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# The short- and long-run effects of medical malpractice lawsuits on medical spending and hospital operations in China[☆]

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ABSTRACT

China is experiencing a surge in medical malpractice lawsuits. Using administrative hospital panel data, this paper investigates both short- and long-run impacts of medical malpractice lawsuits on patient medical spending and hospital operations. We find that after the occurrence of an additional malpractice lawsuit in a hospital, total medical spending per patient visit increases by 2.8% in the current year and by as much as 8.8% in the long run. This increase is mainly driven by spending on prescription drugs and diagnostic tests. In response, hospitals invest more in medical devices and procure more drugs. We find little evidence of changes in patient outcomes. Our findings show that the surge of medical malpractice lawsuits leads to defensive medicine and fuels the secular growth of medical spending in China.

## 1. Introduction

China has implemented a series of health system reforms in recent years, such as expanding basic health insurance coverage and establishing a national essential medicine program for primary care (Milcent, 2018). Many improvements have been achieved, yet new challenges emerge. Over the past decade, medical malpractice lawsuits have skyrocketed in China. According to litigation records from China Judgment Online – the official website of China's Supreme People's Court – the number of medical malpractice lawsuits has increased more than 100-fold, from less than 100 in 2008 to over 11,000 in 2018 (see Fig. 1).[1]

The soaring number of malpractice lawsuits not only reflects a fast-changing landscape of China's medical malpractice system, but may result in far-reaching consequences on the entire health system. Because malpractice liabilities are frequently documented to affect physician's practice patterns and increase medical costs (Kessler et al., 2006; Kessler and McClellan, 1996; Frakes and Gruber, 2019), the steep trajectory of malpractice lawsuits in China may have substantial long-term economic impacts for China's

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[1] China Judgment Online was established in 2014 and started to make more litigation cases publicly accessible since 2014.

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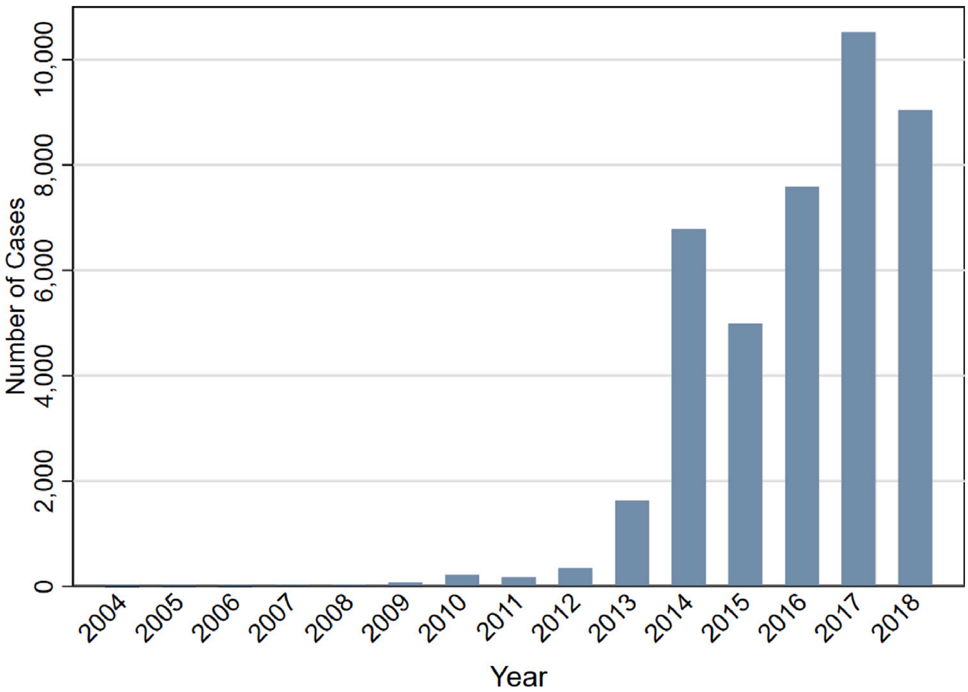


**Fig. 1.** Trend of medical malpractice lawsuits in China from 2004–2018. *Notes*: In this figure, the *y*-axis plots the number of medical malpractice lawsuits (see Section 2.2 for the definition of a medical malpractice case).
*Data source:* China Judgment Online.

rapidly expanding healthcare market.[2] It is thus extremely policy-relevant to evaluate the magnitude and persistence of the effects of malpractice lawsuits on physician practice, patient health, and medical spending in China, and to inform the policy making in China's medical tort system. Yet, quantitative evidence on the economic impacts of malpractice lawsuits is lacking in China.

The literature on malpractice lawsuit and provider behaviors is large but focuses on the developed economies. The general consensus is that malpractice litigations, or the risk of it, have substantial impacts on both physicians' defensive practices and the cost of medical care (Kessler and McClellan, 1996; Danzon, 2000; Studdert et al., 2005).[3] In the US, the annual cost of the overuse of tests and procedures that arise from the physicians' avoidance of malpractice litigation is estimated to be $46 billion or more (Mello et al., 2010; Rothberg et al., 2014; Chandra et al., 2013). Carrier et al. (2010) find that physicians' fears of malpractice lawsuits are not assuaged by tort reforms that reduce the financial burden of malpractice lawsuits, suggesting substantial non-pecuniary cost of malpractice lawsuits for physicians. Although existing evidence suggests that malpractice lawsuits can change the physician's practice style and lead to long-run consequences, few studies have systematically estimated the *long-run* economic impacts of malpractice lawsuits.

Causal analysis of the malpractice lawsuit's impact on hospital responses faces two important challenges in China's context. First, as in most healthcare markets, the occurrence of a malpractice case is endogenous. Both the risk of malpractice and the likelihood of patient's filing a lawsuit may correlate with unobservable characteristics of the local tort system, medical providers, patients, and the interactions of the three, which engenders omitted variable bias. To deal with this endogeneity issue, a common practice is to exploit the exogenous change in the cost or the risk of malpractice lawsuits generated by tort reforms that vary across locations and time, and compare the reform-affected group of providers against unaffected or less affected groups over time (see, for example, Kessler and McClellan (1996)). Such a practice that derives exogenous variations in malpractice lawsuits from region-specific tort reforms is infeasible in China's context, because tort reforms are implemented at the national or provincial level (see Section 2.2) and a longitudinal dataset of hospitals across multiple provinces is unavailable in China. On the other hand, without exogenous variation

[2] The state news outlet, Xinhuanet, has reported that the Chinese government has spent more than 1.5 trillion yuan (about $222 billion) on its healthcare sector in 2018, posting an average annual growth of 11.7% from the previous year. Link: http://www.xinhuanet.com/english/2019-05/17/c_138066359.htm.

[3] For example, Keyhani et al. (2009) found that a majority (91%) of physicians in the US believed physicians order more tests and procedures than necessary to protect themselves from malpractice lawsuits. O'Leary et al. (2012) discovered most medical students (92%) and residents (96%) in the US sometimes or often encountered at least one practice of defensive medicine, with 53% reporting that their attending physicians taught them to take liability into account when making clinical decisions. Moreover, research has found rising malpractice liability is strongly associated with higher malpractice insurance premium and medical spending (Mello et al., 2010; Baicker et al., 2007; Kessler et al., 2006).

in the local tort system, it is difficult to find external factors that change the likelihood of malpractice lawsuits but do not otherwise directly affect provider behaviors and patient outcomes.[4]

Second, hospital decision making is dynamic in nature for Chinese hospitals. Most of hospital operational outcomes, such as hospital employment, are serially correlated. This is because most hospitals are public and health professionals – such as doctors and nurses – are public-sector employees (Milcent, 2018). Hiring and firing of hospital employees are thus costly and hospital's procurement of high-end medical equipments is subject to a long process of application and approval with the state regulators (Zhen, 2011).[5] As a result, we expect hospitals' outcomes to adjust with delay and depend on the previous year's value, which argues for a dynamic model, in which the lagged value of a hospital outcome is an important determinant of its current level. However, if we apply an ordinary least squares (OLS) approach with hospital fixed effects to model this dynamic process, i.e., through first-differencing or within transformation, one immediate problem is that the transformed lagged outcome variable is correlated with the transformed error term, which gives rise to the "dynamic panel bias" (Nickell, 1981; Arellano and Bover, 1995).

We adopt the system generalized method of moments (GMM) to address both challenges (Blundell and Bond, 1998; Arellano and Bover, 1995). We estimate a dynamic panel-data model by regressing the hospital outcome variable on the lagged outcome variable and the number of malpractice lawsuits. The system GMM estimates two equations simultaneously: In the *difference* equation, all variables are first differenced across years, and the higher-order lagged outcome variable and lagged number of lawsuits as used as instruments. In the *level* equation, the first-differenced lagged outcome variable and the number of lawsuits are used as instruments. Both *difference* and *level* equations control for year fixed effects and hospital fixed effects. Blundell and Bond (1998) demonstrate that system GMM estimators are consistent and robust, especially when the outcome variable is highly persistent. Overall, with the system GMM, we can consistently estimate both the contemporaneous effects of malpractice lawsuits and the degree of serial correlation of outcome variables. Combining these two estimates, we compute the long-run effects of malpractice lawsuits on outcomes of interest, including medical spending, hospital operations, and patient outcomes.

We obtain a unique administrative longitudinal dataset of hospital annual reports in Chengdu, the capital city of Sichuan province, from 2009 to 2014. The hospital annual reports are collected and audited by the National Health and Family Planning Commission. The annual report is thus based on a uniform data standard. It represents a hospital's year-end balance sheet and contains three categories of hospital metrics: the volume of patient visits and medical spending, hospital financial statement and operational metrics, and a limited set of patient health outcomes. A unique variable that makes this study feasible is the number of medical malpractice lawsuits occurred in each hospital in a given year. To our best knowledge, this is the first dataset in China that provides official records of the number of malpractice lawsuits at the hospital level. With this dataset, we assess the following research questions: Does the increase in malpractice lawsuits leads to higher medical spending and changes in provider behaviors in China? If yes, how large is the effect in both short and long run, and through what channel does it affect physician practice, hospital operations, and patient outcomes?

Our estimation results show that one additional malpractice lawsuit (against an average of 0.2 cases per hospital per year) leads to an average of 2.8% increase in total medical spending per patient visit in the short run and 8.8% increase in the long run. To break down spending into outpatient and inpatient components, we find the short-run increase in outpatient spending per outpatient visit is 3.0% and that in inpatient spending per admission is 2.5%. Both estimates are statistically significant at the 5% level. The corresponding long-run increases are higher – 8.1% and 12.9%, respectively – and are statistically significant at the 5% level. The increase in medical spending is most pronounced in prescription drugs and diagnostic tests, which are above 2.6% in both outpatient and inpatient settings in the short run, and above 9.6% in the long run. By contrast, the spending increases in general care, consultation services, and surgeries are close to zero and statistically insignificant. Consistent with the pattern of spending increases, we find hospitals invest more in high-end diagnostic devices and procure more prescription drugs in response to the increases in malpractice lawsuits, and with statistically significantly estimated long-run effects. We find little evidence of changes in patient outcomes. Overall, our findings suggest medical malpractice lawsuits motivate medical providers to practice defensive medicine, which fuels the secular growth of medical spending in China.

Our study contributes to the literature on medical malpractice lawsuits and the associated impacts on the health system. The existing research has found medical malpractice liability leads to the practice of defensive medicine and increases medical cost (Mello et al., 2010; Baicker et al., 2007; Kessler, 2011; Kessler and McClellan, 1996; Kessler et al., 2006; Frakes and Gruber, 2019). In particular, Kessler and McClellan (1996) find malpractice reforms in the US in the 1980s that directly reduced provider's malpractice liability led to a reduction in medical spending of 5% to 9% without substantial effects on mortality or medical complications. Existing studies focus almost exclusively on developed countries; our research provides the first piece of evidence on the economic impact of malpractice lawsuits in China, and assess the channels through which providers adjust their medical practices. Considering the surge in malpractice lawsuits in recent years, our findings on the substantive long-run effects of lawsuits on medical spending and providers' defensive responses have critical implications for policymaking in China's healthcare and medical-legal system.

