure	-5.39***	-145,288.64***
	(0.61)	(16,848.98)
Scaled β (75th – 25th percentile)†	-0.59	-15,981.75
Mean value of outcome pre-shortage	8.49	236,126.54
Percent change††	-6.95%	-6.77%
Sample: States with below median exposure	-1.84*	-53,390.51*
	(1.07)	(29,981.82)
Scaled β (75th – 25th percentile)†	-0.20	-5,872.96
Mean value of outcome pre-shortage	2.13	59,052.36
Percent change††	-9.39%	-9.95%

Notes: This table reports results from a regression of extended-release amphetamine salts prescription outcomes on an interaction between county-level exposure and an indicator for the post-shortage period separately by states that have above at or above/below median baseline exposure. The data source is IQVIA Q1 2018 to Q3 2021. The outcomes are claims count or supply day count per 1,000 in each county. Exposure is measured as the average monthly proportion of individuals with an extended-release amphetamine salts prescription Q1 2015 to Q4 2017 in each county. The unit of observation is a county in a quarter of a year. The regression is estimated with OLS and includes county-level time-varying covariates, county fixed effects, and state-by-time (state-year-quarter) fixed effects. The county-level population is the weight. The total number of observations is 47,055 though observations are dropped if they are singletons or separated by a fixed effects.
***, **, * = statistically different from zero at the 1%, 5%, and 10% levels.
†The coefficient estimate ($\hat{\beta}$) is scaled to reflect the difference between the county at the 75th and 25th percentile of the pre-shortage exposure measure.
††Percent change = scaled $\beta \div$ mean value of outcome pre-shortage $\times$ 100%.

Table A14: Heterogeneity by the number of providers in the effect of a national drug shortage on extended-release amphetamine salts prescription outcomes using difference-in-differences methods: IQVIA Q1 2018 to Q3 2021

Outcome variable →	Claims	Supply days
Pharmacy heterogeneity		
Sample: States at or above median in 2019	-4.88***	-130,914.28***
	(0.53)	(14,565.11)
Scaled β (75th – 25th percentile)†	-0.54	-14,400.57
Mean value of outcome pre-shortage	7.22	200,915.44
Percent change††	-7.48%	-7.17%
Sample: States with below median in 2019	-4.86***	-127,530.71***
	(1.77)	(49,202.49)
Scaled β (75th – 25th percentile)†	-0.53	-14,028.38
Mean value of outcome pre-shortage	3.77	103,989.53
Percent change††	-14.06%	-13.49%
Mental healthcare providers heterogeneity		
Sample: States with at or above median in 2019	-4.24***	-112,233.31***
	(0.76)	(21,149.31)
Scaled β (75th – 25th percentile)†	-0.47	-12,345.66
Mean value of outcome pre-shortage	7.41	205,944.84
Percent change††	-6.34%	-5.99%
Sample: States with below median in 2019	-6.40***	-172,904.89***
	(0.69)	(19,293.51)
Scaled β (75th – 25th percentile)†	-0.70	-19,019.54
Mean value of outcome pre-shortage	5.62	156,145.33
Percent change††	-12.46%	-12.18%
General physicians heterogeneity		
Sample: States with at or above median in 2019	-4.87***	-130,617.41***
	(0.53)	(14,647.69)
Scaled β (75th – 25th percentile)†	-0.54	-14,367.92
Mean value of outcome pre-shortage	7.22	200,639.87
Percent change††	-7.48%	-7.16%
Sample: States with below median in 2019	-3.48**	-87,248.07*
	(1.78)	(50,027.25)
Scaled β (75th – 25th percentile)†	-0.38	-9,597.29
Mean value of outcome pre-shortage	3.40	93,787.67
Percent change††	-11.18%	-10.23%

Notes: This table reports results from a regression of extended-release amphetamine salts prescription outcomes on an interaction between county-level exposure and an indicator for the post-shortage period separately by states' amount of providers. The data source is IQVIA Q1 2018 to Q3 2021. The outcomes are claims count or supply day count per 1,000 in each county. Exposure is measured as the average monthly proportion of individuals with an extended-release amphetamine salts prescription Q1 2015 to Q4 2017 in each county. The unit of observation is a county in a quarter of a year. The regression is estimated with OLS and includes county-level time-varying covariates, county fixed effects, and state-by-time (state-year-quarter) fixed effects. The county-level population is the weight. The total number of observations is 47,055 though observations are dropped if they are singletons or separated by a fixed effects. The number of pharmacies and healthcare professionals are based on 2019 data.

