Curing is Caring? Liability Reforms, Defensive Medicine and Malpractice Litigation in a Post-Pandemic World

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Abstract

We analyze different scenarios of defensive medicine in a unique game theoretic framework, representing a healing relationship between a physician and a patient. The physician should choose between providing the optimal treatment or an inferior one, which can amount to practicing defensive medicine. The patient should choose whether to litigate or not, if an adverse event occurs. When both agents have no dominant strategy, we obtain four scenarios representing the positive and negative forms of defensive medicine, with or without physician's moral hazard. We find that certain legal parameters can have opposite effects on the probabilities that physicians practice defensive medicine and that patients litigate, depending respectively on the form of defensive medicine and on the presence of moral hazard. This result can explain the ambiguous results, reported in empirical literature, of legal reforms aimed at discouraging defensive medicine and medical malpractice litigation.

Keywords: game theory; clinical risk; defensive medicine; epidemics; malpractice litigation.

1. Introduction

Defensive medicine is a deviation from sound medical practice motivated by the threat of liability. It can take two forms: 'positive' defensive medicine entails performing unnecessary tests or procedures so that physicians attempt to legally protect themselves by being over-cautious, while 'negative' defensive medicine entails avoidance of risky treatments, or denial of appropriate care to patients deemed too risky, to reduce the exposure to malpractice litigation. In both cases, physicians depart from optimal practice without the purpose of improving patient health. Defensive practices can expose patients to the risk of harm from inappropriate procedures, and the healthcare system to a substantial increase in unnecessary costs. Health malpractice prompted by defensive motives includes, among others, excessive use of Caesarean section on low-risk women (Currie and MacLeod, 2017; Feess, 2012), and excessive exposure to radiation in diagnosis (Hendee et al., 2010).

Defensive medicine practices have been reported worldwide, with relevant social and human costs. In the US, 93% of physicians in high-risk specialties, who responded to a survey, reported practicing it (Studdert et al., 2005), and analogous results have been found in Europe, China, and Japan (Ramella et al., 2015; He, 2014; Hiyama et al., 2006). The medical liability system, including defensive medicine, has been estimated to cost US more than \$55 billion annually, or between 2.4%-9% of total healthcare spending (Mello et al., 2010; US Department of Health, 2003; Kessler and McClellan, 1996). In Italy, defensive medicine may cost to the public healthcare system more than 10 billion annually, or 10.5% of its overall expenses (Palagiano, 2013). In Austria, only for radiology, orthopedic and trauma surgery, it may cost to the public system around 420.8 million annually, or 1.62% of overall expenses (Osti and Steyree, 2016).

Medical liability reform has been a heated topic among practitioners and policymakers in the last decades (Baker, 2005). This is particularly true for the US, where several tort reforms have been enacted since the mid-1970s, following sharp increases in lawsuits and in liability insurance premiums. Frequency of malpractice claims per physician increased annually at nearly 10% in the 1970s and 1980s (Danzon, 1991), while since then it has been moderately stable with a decreasing trend (Mello et al., 2014; Kessler, 2011; Jena et al., 2011).

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Despite considerable research effort, measuring the effects of liability reforms has produced ambiguous results, both empirically (Dickson er al., 2016; Kessler, 2011; Kachalia and Mello, 2011; Currie and MacLeod, 2008) and theoretically (Montanera, 2016; Zeiler and Hardcastle, 2012). Our study suggests a possible explanation for this phenomenon, which may be due to unobserved factors related to the form of defensive medicine, whether positive or negative, and to the presence of moral hazard. Our paper also contributes to the literature on liability in markets for credence goods (see also Chen et al., 2017), by exploring the specific case of defensive medical practice.