Our analysis of both short- and long-run effects of malpractice lawsuits adds to the understanding of the consequences of medical malpractice in the healthcare system. We adopt the system GMM method to overcome the challenges of dynamic panel bias and endogeneity bias and estimate the long-run effect of malpractice lawsuits. We demonstrate that many hospital outcome variables are

[4] A recent exception is Frakes and Gruber (2019), who exploit a unique setting of U.S. military medical liability system that grants physicians immunity to malpractice litigations from active-duty patients in military facilities but not when physicians practice in civilian facilities. The authors then exploit the exogenous variation in physician's exposure to litigation risk from base-hospital closures.

[5] For example, the purchase of high-end medical equipment in a public hospital – such as a Computed Tomography (CT) or a Magnetic resonance imaging (MRI) machine – often takes months or even years to complete as such a purchase may go through layers of application and approvals.

strongly serially correlated, and if not dealt with, such serial correlation in the outcome variable will make the estimation inconsistent in conventional static fixed-effects estimation (Arellano and Bover, 1995). Having accounted for both the serial correlation of outcome variables and the endogeneity of malpractice lawsuits, we find long-run effects of malpractice lawsuits on medical spending are substantially higher than short-run effects, suggesting that prior estimates of the contemporaneous effect of malpractice liability may underestimate its overall fiscal impact. Our finding highlights the long-run implication of malpractice liability for the financial sustainability of the health system as medical costs are rising dangerously in China, US, and many other countries.

We proceed as follows. Section 2 describes the background of the Chinese health system and the judicial system for medical malpractice lawsuits. Section 3 describes the data source and presents the summary statistics. Section 4 describes the system GMM methodology. Section 5 presents estimation results on the short- and long-run effects of malpractice lawsuits, and evidence on defensive medicine. Section 6 conducts robustness checks. Section 7 discusses the policy implications of our findings and concludes.

## 2. Institutional background

In this section, we discuss the institutional background and key features of China's health system and medical tort system. Based on this background, we propose our research hypothesis that hospitals and physicians may respond proactively to the occurrence and the risk of medical malpractice lawsuits in China.

### *2.1. China's health system*

China's health system has undergone three stages of development over the past 50 years. China introduced its public health system in 1949. Backed by government funding, China's hybrid model of public hospitals with grassroots clinics was successful in improving health and life expectancy across the country. China's public hospital system primarily relies on a three-tier structure, which has remained mostly intact since its establishment (NBS, 2015). The three-tier system differentiates large city-level or province-level research hospitals (tier-3) from township-level or district-level hospitals (tier-2) and smaller, primary-care-focused facilities (tier-1). In 1984, the World Bank and the World Health Organization highly praised the "China Model" as an effective model for other developing countries (Jamison, 1984).

Following the nationwide economic reforms in 1979, the market-oriented healthcare reforms of the 1980s and 1990s shifted the health system onto a different track. The reforms granted more autonomy to public hospitals, but dramatically cut public financing while maintaining strict price regulation. Government subsidies fell to a mere 10% of a hospital's total revenues by the early 1990s and have remained low since (Milcent, 2018). Grassroots facilities gradually disbanded. Mounting pressure for self-sufficiency intensified hospitals' competition for revenue, which undermined the nonprofit nature of public hospital services and distorted providers' financial incentives. Under the fee-for-service payment system and a fixed price schedule that overpaid for drugs and diagnostic tests and underpaid for preventive and primary care, medical providers were incentivized to prescribe more drugs and tests, leading to the rapid growth of medical spending (Hu et al., 2008; Blumenthal and Hsiao, 2015). As a result, out-of-pocket medical spending soared.

Recognizing these problems, the central government implemented a series of nationwide healthcare reforms since 2009. The reform's first phase (2009 to 2011) focuses on expanding public health insurance coverage for the population and strengthening health infrastructure at the grassroot level. The second phase (since 2012) put more emphasis on health care delivery reform (Yip et al., 2019).[6] This second phase includes a national mandate of zero-markup drug policy in all public hospitals (removing the 15% mark-up on prescribed drugs), adjusting service fee schedules, adopting performance-based provider payment system, and building an integrated primary-care-based health network.

Recognizing the complexity of the delivery reform, the central government issued general guidelines and encouraged local governments to innovate and experiment with delivery models that best fitted their institutional context. In Chengdu, the public hospital reform was implemented at county-level hospitals since June 2014 (*Cheng Ban Fa* [2014] No 29) and at city-level hospitals since December 2016 (*Cheng Ban Han* [2016] No 120). In particular, the zero-markup drug policy has been implemented at all Chengdu hospitals since 2016; and public hospitals started to rollout the diagnosis-related groups payment system and provider payment reforms since December 2017.[7] Overall, the public hospital reform was progressively implemented in Chengdu's hospital market since the late 2014.

Ten years into the reform, challenges remain. The aging population, shifting disease profile, and mounting healthcare demand spurred by rising income continue to test the limits of China's health system (Wang and Chen, 2014; Yang et al., 2008). Congestion and rationing increases in public hospitals and deteriorates the patient–doctor relationship, and violence against doctors is on the rise (Wang et al., 2012; Hesketh et al., 2012). Moreover, a striking, yet less studied, trend has emerged in the last decade: the number of medical malpractice lawsuits is skyrocketing. This increase may be attributed to the rising tension between patients and doctors, but also reflects the changing landscape of China's medical malpractice system.

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[6] Yip et al. (2019) provide an excellent overview of the health reform since 2009 and Xu et al. (2019) provide a detailed discussion of reform policies and official documents issued by the central government. Early appraisal of these reforms has affirmed the positive effects of reforms on China's health system (Yip et al., 2012; Milcent, 2018).

[7] See the official report on Chengdu's public hospital reform at http://www.nhc.gov.cn/tigs/ygjb/201812/726c1e6f6daf4e5b84c00bfccbbdb2aa.shtml (in Chinese).

### 2.2. China's legal system for medical malpractice

The legal framework for medical malpractice litigation in China has undergone major changes over the past 50 years. Before 1987, no national law on medical malpractice was in effect, and medical malpractice claims were handled by local judicial bodies. This lack of uniformity in handling malpractice cases prompted the central government to establish a national standard. In 1987, the State Council issued the *Regulations on the Handling of Medical Accidents* and established a set of national rules and regulations that held healthcare providers liable for medical malpractices. However, the 1987 regulations were widely criticized for the narrow scope of liability and stringent limitations on compensable damages (Harris and Wu, 2005). In essence, it severely limited the feasibility of a legal resolution of a malpractice case for the plaintiff patient (Liebman, 2013).

A series of reforms were implemented on the tort system since 2000. The *Regulations on the Handling of Medical Accidents in 2002* replaced the 1987 version and increased the adequacy and fairness of compensation (Harris and Wu, 2005). Subsequently, a new and independent judicial system of malpractice lawsuits was established in early 2000s. Created and supervised by China's Supreme People's Court, the new system can process a malpractice claim even if the case was previously rejected under the traditional system (Li et al., 2014). As a result, a two-track legal system was officially established to address medical malpractice claims in China. More recently, the Tort Liability Law was enacted in 2010 to further integrate these two tracks (Liebman, 2013). In summary, the post-2000 reforms take a more pro-plaintiff stance and increase the feasibility of and compensation for malpractice lawsuits, which may contribute to the rapid increase in malpractice lawsuits shown in Fig. 1. Reforms in the jurisdiction for medical malpractice represent a steady progress toward the rule of law in the Chinese medical-legal system.

### 2.3. Provider's response to malpractice lawsuits

Four features of China's public hospital system and medical tort system lead to our hypothesis that medical providers may respond strongly to the occurrence of malpractice lawsuits. First, doctors are direct hospital employees in all public hospitals. Public hospitals provide over 92% of all medical services in China (NBS, 2015). This feature stands in contrast to the US hospital system, in which private hospitals provide most of medical services and doctors are independent contractors rather than hospital employees. Second, in public hospitals, doctors' income mainly consists of a fixed salary and a flexible, commission-based component, while the latter depends on the hospital revenue and usually accounts for as high as three-quarters of a doctor's total income (Milcent, 2018). Consequently, doctors' financial incentives align closely with the employer-hospital. Third, China's tort laws stipulate that the hospital, rather than doctors, is the subject of a malpractice lawsuit, and bears the liability arising from medical malpractice and the resulted compensation of damages to patients. Should a malpractice lawsuit occurs, the hospital and doctors would suffer substantial loss in compensation of damages, time in court, and reputational damages.[8] Lastly, malpractice insurance was nonexistent during our sample period, thus all compensations were paid in full by the hospital. These factors explain why hospitals and doctors may respond strongly to the occurrence, and even the *risk*, of malpractice lawsuits.

Hospitals and doctors may also respond strongly to the greater number of malpractice *disputes*, which have the risk of escalating into a lawsuit. According to a report by the National Health Commission of China, about 20% of malpractice disputes ended up in court in 2016 (Li, 2017; Li et al., 2020). Malpractice disputes that are not resolved in court may also result in a loss of working hours and an increase of distress for doctors,[9] and in extreme cases, abuse and physical violence against doctors (Hesketh et al., 2012; Wang et al., 2012). Therefore, the compensation payment of malpractice lawsuits represents only the tip of iceberg for the substantial financial, psychological, and reputational damages of malpractice cases for hospitals and doctors. In subsequent empirical analyses, we use the number of malpractice lawsuits as a proxy measure of the overall cost of malpractice cases faced by both the hospital and doctors.

## 3. Data

### 3.1. Data source and sample restriction

We obtain administrative longitudinal hospital data from the Annual Report of Medical and Health Institutions in Chengdu, the capital city of Sichuan province. Chengdu is one of the most populous cities in China – its 2018 population was over 16.3 million and close to that of the Netherlands – and ranks 8th in annual GDP among Chinese cities. Our dataset is annually collected, regularly audited, and maintained by the National Health and Family Planning Commission, which is the state regulator of hospitals and the health system. The dataset contains a rich set of information on patient spending and hospital operations and covers all hospitals in Chengdu. The unit of observation is the hospital-year.

[8] Li et al. (2020) analyze 4380 medical malpractice claims in China for 2008–2017 and find an average compensation payment of RMB 204,600, or equivalently, US$31,430. Li et al. (2014) find that the average time span between the occurrence of the injury and closure of claims was 3 years. The reputational damages of malpractice lawsuits for doctors and hospitals may be even more substantial. Liebman (2013) finds that the occurrence of a malpractice lawsuit can seriously dampen the career prospect of individual doctors, and if the case is covered unfavorably by the media, impairs the hospital administrators' relationship with their government supervisors.

[9] In a recent anonymous survey of 800+ physicians, 47% expressed turnover intention, 46% experienced burnout, and 75% experienced stress and depression after a malpractice dispute (Sun et al., 2021).

We make two sample restrictions. First, we exclude hospital observations with missing data on patient flow or medical spending, and those that have changed the hospital type (public vs private) during the sample period. This step excludes 13 hospitals out of 514 hospitals (3 changed hospital type) and 73 observations (3% of original sample). Second, we exclude hospitals with less than three years of observations (as required by the system GMM estimation with a lagged dependent variable as regressor). This second step excludes 14 hospitals and 164 observations (6.8% of original sample). We hereafter refer to the sample after restrictions as the baseline sample. The baseline sample consists of 487 hospitals and 2174 observations.

Appendix Table A1 summarizes main variables after each step of sample restrictions. The sample statistics remain similar after each step. The main source of change is that the share of higher-tier hospitals slightly increases; for example, the share of tier-3 hospitals increases from 6.8% to 7.5%. This is because higher-tier hospitals have better data completeness in terms of outcome variables and years of observation, thus are less likely to be dropped during the sample restrictions. The baseline sample includes 67 tier-1 hospitals, 91 tier-2, 44 tier-3, and 285 non-tiered hospitals. See Section 2.1 for a discussion of China's three-tier hospital system.

