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Sebastian Panthöfer

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Do Doctors Prescribe Antibiotics Out of Fear of Malpractice?

Sebastian Panthöfer*
Universidad Carlos III de Madrid

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Abstract

This paper investigates whether doctors prescribe antibiotics to protect themselves against potential malpractice claims. Using data from the National Ambulatory Medical Care Survey on more than half a million outpatient visits between 1993 and 2011, I find that doctors are 6% less likely to prescribe antibiotics after the introduction of a cap on noneconomic damages. Over 140 million discharge records from the Nationwide Inpatient Sample do not reveal a corresponding change in hospital stays for conditions that can potentially be avoided through antibiotic use in the outpatient setting. These findings, as well as a stylized model of antibiotic prescribing under the threat of malpractice, suggest that liability-reducing tort reforms can decrease the amount of antibiotics that are inappropriately prescribed for defensive reasons.

Keywords: Antibiotic misuse; Antibiotic resistance; Liability pressure; Defensive medicine
JEL Classification: I11, I18, K13

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1 Introduction

Doctors in the U.S. (and elsewhere) prescribe too many antibiotics. According to recent estimates, up to 50% of antibiotics prescribed in the ambulatory care setting are inappropriate (CDC 2013). The misuse of antibiotics promotes the growth of antibiotic resistance, which is one of the most pressing public health issues that many developed countries face today. Worldwide, at least 700,000 patients die every year because of antibiotic resistance, and many more become infected with antibiotic-resistant bacteria (O'Neill 2014). In light of this, the question becomes, why do doctors prescribe unnecessary antibiotics?

A possible explanation for why U.S. doctors prescribe so many antibiotics lies in the medical malpractice system. Doctors in the U.S. face considerable liability pressure as about one in 14 is sued in every given year (Jena *et al.* 2011). In response to this pressure, doctors have been found to resort to defensive medicine, that is, to administer tests, treatments, or medications with expected benefits below cost in order to protect themselves against potential legal proceedings (see the review by Kessler *et al.* 2006). The frequent use of antibiotics may constitute a form of defensive medicine: doctors may feel inclined to prescribe an antibiotic against their own clinical judgement because the antibiotic presents a safeguard against serious bacterial infections, which may trigger a malpractice claim if left untreated. Anecdotal evidence and physician surveys support this theory,[1] but, to date, no attempt has been made to examine whether liability pressure plays a role in actual clinical decisions to prescribe antibiotics.

This paper is the first to systematically analyze the impact of liability pressure on antibiotic prescriptions. I begin by constructing a stylized model of antibiotic prescribing under the threat of malpractice. Based on patient symptoms, a physician has to decide whether or not to prescribe an antibiotic, taking into account the patient's expected utility; expected medical liability costs; and the external cost of increased antibiotic resistance. The model shows that an increase in liability pressure can lead to an increase or decrease in antibiotic prescriptions, depending on how much of a bias the tort law introduces towards (or against, for that matter) prescribing antibiotics relative to what the physician would choose in its absence. Given that two arguably realistic assumptions are satisfied, the model says that direction of the change in antibiotic prescriptions after a change in liability pressure is informative of the social wastefulness of these antibiotics. As such, the model gives rise to a test of defensive medicine whose only requirement is an estimate of the causal effect of liability pressure on antibiotic prescriptions.

Using data from the National Ambulatory Medical Care Survey (NAMCS), a nationally

[1]For instance, of the 669 physicians who participated in a survey in Pennsylvania, 33% reported that they frequently prescribe more medication than medically indicated in response to liability pressure, and an additional 36% reported that they occasionally prescribe medication to avoid potential litigation (Studdert *et al.* 2005).

representative sample of visits to office-based physicians in the U.S., I estimate the causal effect of liability pressure on antibiotic prescriptions with a difference-in-differences design based on the variation in tort reforms across U.S. states from 1993 to 2011. I allow for heterogenous responses to reforms across doctors and patients, for example, based on the patient's type of health insurance. Throughout the analysis, I carefully consider the possibility that preexisting trends in medical care cause tort reforms and not vice versa.

Results show that doctors respond to liability pressure by prescribing more antibiotics. After the introduction of a cap on noneconomic damages – a commonly adopted tort reform that reduces the liability pressure on physicians – doctors are about 6 percent less likely to prescribe antibiotics. Extrapolating to the U.S. population, I estimate that, per year, there would be 3.2 million fewer ambulatory care visits in which doctors prescribe antibiotics if all states adopted caps on noneconomic damages. Results also show that doctors do not prescribe more drugs per patient visit, suggesting that antibiotics act as a substitute for other drugs. With regard to potential heterogeneous effects, I find that patients aged 65 and above are not affected by tort reforms. This can be explained by the fact that, as others have noted before, older patients pose less of a malpractice risk to physicians because of lower future earnings losses. Contrary to some previous studies, I do not find evidence for heterogeneous reform effects for patients who are insured by Medicaid or physicians who are associated to an HMO.

Adopting the same difference-in-differences strategy as described above but using data from the Nationwide Inpatient Sample (NIS), I investigate whether noneconomic damages cap reforms lead to a change in hospital stays for conditions that can be prevented through the timely use of antibiotics. With the possible exception of mastoiditis, I do not find evidence that noneconomic damage caps affect the number of hospital discharges for such conditions. Given the large number of inpatient records in the NIS, the effects are fairly precisely estimated zeros.

Taken together, the empirical results suggest that liability pressure induces physicians to prescribe antibiotics that have no clear health benefits, or in other words, that some antibiotics are used as defensive medicine. This is also what the theoretical model predicts: the model says that antibiotics are prescribed defensively if and only if an increase in liability pressure leads to an increase in antibiotic prescriptions. While the monetary cost of defensive medication treatments may be small compared to other cases of defensive medicine (after all, antibiotics are relatively cheap), there is also the indirect cost tied to increased antibiotic resistance. In this regard, antibiotics are a particularly alarming case of defensive medicine, given that defensively used antibiotics do not only constitute a waste of resources but also negatively affect the health of others due to their external effect on antibiotic resistance.

The rest of this paper is structured as follows. Section 2 provides background information and references to the relevant literatures. Section 3 presents the theory. Section 4 describes the data and provides summary statistics. Section 5 explains the empirical strategy. Section 6 presents the empirical results. Section 7 concludes. Two appendices contain additional tables and information.

2 Background

2.1 Antibiotic Resistance

Antibiotics are used to treat bacterial infections and represent a cornerstone of modern medicine. They are essential for many medical procedures, including chemotherapy, dialysis, Cesarean sections, and organ transplants, because of their ability to prevent infectious complications in vulnerable patients. Antibiotics are also used in the husbandry of livestock, partially, to promote the growth of animals; a practice that has recently come under scrutiny.

The efficacy of antibiotics cannot be taken for granted. Bacteria evolve and develop mechanisms to resist the antibiotics that are used to combat them. Over the course of the last 20 years, antibiotic resistance has become an increasingly alarming issue due to the combination of two major factors: a sharp increase in antibiotic consumption and a shortage of new antibiotics to replace those which have become ineffective. Today, it is estimated that over 2 million U.S. residents acquire antibiotic-resistant infections in a given year, and that these infections result in more than 23,000 annual deaths (CDC 2013). Mortality from MRSA (methicillin-resistant Staphylococcus aureus), which is just one of many microorganisms that have developed resistance to antibiotics, exceeds mortality due to asthma, homicide, or HIV/AIDS (Klevens *et al.* 2007, CDC 2015). The economic impact of antibiotic resistance, while difficult to measure, is likely to be huge: estimates of the annual cost of antibiotic resistance to the world economy range up to $2.85 trillion (O'Neill 2014), corresponding to the GDP of the United Kingdom. In response to this growing problem, many influential institutions, among them the World Health Organization and the Centers for Disease Control and Prevention, have issued reports and called for action to combat the rise in antibiotic resistance (WHO 2014, CDC 2013).

Any use of antibiotics, no matter how conservative and appropriate, contributes to the development of resistant bacteria. But, the widespread misuse of antibiotics that we observe in practice, for example for acute respiratory tract infections such as the common cold, makes the problem worse. For the U.S., which is among the countries with the highest per capita consumption of antibiotics in the world (Van Boeckel *et al.* 2014), it is estimated that between 25 and 50% of all antibiotics are prescribed unnecessarily (CDC 2013, Shapiro *et al.* 2014).[2] Furthermore, there exist large differences in antibiotic usage across U.S. states, with

[2]On top of promoting the growth of antibiotic resistance, inappropriately prescribed antibiotics directly cost the U.S. healthcare system more than $1.1 billion per year (Fendrick *et al.* 2003) and lead to a myriad of

some states prescribing twice as many antibiotics on a per capita basis as others (Hicks *et al.* 2013). Finally, even if antibiotics are indicated for treatment, physicians often prescribe non-recommended broad-spectrum antibiotics, which contribute more to the growth in antibiotic resistance, instead of relying on equally effective (and cheaper) narrow-spectrum antibiotics (Linder and Stafford 2001).