Defensive medicine issues are at risk of a further escalation during the current pandemic crisis. On the one hand, being COVID-19 a new disease for which effective therapeutic approaches are still under development and experimentation, and long-term clinical consequences are still ill-understood and partly unknown, physicians are particularly incentivized to shield themselves from the possible consequences of ex-post ineffective or wrong therapeutic choices. Moreover, the social awareness and alarm around COVID-19 conditions and their threatening complications is especially high across the population, and this is likely to make patients particularly prone to critical questioning of medical practices and potential litigation. Finally, as COVID-19 symptoms in their early phases largely overlap with symptoms of common seasonal diseases such as winter flu, it is likely that, when facing patients with potentially ambiguous symptoms, physicians will engage in both negative and positive defensive medicine practices, including failing to provide proper diagnostic screening or even necessary medical assistance to potentially contagious patients. As the pandemic crisis is not expected to be solved in the short term, we can anticipate that defensive medicine practices will gain further momentum and will become a major threat to the efficient functioning of health care systems in a critical juncture where they are exposed to considerable and prolonged stress. Therefore, research on possible mitigation or countervailing strategies is of special importance and of substantial public interest. Our paper positions itself in this emerging stream of literature.

We develop a game theoretic framework representing a therapeutic relationship between a physician and a patient. The latter can resort to litigation if an adverse event occurs, while the former must choose between providing two risky treatments. Depending on parameter values, we obtain four scenarios in which providing one treatment can amount to practicing defensive medicine, either positive or negative, with or without moral hazard on the physician's side. We assess what are the probabilities that the physician practices defensive medicine and the patient is litigious, respectively, and we find that the effects of changes in certain legal parameters can be opposite in the various scenarios. Our analysis therefore makes a case against general legal recipes to contrast defensive medicine or mitigate its effects, and for a context-specific approach that tailors legal measures to the features and critical aspects of the prevailing scenario.

Specifically, we consider a game between a physician and a patient, which represents an abstraction of a typical health care interaction. The physician treats the patient, and has to choose between providing a clinically inferior treatment D, or a superior treatment *ND*. The former can be considered equivalent to practicing defensive medicine, under some conditions explained in the following sections. The latter can be considered the optimal therapy, the one the physician should choose if acting solely for the benefit of the patient. In the specific context of the COVID-19 pandemic crisis, in which there is no established therapeutic protocol, in a situation of negative defensive medicine one can interpret D as prescribing a likely ineffective but widely adopted therapy with relatively less serious side effects (e.g. hydroxychloroquine plus azithromycin; Kim et al, 2020) as compared to *ND*, a possibly effective but relatively more risky and still experimental therapy (e.g. tocilizumab; Luo et al, 2020). We are intentionally using examples of treatments available and widely debated in the early stages of the pandemic in 2020 to illustrate a situation of high uncertainty with little empirical basis to assess their effectiveness, which is the one where the dilemmas posed by defensive medicine practices are most pressing. Whether or not the former option could make the physician more likely liable in case of an unfavorable or fatal outcome for the patient depends on the judiciary orientation, that might either favor the most widely adopted protocol or the one that has been (possibly ex-post) clinically proven to be more effective despite higher risk. In a scenario of positive defensive medicine, we instead have that the likely ineffective treatment D (again, hydroxychloroquine plus azithromycin) which is widely adopted, has now a relatively higher clinical risk in terms of side-effects with respect to the alternative treatment *ND*, such as for instance convalescent plasma therapy (Chen et al, 2020),which is however less widely used (and/or, as in the example of convalescent plasma theory, could raise therapy-specific issues such as non-standardizable dosage of antibodies). Once again, which choice makes the physician more liable depends on the current judiciary orientation favoring the less effective treatment with higher clinical risk but widely adopted, or the more effective treatment with lower clinical risk but less widely adopted. Frequency of adoption of treatments is likely to depend on the recommendations of national health agencies, that are based on preliminary evidence and are relatively slow to adapt to the availability of new clinical data that are still awaiting official validation. For this reason, in a pandemic scenario like the current one physicians will typically find themselves in a dilemma situation where the generally prescribed approach may result less effective than alternative ones, irrespectively or associated clinical risks, but where choosing the best available alternative entails a potentially risky departure from the current conventional wisdom. Sticking to the conventional option in such cases amounts to an instance of defensive medicine, whether positive or negative depending on the relative levels of clinical risk. However, the extent to which such defensive strategies ensure best legal protection in case of litigation in a pandemic scenario ultimately depends on the prevailing judiciary orientation on what constitutes an optimal therapy when no fully legitimized therapeutic protocol is available yet.