### 3.2. Variable definitions

The explanatory variable of interest is the total number of medical malpractice lawsuits in a given hospital in a year.[10] A medical malpractice lawsuit is defined as a malpractice claim that is resolved in court. It does not include malpractice dispute cases that are resolved through off-court negotiation or third-party mediation. A hospital's number of malpractice lawsuits is unlikely to be underreported in our sample for two reasons. First, the Chengdu city government has issued a series of *Rules on Prevention and Handling of Medical Disputes* (*Rules* for short) since 2010. The *Rules* has required all hospitals to truthly report all cases of malpractice disputes and lawsuits, stipulated penalizing measures against misreporting, and coordinated the health and legal systems for lawsuit handling and reporting.[11] Second, all the malpractice lawsuits are recorded in the government's legal system and are regularly audited by the state regulator, it is thus easily detectable if a malpractice lawsuit is misreported. Indeed, the aggregate number of malpractice lawsuits recorded in our data is in line with the number reported by the China Judgment Online as documented by Wang et al. (2017).[12]

We analyze three main categories of outcome variables: patient medical spending, hospital operations, and patient outcomes. Total medical spending per patient visit is the total amount of outpatient and inpatient spending divided by the total number of patient visits in a hospital for a given year. Outpatient and inpatient spending per visit is the outpatient and inpatient spending divided by total outpatient visits and total inpatient admissions, respectively. Medical spending is further categorized into physician services (consultation services for outpatient, and specialist care and nursing care for inpatient), diagnostic tests, prescription drugs, and surgeries.

Hospital operations variables have three main groups: hospital expenditure, the number of high-end diagnostic devices, and the employment of health professionals. Hospital expenditure is the total operational expenditure, which mainly includes wage expenditure and drug procurement expenditure. The number of high-end diagnostic devices is the number of diagnostic devices that are valued at more than 100,000 RMB (about 15,000 USD), which can be either purchased or rented, in a hospital for a given year. An example of the high-end diagnostic device is the CT scanner. We also use the total number of diagnostic devices valued at more than 10,000 RMB (devices valued below 10,000 RMB are not recorded in the data) and the total value of diagnostic devices as alternative measures. Total employment of health professionals includes the number of physicians, nurses, pharmacists, and medical technicians. Physicians include licensed physicians and licensed assistant physicians. Medical technicians include technicians for screening-based diagnostic tests and laboratory tests.

We assess four measures of patient outcomes: inpatient mortality, the rate of adverse drug reactions, average patient days per admission, and the ratio of nurses to patient-days. Inpatient mortality is commonly adopted as a key indicator for the quality of care and patient outcome in the literature on malpractice lawsuits (Kessler and McClellan, 1996; Sloan and Shadle, 2009; Frakes and Gruber, 2019) as well as in general studies of health care market (Finkelstein, 2007; Miller et al., 2021; Soni et al., 2020). Besides mortality, we also assess three measures of patient outcomes/quality of care that are relevant for a more general population of patients. The rate of adverse drug reactions is frequently adopted in the medical literature as an important indicator of the quality of care (Edwards and Aronson, 2000). An adverse drug reaction is defined as an unintended, harmful event attributed to the use of medicines, and it strongly correlates with other adverse patient outcomes such as mortality, morbidity, and readmission (Davies et al., 2009; Davies and O'mahony, 2015; Laroche et al., 2007). In our data, we define the adverse drug reaction rate as the share of adverse drug reaction events in total patient visits. Patient days measures the average amount of medical care provided during an episode of inpatient care, and the ratio of nurses to patient-days is a frequent measure of the quality of inpatient care (Caminiti et al., 2013; Jha et al., 2008). We define the average patient days per admission as the total number of occupied bed days divided by the total admission, and the ratio of nurses to patient-days as the number of nurses divided by the average patient days.

[10] The literature on medical malpractice in China often faces the limitation that official records of malpractice cases are reported at the national level (Wang et al., 2017). Our dataset enables us to conduct the first study in China that evaluates the effect of malpractice lawsuits at the hospital level.

[11] See the interim *Rules* at https://news.ifeng.com/mainland/200910/1001_17_1372876.shtml and the official *Rules* at http://gk.chengdu.gov.cn/govInfo/detail.action?id=67104&tn=6.

[12] Wang et al. (2017) collect all malpractice lawsuits released in China Judgments Online and report the aggregate number of cases at the province level. They report a total of 588 malpractice lawsuits in Sichuan Province, of which Chengdu is the capital city and the central hub of healthcare services, from 2010–2015. Our sample counts 500+ cases in Chengdu from 2009–2014, which is similar in magnitude.

We include a rich set of hospital characteristics as control variables, including hospital tier dummies, an indicator for whether the hospital has a hospital information system (HIS), whether it has a medical imaging system, whether it has a clinical laboratory, whether it uses an electronic medical records (EMR) system, whether it is linked to the public health insurance, whether it is covered by the ambulance network, and its outpatient and inpatient case mix. We calculate the outpatient case mix as the proportion of outpatients treated in departments for acute and chronic ambulatory care-sensitive conditions (ACSC), and the inpatient case mix as the proportion of inpatient admissions to departments for ACSC conditions (CMS, 2016).

### 3.3. Summary statistics of main outcomes and covariates

We present the summary statistics in Table 1. Hospitals in our analytical sample have an average of 110,585 outpatient visits and 5857 inpatient admissions per year. The average hospital size measured in patient flow and the workforce of health professionals is similar between our sample and the national average. According to the 2018 China's Health Statistical Yearbook, hospitals in China treats an average of 108,455 outpatients and 6064 inpatients per year. The number of health professionals (physicians and nurses) per hospital is also similar between our sample and the national average: 195 and 186, respectively.

Total medical spending per patient visit is 656 RMB, outpatient spending per outpatient visit is 244 RMB, and inpatient spending per inpatient admission is 5653 RMB. In outpatient spending, spending on drugs averages 150 RMB per visit and takes the largest share (61%), followed by spending on diagnostic tests (64 RMB, 26%). In inpatient spending, spending on drugs averages 2172 RMB and again takes the leading share of 38%, followed by spending on surgeries (1681 RMB, 30%) and spending on diagnostic tests (1153 RMB, 20%). On average, hospitals in our analytical sample employ 195 health professionals, which includes an average of 100 nurses, 68 physicians, 15 pharmacists, and 10 medical technicians. On average, each hospital has 170 diagnostic devices with a total value of 22 million RMB. Each hospital is, on average, equipped with about 30 high-end diagnostic devices that are valued at more than 100,000 RMB, such as a MRI machine. Total expenditure is about 61 million RMB per year, with about 23 million on drug procurement and 20 million on wage expenditure. The inpatient mortality rate is 5.6 deaths per 1000 inpatient admissions; and the rate of adverse reaction to drugs is 0.075 cases per 1000 visits. The average patient days is 12.6 days per admission; and the ratio to nurses per patient-day is 0.2.

With respect to the three-tier public hospital system in China (see Section 2.1), Appendix Table A2 presents the summary statistics of basic hospital characteristics across tiers. As expected, higher-tier hospitals generally have higher medical expenditure per patient visit, employ more health professionals, equip with more high-end diagnostic devices, and are better equipped with modern hospital information systems.

### 3.4. Distribution of malpractice lawsuits

The baseline sample reports a total of 544 medical malpractice lawsuits from 2009 to 2014, with an average of 0.229 cases per hospital per year, and each health professional faces an 0.14% chance of experiencing a malpractice lawsuit annually.[13] According to a report in the National Health Commission of the China, every 98 health professionals face a medical dispute every year, and about 20% of medical disputes end as malpractice lawsuits (Li, 2017; Li et al., 2020). This suggests that, at the national scale, each health professional faces an 0.21% chance of experiencing a malpractice lawsuit per year.

The distribution of malpractice lawsuits is highly right-skewed, concentrated in tier-3 hospitals, but stable over time in our sample window. About 10% of hospital-year observations have positive lawsuit cases, 8% have 1 to 10 cases per year, and 0.5% (12 observations) having more than 10 cases.[14] Two-third of these lawsuits occurred in tier-3 hospitals, which is expected as these hospitals treat about half of all patients in the hospital market of Chengdu. Appendix Figure B1 plots the histogram of lawsuits across hospital tiers and shows that, while malpractice lawsuits are rare in lower-tier hospitals (less than 5% in probability), they are more common and distributed less right-skewed in tier-3 hospitals. Appendix Table A3 provides detailed summary statistics of lawsuits across hospital tiers. The annual number of malpractice lawsuits in tier-1 to 3 hospitals are 0.02, 0.29, and 2.22 cases, respectively. Taking into account the size of patient flow, the probability of malpractice lawsuits per patient visit is about 6 times and 2 times higher in tier-3 hospitals than tier-2 and tier-1 hospitals, respectively. Overall, the skewness of the distribution of lawsuits in our sample is mostly driven by the cross-tier differences in lawsuit occurrence probability, as malpractice lawsuit is more frequent in the top-tier hospitals (Li et al., 2014, 2020). This skewness of overall distribution of lawsuits would be mitigated by the inclusion of hospital fixed effects, under which the variation of lawsuits in estimation mainly comes from the within-hospital, year-to-year variation in lawsuit occurrence. In addition, the distribution of lawsuits is stable over time. Appendix Figure B2 shows that the per-year distribution of lawsuits is similar from 2009 to 2014, suggesting a relatively stable medical tort environment in the local hospital market during our sample period.

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[13] A limitation of the variable of malpractice lawsuit in our sample is that, other than knowling all recorded lawsuits have ended in court, we have no further information on characteristics of lawsuits, such as the value of compensatory damages resulted from the lawsuit, or information on the number of malpractice cases ended through third-party mediation rather than in court. This limitation restricts our analysis to estimating the effect of lawsuit occurrence rather than the severity of related damages or other types of malpractice cases.

[14] The system GMM does not restrict the skewness of the regressors. However, the skewness of the number of malpractice lawsuits could turn some of our instruments for the level equation less valid after the first-difference transformation. After conducting the set of statistical tests including the Hansen test and difference-in-Hansen tests, we do not reject the null hypotheses that all instruments, or subset of them, are valid. In addition, as the skewness of lawsuits is mostly driven by the difference across hospital tiers, the inclusion of hospital fixed effects would mitigate this skewness. The estimation thus exploits the within-hospital, year-to-year variation in lawsuits. Therefore, the skewness of the malpractice lawsuits is unlikely to severely bias the system GMM estimation.