***, **, * = statistically different from zero at the 1%, 5%, and 10% levels.

†The coefficient estimate ($\hat{\beta}$) is scaled to reflect the difference between the county at the 75th and 25th percentile of the pre-shortage exposure measure.

††Percent change = scaled $\beta \div$ mean value of outcome pre-shortage $\times$ 100%.

Table A15: Place of service descriptions for emergency department visits and hospitalization

Service setting ↓	**Place of service descriptions**
Emergency department	Emergency room - hospital
	Licensed freestanding emergency
	Medical facility
Hospital	Inpatient hospital
	Hospital inpatient (including Medicare Part A)
	Inpatient psychiatric facility
	Comprehensive inpatient rehabilitation facility
	Hospital inpatient (Medicare Part B only)
Outpatient	Office
	Outpatient hospital
	Ambulatory surgical center
	Birthing center
	Military treatment facility
	Independent clinic
	Federally Qualified Health Center
	State or local public health clinic
	Independent laboratory
	Other unlisted facility

Notes: This table reports place of services we use to identify emergency department and hospitalization outcomes. The data source is IQVIA Q1 2018 to Q3 2021.

Table A16: The effect of a national drug shortage on ADHD-related emergency department visits and hospitalizations using difference-in-differences methods: IQVIA Q1 2018 to Q3 2021

Outcome variable →	Emergency department	Hospital	Outpatient
$Post_t \times exposure_c$	-0.0436**	0.0419	-16.27***
	(0.0196)	(0.1186)	(1.89)
Scaled β (75th – 25th percentile)†	-0.0049	0.0047	-1.84
Mean value of outcome pre-shortage	0.0378	0.2318	11.24
Percent change††	-12.25%	2.01%	-16.34%

Notes: This table reports results from a regression of emergency department and hospitalization outcomes on an interaction between county-level exposure and an indicator for the post-shortage period. The data source is IQVIA Q1 2018 to Q3 2021. The outcomes are claims count per 1,000 in each county. Exposure is measured as the average monthly proportion of individuals with an extended-release amphetamine salts prescription Q1 2015 to Q4 2017 in each county. The unit of observation is a county in a quarter of a year. The regression is estimated with OLS and includes county-level time-varying covariates, county fixed effects, and state-by-time (state-year-quarter) fixed effects. The county-level population is the weight. The total number of observations is 47,055 though observations are dropped if they are singletons or separated by a fixed effects.

***, **, * = statistically different from zero at the 1%, 5%, and 10% levels.

†The coefficient estimate ($\hat{\beta}$) is scaled to reflect the difference between the county at the 75th and 25th percentile of the pre-shortage exposure measures.

††Percent change = scaled $\beta \div$ mean value of outcome pre-shortage $\times$ 100%.

Table A17: The effect of a national drug shortage on extended-release amphetamine salts prescription outcomes using difference-in-differences methods with unweighted regression: IQVIA Q1 2018 to Q3 2021

Outcome variable →	Claims	Supply days
$Post_t \times exposure_c$	-5.98***	-163,297.60***
	(0.54)	(14,934.99)
Scaled β (75th – 25th percentile)†	-0.66	-17,962.74
Mean value of outcome pre-shortage	4.78	132,423.47
Percent change††	-13.81%	-13.56%

Notes: This table reports results from a regression of extended-release amphetamine salts prescription outcomes on an interaction between county-level exposure and an indicator for the post-shortage period. The data source is IQVIA Q1 2018 to Q3 2021. The outcomes are claims count or supply day count per 1,000 in each county. Exposure is measured as the average monthly proportion of individuals with an extended-release amphetamine salts prescription Q1 2015 to Q4 2017 in each county. The unit of observation is a county in a quarter of a year. The regression is estimated with OLS and includes county-level time-varying covariates, county fixed effects, and state-by-time (state-year-quarter) fixed effects. Data are unweighted. The total number of observations is 47,055 though observations are dropped if they are singletons or separated by a fixed effects. ***, **, * = statistically different from zero at the 1%, 5%, and 10% levels.
†The coefficient estimate ($\hat{\beta}$) is scaled to reflect the difference between the county at the 75th and 25th percentile of the pre-shortage exposure measures.
††Percent change = scaled $\beta \div$ mean value of outcome pre-shortage $\times$ 100%.