The paper is organized as follows. The model and the assumptions regarding defensive medicine are presented, respectively, in Sections 2 and 3. The mathematical results are presented in Sections 4 and 5, and discussed in Section 6. Finally, we draw our conclusions in Section 7.

2. The Model

In our model, treatments D and ND as defined above yield the physician immediate benefits B_D and B_{ND} respectively, whereas they provide the patient, respectively, with sure benefits B_D^{PA} and B_{ND}^{PA} and an uncertain harm H, which can occur with exogenous probabilities q_D and q_{ND}. Accordingly, the patient's *expected* benefits are $\tilde{B}_D = B_D^{PA} - q_D H$ and $\tilde{B}_{ND} = B_{ND}^{PA} - q_{ND} H$. We assume $\tilde{B}_{ND} > \tilde{B}_D$, that is, providing treatment ND is the optimal therapy in terms of improvement of the patients health condition.

When suffering a harm, the patient (or family) can choose, at a cost $C_L > 0$, to sue the physician for medical malpractice. If winning the litigation, the patient obtains a compensation $R > 0$ from the liable physician. The court will order the physician to pay compensation with a probability p_D or p_{ND}, depending on the treatment provided.

The game unfolds as follows. The physician can play two (pure) strategies, D or ND, representing, respectively, the provision of the inferior or the better treatment. The patient can play two strategies, L or NL, representing respectively litigating or not, if harmed by medical treatment. We assume that both players choose their strategy simultaneously. This amounts to assuming that the type of therapeutic interaction we study is not affected by the sequential interaction between physician and patient. For instance, it may concern a therapeutic decision for an already hospitalized patient, as it is typical of COVID-19 related treatments. The simultaneity assumption deserves some further comment. As a matter of fact, it is not needed that the two players choose simultaneously for it to make sense. Simultaneous games can be defined as games where both players choose their strategies without knowing the other player's choice. As it is widely recognized in the literature, this framework applies not only to the case in which both players move simultaneously, but also to the one in which a player is unaware of the other player's earlier choice. And this is exactly what happens in our model. By choosing first, the physician is obviously unaware of the patient's strategy. Since we consider a simultaneous game, we implicitly assume that, when choosing her/his strategy, the patient is also unaware of the strategy chosen by the physician. This is typical of pure credence goods such as medical treatment: Medical treatment is an example of a credence good: only the physician knows the appropriate treatment, the patient does not. Even after a consultation, the patient is not sure whether he received the right treatment or whether he was perhaps overtreated (Huck et al, 2016, p. 78). Therefore, once acknowledged that the medical treatment is a pure credence good, it is impossible for the patient to ascertain whether the physician practiced defensive medicine or not, and the choice of considering the medical-patient interaction as a simultaneous game is not only fully justified, but as a matter of fact logically inevitable.
Keeping this in mind, the physician's payoff matrix is:

	L	NL
D	$B_D - q_D p_D R$	B_D
ND	$B_{ND} - q_{ND} p_{ND} R$	B_{ND}

(1)

The patient's payoff matrix is:

	D	ND
L	$\tilde{B}_D - q_D (C_L - p_D R)$	$\tilde{B}_{ND} - q_{ND} (C_L - p_{ND} R)$
NL	$\tilde{B}_D$	$\tilde{B}_{ND}$

(2)

with: $\tilde{B}_{ND} > \tilde{B}_D$; C_L, $R > 0$; and $0 < q_D$, q_{ND}, p_D, $p_{ND} < 1$.

Payoffs are expressed in terms of expected utility, in order to include non-monetary factors (such as risk aversion and other psychological, ethical or reputational elements) that can be important drivers of agents' behaviors (see, e.g.,Vincent et al. 1994).