**Table 1**
Summary statistics.

| Variables | Observations | Mean | S.D. |
|---|---|---|---|
| **Panel A: Malpractice lawsuits** | | | |
| Number of malpractice lawsuits | 2174 | 0.229 | 1.382 |
| **Panel B.1: Total patient flow** | | | |
| Outpatient visits | 2174 | 110,585 | 292,136 |
| Inpatient admissions | 2174 | 5857 | 14,402 |
| **Panel B.2: Total medical spending per capita (RMB)** | | | |
| Total medical spending per patient visit | 2174 | 656.4 | 941.6 |
| Outpatient spending per outpatient visit (abbrev. p.v.) | 2174 | 244.5 | 332.1 |
| Inpatient spending per admission (abbrev. p.a.) | 2122 | 5653 | 6103 |
| **Panel B.3: Outpatient spending per capita (RMB)** | | | |
| Outpatient spending on physician services p.v. | 2174 | 6.705 | 13.49 |
| Outpatient spending on diagnostic tests p.v. | 2174 | 64.29 | 127.7 |
| Outpatient spending on drugs p.v. | 2174 | 150.1 | 246.6 |
| Outpatient spending on surgery p.v. | 2174 | 23.55 | 94.23 |
| **Panel B.4: Inpatient spending per capita (RMB)** | | | |
| Inpatient spending on general care p.a. | 2122 | 680.3 | 1568 |
| Inpatient spending on diagnostic tests p.a. | 2122 | 1153 | 1925 |
| Inpatient spending on drugs p.a. | 2122 | 2172 | 2451 |
| Inpatient spending on surgery p.a. | 2122 | 1681 | 3166 |
| **Panel B.5: Employment** | | | |
| Total employment of health professionals | 2174 | 195.2 | 446.6 |
| Employment of physicians | 2174 | 67.84 | 144.8 |
| Employment of nurses | 2174 | 100.8 | 229.1 |
| Employment of pharmacists | 2174 | 15.36 | 18.85 |
| Employment of medical technicians | 2174 | 10.46 | 23.78 |
| **Panel B.6: Medical devices** | | | |
| Number of high-end diagnostic devices (>100k RMB) | 2174 | 29.78 | 121.0 |
| Total number of diagnostic devices | 2174 | 170.2 | 620.2 |
| Total Value of diagnostic devices (million RMB) | 2174 | 21.71 | 94.20 |
| **Panel B.7: Hospital cost (million RMB)** | | | |
| Total hospital expenditure | 2174 | 60.62 | 248.2 |
| Wage expenditure | 2174 | 20.42 | 74.27 |
| Expenditure on drug procurement | 2174 | 23.31 | 87.62 |
| Expenditure on essential drug procurement | 2047 | 7.647 | 29.06 |
| **Panel B.8: Measures of patient health outcome** | | | |
| Inpatient mortality rate (cases per 1000 admissions) | 2050 | 5.590 | 9.517 |
| Adverse reaction to drugs (cases per 1000 patient visits) | 2174 | 0.075 | 0.917 |
| Patient days | 2174 | 12.65 | 17.66 |
| Ratio of nurses to patient days | 2050 | 0.217 | 0.666 |
| **Panel C: Control variables** | | | |
| Hospital tier | 2174 | 0.811 | 1.027 |
| Outpatient case mix[a] | 2174 | 0.278 | 0.187 |
| Inpatient case mix[a] | 2174 | 0.303 | 0.210 |
| Designated hospital for public health insurance | 2174 | 0.931 | 0.254 |
| Covered by the ambulance network | 2174 | 0.731 | 0.444 |
| Equipped with a hospital information system | 2174 | 0.389 | 0.488 |
| Equipped with a medical imaging system | 2174 | 0.733 | 0.443 |
| Equipped with a clinical laboratory | 2174 | 0.851 | 0.356 |
| Equipped with electronic medical records | 2174 | 0.614 | 0.487 |
| Number of hospitals | 487 | | |

*Notes*: This table presents summary statistics for all variables in the empirical analyses. Panel A presents the number of medical malpractice lawsuits. Panel B presents six categories of outcome variables: Panels B.1 to B.3 list variables of patient medical spending, Panels B.4 to B.6 list variables of hospital operations, and Panel B.7 lists variables of patient health outcomes. Panel C presents the control variables.

[a]Outpatient case mix is the proportion of outpatients treated in departments for acute and chronic ambulatory care-sensitive conditions (ACSC) conditions.

[b]: Inpatient case mix is the proportion of inpatient admissions to departments for ACSC conditions.

We conduct a simple correlation analysis to detect important correlates of malpractice lawsuits. Appendix Table A4 shows that, among the set of time-invariant hospital characteristics, hospital tier is the most important correlate of lawsuits. Among time-varying correlates, hospital bed occupation rate (measured by the number of patients treated per hospital bed) is the most important correlate once hospital fixed effects are controlled for; in contrast, the number of malpractice lawsuits is not strongly correlated with the total size of patient flow (in outpatient or inpatient) or the patient case mix. This pattern of correlation is consistent with anecdotal evidence and observational research findings that over-crowdedness is a primary cause of doctor–patient conflicts and medical disputes in Chinese hospitals (Hesketh et al., 2012; Wang et al., 2012).

Overall, these findings suggest the need to deal with the endogeneity of the occurrence of malpractice lawsuits (similarly, hospital crowdedness is also endogenous) and the need to include hospital fixed effects in the empirical analysis.

## 4. The system GMM

### 4.1. Specification

We adopt the method of system GMM to deal with two challenges in the empirical analysis: the endogeneity of the number of malpractice lawsuits and the serial correlation of outcome variables. We estimate the following linear dynamic panel-data model:

$$y_{i,t} = \beta_0 + \beta_1 y_{i,t-1} + \beta_2 lawsuit_{i,t} + X_{i,t}\beta_3 + \delta_t + \eta_i + \epsilon_{i,t}, \tag{1}$$

where $i$ and $t$ index hospital and year ($i = 1, \dots, I$ and $t = 1, \dots, T$), respectively; $y_{i,t}$ denotes the set of outcome variables, $lawsuit_{i,t}$ represents the number of medical malpractice lawsuits, $X_{i,t}$ is a vector of control variables, $\delta_t$ is year fixed effects, $\eta_i$ is the hospital fixed effects, and $\epsilon_{i,t}$ is the idiosyncratic shocks. Coefficients $\beta_1$ and $\beta_2$ are of primary interest. Standard errors are clustered at the hospital level, estimated using a two-step approach, and adjusted using Windmeijer's finite-sample correction (Windmeijer, 2005).

Eq. (1) differs from the standard static fixed-effects model because of the inclusion of the lagged outcome variable $y_{i,t-1}$. Inclusion of $y_{i,t-1}$ is essential because many hospital outcomes are adjusted with delays and depend on the previous year's values. By including the lagged outcome variable, we are able to elicit how additional malpractice lawsuits affect the short-run hospital outcome conditional on the history of the hospital outcome.

An additional nice feature of Eq. (1) is that, combining the short-run effect ($\beta_1$) and the measure of time-persistency of the outcome variable ($\beta_2$), we can compute the long-run effect of malpractice lawsuits. Specifically, $\beta_2$ measures the effect of one additional malpractice lawsuit on the hospital outcome in the current year, $\beta_2 \times \beta_1$ measures the effect in the subsequent year, and so on. The long-run effect is $\frac{\beta_2}{1-\beta_1} = \beta_2 + \beta_2 \times \beta_1 + \beta_2 \times \beta_1^2 + \cdots$ as the sum of accumulated per-period effects. For estimates of all subsequent-year effects of malpractice lawsuits, we use the delta method to compute the standard error. We refer to $\beta_2$ as the *short-run* effect and $\frac{\beta_2}{1-\beta_1}$ as the *long-run* effect throughout the paper.

The inclusion of lagged outcome variable $y_{i,t-1}$ in Eq. (1) gives rise to the dynamic panel bias (Nickell, 1981). For the ease of discussion, we first assume that $lawsuit_{i,t}$ is exogenous for the moment. To see the dynamic panel bias arising from the inclusion of $y_{i,t-1}$, consider that a standard fixed-effects estimation of Eq. (1) is equivalent to the pooled OLS estimation when all variables are demeaned through a within-group transformation. Specifically, the lagged outcome variable $y_{i,t-1}$ is subtracted by its within-group mean $\overline{y_i} = \frac{1}{T-1}(y_{i,2} + \cdots + y_{i,T})$.[15] Similarly, the idiosyncratic error term $\epsilon_{i,t}$ is subtracted by $\overline{\epsilon_i} = \frac{1}{T-1}(\epsilon_{i,2} + \cdots + \epsilon_{i,T})$.

However, such a within-group transformation does not eliminate the bias:

$$E[(y_{i,t-1} - \overline{y_i})(\epsilon_{i,t} - \overline{\epsilon_i})] \neq 0, \tag{2}$$

because, for example, $y_{i,t-1}$ correlates with the $\frac{1}{T-1}\epsilon_{i,t-1}$ term in $\overline{\epsilon_i}$, and similarly, $\epsilon_{i,t}$ correlates with the $\frac{1}{T-1}y_{i,t}$ term in $\overline{y_i}$. There exist other correlating term pairs in Eq. (2) but their impacts decay multiplicatively with a factor of $1/(T-1)$. If $T$ were large, these correlating terms would become insignificant; but in "large $N$, small $T$" samples such as ours, the dynamic panel bias presents a serious problem (Nickell, 1981).

Arellano and Bover (1995) develop a difference GMM to address this problem arising from Eq. (2). We take a first difference in Eq. (1):

$$\Delta y_{i,t} = \beta_1 \Delta y_{i,t-1} + \beta_2 \Delta lawsuit_{i,t} + \Delta X_{i,t}\beta_3 + \Delta\epsilon_{i,t}, \tag{3}$$

where $\Delta$ is the first-difference operator. Again, $\Delta y_{i,t-1}$ is endogenous because

$$E[\Delta y_{i,t-1}\Delta\epsilon_{i,t}] = E[(y_{i,t-1} - y_{i,t-2})(\epsilon_{i,t} - \epsilon_{i,t-1})] = E[y_{i,t-1}\epsilon_{i,t-1}] \neq 0.$$

However, unlike the case with a within-group transformation, longer lag of the outcome variable remain orthogonal to the error term and available as instruments in Eq. (3) as long as the error term $\epsilon_{i,t}$ are not serially correlated. Therefore, the key assumption here is that error term $\epsilon_{i,t}$ are serially uncorrelated: $E[\epsilon_{i,t}\epsilon_{i,s}] = 0$ for $t \neq s$. In addition, as in Blundell and Bond (1998), we make two standard assumptions: (1) $E[\eta_i] = E[\epsilon_{i,t}] = E[\eta_i\epsilon_{i,t}] = 0$ and (2) $E[y_{i,1}\epsilon_{i,t}] = 0$ for $t = 2, \dots, T$. Under these assumptions, we derive moment conditions for the difference GMM as follows:

$$E[y_{i,t-s}\Delta\epsilon_{i,t}] = 0 \text{ for } t = 3, \dots, T \text{ and } s \geq 2. \tag{4}$$

[15] The inclusion of the lagged outcome variable restricts the sample to $t = 2, \dots, T$.

Thus, all $y_{i,t-s}$ for $s \geq 2$ are valid instruments for $\Delta y_{i,t-1}$ in Eq. (3).

We address the endogeneity of $lawsuit_{i,t}$ in Eq. (1) in a similar fashion. The endogeneity of $lawsuit_{i,t}$ arises from the potential correlation between the occurrence of malpractice lawsuits with unobserved time-varying hospital factors in current and previous years, that is, $E[lawsuit_{i,t}\epsilon_{i,s}] \neq 0$ for $s \leq t$. However, the occurrence of malpractice lawsuits is uncorrelated with future values of error term, that is, $E[lawsuit_{i,t}\epsilon_{i,s}] = 0$ for $s > t$. Therefore, longer lags of lawsuits remain orthogonal to the error and available as instruments in Eq. (3). The moment condition for lawsuits becomes

$$E[lawsuit_{i,t-s}\Delta\epsilon_{i,t}] = 0 \text{ for } t = 3, \ldots, T \text{ and } s \geq 2, \tag{5}$$

which makes $lawsuit_{i,t-s}$ for $s \geq 2$ valid instruments for $\Delta lawsuit_{i,t}$ in Eq. (3). Therefore, the difference GMM exploits moment conditions (4) and (5) to estimate Eq. (3).

Blundell and Bond (1998) show that when the time period is short ($T$ is small) or the outcome variable is highly time-persistent ($|\beta_1|$ is close to 1), the difference GMM may suffer from the problem of weak instruments. They label Conditions (4) and (5) as moment conditions in *differences*. To resolve the weak instrument problem, they exploit an additional set of moment conditions in *levels*. Instead of transforming the regressors to expunge the fixed effects, this approach takes the first difference of the instruments to make them exogenous to fixed effects:

$$E[\Delta y_{i,t-2}\eta_i] = 0 \text{ for } t = 2, \ldots, T. \tag{6}$$

$$E[\Delta lawsuit_{i,t-1}\eta_i] = 0 \text{ for } t = 2, \ldots, T, \tag{7}$$

Conditions (6) and (7) are labeled the "mean stationarity" assumption as they assume that the differenced variables $\Delta y_{i,t-2}$ and $\Delta lawsuit_{i,t-1}$ are uncorrelated with the fixed effects $\eta_i$. As pointed out in Blundell and Bond (1998) and further illustrated in Roodman (2009b), these assumptions put restriction on initial conditions, which require deviations from long-run means at the first period to be uncorrelated with the fixed effects. Therefore, these two additional assumptions are also commonly referred to as the initial-condition assumptions. Combined with the aforementioned assumption that the idiosyncratic errors $\epsilon_{i,t}$ are not serially correlated, Conditions (6) and (7) imply that the differenced instruments are uncorrelated with the composite error term $v_{i,t}$, that is, $E[\Delta lawsuit_{i,t-1}v_{i,t}] = E[\Delta lawsuit_{i,t-1}\eta_i] + E[lawsuit_{i,t-1}\epsilon_{i,t}] - E[lawsuit_{i,t-2}\epsilon_{i,t}] = 0$. Similarly, $E[\Delta y_{i,t-2}v_{i,t}] = 0$. As a result, under Conditions (6) and (7), $\Delta y_{i,t-2}$ and $\Delta lawsuit_{i,t-1}$ are valid instruments for $y_{i,t-1}$ and $lawsuit_{i,t}$ in the level Eq. (1).