Table A18: The effect of a national drug shortage on extended-release amphetamine salts prescription outcomes using difference-in-differences methods (replacing state-by-time fixed effects with time fixed effects): IQVIA Q1 2018 to Q3 2021

Outcome variable →	Claims	Supply days
$Post_t \times exposure_c$	-4.89***	-133,682.50***
	(0.52)	(14,340.68)
Scaled β (75th – 25th percentile)†	-0.54	-14,705.07
Mean value of outcome pre-shortage	6.95	193,230.12
Percent change††	-7.77%	-7.61%

Notes: This table reports results from a regression of extended-release amphetamine salts prescription outcomes on an interaction between county-level exposure and an indicator for the post-shortage period. The data source is IQVIA Q1 2018 to Q3 2021. The outcomes are claims count or supply day count per 1,000 in each county. Exposure is measured as the average monthly proportion of individuals with an extended-release amphetamine salts prescription Q1 2015 to Q4 2017 in each county. The unit of observation is a county in a quarter of a year. The regression is estimated with OLS and includes county-level time-varying covariates, county fixed effects, and time (state-year-quarter) fixed effects. The county-level population is the weight. The total number of observations is 47,055 though observations are dropped if they are singletons or separated by a fixed effects.

***, **, * = statistically different from zero at the 1%, 5%, and 10% levels.

†The coefficient estimate ($\hat{\beta}$) is scaled to reflect the difference between the county at the 75th and 25th percentile of the pre-shortage exposure measure.

††Percent change = scaled $\beta \div$ mean value of outcome pre-shortage $\times$ 100%.

Table A19: The effect of a national drug shortage on extended-release amphetamine salts prescription outcomes using difference-in-differences methods: IQVIA Q1 2018 to Q3 2021

Outcome variable →	Claims	Supply days
Specification: Logarithm of rate		
$Post_t \times exposure_c$	-0.21***	-0.19***
	(0.05)	(0.05)
Scaled β (75th – 25th percentile)†	-0.02	-0.02
Mean value of outcome pre-shortage	1.70	5.03
Percent change††	-1.98%	-1.98%
Specification: Count with population as control		
$Post_t \times exposure_c$	-1,303.37***	-33,667.49***
	(422.79)	(11,558.88)
Scaled β (75th – 25th percentile)†	-143.37	-3,703.42
Mean value of outcome pre-shortage	6,082.59	168,977.44
Percent change††	-2.36%	-2.19%
Specification: Poisson model		
$Post_t \times exposure_c$	-0.17**	-0.15**
	(0.07)	(0.07)
Scaled β (75th – 25th percentile)†	-0.01	-0.01
Mean value of outcome pre-shortage	6,082.59	168,977.44
Percent change††	-1.00%	-1.00%

Notes: This table reports results from a regression of extended-release amphetamine salts prescription outcomes on an interaction between county-level exposure and an indicator for the post-shortage period. The data source is IQVIA Q1 2018 to Q3 2021. The outcomes are claims count or supply day count per 1,000 in each county. Exposure is measured as the average monthly proportion of individuals with an extended-release amphetamine salts prescription Q1 2015 to Q4 2017 in each county. The unit of observation is a county in a quarter of a year. The regression is estimated with OLS in panels A and B, and a Poisson model in Panel C. The regression includes county-level time-varying covariates, county fixed effects, and state-by-time (state-year-quarter) fixed effects. The county-level population is the weight and, in Panel C, the exposure variable. In Panel C, the coefficient estimate is converted to the average marginal effect. The total number of observations is 47,055 though observations are dropped if they are singletons or separated by a fixed effects.
***, **, * = statistically different from zero at the 1%, 5%, and 10% levels.
†The coefficient estimate ($\hat{\beta}$) is scaled to reflect the difference between the county at the 75th and 25th percentile of the pre-shortage exposure measure.
††Percent change = scaled $\beta \div$ mean value of outcome pre-shortage $\times$ 100%.