The question is, why do physicians prescribe so many antibiotics? Prior research has shown that physicians prescribe more antibiotics if they can benefit financially from prescribing (Currie *et al.* 2014), patient expectations play an important role (Mangione-Smith *et al.* 1999), peer effects matter (Kwon and Jun 2015), and provider competition can encourage antibiotic use (Fogelberg 2014). One lesson that can be drawn from these findings from different countries is that physicians are influenced by the institutional setup of the healthcare system they practice in. Physicians who practice in the U.S. generally invoke three reasons why they prescribe antibiotics that may not be clinically indicated: patient pressure, to end the visit rapidly, and to avoid potential litigation (Bauchner *et al.* 1999). The latter reason is the focus of this study and will be discussed in more detail in the following sections.

2.2 Liability for Medical Malpractice and Defensive Medicine

In most countries around the world, patients can sue the attending physician when they suffer harm. In the U.S., liability for medical malpractice is generally based on the negligence standard. To prove a case of medical malpractice, a plaintiff must establish that: (1) the care that he or she received fell below the standard of care that is expected from physicians in the community, (2) the care that he or she received was performed negligently, and (3) there is a causal connection between the injury that he or she suffers from and the care that the physician provided.

Even though many adverse events that are caused by medical negligence do not result in the patient filing a malpractice claim (Localio *et al.* 1991), physicians in the U.S. still have to defend a large amount of claims each year. Jena *et al.* (2011) estimate that 7.4% of all physicians are sued in a given year, and that the lifetime risk of being sued ranges between 75% and 99%, depending on physician specialty. Defending a malpractice claim is costly for physicians mainly because there are large nonmonetary costs that are associated with being sued, two of which are particularly important. First, physicians have to devote a considerable amount of time to defending malpractice claims. Seabury *et al.* (2013) show that the average physician spends more than four years with an unresolved malpractice claim, and Studdert *et al.* (2006) report that the average time between injury and closure of a claim is five years. Second, a malpractice incidence can severely damage a physician's reputation, and as Dranove *et al.* (2012) have shown, such reputational damages are associated with economically

preventable adverse drug reactions (CDC 2013).

significant costs. Direct monetary costs arise relatively seldom from a malpractice claim, as most physicians are fully insured against malpractice risks (Danzon 2000, Zeiler *et al.* 2007). For this reason, physicians should care more about the probability of being sued than awards.

One goal of liability for medical malpractice is to align the interests of physicians and other healthcare providers with those of patients: by punishing healthcare professionals for providing too little care, liability is supposed to reduce adverse health outcomes. However, as we know since at least from Kessler and McClellan (1996), liability can also induce physicians to provide too much care. This is referred to as defensive medicine, which, in the economics literature, is defined as care that physicians order to avoid lawsuits but for which cost exceeds expected benefits. The empirical evidence suggests that physicians practice defensive medicine by increasing treatment intensity for heart attack patients (Kessler and McClellan 1996, Avraham and Schanzenbach 2015) and ordering more imaging services (Baicker *et al.* 2007). The evidence regarding the rates of Cesarean sections, whose excessive use is often attributed to liability pressure, is less conclusive: while Dubay *et al.* (1999) and Shurtz (2013) find that physicians perform more Cesarean sections following an increase in liability pressure, Currie and MacLeod (2008) and Amaral-Garcia *et al.* (2015) find the opposite.

Whether physicians prescribe medication to protect themselves against potential malpractice claims has not yet been investigated in actual clinical situations. Errors of medication are a common cause of medical misadventures and often lead to malpractice claims (Leape *et al.* 1991, Rothschild *et al.* 2002). Not surprisingly therefore, two surveys suggest that about a third of physicians regularly prescribe more medication in response to liability pressure (Summerton 1995, Studdert *et al.* 2006). In the context of antibiotics, it is clear that not prescribing an antibiotic to a patient with a bacterial infection can trigger a malpractice claim against the physician, for example when the patient suffers from pneumonia or meningitis.[3] Adding to this, it is often difficult for physicians to differentially diagnose between conditions that require an antibiotic and those that do not (Coenen *et al.* 2000). As antibiotics are relatively safe and inexpensive, physicians may be inclined to prescribe them in marginal cases and even when an antibiotic is not clinically indicated. On the other hand, prescribing antibiotics bears the risk of adverse drug reactions, which may as well lead to a malpractice claim. Hence, when it is clear that the patient does not require an antibiotic, physicians are better off not prescribing one when they want to minimize the risk of litigation.

Another open question is whether liability pressure affects the type of antibiotics that physicians prescribe. One may expect that physicians who are worried about potential malpractice claims prescribe relatively more broad-spectrum antibiotics, given that these act

[3] There exist numerous examples of malpractice claims in which patients sue their physician for delaying or denying antibiotic treatment; see, for example, *Pasquale v. Miller* (1993), *Gartner v. Hemmer* (2002), and *Burgess v. Mt. Vernon Developmental Center* (2009). Moreover, by prescribing an antibiotic, physicians can also hope to avoid malpractice claims which are based on a failure to diagnose a bacterial infection.

against a wider range of bacteria than narrow-spectrum antibiotics.[4]

2.3 Tort Reform

The terms on which patients in the U.S. can sue their physician are determined by the tort law, which differs across states. Spurred in part by three major medical malpractice crises (in the 1970s, 1980s, and 2000s), most states have reformed their tort laws to keep malpractice insurance from becoming unaffordable and to mitigate the liability pressure on physicians. The following four are the most commonly adopted reforms over the period from 1993 to 2011.

1. Caps on noneconomic damages: Noneconomic damages are awarded for nonpecuniary harms, such as pain and suffering, loss of consortium, and emotional distress. They account for about 50% of the typical medical malpractice award (Hyman *et al.* 2009) and are often controversial, given that nonmonetary losses are inherently hard to quantify. Following the example of California, which introduced a cap of $250,000 in 1975, the majority of states have now adopted caps on noneconomic damages.

2. Caps on punitive damages: Punitive damages are designed to punish tortfeasors and deter misconduct. As they are usually restricted to cases that involve intent, actual malice, or gross negligence, punitive damages are awarded relatively infrequently in medical malpractice cases. Many states cap the amount of punitive damages that can be awarded, where the cap can be a fixed amount, a ratio between punitive damages and compensatory damages that cannot be exceed, an amount that is determined by the defendant's net worth or income, or a combination thereof. Some states, such as Michigan, do not allow for punitive damages unless they are specifically provided by statute, and other states, such as Nebraska, impose an outright ban on punitive damages.

3. Modifications of the collateral-source rule (CSR): The common law CSR prohibits the admission of evidence that the plaintiff has been compensated for his or her losses from sources other than the defendant, such as the plaintiff's health insurance. Tort reform advocates argue that the rule allows plaintiff to be compensated twice for the same injury and lobby for its abrogation. In fact, the majority of states have now altered or abolished the common law CSR.

4. Modifications of the joint-and-several liability (JSL) rule: Under the common law JSL rule, plaintiffs can recover damages from multiple defendants collectively or from each defendant individually, regardless of the shares of liability that are apportioned to the

[4] For example, in *McIntiry v. Stubbs* (1983), the physician prescribed narrow-spectrum antibiotics, which did not cure the patient's meningitis, and was sued for failing to prescribe broad-spectrum antibiotics.

defendants. If a plaintiff recovers all damages from one defendant, it is then up to this defendant to pursue the other defendants to contribute for their respective shares of the liability. More than two-thirds of states have limited the application of JSL or replaced it with the proportionate liability rule, under which defendants cannot be asked to pay for more than what they are responsible for.

A large body of research investigates the effect of tort reforms on the medical malpractice environment.[5] The conclusion that has emerged from this literature is that caps on noneconomic damages are the only reform with a significant and consistent impact on liability pressure: they reduce jury awards (Hyman *et al.* 2009), settlement amounts (Avraham 2007, Friedson and Kniesner 2012), claim frequency (Waters *et al.* 2007, Paik *et al.* 2013), and insurance premiums (Thorpe 2004, Kilgore *et al.* 2006), giving rise to an overall reduction in liability pressure. Other reforms, including caps on punitive damages and modifications of the collateral-source and joint-and-several liability rule, have no significant impact on payments or claim frequency, or they increase one and decrease the other.

Several pieces of evidence suggest that changes in the tort law are not related to specific trends in medical care, such as antibiotic prescribing rates, which is crucial for the empirical analysis. First, political factors, such as the political power of the Republican party, appear to be the main drivers of tort reform, whereas private interest groups, including physician associations, do not play an important role (Deng and Zanjani 2014, Matter and Stutzer 2015). Second, most tort reforms affect all kinds of torts equally and are not limited to medical malpractice cases. In fact, many of the reforms concerning punitive damages are an indirect consequence of the public debate revolving around frivolous litigation and the infamous hot coffee lawsuit (*Liebeck v. McDonald's Restaurants*, 1992). Finally, many tort reforms have been ruled unconstitutional by state supreme courts. These court rulings are plausibly exogenous to trends in medical care and will be exploited in the empirical analysis.

3 A Model of Prescriptions under the Threat of Malpractice

This section introduces a model of the physician's decision to prescribe an antibiotic under the threat of malpractice. The physician (she) sees a patient (he) who suffers from an infection, i. The infection is either viral ($i = v$) or bacterial ($i = b$), but the physician does not observe i. Instead she observes the patient's symptoms, from which she can infer the risk that the infection is bacterial, $r = \Pr(i = b)$.