Blundell and Bond (1998) call this method the system GMM that estimates the level Eq. (1) and the difference equation (3) simultaneously by exploiting all moment conditions (4) to (7). They demonstrate that the system GMM estimator is robust and outperforms other GMM estimators in terms of asymptotic efficiency as well as small sample bias (especially when the outcome variable is highly time-persistent).

### 4.2. Testing the validity of assumptions

The consistency of the system GMM estimator relies on two sets of assumptions. The first is that the idiosyncratic error $\epsilon_{i,t}$ are serially uncorrelated. Arellano and Bond (1991) propose to check for first-order serial correlation in levels of $\epsilon_{i,t}$ through the second-order correlation in differences $\Delta\epsilon_{i,t}$. Because $\Delta\epsilon_{i,t}$ is mechanically correlated with $\Delta\epsilon_{i,t-1}$, serial correlation at the first order is expected. The primary test is thus on the serial correlation at the second order. If serial correlation is detected at the second order, then $y_{i,t-2}$ are correlated with $\Delta\epsilon_{i,t}$ in differenced equation and are no longer valid instruments. In such a case, longer lags of the instrument set are needed. We report the autocorrelation test statistics at both first and second orders in all estimation results and do not detect serial correlation at the second order.

The second set of assumption is the mean-stationarity conditions. Because these conditions introduce additional instruments to the level Eq. (1), the empirical literature generally tests the validity of mean stationarity assumption using the difference-in-Hansen test, which is based on the difference of the minimized GMM criterion functions between the system GMM and the difference GMM (Roodman, 2009b). We report the test statistics and $p$-values of the difference-in-Hansen test in our empirical analysis. We also adopt the recently developed Magazzini et al. (2021)'s Lagrange Multiplier (LM) test for initial conditions/mean stationarity, which has higher power than the difference-in-Hansen test (Magazzini and Calzolari, 2020), as a robustness check. In addition, we report the Hansen (1982)'s $J$-statistics to test the validity of all instruments for both the level and difference equations.

The Hansen test and the difference-in-Hansen test can be weakened in system GMM due to instrument proliferation (Roodman, 2009b,a; Bowsher, 2002). Because the size of the instrument set can grow quadratically with the length of sample period $T$, instrument proliferation can overfit endogenous variables and fail to expunge the endogeneity; consequently, it can weaken the power of Hansen test. We conduct three adjustments following the literature's suggestions (Roodman, 2009b,a): (1) limit the lag distance of instruments, (2) use "collapsed" instruments in estimation, and (3) report the instrument count in baseline results, and conduct robustness checks using alternative lags of instrument sets. In baseline analyses, we adopt the collapsed instrument set with 2 lag distance (i.e., 2 instruments per equation and 4 in total) and check the robustness to alternative instrument sets in the robustness checks.

In summary, several advantages are derived from using system GMM to estimate the effects of malpractice lawsuits on hospital outcomes. First, unobservable time-invariant hospital heterogeneities that may affect both malpractice lawsuits and hospital operations are eliminated. Second, the lagged outcome variable is controlled for in the regression equation, as many hospital outcomes, such as hospital employment and procurement of diagnostic devices, exhibit strong time persistence. Third, the potential endogeneity of our key explanatory variable, the number of malpractice lawsuits, is dealt with. Overall, we adopt the system GMM

**Table 2**
System GMM estimates of effects of malpractice lawsuits on patient spending.

| Variables | (1) Total patient spending per patient | (2) Outpatient spending per visit | (3) Inpatient spending per admission |
|---|---|---|---|
| Lagged outcome variable | 0.686*** | 0.631*** | 0.804*** |
| | (0.085) | (0.093) | (0.063) |
| # malpractice lawsuits | 0.028*** | 0.030*** | 0.025** |
| | (0.010) | (0.010) | (0.011) |
| Observations | 2174 | 2174 | 2174 |
| # of hospitals | 487 | 487 | 487 |
| Controls | Yes | Yes | Yes |
| Hospital FE | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes |
| Long-run effect | 0.088*** | 0.081*** | 0.129** |
| | (0.033) | (0.029) | (0.059) |
| Excluded instrument count | 4 | 4 | 4 |
| Hansen test statistics | 2.587 | 1.330 | 3.802 |
| Hansen *p*-value | 0.629 | 0.856 | 0.434 |
| Diff-in-Hansen statistics | 1.197 | 0.969 | 2.371 |
| Diff-in-Hansen *p*-value | 0.550 | 0.616 | 0.306 |
| AR(1) statistics | −4.040 | −4.165 | −5.461 |
| AR(1) *p*-value | 0.000 | 0.000 | 0.000 |
| AR(2) statistics | −0.632 | −1.160 | −0.548 |
| AR(2) *p*-value | 0.527 | 0.246 | 0.584 |

*Notes*: This table reports the estimated effect of malpractice lawsuits on total medical spending, outpatient spending, and inpatient spending. The independent variable is the number of medical malpractice lawsuits. Outcome variables are total medical spending per patient visit (column 1), outpatient spending per outpatient visit (column 2), and inpatient spending per admission (column 3). All outcome variables are in logarithmic terms. All regressions control for hospital characteristics, patient case mix, and hospital fixed effects and year fixed effects. The excluded instrument count includes collapsed instruments of 2 lag distance. Robust standard errors reported in the bracket are clustered at the hospital level, computed using the two-step procedure, and adjusted using the Windmeijer (2005)'s adjustment.

to estimate the causal effect of malpractice lawsuits on hospital operations conditional on the history of the outcome variable. Combining the estimated short-run effects of malpractice lawsuits and the degree of time persistency of outcome variables, we estimate the long-run effects of malpractice lawsuits on medical spending and hospital operations. We also assess the validity of the system GMM assumptions with a series of statistical tests and robustness checks.

## 5. Results

### *5.1. Medical spending*

We first estimate the effect of malpractice lawsuits on patient medical spending. Table 2 reports the estimation results of Eq. (1) and shows that an increased number of malpractice lawsuits leads to higher total, outpatient, and inpatient spending for each patient visit.[16] Results in column (1) show that the coefficient before the number of malpractice lawsuits is 0.028 (statistically significant at the 1% level), which indicates one additional medical malpractice lawsuit increases total medical spending per patient visit by 2.8% contemporaneously. Moreover, the estimated coefficient for the lagged outcome variable is 0.686 and is statistically significant at the 1% level, which shows the outcome variable is strongly serially correlated. Combining the coefficients of the number of malpractice lawsuits and the lagged outcome variable, we can compute that one additional malpractice lawsuit increases total medical spending by 1.92% ($= 2.8\% * 0.686$) in the second year, 1.32% ($= 2.8\% * 0.686^2$) in the third year, and accumulatively by as much as 8.8% ($= 2.8\%/(1 - 0.686)$) in the long run. The long-run effect on total medical spending is more than four times greater than the effect in the first year. Finally, the Hansen test fails to reject that the null hypothesis that all instruments are valid ($p$-value = 0.629). Difference-in-Hansen test fails to reject the mean stationarity assumption ($p$-value = 0.550). Durbin–Watson autocorrelation (AR) tests shows the existence of first-order serial correlation (AR(1) $p$-value = 0.000, due to the inclusion of the lagged outcome variable) and verify the absence of second-order serial correlation (AR(2) $p$-value = 0.527).

Similarly, column (2) shows that one additional malpractice lawsuit increases outpatient spending per outpatient visit by 3.0% in the short run and by 8.1% in the long run, and both estimates are statistically significant at the 1% level; column (3) shows the corresponding increase in inpatient spending per inpatient admission is 2.5% in the short run and 12.9% in the long run, and both estimates are statistically significant at the 5% level. The estimated short-run effect of malpractice lawsuits on inpatient spending is similar to that of Frakes and Gruber (2019), who find immunity from malpractice liability in the US military health system leads

[16] The effects of malpractice lawsuits on aggregate medical spending (Appendix Table A5) are similar to those on per-patient spending (Table 2) and the effects of lawsuits on total patient visits are close to zero (Appendix Table A6). We thus focus on per-patient spending throughout the baseline analysis.

**Table 3**
System GMM estimates of effects of malpractice lawsuits on outpatient spending.

| Variables | (1) Outpatient: Diagnostic tests | (2) Outpatient: drugs | (3) Outpatient: Consultation | (4) Outpatient: Surgery |
|---|---|---|---|---|
| Lagged outcome variable | 0.729*** | 0.648*** | 0.730*** | 0.825*** |
| | (0.086) | (0.082) | (0.068) | (0.066) |
| # malpractice lawsuits | 0.036* | 0.034** | −0.014 | −0.000 |
| | (0.020) | (0.017) | (0.014) | (0.017) |
| Observations | 2174 | 2174 | 2174 | 2174 |
| # of hospitals | 487 | 487 | 487 | 487 |
| Controls | Yes | Yes | Yes | Yes |
| Hospital FE | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes |
| Long-run effect | 0.134* | 0.096* | −0.051 | −0.001 |
| | (0.079) | (0.050) | (0.057) | (0.097) |
| Excluded instrument count | 4 | 4 | 4 | 4 |
| Hansen test statistics | 1.756 | 1.406 | 3.179 | 0.783 |
| Hansen *p*-value | 0.781 | 0.843 | 0.528 | 0.941 |
| Diff-in-Hansen statistics | 0.640 | 0.953 | 2.405 | 0.617 |
| Diff-in-Hansen *p*-value | 0.726 | 0.621 | 0.300 | 0.735 |
| AR(1) statistics | −5.687 | −4.890 | −5.667 | −5.785 |
| AR(1) *p*-value | 0.000 | 0.000 | 0.000 | 0.000 |
| AR(2) statistics | 0.128 | −0.507 | −0.238 | 0.892 |
| AR(2) *p*-value | 0.898 | 0.612 | 0.812 | 0.372 |

*Notes*: This table reports the estimated effect of malpractice lawsuits on itemized spending in outpatient visits. The independent variable is the number of medical malpractice lawsuits. Outcome variables are outpatient spending per patient visit on diagnostic tests (column 1), drugs (column 2), physician services (column 3), and surgeries (column 4). All outcome variables are in logarithmic terms. All regressions control for hospital characteristics, patient case mix, and hospital fixed effects and year fixed effects. The excluded instrument count includes collapsed instruments of 2 lag distance. Robust standard errors reported in the bracket are clustered at the hospital level, computed using the two-step procedure, and adjusted using the Windmeijer (2005)'s adjustment.

to a 5% reduction of inpatient spending. Across all columns, the estimated coefficients of lagged outcome variables are statistically significant at the 1% level. The Hansen test fails to reject the null hypothesis that all excluded instruments are valid; the difference-in-Hansen test fails to reject the null hypothesis of mean stationarity; and the AR tests show error terms are serially correlated at the first order but not at the second order.

Fig. 2 plots the estimates of the dynamic effect of medical malpractice lawsuits in the first through the 10th year, together with the corresponding 90% confidence intervals. We also report the estimate of long-run effect and its *p*-value in each figure. Fig. 2 shows the effects of malpractice lawsuits on patients' medical spending are large and statistically significant in the first year and remain persistent years afterward.