Based on the patient's symptoms, the physician has to decide whether to prescribe an

[5]For two excellent surveys of the literature until the early 2000s, see Holtz-Eakin (2004) and Mello (2006).

antibiotic ($a = 1$) or not ($a = 0$). She chooses a to maximize her expected utility,

$$V(a, r \mid \text{law}) = U(a, r) - L(a, r \mid \text{law}) - \lambda a,$$

where $U(a, r) = ru(a \mid i = b) + (1 - r)u(a \mid i = v)$ is the patient's expected utility; $L(a, r \mid \text{law}) = rl(a \mid i = b, \text{law}) + (1 - r)l(a \mid i = v, \text{law})$ is the physician's expected medical liability; and $\lambda \geq 0$ measures how the physician internalizes the risk of increased antibiotic resistance.

The patient's expected utility is determined by his health and out-of-pocket cost, if any. An antibiotic increases the patient's health, but only in the case of a bacterial infection. On the other hand, an antibiotic can cause side effects or lead to an adverse drug reaction, and it may imply an out-of-pocket cost for the patient. Therefore, I assume that the patient prefers to receive an antibiotic if he has a bacterial infection, $u(1 \mid i = b) > u(0 \mid i = b)$, and he prefers not to receive one otherwise, $u(1 \mid i = v) < u(0 \mid i = v)$.[6] Given these two assumptions, there exists a unique and interior value of r, which is denoted by r_{pat}, such that $U(0, r_{\text{pat}}) = U(1, r_{\text{pat}})$. If the patient could prescribe an antibiotic to himself, he would do so if and only if $r \geq r_{\text{pat}}$.

The physician's expected liability is essentially the probability that a malpractice claim against her is brought forward times the monetary and nonmonetary costs that are associated with a claim, where the tort law potentially affects both the incentives for patients to sue the physician and the costs to the physician that result from a claim. In our setup, the physician can be held liable for medical malpractice for failing to prescribe an antibiotic and for provoking an adverse drug reaction. When the patient suffers from a viral infection, prescribing an antibiotic gives rise to greater expected liability than not prescribing an antibiotic, $l(1 \mid i = v, \text{law}) > l(0 \mid i = v, \text{law})$. This is because the physician cannot be held responsible for failing to prescribe an antibiotic to a patient with viral infection but she can potentially be held responsible for an adverse drug reaction. On the other hand, not giving an antibiotic to a patient with a bacterial infection can result in the patient being severely harmed and is most likely to result in a medical malpractice claim in our setup, considering that adverse drug reactions from antibiotics are relatively rare.[7] Therefore, prescribing an antibiotic minimizes expected liability when the patient suffers from a bacterial infection, $l(1 \mid i = b, \text{law}) < l(0 \mid i = b, \text{law})$. It follows that there exists a unique and interior value of r, which is denoted by r_{law}, such that $L(0, r_{\text{law}} \mid \text{law}) = L(1, r_{\text{law}} \mid \text{law})$. Furthermore, we have that $L(1, r \mid \text{law}) \geq L(0, r \mid \text{law})$ if and only if $r \leq r_{\text{law}}$.

In essence, the liability system is aligned with the patient's preferences: it is optimal to pre-

[6]Both assumptions can be relaxed, to some extent, without affecting the results that follow in the next sections. Thus, the model can also accommodate patients with a bias towards (or against, for that matter) antibiotics.

[7]Less than two percent of the patients in a sample of Medicare enrollees taking antibiotics in the ambulatory care setting experienced an adverse drug reaction (Gurwitz *et al.* 2003).

scribe (not to prescribe) an antibiotic to a patient with a high (low) risk of bacterial infection from both a legal and patient point of view. However, the liability system must not perfectly mirror the patient's preferences.[8] For example, if $r_{\text{law}} < r_{\text{pat}}$, then the liability system exhibits a bias towards prescribing more antibiotics relative to what is optimal for the patient. In what follows, we will see that such a legal bias affects both the physician's decision to prescribe an antibiotic and the effect that tort reforms have on the physician's prescribing behavior.

3.1 The Physician's Prescription Decision

The physician prescribes an antibiotic if and only if $V(1, r \mid \text{law}) \geq V(0, r \mid \text{law})$. She does does not prescribe an antibiotic to a patient who is certain to have a viral infection, given that $V(1, 0 \mid \text{law}) < V(0, 0 \mid \text{law})$. If λ is sufficiently small, then $V(1, 1 \mid \text{law}) > V(0, 1 \mid \text{law})$, which implies that the physician prescribes an antibiotic to a patient who is certain to have a bacterial infection. As $V(\cdot)$ has strictly increasing differences in (a, r), the physician's optimal decision rule is a cut-off strategy: $a(r) = 1$ if $r \geq r_{\text{phy}}(\text{law})$ and $a(r) = 0$ if $r < r_{\text{phy}}(\text{law})$. The cut-off, which is denoted by $r_{\text{phy}}(\text{law})$, is interior, depends on the tort law, and is determined by the following equation:

$$\triangle U\left(r_{\text{phy}}(\text{law})\right) - \lambda = \triangle L\left(r_{\text{phy}}(\text{law}) \mid \text{law}\right), \tag{1}$$

where $\triangle U(r) \equiv U(1, r) - U(0, r)$ and $\triangle L(r \mid \text{law}) \equiv L(1, r \mid \text{law}) - L(0, r \mid \text{law})$.

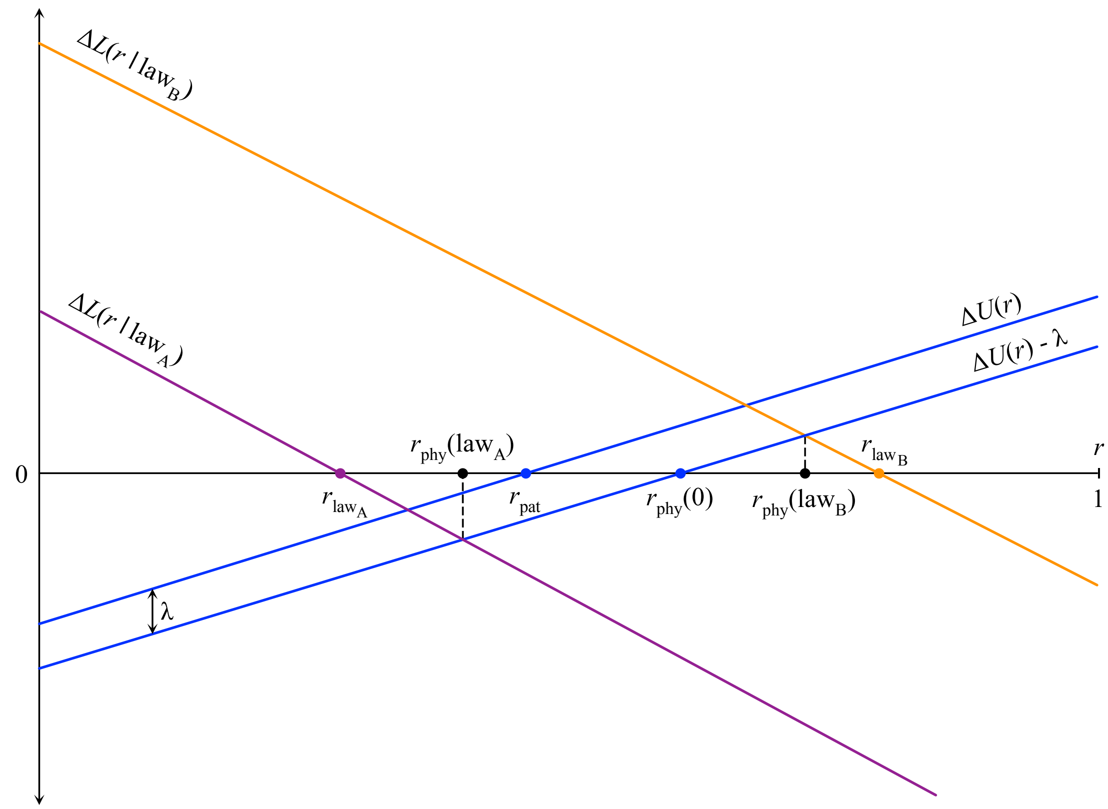
For the marginal patient, the incremental expected utility from receiving an antibiotic minus the cost the physician attributes to the risk of increased antibiotic resistance is equal to the increment in expected liability due to the antibiotic prescription. The physician's optimal choice is depicted in Figure 1, where $r_{\text{phy}}(0)$ is the cut-off the physician would choose in the absence of a liability system. The physician's cut-off as a function of the law is characterized as follows.

Proposition 1. $r_{\text{phy}}(\text{law})$ *is unique and satisfies* $\min\{r_{\text{phy}}(0), r_{\text{law}}\} \leq r_{\text{phy}}(\text{law}) \leq \max\{r_{\text{phy}}(0), r_{\text{law}}\}$, where the inequalities are strict if $r_{\text{phy}}(0) \neq r_{\text{law}}$.