We break down total medical spending into itemized services and find the increase in total spending is mainly driven by diagnostic tests and prescription drugs. Table 3, columns (1) and (2), show that one additional malpractice lawsuit increases the outpatient spending on diagnostic tests and drugs by 3.6% and 3.4%, respectively, in the short run. The long-run effects are 13.4% and 9.6%, respectively. All estimated effects are statistically significant at the 10% level. By contrast, the effects on outpatient consultation services and surgeries are small and statistically insignificant (columns 3 and 4). We find similar patterns for the breakdown of inpatient spending per admission. Table 4, columns (1) and (2), show that one additional malpractice lawsuit increases inpatient spending on tests and drugs by 2.7% and 2.6%, respectively, in the short run; and are 12.7% and 11.8% in the long run. The effects on inpatient spending on general care and surgeries are small and statistically insignificant.

Results in Tables 3 and 4 show that an increased number of malpractice lawsuits leads to higher medical spending, especially on low-risk procedures and services such as diagnostic tests and drugs, but not on higher-risk services such as surgeries. This pattern of responses is similar to that in Baicker et al. (2007), who find the use of low-risk, discretionary services such as diagnostic tests, imaging services, and minor procedures is more sensitive to the increasing liability of malpractice litigation than elective surgeries. In addition, He (2014) documents a similar pattern that doctors overprescribe drugs to avoid potential doctor–patient conflicts based on a doctor survey in Shenzhen, another developed Chinese city similar to Chengdu.

The finding that the long-run effects of malpractice lawsuits on medical spending are larger than the short-run effects has two implications. First, it means the effect of malpractice lawsuits is persistent and may exacerbate the inefficient use of limited medical resources in the long run. This persistency poses a large threat to the financial sustainability of China's health system, which has been increasingly burdened by population aging and the rising prevalence of chronic illnesses (Wang and Chen, 2014; Yang et al., 2008). Second, the persistency of the effect suggests the risk of malpractice lawsuits may increase chronic stress in physicians and exert long-term effects on physicians' treatment styles. Charles (2001) uses survey and interview data to show physicians experience an extended period of emotional turmoil after being sued for malpractice. Shanafelt et al. (2003) raise similar concerns that physicians may confront chronic stresses when facing increasing malpractice accusations and suits. The rising stresses may affect physicians' performance, which in turn increases the likelihood of medical errors and negligence. Carrier et al. (2010) find physicians' fears of malpractice lawsuits are not assuaged by tort reforms that reduce the financial liability of malpractice, suggesting the importance of

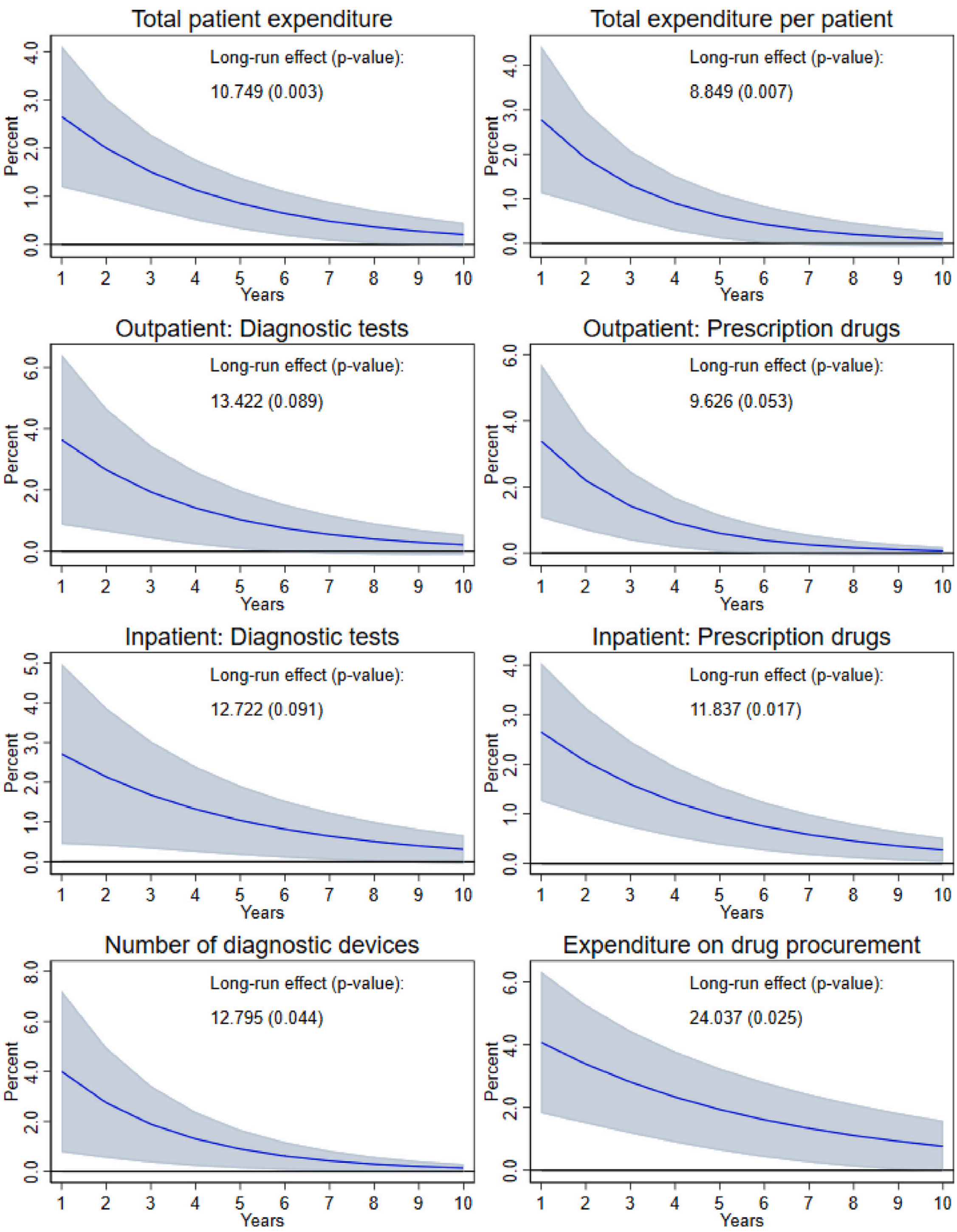


**Fig. 2.** Effects of medical malpractice lawsuits on medical spending and hospital operations. *Notes*: This figure plots the estimated effects of medical malpractice lawsuits on various healthcare outcomes. The *x*-axis plots the number of years since the occurrence of a medical malpractice lawsuit; the *y*-axis plots the estimated effects of medical malpractice lawsuits. See the definition of outcomes in Section 3.2. Shaded areas are the 90% confidence intervals. The long-run effects (*p*-value) are reported at the top of each subgraph. See Section 4 for detailed computation of per-period effects and long-run effects.

**Table 4**
System GMM estimates of effects of malpractice lawsuits on inpatient spending.

| Variables | (1) Inpatient: Diagnostic tests | (2) Inpatient: Drugs | (3) Inpatient: General Care | (4) Inpatient: Surgery |
|---|---|---|---|---|
| Lagged outcome variable | 0.787*** | 0.776*** | 0.804*** | 0.864*** |
| | (0.064) | (0.046) | (0.045) | (0.037) |
| # malpractice lawsuits | 0.027* | 0.026*** | 0.001 | 0.001 |
| | (0.016) | (0.010) | (0.011) | (0.014) |
| Observations | 2174 | 2174 | 2174 | 2174 |
| # of hospitals | 487 | 487 | 487 | 487 |
| Controls | Yes | Yes | Yes | Yes |
| Hospital FE | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes |
| Long-run effect | 0.127* | 0.118** | 0.003 | 0.005 |
| | (0.075) | (0.050) | (0.059) | (0.100) |
| Excluded instrument count | 4 | 4 | 4 | 4 |
| Hansen test statistics | 4.021 | 3.733 | 2.849 | 1.023 |
| Hansen *p*-value | 0.403 | 0.443 | 0.583 | 0.906 |
| Diff-in-Hansen statistics | 3.983 | 2.317 | 2.772 | 0.183 |
| Diff-in-Hansen *p*-value | 0.137 | 0.314 | 0.250 | 0.913 |
| AR(1) statistics | −6.436 | −5.840 | −4.646 | −7.042 |
| AR(1) *p*-value | 0.000 | 0.000 | 0.000 | 0.000 |
| AR(2) statistics | 1.162 | 0.720 | 1.385 | 1.081 |
| AR(2) *p*-value | 0.245 | 0.472 | 0.166 | 0.280 |

*Notes*: This table reports the estimated effect of malpractice lawsuits on itemized spending in inpatient admission. The independent variable is the number of medical malpractice lawsuits. Outcome variables are inpatient spending per inpatient admission on diagnostic tests (column 1), drugs (column 2), general care (including physician services, nursing care, and inpatient facility charges) (columns 3), and surgeries (column 4). All outcome variables are in logarithmic terms. All regressions control for hospital characteristics, patient case mix, and hospital fixed effects and year fixed effects. The excluded instrument count includes collapsed instruments of 2 lag distance. Robust standard errors reported in the bracket are clustered at the hospital level, computed using the two-step procedure, and adjusted using the Windmeijer (2005)'s adjustment.

nonfinancial impacts of malpractice lawsuits on physicians. Considering the skyrocketing number of malpractice lawsuits in China in the recent decade (Fig. 1), the long-run impact of the malpractice lawsuits on China's health system may be enormous.

### *5.2. Hospital operations*

We then analyze the effects of lawsuits on hospital operational outcomes. Table 5 shows that hospitals respond to malpractice lawsuits by procuring more diagnostic devices and drugs. Column (1) shows that one additional malpractice lawsuit increases a hospital's number of high-end diagnostic devices (valued at more than 100k RMB) by 4.0% in the short run and 12.8% in the long run.[17] Both estimates are statistically significant at least the 10% level. We consider two alternative measures of the diagnostic devices: the total number of devices valued more than 10k RMB and the total value of these devices (devices valued below 10k RMB are not recorded in the data). Column (2) shows the short-run increase in the total number of diagnostic devices is estimated to be 5.2% and the long-run increase is 16.3%, both are statistically significant at the 10% level. The estimated short- and long-run increases in the total value of diagnostic devices are similar in magnitude but are statistically insignificant (column 3). Overall, results in Table 5 are consistent with those in Tables 3 and 4, columns (1) that doctors order more diagnostic tests when facing a higher risk of malpractice lawsuits.

In terms of hospital expenditure, Table 6, column (1), shows that one additional malpractice lawsuit increases a hospital's total expenditure by 4.4% in the short run and 14.7% in the long run. Moreover, the long-run increase in total expenditure is largely driven by the expenditure on drug procurement rather than on wage expenses: the short-run effect on expenditure of drug procurement is 4.1%, compared with 1.6% for wage expenditure, and the long-run effect is 24.0% compared with 8.1%. Results are similar if we consider the expenditure on procurement of essential drugs, that is, drugs listed on the National Essential Medicine List and heavily subsidized by public health insurance. All the estimated long-run increases in hospital expenditure are statistically significant at the 5% level. The results on drug procurement are consistent with those in Tables 3 and 4, column (2) and suggest that doctors prescribe more drugs when facing a higher risk of malpractice lawsuits. Fig. 2 plots the dynamic effects of malpractice lawsuits on the number of high-end diagnostic devices in use and the procurement of drugs, and shows the estimated effects remain positive and statistically significant five years after the occurrence of malpractice lawsuits.

Table 7 shows that malpractice lawsuits have a limited effect on hospital employment of health professionals: both the short-run and long-run effects are close to zero, regardless of whether we separately consider the employment of physicians, nurses, pharmacists, or medical technicians. None of the estimated effects on hospital employment are statistically significant. As expected,

[17] We focus on high-end devices valued more than 100k RMB because most of discretionary diagnostic and imaging procedures analyzed in the malpractice literature – such as CT/MRI and chest X-ray (Baicker et al., 2007) – are conducted with devices of this price range.