Proof: Define $\triangle V(r \mid \text{law}) \equiv V(1, r \mid \text{law}) - V(0, r \mid \text{law})$ and note that $\triangle V(\cdot \mid \text{law})$ is strictly increasing and $r_{\text{phy}}(\text{law})$ solves $\triangle V(r \mid \text{law}) = 0$. This implies that $r_{\text{phy}}(\text{law})$ is unique. Suppose that $r_{\text{phy}}(0) < r_{\text{law}}$. Note that $\triangle V(r_{\text{phy}}(0) \mid \text{law}) = -\triangle L(r_{\text{phy}}(0) \mid \text{law}) < 0$ since $\triangle L(\cdot \mid \text{law})$ is strictly decreasing and $r_{\text{phy}}(0) < r_{\text{law}}$. Since $\triangle V(\cdot \mid \text{law})$ is strictly increasing, it must be that $r_{\text{phy}}(\text{law}) > r_{\text{phy}}(0)$. Moreover, we have that $\triangle V(r_{\text{law}} \mid \text{law}) = \triangle U(r_{\text{law}}) - \lambda > 0$ since $\triangle U(\cdot)$ is strictly increasing and $r_{\text{law}} > r_{\text{phy}}(0)$. It follows that $r_{\text{phy}}(0) < r_{\text{phy}}(\text{law}) < r_{\text{law}}$. The other two cases follow analogously. *Q.E.D.*

[8] In this regard, the model departs from Shurtz (2014) and other studies in the literature that assume a perfect liability system.

Figure 1: The physician's prescription decision



Notes: Figure depicts the physician's prescription decision for two different legal regimes. If the patient could decide for himself, he would choose to receive an antibiotic whenever $r \geq r_{\text{pat}}$. If there was no liability system, the physician would prescribe an antibiotic whenever $r \geq r_{\text{phy}}(0)$. Under the purple legal regime, law_{A}, the physician prescribes an antibiotic whenever $r \geq r_{\text{phy}}(\text{law}_{\text{A}})$. Under the orange legal regime, law_{B}, the physician prescribes an antibiotic whenever $r \geq r_{\text{phy}}(\text{law}_{\text{B}})$.

The physician's cut-off will generally differ from the patient's preferred cut-off because the physician balances her concern for the patient's utility against the legal implications of the prescription decision and the risk of increased antibiotic resistance. If the tort law introduces a bias against prescribing antibiotics relative to what is optimal for the patient, such as law_{B} in Figure 1, then the physician will prescribe fewer antibiotics than the patient desires. On the other hand, the physician may also prescribe more antibiotics than what is optimal for the patient. This happens when the tort law exhibits a sufficiently large bias towards prescribing antibiotics, such as law_{A} in Figure 1.

3.2 Tort Reforms and Antibiotic Prescriptions

Applying the implicit function theorem to equation (1) yields the effect of a marginal change in the tort law on the cut-off that the physician applies to prescribe an antibiotic:

$$\frac{dr_{\text{phy}}\,(\text{law})}{d\text{law}} = \frac{\triangle L_{\text{law}}\,(r_{\text{phy}}\,(\text{law}) \mid \text{law})}{\triangle U_r\,(r_{\text{phy}}\,(\text{law})) - \triangle L_r\,(r_{\text{phy}}\,(\text{law}) \mid \text{law})}. \tag{2}$$

The denominator is positive, so that the sign of the tort reform's effect on $r_{\text{phy}}(\text{law})$ is the same as the sign of the numerator in equation (2). In order to proceed, it is necessary to take a stance on the effect of tort reforms on the liability pressure that physicians experience. I make the following assumption in this regard.

Assumption 1. *Tort reforms have a proportional impact on the liability pressure that physicians experience:* $L_{\text{law}}(a, r \mid \text{law}) = \mu L(a, r \mid \text{law})$ *for all* a*,* r*, and* law.

In other words, tort reforms have a greater effect on the liability pressure resulting from high-risk patients and medication treatments than on the pressure resulting from low-risk patients and medication treatments. As such, tort reforms that increase the liability pressure on physicians ($\mu > 0$) disproportionately increase the liability pressure that physicians experience while treating high-risk patients and performing high-risk medication treatments. Tort reforms that satisfy Assumption 1 have the appealing feature that they do not change the cut-off r_{law}, which determines when, in expectation, it is preferred from a legal perspective to prescribe an antibiotic and when not. In practice, tort reforms are not enacted to increase or decrease the use of a specific medical procedure. Any theory that would predict a change in the cut-off r_{law} after a reform would therefore be hard to rationalize. Besides that, Assumption 1 is also compatible with several functional forms for the liability function that are commonly adopted in the medical malpractice literature.[9]

[9]One example that satisfies Assumption 1 is the liability function proposed by Shurtz (2014), according to which the tort law affects only the cost to the physician that results from a malpractice claim and not the patient's propensity to sue the physician.

We are now in a position to characterize the effect of tort reforms on antibiotic prescriptions.

Proposition 2. *Suppose that Assumption 1 holds. A liability-reducing tort reform, such as a cap on noneconomic damages, causes physicians to prescribe fewer (more) antibiotics if and only if* $r_{\text{law}} < (>) \ r_{\text{phy}}(0)$.

Proof: Assumption 1 implies that $\triangle L_{\text{law}}(r \mid \text{law}) = \mu \triangle L(r \mid \text{law})$ for all r and law. Substituting into equation (2), we obtain sign$\{dr_{\text{phy}}(\text{law})/d\text{law}\}$ = sign$\{\mu \triangle L(r_{\text{phy}}(\text{law}) \mid \text{law})\}$, which boils down to sign$\{dr_{\text{phy}}(\text{law})/d\text{law}\}$ = sign$\{-\triangle L(r_{\text{phy}}(\text{law}) \mid \text{law})\}$ in the case of a liability-reducing tort reform. Proposition 1 shows that $r_{\text{phy}}(\text{law}) > (<) \ r_{\text{law}}$ if and only if $r_{\text{law}} < (>) \ r_{\text{phy}}(0)$. Recalling that $\triangle L(\cdot \mid \text{law})$ is strictly decreasing and $\triangle L(r_{\text{law}} \mid \text{law}) = 0$, it follows that $dr_{\text{phy}}(\text{law})/d\text{law} > (<) \ 0$ in the case of a liability-reducing tort reform if and only if $r_{\text{law}} < (>) \ r_{\text{phy}}(0)$. *Q.E.D.*

Figure 2 illustrates Proposition 2. We see that a tort reform that puts less liability pressure on physicians can increase or decrease the number of antibiotic prescriptions. The effect of the reform depends on whether the liability system introduces a bias towards or against prescribing antibiotics relative to what the physician would choose in the absence of a liability system. If the liability system introduces a bias towards prescribing more antibiotics, such as law_{A}, then a reduction in liability pressure will lead physicians to prescribe fewer antibiotics. Conversely, if the liability system introduces a bias against prescribing antibiotics, such as law_{B}, then a reduction in liability pressure implies more antibiotic prescriptions.

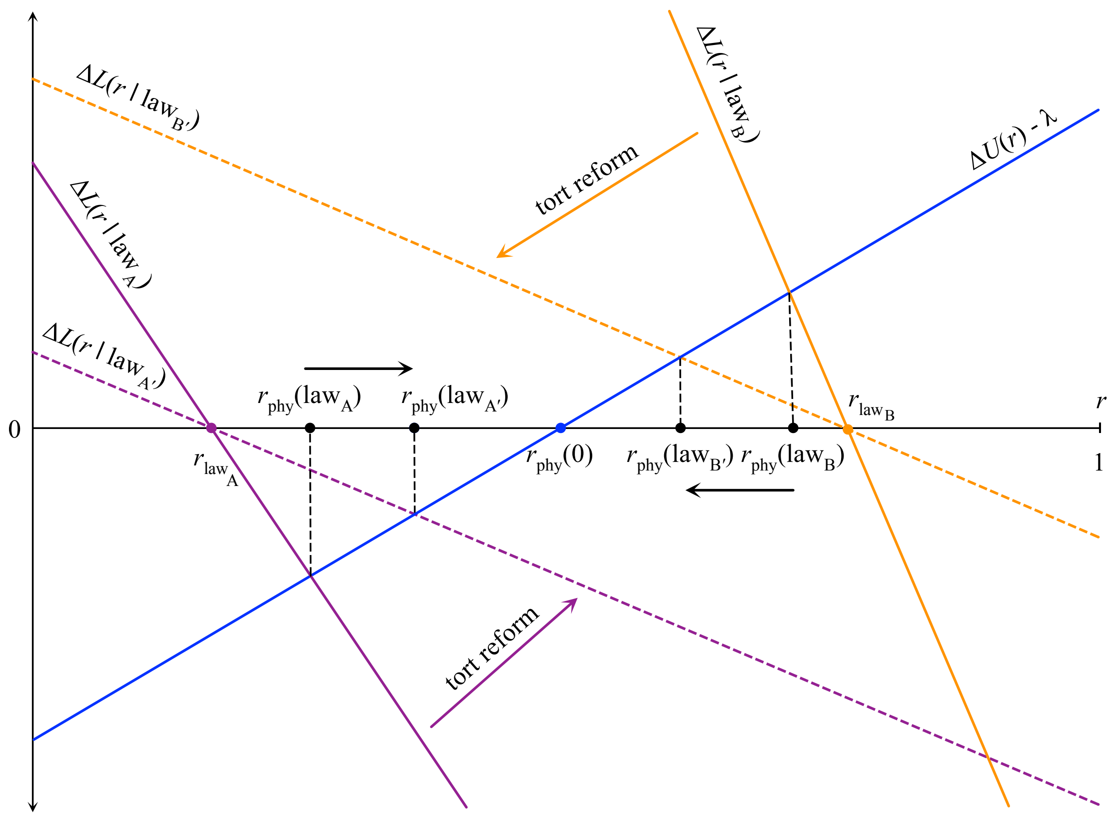
3.3 The Social Optimum and Defensive Medicine