**Table 5**
System GMM estimates of effects of malpractice lawsuits on the procurement of diagnostic devices.

| Variables | (1)<br># diagnostic devices<br>(>100k RMB) | (2)<br># diagnostic devices<br>(>10k RMB) | (3)<br>Value of diagnostic<br>devices (million) |
|---|---|---|---|
| Lagged outcome variable | 0.687*** | 0.681*** | 0.832*** |
| | (0.042) | (0.044) | (0.116) |
| # malpractice lawsuits | 0.040** | 0.052* | 0.033 |
| | (0.020) | (0.029) | (0.036) |
| Observations | 2174 | 2174 | 2174 |
| # of hospitals | 487 | 487 | 487 |
| Controls | Yes | Yes | Yes |
| Hospital FE | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes |
| Long-run effect | 0.128* | 0.163* | 0.198 |
| | (0.064) | (0.093) | (0.243) |
| Excluded instrument count | 4 | 4 | 4 |
| Hansen test statistics | 0.988 | 5.014 | 4.616 |
| Hansen *p*-value | 0.912 | 0.286 | 0.329 |
| Diff-in-Hansen statistics | 0.238 | 2.746 | 1.503 |
| Diff-in-Hansen *p*-value | 0.888 | 0.253 | 0.472 |
| AR(1) statistics | −6.126 | −7.743 | −4.464 |
| AR(1) *p*-value | 0.000 | 0.000 | 0.000 |
| AR(2) statistics | 0.862 | 0.285 | 0.563 |
| AR(2) *p*-value | 0.389 | 0.776 | 0.573 |

*Notes*: This table reports the estimated effect of malpractice lawsuits on hospital's investment in diagnostic devices. The independent variable is the number of medical malpractice lawsuits. Outcome variables are the number of diagnostic devices valued more than 100k RMB (column 1), the number of high-end diagnostic devices valued over 10k RMB (column 2), and the total value of diagnostic devices (in million RMB) (column 3). All outcome variables are in logarithmic terms. All regressions control for hospital characteristics, patient case mix, and hospital fixed effects and year fixed effects. The excluded instrument count includes collapsed instruments of 2 lag distance. Robust standard errors reported in the bracket are clustered at the hospital level, computed using the two-step procedure, and adjusted using the Windmeijer (2005)'s adjustment.

**Table 6**
System GMM estimates of effects of malpractice lawsuits on hospital expenditure.

| Variables | (1)<br>Total operational<br>expenditure | (2)<br>Wage expenditure | (3)<br>Drug procurement | (4)<br>Essential drug<br>procurement |
|---|---|---|---|---|
| Lagged outcome variable | 0.702*** | 0.802*** | 0.830*** | 0.836*** |
| | (0.132) | (0.086) | (0.053) | (0.052) |
| # malpractice lawsuits | 0.044*** | 0.016* | 0.041*** | 0.045*** |
| | (0.016) | (0.009) | (0.014) | (0.015) |
| Observations | 2174 | 2174 | 2174 | 2047 |
| # of hospitals | 487 | 487 | 487 | 487 |
| Controls | Yes | Yes | Yes | Yes |
| Hospital FE | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes |
| Long-run effect | 0.147** | 0.081** | 0.240** | 0.274** |
| | (0.070) | (0.038) | (0.108) | (0.121) |
| Excluded instrument count | 4 | 4 | 4 | 4 |
| Hansen test statistics | 3.739 | 3.091 | 3.907 | 4.166 |
| Hansen *p*-value | 0.442 | 0.543 | 0.419 | 0.384 |
| Diff-in-Hansen statistics | 3.398 | 2.761 | 2.648 | 3.152 |
| Diff-in-Hansen *p*-value | 0.183 | 0.251 | 0.266 | 0.207 |
| AR(1) statistics | −2.905 | −5.647 | −4.507 | −4.465 |
| AR(1) *p*-value | 0.004 | 0.000 | 0.000 | 0.000 |
| AR(2) statistics | 1.580 | 0.937 | 0.562 | 0.540 |
| AR(2) *p*-value | 0.114 | 0.349 | 0.574 | 0.589 |

*Notes*: This table reports the estimated effect of malpractice lawsuits on hospital's expenditure. The independent variable is the number of medical malpractice lawsuits. Outcome variables are total hospital operational expenditure (column 1), wage expenditure (column 2), the expenditure on drug procurement (column 3), and the expenditure on essential drug procurement (column 4). All outcome variables are in logarithmic terms. All regressions control for hospital characteristics, patient case mix, and hospital fixed effects and year fixed effects. The excluded instrument count includes collapsed instruments of 2 lag distance. Robust standard errors reported in the bracket are clustered at the hospital level, computed using the two-step procedure, and adjusted using the Windmeijer (2005)'s adjustment.

**Table 7**
System GMM estimates of effects of malpractice lawsuits on hospital employment.

| Variables | (1) Total employment | (2) Physicians | (3) Nurses | (4) Pharmacists | (5) Technicians |
|---|---|---|---|---|---|
| Lagged outcome variable | 0.882*** | 0.918*** | 0.828*** | 0.848*** | 0.741*** |
| | (0.034) | (0.049) | (0.103) | (0.070) | (0.086) |
| # malpractice lawsuits | −0.000 | −0.002 | 0.002 | 0.008 | −0.007 |
| | (0.006) | (0.006) | (0.012) | (0.011) | (0.012) |
| Observations | 2174 | 2174 | 2174 | 2174 | 2174 |
| # of hospitals | 487 | 487 | 487 | 487 | 487 |
| Controls | Yes | Yes | Yes | Yes | Yes |
| Hospital FE | Yes | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes | Yes |
| Long-run effect | −0.005 | −0.030 | 0.014 | 0.053 | −0.027 |
| | (0.320) | (0.085) | (0.066) | (0.070) | (0.052) |
| Excluded instrument count | 4 | 4 | 4 | 4 | 4 |
| Hansen test statistics | 4.088 | 0.132 | 4.428 | 4.486 | 5.052 |
| Hansen *p*-value | 0.394 | 0.998 | 0.351 | 0.344 | 0.282 |
| Diff-in-Hansen statistics | 0.154 | 0.059 | 1.913 | 1.896 | 1.021 |
| Diff-in-Hansen *p*-value | 0.926 | 0.971 | 0.384 | 0.388 | 0.600 |
| AR(1) statistics | −2.140 | −2.713 | −6.566 | −6.011 | −5.596 |
| AR(1) *p*-value | 0.032 | 0.007 | 0.000 | 0.000 | 0.000 |
| AR(2) statistics | −0.252 | −1.380 | 1.037 | −0.026 | 0.155 |
| AR(2) *p*-value | 0.801 | 0.168 | 0.300 | 0.979 | 0.876 |

*Notes*: This table reports the estimated effect of malpractice lawsuits on hospital's employment of health professionals. The independent variable is the number of medical malpractice lawsuits. Outcome variables are total employment of health professionals (column 1), including that of physicians (column 2), nurses (column 3), pharmacists (column 4), and technicians (column 5). All outcome variables are in logarithmic terms. The excluded instrument count includes collapsed instruments of 2 lag distance. Robust standard errors reported in the bracket are clustered at the hospital level, computed using the two-step procedure, and adjusted using the Windmeijer (2005)'s adjustment.

**Table 8**
System GMM estimates of effects of malpractice lawsuits on patient health outcomes.

| Variables | (1) Inpatient mortality | (2) Rate of adverse drug reaction | (3) Patient days (log) | (4) Ratio of nurses to patient-days |
|---|---|---|---|---|
| Lagged outcome variable | 0.890*** | 0.634*** | 0.550*** | 0.961*** |
| | (0.225) | (0.132) | (0.111) | (0.159) |
| # malpractice lawsuits | −0.005 | 0.009 | 0.005 | 0.007 |
| | (0.014) | (0.007) | (0.013) | (0.025) |
| Observations | 2174 | 2174 | 2174 | 2174 |
| # of hospitals | 487 | 487 | 487 | 487 |
| Controls | Yes | Yes | Yes | Yes |
| Hospital FE | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes |
| Long-run effect | −0.047 | 0.024 | 0.010 | 0.189 |
| | (0.170) | (0.023) | (0.029) | (0.454) |
| Excluded instrument count | 4 | 4 | 4 | 4 |
| Hansen test statistics | 1.848 | 2.427 | 4.280 | 5.405 |
| Hansen *p*-value | 0.764 | 0.658 | 0.369 | 0.248 |
| Diff-in-Hansen statistics | 1.326 | 0.377 | 3.730 | 0.232 |
| Diff-in-Hansen *p*-value | 0.515 | 0.828 | 0.155 | 0.890 |
| AR(1) statistics | −4.064 | −1.466 | −3.177 | −3.614 |
| AR(1) *p*-value | 0.000 | 0.143 | 0.001 | 0.000 |
| AR(2) statistics | 1.111 | 0.092 | −0.208 | −1.045 |
| AR(2) *p*-value | 0.267 | 0.927 | 0.835 | 0.296 |

*Notes*: This table reports the estimated effect of malpractice lawsuits on patient health outcomes. The independent variable is the number of medical malpractice lawsuits. Outcome variables are inpatient mortality rate per 1000 admissions (column 1), the rate of adverse reactions to drugs per 1000 patient visits (column 2), the log average number of patient days (column 3), and the ratio of nurses to 1000 patient days (column 4). All regressions control for hospital characteristics, patient case mix, and hospital fixed effects and year fixed effects. The excluded instrument count includes collapsed instruments of 2 lag distance. Robust standard errors reported in the bracket are clustered at the hospital level, computed using the two-step procedure, and adjusted using the Windmeijer (2005)'s adjustment.

the hospital employment is more time persistent than the other hospital operational outcomes, as the coefficients of lagged employment outcomes are closer to 1 than those reported in previous tables.

Together, Tables 2 to 7 demonstrate a consistent pattern of physicians' and hospitals' responses to the rising malpractice lawsuits in China. First, the fact that the increase in patients' medical spending is mainly driven by the spending on drugs and diagnostic tests suggests that physicians respond to the rising litigation risk by increasing the order of low-risk producers and services including drugs and diagnostic tests. This pattern of defensive responses is also reflected in hospital's use of high-end diagnostic devices and the procurement of drugs. Second, we find no evidence that malpractice lawsuits increase patient spending on labor-intensive procedures or services such as physician consultation services, nursing care, or surgeries; neither do we find that hospitals adjust the employment of health professionals. Lastly, throughout Tables 2 to 7, coefficients of lagged outcome variables are generally estimated to be 0.6 to 0.8 and statistically significant at the 1% level, which substantiates the time-persistency of the hospital outcome variables. This time persistency of hospital outcomes implies that effects of malpractice lawsuits will persist for years and have long-term implications.

### 5.3. Patient health outcomes

We investigate the effect of malpractice lawsuits on four measures of patient outcomes: inpatient mortality, the rate of adverse drug reactions, patient days in hospitalization, and the ratio of nurses to patient-days. We find that malpractice lawsuits have little effect on these measures of patient outcomes. Table 8, column (1) shows that one additional malpractice lawsuit reduces the inpatient mortality rate by 0.005 deaths per 1000 admissions in the short run, or a change of 0.09% in the average 5.59 deaths per 1000 inpatient admissions in our sample. Estimated short-run effects are also small and statistically insignificant for the rate of adverse-drug-reactions per 1000 cases (coefficient 0.009), log average patient days per admission (coefficient 0.005), and the ratio of nurses per patient-day (coefficient 0.007). The estimated long-run effects on patient outcomes are negligibly small and statistically insignificant.[18] Based on the set of available measures on patient outcomes in our dataset, our findings are consistent with the literature showing that changes in physicians' defensive behaviors induced by tort reforms or malpractice regulations have limited impact on patient outcomes (Frakes and Gruber, 2019; Frakes, 2013; Frakes and Jena, 2016).

A limitation is worth noting. Because the original dataset is collected mainly to track hospital's financial and operational outcomes, it contains limited information on patient outcomes. Except for the aforementioned basic measures such as inpatient mortality and the rate of adverse drug reactions, the dataset does not include other commonly adopted measures of patient outcomes, such as the readmission rate. We therefore take caution to interpret results in Table 8 as strong evidence for no effect of malpractice lawsuits on patient outcomes.

## 6. Robustness

In this section, we check the robustness of our baseline results. First, we verify that our system GMM estimation results and test statistics are not weakened by instrument proliferation. We then explore different functional form specifications of malpractice lawsuits in the estimation model. Last, we explore the heterogeneous effects of malpractice lawsuits across hospital tiers.

### 6.1. Restriction on instrument proliferation

As discussed in Section 4, the validity of system GMM are customarily tested using the Hansen overidentification test and the difference-in-Hansen test. However, both tests can be weakened as the number of instruments – equivalently, the number of moment conditions – grows quadratically when the length of sample period increases (Bowsher, 2002; Roodman, 2009b). In the baseline specification we have limited the lag distance of instruments to two and used the "collapsed" version of instruments (Roodman, 2009a), which limits the total number of instruments to only 4. We now report the robustness checks using alternative lag distance of the instrument set and without the collapsed version.

In Appendix Table A7, we use the non-collapsed instrument set and progressively reduce the lag distance from 4 to 2 in columns (1) to (3), and use the collapsed instrument set from columns (4) to (6). Column (6) is our baseline specification. Across columns, the estimated coefficients on endogenous regressors – lagged outcome variable and the number of lawsuits – are similar, Hansen tests fail to reject the null hypotheses that all instruments are valid, and difference-in-Hansen tests fail to reject of null hypothesis of mean stationarity. We also report the test statistics of the recently developed Lagrange Multiplier (LM) test for mean stationarity, which has higher power than the difference-in-Hansen test (Magazzini and Calzolari, 2020; Magazzini et al., 2021). The LM test fails to reject the null that mean stationarity holds.[19] We conduct the same set of robustness analyses on outpatient, inpatient, and total spending per patient in Appendix Tables A7 to A9, respectively, and find consistent results.

### 6.2. Alternative functional forms of lawsuits

So far we have analyzed the effect of malpractice lawsuits assuming a linear functional form of lawsuits in baseline specification (Eq. (1)). Considering that the occurrence of lawsuits is rare in lower-tier hospitals and concentrated in tier-3 hospitals (Appendix Figure B1), we estimate an alternative specification based on an indicator variable of lawsuits in Eq. (1) (i.e., use $D.(\#lawsuits > 0)$ to replace $\#lawsuits$), referred to as the indicator specification hereafter. Appendix Table A10, column (2) reports the system GMM estimation results (column 1 reports the baseline results as comparison) and shows that the coefficient on the lawsuit indicator is positive but estimated with large standard errors. This is likely because the occurrence of lawsuits is rare in lower-tier hospitals

[18] The only exception is that the estimated long-run effect on the ratio of nurses to patient days is 0.189, but is very imprecisely estimated. The estimated short-run effect is close to zero, and the large estimate of long-run effect is mainly driven by the extremely high time-persistency of the outcome variable (coefficient of lagged outcome is 0.961) as the employment of nurses is very stable across years in our sample. We thus do not consider this as reasonable evidence of long-run effect of malpractice lawsuits on patient outcomes.

[19] The current implementation of the Magazzini et al. (2021)'s LM test is not compatible with the collapsed instruments. We thus have not reported the LM test statistics in the baseline results.

and hospital's responses to such rare events vary considerably in lower-tier hospitals. We estimate the indicator specification on the subsample of lower-tier hospitals and find that, as expected, the coefficient of the lawsuit indicator is estimated with large standard errors (Appendix Table A11).

We adopt a second alternative specification, based on a piecewise linear function of lawsuits, to estimate a nonlinear, potentially marginally decreasing, effect of lawsuits. In particular, we interact the number of lawsuits separately with a dummy of lawsuits being below 3 cases ($\#lawsuits \times D.(0-3)$) and a dummy of lawsuits being over 4 cases ($\#lawsuits \times D.(\geq 4)$). Appendix Table A10, column (3) reports the estimation results and shows that the coefficient of the latter interaction term is smaller than the former one, suggesting that the effect of lawsuits is decreasing marginally when the number of lawsuits increases.

Third, we consider whether lawsuit occurred in previous years may have any direct persistent effect on the current outcome beyond its effect on the lagged outcome variable. We include the first lag of lawsuits together with its current value in the baseline specification and adjust the instrument set accordingly. Appendix Table A10, column (4) reports the estimation results and show that coefficient of the lagged lawsuits is small compared to the coefficient on the current value (0.009 vs 0.028) and is estimated statistically insignificantly. This shows that the time-persistent effect of lawsuits is mainly borne out of the time persistency of the outcome variable.

Appendix Table A10 presents the estimation results of the above three alternative specifications using outpatient spending per patient as outcome variable. The results remain robust to inpatient spending per admission (Appendix Table A12) and total medical spending per patient (Appendix Table A13), respectively.

### *6.3. Heterogeneous effect of lawsuits across hospital tiers*

We proceed to explore the heterogeneous effects of malpractice lawsuits across hospital tiers. Prior studies find that both the frequency and associated severity of injuries of malpractice disputes in tier-3 hospitals are higher than lower-tier hospitals (Hesketh et al., 2012; Wang et al., 2012; Milcent, 2018; Zeng et al., 2018). We find a similar pattern in the frequency of malpractice lawsuits across hospital tiers in our sample (Appendix Figure B1).[20] As malpractice lawsuits pose a greater threat to higher-tier hospitals, we expect hospital responses to lawsuits to be stronger in higher-tier hospitals.

Appendix Table A14 reports estimated heterogeneous effect of lawsuits across hospital tiers. We separately estimate the baseline specification on two subsamples: a lower-tier sample consisting of non-tiered and tier-1 hospitals, and a higher-tier sample consisting of tier-2 and tier-3 hospitals. We group tier-2 and tier-3 hospitals together due to the small sample size of tier-3 hospitals alone (7.5% of sample, Appendix Table A1). The estimated effects of lawsuits on medical spending and measures of provider's defensive medicine (the number of diagnostic devices and drug procurement) are positive and statistically significant in the higher-tier sample, but small and statistically insignificant in the lower-tier sample. It is worth noting that the coefficients of lawsuits are imprecisely estimated in the lower-tier sample, as in the indicator-specification results of Appendix Table A11. We thus take caution to interpret results in Appendix Table A14 as evidence of no response to malpractice lawsuits in lower-tier hospitals. Overall, these results provide suggestive evidence that higher-tier hospitals are on average more responsive to the occurrence of malpractice lawsuits.

This pattern of heterogeneity can be attributed to two potential reasons. First, as is documented by Zeng et al. (2018), malpractice disputes are less likely to be settled by negotiation or mediation, and more likely to escalate into lawsuits, in tier-3 hospitals than lower-tier ones. The restricted means of dispute resolution implies that higher-tier hospitals need to respond more proactively to prevent the occurrence of malpractice disputes and lawsuits. Second, malpractice lawsuits in higher-tier hospitals are generally characterized by a higher severity of injuries and result in a greater burden of financial and reputational damages to doctors and hospitals (Li et al., 2014, 2020; Zeng et al., 2018). For example, Zeng et al. (2018) find that tier-3 hospitals often face a much higher average level of compensatory damages in malpractice lawsuits than their lower-tier counterparts. Overall, our results complement these earlier findings and suggest that malpractice lawsuits lead to stronger defensive responses in higher-tier hospitals.

## 7. Discussion and conclusion

Our empirical findings suggest malpractice lawsuits motivate doctors and hospitals to practice defensive medicine in China. The defensive behaviors are most pronounced in prescription drugs and diagnostic tests, but not in physician consultation, nursing care, or surgeries. This finding is consistent with the long-standing literature on medical malpractice and defensive medicine in western health systems (Mello et al., 2010; Baicker et al., 2007; Kessler et al., 2006) despite the many differences of China's health system with the western ones. We provide the first strand of quantitative evidence of defensive medicine and its impact on medical spending in China against the backdrop of ongoing healthcare reforms and a fast-rising number of malpractice lawsuits. Furthermore, we adopt the system GMM method to estimate a dynamic panel-data model and estimate a much larger long-run effects of malpractice lawsuits on hospital outcomes than the contemporaneous effects.

Our findings show that the short- and long-run cost of malpractice lawsuits far exceeds the direct compensation payment. Based on a national sample of malpractice lawsuits from 2008 to 2017, Li et al. (2020) find that a malpractice lawsuit results in an average of compensation payment of RMB 204,600 (US$31,430).[21] In comparison, we find that a malpractice lawsuit leads to a 2.8% increase

[20] Due to data restriction, we cannot analyze detailed characteristics of malpractice lawsuits except for the number of occurrence in our sample.

[21] This amount is about one-tenth of the average malpractice lawsuit payment in the US, which was $348,065 in 2018, according to the US Department of Health and Human Services.

in per-patient total medical expenditure in the first year and by as large as a 8.8% increase in the long run. Considering that our sampled hospitals treat an average of 116,442 patients per year and the average medical expenditure is RMB 656 per patient visit, a simple back-of-envelope calculation shows that the first-year increase in medical cost of a malpractice lawsuit is RMB 2.1 million per hospital, and the long-run increase amounts to RMB 6.7 million, an order of magnitude larger than the direct compensation payment.[22] Part of this additional cost is paid by patients through out-of-pocket spending, and the rest by the government through the public health insurance. Such a large increase in medical spending without noticable patient health improvement implies an inefficient use of limited medical resources and fuels the secular growth of medical spending in China.

Our findings have implications on designing alternative mechanisms for medical-dispute resolution. The substantive cost of malpractice lawsuits calls for a more cost-effective way to resolve medical disputes and malpractice cases. Two potential remedies are available. First, compared with malpractice lawsuits, out-of-court mediation has been shown to reach more patients who experience adverse events, be more cost and time effective, and improve satisfaction for both patients and healthcare providers (Liebman, 2013). Second, implementing a medical malpractice insurance system is imperative. Malpractice insurance protects physicians from the financial burden of lawsuits and allows them to focus on medical care; it also assures injured patients of appropriate compensation and may deter them or their families from resorting to extreme measures such as violence (Kessler, 2011). Successful initiatives in developed countries, such as Sweden, may offer guidance for the Chinese government to design a malpractice insurance scheme.

Our study of malpractice lawsuits in one provincial capital city of China has implications for the cases of violence against health professionals in other parts of China (Hesketh et al., 2012; Wang et al., 2012). For any given case of medical dispute, the promotion of legal or out-of-court resolution will help reduce the incidence of violence against doctors. Therefore, further development of a malpractice litigation system and out-of-court mediation will not only improve patients' welfare, but also protect doctors' safety and welfare. As the government is conducting reforms to improve the health care quality and access, integrating the development of the medical-legal system into the overall development of the health system is imperative.

Finally, our findings have important implications for the recent scheme of fixing health system inefficiencies through "health care plumbing" in the US, which advocates that a more effective way to resolve health system inefficiencies might be to pay careful attention to a broad set of "one-percent" solutions rather than attempting big-picture overhauls.[23] One of the proposed "one-percent" solutions is to fix the potential waste associated with defensive medicine (Kessler and McClellan, 1996; Frakes and Gruber, 2019), because defensive medicine is estimated to cost the US more than $46 billion per year (Mello et al., 2010). Our findings suggest that if the effects of malpractice liability on providers' behaviors are time-persistent, the potential overall cost will be substantial.

## Appendix A. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.jce.2023.05.002.

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[22] This result also suggests that physicians and hospitals must be facing consequences much more damaging than the direct compensation payment – such as a sharp reduction of working hours, large psychological distress, and substantial reputational damages – so as to induce the adoption of a range of defensive behaviors in order to reduce the future risk of malpractice lawsuits.

[23] This scheme was recently discussed in a *New York Times* article: "How to Tame Health Care Spending? Look for One-Percent Solutions": https://www.nytimes.com/2018/08/27/upshot/rising-health-care-costs-economists-propose-small-solutions.html.

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