The social planner trades off the patient's benefit against the social cost of increased antibiotic resistance. He chooses a to maximize $W(a, r) = U(a, r) - \lambda^* a$, where the social cost of increased antibiotic resistance, λ^*, is potentially different from the cost that the physician takes into account, λ. Not surprisingly, the social optimum is also characterized by a cut-off, which is denoted by r^*, so that it is socially optimal to prescribe an antibiotic if and only if $r \geq r^*$. Given that λ^* is sufficiently small, this cut-off is interior and uniquely determined by

$$\triangle U\left(r^*\right) - \lambda^* = 0. \tag{3}$$

Defensive medicine is defined with respect to the socially optimal level of care: medical care for which the expected social cost exceeds the expected social benefit is considered defensive if it is delivered to avoid potential litigation. In our setup, the expected social cost of an antibiotic exceeds its expected social benefit whenever $r < r^*$. Now if $r_{\text{phy}}(\text{law}) < r^*$, then the physician will prescribe some socially wasteful antibiotics. However, only in the case in

Figure 2: The effect of a liability-reducing tort reform on prescriptions



Notes: Figure depicts the effect of a liability-reducing tort reform on antibiotic prescriptions for two different legal regimes, law_{A} and law_{B}, where the former is more in favor of antibiotics than the latter. Tort reforms that satisfy Assumption 1 correspond to a rotation of the function $\triangle L(\cdot \mid \text{law})$ around the cut-off r_{law}. Under the purple legal regime, law_{A}, a reduction in liability pressure leads to a decrease in antibiotic prescriptions given that $r_{\text{law}_{\text{A}}} < r_{\text{phy}}(0)$. As $r_{\text{law}_{\text{B}}} > r_{\text{phy}}(0)$, a reduction in liability pressure causes an increase in antibiotic prescriptions under the orange legal regime, law_{B}.

which $r_{\text{phy}}(\text{law}) < r_{\text{phy}}(0)$ does the physician prescribe antibiotics to protect herself against the risk of malpractice, for if $r_{\text{phy}}(\text{law}) > r_{\text{phy}}(0)$ then the tort law actually induces the physician to prescribe fewer antibiotics. Therefore, we can say that the physician prescribes antibiotics defensively if and only if $r_{\text{phy}}(\text{law}) < r_{\text{phy}}(0)$ and $r_{\text{phy}}(\text{law}) < r^*$.

How do we know whether these two inequalities are satisfied in practice? From Propositions 1 and 2, we can deduce that the first inequality holds if a liability-reducing tort reform leads physicians to prescribe fewer antibiotics. But without further assumptions, the model is silent about the second inequality. In order to arrive at a test of defensive medicine, I introduce the following assumption.

Assumption 2. *The physician internalizes weakly less of the risk of increased antibiotic resistance than the social planner:* $\lambda \leq \lambda^*$.

In surveys, physicians report that they believe that their prescribing behavior does not significantly affect antibiotic resistance (Kumar *et al.* 2003), that antibiotic resistance carries the least weight in their prescription decision (Metlay *et al.* 2002), and that antibiotic resistance is a community issue and less important than the well being of the individual patient (Butler *et al.* 1998). In light of these self-reports, it seems reasonable to assume that physicians do not fully internalize the cost of increased antibiotic resistance.

Assumption 2 implies that physicians tend to prescribe more antibiotics than socially optimal if there is no liability system in place: $r_{\text{phy}}(0) \leq r^*$.[10] Given this, we know that $r_{\text{phy}}(\text{law}) < r_{\text{phy}}(0)$ is a necessary and sufficient conditions for the two inequalities that determine whether antibiotics are prescribed defensively to be satisfied. The following corollary, which represents the central result of the theoretical analysis, summarizes how we can use tort reforms to test for defensive medicine.

Corollary 1. *Suppose that Assumptions 1 and 2 hold. Antibiotics are prescribed defensively if and only if a liability-reducing tort reform, such as a cap on noneconomic damages, causes a decrease in antibiotic prescriptions.*

In the empirical analysis, I will exploit noneconomic damages cap reforms to obtain causal estimates of the effect of a reduction in liability pressure on antibiotic prescriptions and use these estimates to test for defensive medicine along the lines of Corollary 1. I will complement

[10] Apart from not internalizing the risk of increased antibiotic resistance, there may be other reasons why physicians prescribe more antibiotics than socially optimal. Physicians tend not to internalize the part of the drug cost that health insurance companies have to bear (Lundin 2000, Iizuka 2007). Physicians may also hope to attract new patients or retain current ones by prescribing antibiotics (Bennett *et al.* 2015). Finally, physicians may also prescribe antibiotics because they are receptive to marketing efforts by pharmaceutical companies. On the other hand, there seems to be only one factor that explains why physicians would prescribe fewer antibiotics than socially optimal, which is that they do not consider the positive effect that curing one patient's bacterial infection has on the patient's social network. It seems unlikely that this factor alone could tilt the balance towards physicians prescribing fewer antibiotics than socially optimal in the absence of a liability system.

this approach with a traditional test of defensive medicine à la Kessler and McClellan (1996), in which I contrast changes in antibiotic prescriptions after noneconomic damages cap reforms with corresponding changes in health outcomes that can potentially be improved by antibiotic use.

4 Data and Summary Statistics

4.1 National Ambulatory Medical Care Survey

The National Ambulatory Medical Care Survey is a nationally representative survey of visits to non-federal employed office-based physicians in the U.S., excluding anesthesiologists, pathologists, and radiologists. The National Center for Health Statistics (NCHS), which conducts the survey, employs a three-stage sampling procedure. Each of the about 1,200 physicians who participate annually in the survey is randomly assigned to a one-week reporting period, during which data is collected for a systematic random sample of about 25 patients. Physicians and patients may be sampled in multiple years, but it is not possible to identify longitudinal linkages.

For each visit, the data contains the patient's symptoms, the physician's diagnosis according to the ICD-9-CM, and treatments and medications ordered or provided. Antibiotic prescriptions can be identified using the NCHS-assigned five-digit medication codes in conjunction with the NCHS Ambulatory Care Drug Database System (see Appendix A for more details). Geographic information in the public-use NAMCS data files is limited and restricted to identifiers indicating census region and MSA status. I obtained access to restricted-use NAMCS data at the NCHS Research Data Center, through which it was possible to identify the county and state in which physician practices are located. This information was used to assign the corresponding state tort laws to physicians.

The left panel of Table 1 contains descriptive statistics for the key variables from the NAMCS. The data corresponds to the survey years from 1993 to 2011 and includes a total of 546,990 patient visits. On average, physicians prescribe about two drugs per ambulatory care visit. Antibiotics, which are coded as a dummy variable, are prescribed in about one in eight visits. When physicians prescribe antibiotics, they mostly prescribe broad-spectrum antibiotics, which act against a wider range of bacteria but also imply a higher risk of increased antibiotic resistance than narrow-spectrum antibiotics.

4.2 Nationwide Inpatient Sample

The Nationwide Inpatient Sample is part of the Healthcare Cost and Utilization Project (HCUP), which is sponsored by the Agency for Healthcare Research and Quality. Covering about seven

Table 1: Descriptive statistics of key variables

	NAMCS			NIS		
	Mean	SE	N	Mean	SE	N
Prescription outcomes						
Antibiotic (ABT)	0.1271	(0.0015)	543,125			
Broad-spectrum ABT	0.0902	(0.0012)	543,018			
Narrow-spectrum ABT	0.0367	(0.0006)	543,018			
Number of drugs	1.8583	(0.0224)	543,125			
Health outcomes						
Peritonsillar abscess				0.0004	(0.0000)	141,417,785
Rheumatic fever				0.0000	(0.0000)	141,417,785
Mastoiditis				0.0001	(0.0000)	141,417,785
Septicemia				0.0134	(0.0002)	141,417,785
Pneumonia				0.0315	(0.0002)	141,417,785
Patient						
Female	0.5908	(0.0016)	546,990	0.5869	(0.0009)	141,278,661
Age	44.1265	(0.1849)	546,990	47.2901	(0.1785)	141,392,820
White	0.7546	(0.0095)	513,882	0.6887	(0.0056)	110,044,140
Black	0.0947	(0.0037)	513,882	0.1421	(0.0038)	110,044,140
Latino	0.1085	(0.0081)	513,882	0.1137	(0.0040)	110,044,140
Insurance						
Private	0.5612	(0.0056)	529,019	0.3621	(0.0032)	141,052,576
Medicare	0.2219	(0.0033)	529,019	0.3664	(0.0026)	141,052,576
Medicaid	0.1119	(0.0037)	529,019	0.1855	(0.0027)	141,052,576

Notes: Standard errors accounting for complex survey design in parentheses.

million hospital stays each year, the NIS constitutes the largest publicly available all-payer inpatient healthcare database in the U.S. The data is collected annually from about 1,000 hospitals, which are sampled to approximate a 20-percent stratified sample of U.S. community hospitals, where each hospital reports on all discharges that occur throughout the year. The NIS records include ICD-9-CM codes for the diagnoses and procedures that patients receive, as well as patient and hospital characteristics. Until 2011, the NIS data also includes identifiers for the county and state in which hospitals are located, which were used to assign hospitals the corresponding state tort laws. Not all states participate in the HCUP, but the number of states that do has grown over time (from 8 in 1988 to 17 in 1993 to 46 in 2011).

The right panel of Table 1 contains descriptive statistics for the key variables from the NIS. The data corresponds to the survey years from 1993 to 2011 and includes a total of 142,002,152 inpatient stays. The five health outcomes that are listed in the table represent complications that can potentially be prevented by antibiotic use in primary care. Each complication is captured by a dummy variable that equals one if the primary diagnosis corresponds to the complication.[11] Some of these complications, such as rheumatic fever, represent only a tiny fraction of all inpatient stays. Septicemia and pneumonia, however, together account for almost five percent of all inpatient stays during the sample period. In contrast to the NAMCS data, there is a lower share of privately insured individuals in the NIS data, which could be due to differences in inpatient and outpatient use by insurance status or due to different coding practices by the two surveys. Patient demographics are similar between the NAMCS and NIS data.

4.3 State Tort Laws

I collected information about the state tort laws from various sources and merged it onto the NAMCS and NIS data. I built on Ronen Avraham's Database of State Tort Law Reforms (Avraham 2014) and the state law data provided in an appendix to Currie and MacLeod (2008) and supplemented these two sources with information from the American Tort Reform Association and the state codes. The final product is a dataset covering the four reforms discussed earlier – caps on noneconomic damages, caps on punitive damages, modifications of the collateral-source rule, and modifications of the joint-and-several liability rule – and the years from 1992 to 2012 on a monthly basis, where the years 1992 and 2012 are covered to allow for the inclusion of reform lags and leads of up to one year. Following Frakes (2012), I classify states as having an active noneconomic damages cap if they cap the amount of total damages that can be awarded.[12]

[11]The corresponding ICD-9-CM codes are 475 for peritonsillar abscess, 390-392 for rheumatic fever, 383 for mastoiditis, 038 for septicemia, and 481-486 for pneumonia (bacterial or unspecified).

[12]This rule applies to four states (Indiana, Nebraska, South Dakota, and Virginia), all of which enact the total damages cap before the beginning of the sample period and do not experience a change in the noneconomic

Table 2: Noneconomic damages cap reforms, 1993-2011

Cap enacted			Cap abolished		
IL	03/09/1995	$500,000+	IL	12/18/1997	$500,000+
ND	08/01/1995	$500,000*	OH	02/25/1998	$1,000,000
MT	10/01/1995	$250,000*	OR	07/15/1999	$500,000
OH	01/27/1997	$1,000,000	WI	07/14/2005	$350,000*+
NV	10/01/2002	$350,000*	IL	02/04/2010	$500,000*
MS	01/01/2003	$500,000*	GA	03/22/2010	$350,000*
OK	07/01/2003	$300,000*			
TX	09/01/2003	$250,000*			
GA	02/16/2005	$350,000*			
SC	07/01/2005	$350,000*			
IL	08/24/2005	$500,000*			
WI	04/06/2006	$750,000*			
NC	10/01/2011	$500,000*			
TN	10/01/2011	$1,000,000			

Notes: * indicates that the cap applies only to medical malpractice rather than to all torts. + indicates that the cap is adjusted for inflation on a regular basis.

Recall that the literature on the effect of tort reforms on the medical malpractice environment says that caps on noneconomic damages are the only policy that have a clear-cut impact on liability pressure. For this reason, I focus on noneconomic damages caps to identify the effect of liability pressure on prescription and health outcomes. Table 2 lists the 20 noneconomic damage cap reforms that have taken place over the sample period. In total, 14 different states enacted tort reforms between 1993 and 2011.

5 Empirical Strategy

The empirical strategy is based on the assumption that states that adopt noneconomic damages caps would, if they had not adopted a cap, experience the same trends in prescription and health outcomes as states that do not adopt noneconomic damages caps. This assumption leads to the following difference-in-differences specification, which can be consistently estimated by ordinary least squares (OLS),

$$Y_{ist} = \alpha + \beta \text{CAP}_{st} + \gamma X_{ist} + \delta Z_{st} + \theta_t + \phi_s + \varepsilon_{ist}. \tag{4}$$

The subscripts i, s, and t stand for, respectively, a visit, a state, and a year-month combination. Y_{ist} represents a prescription or health outcome. CAP_{st} indicates whether state s imposes a cap

damages cap indicator during the sample period.

on noneconomic damages in period t. X_{ist} is a vector of controls and includes dummies for patient age (<5, 5-17, 18-44, 45-64, 65-79, 80+), patient gender, patient race and ethnicity (white, black, latino, other), patient health insurance (private, Medicare, Medicaid, other), physician degree (MD, DO), physician specialty (14 categories), physician age (<35, 35-54, 55+), physician gender, and practice/hospital location (MSA, non-MSA).[13] Z_{st} controls for the presence of caps on punitive damages, modifications of the collateral-source rule, and modifications of the joint-and-several liability rule. θ_t and ϕ_s are year-month and state dummies, respectively, and ε_{ist} is the error term. Throughout the analysis, I use sampling weights to make the resulting estimates nationally representative. As is customary in the estimation of difference-in-differences models with policies that vary at the state level, I report standard errors that are clustered at the state level (Bertrand *et al.* 2004).

I focus on four different prescription outcomes: whether or not the physician prescribes an antibiotic; whether or not the physician prescribes a broad-spectrum antibiotic; whether or not the physician prescribes a narrow-spectrum antibiotic; and the total number of medications that the physician prescribes, which is topcoded (at 5 in 1993/1994, at 6 from 1995 to 2002, and at 8 from 2003 onwards). Following Little *et al.* (2002) and other studies in the medical literature, I concentrate on the following five health conditions, which can potentially be avoided through antibiotic use in primary care: peritonsillar abscess (quinsy), rheumatic fever, mastoiditis, septicemia, and pneumonia. If noneconomic damages caps influence the physicians' prescribing behavior but do not affect any of the related health outcomes, this would be evidence of defensive medicine.

To study which doctors and patients are particularly affected by noneconomic damages caps, I estimate models that include interaction terms between the cap indicator and variables such as the patient's type of health insurance and the physician's association to an HMO, which have previously been identified as sources of heterogeneity in the malpractice literature. I also perform several tests to support the notion that noneconomic damages cap reforms are exogenous and not driven by preexisting trends in the outcome variables. Finally, I conduct a variety of specification checks, which include the estimation of nonlinear models and models including county fixed effects.

6 Results

6.1 Prescription Outcomes

Table 3 shows how noneconomic damages caps affect the four prescription outcomes under study. We can see that the introduction of a noneconomic damages cap implies that doc-

[13]The controls for physician characteristics are included only in prescription outcome regressions as this kind of information is not available in the NIS data.

Table 3: Impact of noneconomic damages caps on prescriptions

Dep. variable:	Antibiotic (ABT)	Broad-spectrum ABT	Narrow-spectrum ABT	Number of drugs
CAP	-0.80***	-0.43	-0.39***	-0.04
	(0.26)	(0.27)	(0.14)	(6.23)
R^2	0.07	0.06	0.02	0.23
N	479,009	478,914	478,914	479,009

Notes: Table reports results from OLS estimation of equation (4). The coefficients on the cap on noneconomic damages and the corresponding standard errors, which are shown in parentheses, are multiplied by 100. Standard errors are adjusted for clustering at the state level. * p<0.1, ** p<0.05, *** p<0.01.

tors are 0.8 percentage points less likely to prescribe an antibiotic, which translates into a reduction of 6.3 percent over baseline. This effect is statistically and economically significant. Using the NAMCS survey weights to extrapolate the effect to the U.S. population as a whole, I estimate that, in the year 2011 alone, there would have been about 3.2 million fewer ambulatory care visits that culminate in the prescription of antibiotics if all states had adopted a cap on noneconomic damages (29 states had an active cap at the end of 2011). To put this number into perspective, in total, doctors prescribe antibiotics in about 120 million ambulatory care visits per year. Hence, through the introduction of noneconomic damages caps, one could achieve a reduction of ambulatory care visits with antibiotic prescriptions of almost 3 percent.

Comparing the second and third column of Table 3, we see that narrow-spectrum antibiotics are statistically significantly affected by the introduction of noneconomic damages caps, whereas broad-spectrum antibiotics are not affected. It appears that physicians mostly prescribe narrow-spectrum antibiotics to protect themselves against liability pressure, which goes against the notion that broad-spectrum antibiotics offer more protection against legal proceedings. A possible explanation for why physicians resort to narrow-spectrum antibiotics under liability pressure is that these are generally cheaper than broad-spectrum antibiotics. If physicians are under the impression that they have to prescribe an antibiotic although the antibiotic is not medically justified, and if physicians take into account the patient's out-of-pocket spending or the cost to the health insurer, then prescribing narrow-spectrum antibiotics could be a second-best solution.

The last column of Table 3 illustrates that caps on noneconomic damages do not affect the total number of drugs that are being prescribed. Apparently, physicians substitute antibiotics for other drugs. Among the drugs that are most frequently prescribed together with antibiotics or for conditions for which antibiotics are commonly prescribed are antihistamines and anti-inflammatories. It could be that physicians prescribe less of these drugs and more antibiotics

Table 4: Heterogeneous impact of noneconomic damages caps on antibiotic prescriptions

Patient age		Patient race		Health insurance		HMO	
CAP	-1.37***	CAP	-0.67**	CAP	-0.81***	CAP	-0.90**
	(0.31)		(0.26)		(0.29)		(0.34)
CAP × 0-4	-0.08	CAP × white	0.00	CAP × private	0.00	CAP × HMO	-1.21
	(1.39)		—		—		(1.09)
CAP × 5-17	1.08	CAP × black	-0.83	CAP × Medicare	0.75		
	(0.87)		(0.59)		(0.50)		
CAP × 18-44	0.00	CAP × latino	-0.53	CAP × Medicaid	0.19		
	—		(0.85)		(0.70)		
CAP × 45-64	0.46	CAP × other	1.38**	CAP × other	-1.25***		
	(0.33)		(0.64)		(0.39)		
CAP × 65-79	0.94**						
	(0.41)						
CAP × 80+	2.33***						
	(0.65)						
F-test (p-value)	0.02		0.09		0.00		0.27
R^2	0.07		0.07		0.07		0.06
N	479,009		479,009		479,009		356,947

Notes: Table reports results from OLS estimation of equation (4) augmented for interaction terms. F-tests are for the joint significance of the interaction terms. Coefficients and standard errors (in parentheses) are multiplied by 100. Standard errors are adjusted for clustering at the state level. * p<0.1, ** p<0.05, *** p<0.01.

if they face higher liability pressure.

Table 4 shows that noneconomic damages caps do not affect all patients and physicians equally. Older patients, for example, are not less likely to be prescribed an antibiotic after the introduction of a noneconomic damages cap, which can be explained by the fact that older patients pose less of a malpractice risk to physicians because of lower future earnings losses and fewer years of pain and suffering. When it comes to the patient's race, there is no statistical evidence for a different reaction to the cap based on whether the patient is black or white, although prior research has highlighted that blacks are perceived as high-risk patients by physicians (Dubay *et al.* 2001). The third panel of Table 4 shows that physicians react more strongly to the cap when the patient's health insurance belongs to the category "other", which includes self-pay, worker's compensation, and no charge. Contrary to earlier findings (Dubay *et al.* 1999), there is no statistically significant difference in the reform effect between Medicaid and privately insured individuals. The last panel of Table 4 shows that physicians who work in HMO-owned practices do not react differently to noneconomic damages caps

Table 5: Impact of noneconomic damages caps on health outcomes

Dep. variable:	Peritonsillar abscess	Rheumatic fever	Mastoiditis	Septicemia	Pneumonia
CAP	0.00	-0.00	0.00**	0.05	0.11
	(0.00)	(0.00)	(0.00)	(0.07)	(0.11)
R^2	0.00	0.00	0.00	0.01	0.02
N	98,275,213	98,275,213	98,275,213	98,275,213	98,275,213

Notes: Table reports results from OLS estimation of equation (4). The coefficients on the cap on noneconomic damages and the corresponding standard errors, which are shown in parentheses, are multiplied by 100. Standard errors are adjusted for clustering at the state level. * p<0.1, ** p<0.05, *** p<0.01.

than their peers who work in practices that are not owned by HMOs, at least not in statistical terms. However, this finding should not be viewed as conclusive evidence given that there are only few observations of physicians practicing in HMOs and given that the variable that indicates whether a practice is owned by an HMO is not available in all survey years.

The evidence presented so far suggests that physicians prescribe more antibiotics in response to liability pressure. What we do not know is whether these antibiotics are socially justified or wasteful. If the assumptions of the theoretical model hold, then we should believe that the latter is true: the model predicts that antibiotics are prescribed defensively if a liability-reducing tort reform causes a decrease in antibiotic prescriptions, which is what we observe in the NAMCS data. To provide further evidence on this matter, we will now turn to a test of defensive medicine à la Kessler and McClellan (1996), for which we contrast the changes in antibiotic prescriptions with changes in health conditions that can potentially be prevented by the timely use of antibiotics.

6.2 Health Outcomes

Table 5 suggests that noneconomic damages caps are not causing a change in hospital discharges for peritonsillar abscess, rheumatic fever, septicemia, and pneumonia. Given the large number of observations, the effects are fairly precisely estimated zeros. Only for mastoiditis do we observe a statistically significant increase in hospital discharges after the introduction of a noneconomic damages cap. While the effect size is small in absolute terms (0.0013 percentage points), it represents a 26-percent increase over the baseline estimate of 35,107 hospital discharges for mastoiditis that occur in the U.S. in the period from 1993 to 2011.

These findings support the notion that some antibiotics are used for defensive reasons and have little or no health benefits. Even though there is a statistically significant increase in the number of discharges with the primary diagnosis mastoiditis, the cost of these additional discharges is likely to be inferior to the cost savings through a reduction in antibiotic prescriptions. In 2011, there are an estimated 2,067 hospitalizations with the primary diagnosis mastoiditis and 119,452,115 ambulatory care visits in which doctors prescribe antibiotics. The difference-in-differences estimates predict that the former increase by 26% after the introduction of a cap and the latter by 6.3%. Hence, the cost of one mastoiditis hospitalization, which amounts to about $25,000 in 2011 according to the NIS data, should be greater than the cost of approximately 14,000 antibiotic prescriptions in ambulatory care in order for us to conclude that the liability-induced antibiotics are not socially wasteful. That is, an antibiotic prescription should cost less than $1.79. Considering the direct cost of antibiotics, the risk of adverse drug events, and the cost of increased antibiotic resistance, this is unlikely to be true.

In sum, the health outcome results confirm the prediction of the theoretical model that liability-induced antibiotics are socially wasteful if the amount of antibiotic prescriptions decreases after the introduction of noneconomic damages caps. This alignment between the theory and the empirical findings is reassuring given that the model is based on two main assumptions, which appear reasonable but are hard to verify.

6.3 Threads to Validity

This section assesses the validity of the empirical results. I discuss five potential threats to validity: legislative endogeneity, changes in the composition of the treatment and control group, model misspecification, the use of weights and imputed values, and bad controls.

The main identifying assumption behind every difference-in-differences setup is that the treatment and control group would experience parallel trends if both were left untreated. Legislative endogeneity – the possibility that preexisting trends in medical care cause tort reforms – poses a threat to the parallel trends assumption. Table 7 in Appendix B presents four pieces of evidence suggesting that noneconomic damages caps are not subject to legislative endogeneity. First, preprogram regressions (Heckman and Hotz 1989) show that leads of noneconomic damages caps are not statistically significantly affecting prescription and health outcomes.[14] Second, when noneconomic damages caps are turned off, which arguably resembles a truly exogenous change in liability pressure given that caps are turned off almost exclusively because they are ruled unconstitutional, there is also a statistically significant effect on antibiotic prescriptions (positive in this case because liability pressure increases). Third, when we focus on noneconomic damages caps that are not specific to medical malpractice, of which there are few, then there is still a negative effect of noneconomic damages caps on antibiotic prescriptions (albeit it is no longer statistically significant due to a considerable loss

[14]The corresponding column in Table 7 contains the coefficient on the lead indicator. The coefficient estimates on the cap on noneconomic damages are qualitatively not affected by the inclusion of the lead indicator.

of precision). Fourth, the inclusion of state-specific time trends does not qualitatively affect how noneconomic damages caps influence antibiotic prescriptions.

A second identifying assumption behind every difference-in-differences setup is that the composition of the treatment and control group does not change as a result of the treatment. With regard to tort reforms, one concern could be that physicians move across states in response to liability reforms. But, the literature on tort reforms and physician labor supply largely refutes this concern. For the period from 1992 to 2011, Paik *et al.* (2016) find no evidence that noneconomic damages caps affect the supply of patient care physicians, the supply of physicians working in high-risk specialties, or the supply of physicians practicing in rural areas. Using the same data as Paik *et al.* (2016), I obtain equivalent results (available upon request) for the sample period of this paper.

Most of the outcomes in the preceding two sections are dummy variables, indicating either the prescription of a given medication or the diagnosis of a given disease. Based on this, one may argue that it is more appropriate to fit nonlinear models, such as Probit or Logit, instead of relying on a linear regression model. The choice of the linear probability model is motivated by computational concerns, which are fueled by the combination of a large number of observations and dependent variables, particularly in the case of the Nationwide Inpatient Sample. Notwithstanding these computational challenges, I have estimated the baseline antibiotic and health outcome regressions using Probit. The results, which are displayed in Table 8 in Appendix B, mirror those of the linear probability model.

Throughout the analysis, I use the sampling weights that are provided with the NAMCS and NIS data. Table 8 in Appendix B shows that the use of weights does not drive the results, in the sense that the weighted and unweighted results are qualitatively and quantitatively similar. Table 8 also shows that excluding observations for which one or more of the covariates are imputed in the NAMCS data does not affect the results either.

A final issue concerns the choice of covariates in equation (4). In principle, no covariates are needed for the difference-in-differences strategy to be viable. But, including covariates can help to increase the predictive power of the regression model, resulting in lower standard errors of the estimates. A drawback arises when one or more of the covariates are themselves outcomes of the treatment (see, for example, Angrist and Pischke 2008). To mitigate potential concerns about bad controls, I have estimated the baseline antibiotic and health outcome regressions with different sets of controls (see Table 8 in Appendix B) and included the covariates one by one as dependent variables in placebo tests (see Table 9 in Appendix B). Qualitatively, none of the results are affected by changes in the set of controls. However, not controlling for visit-level controls such as the patient's age and race leads to a large drop in the R-squared of the regression model, resulting in insignificant coefficients on the cap on noneconomic damages in the antibiotics regressions.[15] In sum, the results from the models

[15] Restricting the sample to patients who visit the physician with symptoms related to respiratory conditions,

with different sets of controls suggest that bad controls are not an issue, and the placebo tests tell a similar story.

7 Conclusion

By holding healthcare professionals accountable, the medical malpractice system is supposed to improve patient outcomes and deter healthcare providers from providing too little care. An unintended consequence of the malpractice system is that it can induce healthcare professionals to provide too much care, a phenomenon known as defensive medicine.

This paper shows that antibiotics are used as defensive medicine. Noneconomic damages cap reforms affect the likelihood with which doctors prescribe antibiotics but do not affect hospital stays for conditions that can be prevented through the timely use of antibiotics, with the possible exception of mastoiditis. A theoretical model complements the empirical analysis and predicts likewise that antibiotics are used defensively. Considering the large burden of antibiotic resistance, policymakers may contemplate adopting liability-reducing tort reforms to decrease the inappropriate use of antibiotics. The results from this paper suggest that if all states adopted a cap on noneconomic damages, this would reduce the number of ambulatory care visits that result in the patient receiving a prescription for antibiotics by approximately 3.2 million.

which arguably account for the largest fraction of discretionary antibiotic prescribing, restores significance of the coefficient on the cap on noneconomic damages even without including any controls.

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Table 6: Classification of antibiotics based on spectrum of activity

Spectrum	Antibiotics
Narrow	1st- and 2nd-generation cephalosporins, aztreonames, colistines, daptomycin, linezolides, metronidazoles, novobiocins, polymyxin, narrow-spectrum penicillins, tetracyclines, sulfonamides, glycopeptides
Broad	carbapenems, 3rd- and 4th-generation cephalosporins, macrolides, bacitracin, chloramphenicol, rifaximin, furazolidone, aminoglycosides, pentamidines, methenamines, fosfomycins, nitrofurantoins, quinolones, broad-spectrum penicillins, glycylcyclines

A Identification and Classification of Antibiotics

The NAMCS questionnaire asks physicians to record information on up to eight drugs (five drugs in 1993 and 1994, six drugs from 1995 to 2002). The recorded verbatim responses are assigned a unique five-digit code according to a classification scheme developed by the NCHS. Using the NCHS Ambulatory Care Drug Database System,[16] which is based on the Lexicon Plus classification of drugs by Cerner Multum Inc., I have identified the following subcategories of anti-infective drugs as antibiotics: carbapenems, cephalosporins, macrolide derivatives, penicillins, quinolones, sulfonamides, tetracyclines, urinary anti-infectives, aminoglycosides, lincomycin derivatives, glycylcyclines, glycopeptide antibiotics, and miscellaneous antibiotics. Following the medical literature, in particular Shapiro *et al.* (2014), I have classified antibiotics into broad- and narrow-spectrum antibiotics as shown in Table 6. For a small number of cases (117 out of 546,990 of visits), it was not possible to assign a spectrum of activity to the antibiotic that was prescribed during the visit. The following NCHS drug entry codes could not be classified: empiric antibiotics, SBE prophylaxis, antimicrobial, endomycin, sulfametin, bacteriostatic, IV antibiotics, antifungal agent, antiinfective agent, antitubercular agent, tuberculin medication, ringworm medicine, antibacterial agent.

B Robustness Checks

This section contains the tables corresponding to section 6.3, which assesses potential threads to the validity of the empirical design. Table 7 assesses the likelihood of legislative endogeneity. Table 8 tests for model misspecification and bad controls. Table 9 further analyzes the issue of bad controls.

[16]http://www.cdc.gov/nchs/ahcd/ahcd_database.htm (last accessed June 3, 2016).

Table 7: Tests for legislative endogeneity

	Six-month lead of CAP	Only caps turning off	Only caps nonspecific to medical malpractice	State-specific time trends
Antibiotic	0.91	0.72***	-0.40	-0.58
	(1.28)	(0.22)	(0.74)	(0.51)
Peritonsillar abscess	-0.00	-0.00**	-0.02***	0.00
	(0.00)	(0.00)	(0.00)	(0.00)
Rheumatic fever	0.00	0.00	0.00	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)
Mastoiditis	0.00	-0.00***	-0.01***	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)
Septicemia	-0.01	-0.06	0.10	0.15***
	(0.07)	(0.06)	(0.13)	(0.05)
Pneumonia	-0.14	-0.17**	0.01	0.17**
	(0.09)	(0.08)	(0.31)	(0.06)

Notes: Table reports results from OLS estimation of equation (4), where each cell reports the results from a separate regression. Rows indicate the dependent variable. Column 1 reports the coefficient on a dummy that equals one in the six months before a noneconomic damages cap turns on. Column 2 reports the coefficient on a dummy that equals one as long as a noneconomic damages cap has been turned off. Column 3 reports the coefficient on the noneconomic damages cap indicator, where caps that are specific to medical malpractice do not affect the indicator. Column 4 reports the coefficient on the noneconomic damages cap indicator from a model that includes state-specific time trends. Standard errors adjusted for clustering at the state level in parentheses. All coefficients and standard errors are multiplied by 100. * $p<0.1$, ** $p<0.05$, *** $p<0.01$.

Table 8: Sensitivity Analysis

	Probit	OLS without weights	OLS excluding imputed	OLS no controls	OLS only visit-level controls	OLS only state-level controls	OLS county fixed effects
Antibiotic	-3.90***	-0.58*	-0.80**	-0.16	-0.75**	-0.43	-0.75***
	(1.38)	(0.29)	(0.31)	(0.32)	(0.30)	(0.32)	(0.27)
Perit. abscess	2.58	0.00	—	0.00	0.00	0.00*	-0.00*
	(2.18)	(0.00)		(0.00)	(0.00)	(0.00)	(0.00)
Rheum. fever	-2.54	-0.00	—	0.00	-0.00	0.00	0.00
	(2.64)	(0.00)		(0.00)	(0.00)	(0.00)	(0.00)
Mastoiditis	5.18**	0.00**	—	0.00***	0.00**	0.00***	0.00
	(2.60)	(0.00)		(0.00)	(0.00)	(0.00)	(0.00)
Septicemia	3.12	0.09	—	-0.01	0.05	0.02	0.27**
	(2.27)	(0.07)		(0.06)	(0.07)	(0.05)	(0.12)
Pneumonia	1.69	0.14	—	-0.12	0.07	-0.02	-0.16***
	(1.74)	(0.10)		(0.12)	(0.13)	(0.11)	(0.06)

Notes: Table reports the coefficient on the cap on noneconomic damages from estimations of equation (4), where each cell reports the results from a separate regression. Rows indicate the dependent variable. Standard errors adjusted for clustering at the state level in parentheses. All coefficients and standard errors are multiplied by 100. * p<0.1, ** p<0.05, *** p<0.01.

Table 9: Placebo tests

	NAMCS	NIS
Patient age	-0.0426	-0.2915
	(0.2507)	(0.2214)
Patient female	0.0081*	0.0036
	(0.0048)	(0.0025)
Patient white	-0.0059	0.0019
	(0.0094)	(0.0077)
Patient black	0.0017	0.0087
	(0.0067)	(0.0059)
Patient latino	0.0118	-0.0012
	(0.0072)	(0.0041)
Private insurance	0.0220**	0.0259***
	(0.0108)	(0.0057)
Medicare	-0.0073	-0.0161***
	(0.0045)	(0.0032)
Medicaid	0.0014	-0.0041
	(0.0070)	(0.0043)
MD (vs. DO)	-0.0093	—
	(0.0096)	
Primary care physician (vs. specialist)	0.0105	—
	(0.0212)	
Physician age	0.9648	—
	(1.9689)	
Physician female	-0.0270**	—
	(0.0117)	
Practice/hospital in MSA	-0.0318	0.0038
	(0.0289)	(0.0237)

Notes: Table reports results from estimations of equation (4), where each cell reports the results from a separate regression. Rows indicate the dependent variable, which is excluded from the vector of controls in the corresponding regression. Column 1 (2) reports placebo tests for the covariates from the NAMCS (NIS) data. Standard errors adjusted for clustering at the state level in parentheses. * $p<0.1$, ** $p<0.05$, *** $p<0.01$.