To simplify notation, we define the parameters:

$$B := B_D - B_{ND}, P := q_D p_D - q_{ND} p_{ND} \tag{3}$$

The parameter B represents the increase in sure benefit, for the physician, from providing the inferior treatment D instead of the optimal treatment ND. We can also consider B as a measure of the physician's moral hazard.

The composite parameter P measures the incremental probability of being condemned, for a physician providing the inferior treatment D, when matched to a litigious patient. It includes both clinical and legal risk factors and spans a variety of different circumstances. For instance, $P > 0$ may be due to the court's tendency to overcompensate, by selective punishment of negligent physicians (who provided treatment D), the possibly higher clinical risk experienced by physicians who provided the better treatment ND. However, $P > 0$ may also cover the very different case where the inferior treatment has a larger clinical risk, but defensive physicians are (moderately) less likely to be found liable than non-defensive ones, and yet in view of the difference in clinical risk defensive physicians end up being found liable more often. Opposite implications hold if $P < 0$.

For an analysis of dominance strategies, see the Appendix. Hereafter, we analyze the context in which no strategy dominates the other, in both populations of physicians and patients. Finally, we introduce here our definitions of positive and negative defensive medicine, respectively. We speak of *positive* defensive medicine under the assumptions that the defensive treatment D has a higher clinical risk than the optimal treatment ND, that is $q_D \geq q_{ND}$. We speak instead of *negative* defensive medicine under the assumptions that the defensive treatment D has a lower clinical risk than the optimal treatment ND, that is $q_D < q_{ND}$. In both cases, the defensive medicine treatment may or may not ensure the physician a lower probability of losing a possible lawsuit, depending on the prevailing judiciary orientation.

This paper is related to Antoci et al. (2016) and Antoci et al. (2018a), where the adoption dynamic of strategies D, ND, L, and NL is analyzed via replicator equations. Antoci et al. (2016) focuses on a specific case of positive defensive medicine, in which $q_D = q_{ND}$ and $p_D < p_{ND}$; that is, D and ND are characterized by the same clinical risk, and D shields physicians in court in case of litigation. Antoci et al. (2018a) focuses, instead, on a specific case of negative defensive medicine, that in which $q_D < q_{ND}$ and $p_{ND} < p_D$; that is, the judiciary system is able to hold the physician adopting D liable in the case of an adverse clinical outcome. Therefore, the present work offers a generalization of the previous models in that, in both cases of positive and negative defensive medicine, it does not put restrictions on the relative values of p_D and p_{ND}. This allows us to analyze the effects of legal reform as related to the level of efficiency of the judiciary system (as measured, in our model, by the composite parameter P). Moreover, the present work focuses on the static game to emphasize the role of expectations in the behavior of patients and physicians and in bringing about the equilibrium choices of the two types of agents.

3. Strategic interaction and players' choices

Consider the one-shot game as defined by the payoff matrix (1) and (2). We denote by d the probability that the physician chooses strategy D, and by l the probability that the patient chooses strategy L. Consequently, $1 - d$ stands for the probability that the physician chooses strategy ND, and $1 - l$ for the probability that the patient chooses strategy NL. Since l and d are defined as probabilities, we have to always ensure that their values belong to the interval $[0, 1]$.

Let us indicate by G^{PH} and G^P the payoff matrix (1) and (2), respectively. Let's assume the physician chooses the mixed strategy $(d,\ 1-d)$ (that is, chooses to play D with probability d and ND with probability $1 - d$) that maximizes the expected value of her/his own payoff:

$$E^{PH} = \begin{pmatrix} d & 1-d \end{pmatrix} G^{PH} \begin{pmatrix} l \\ 1-l \end{pmatrix} \tag{4}$$

on the basis of the probabilities l and $1 - l$ with which the physician expects that the strategies L and NL will be played, respectively, by the patient.

Likewise, let's assume that the patient chooses the mixed strategy $(l,\ 1-l)$, that is, chooses to play L with probability l and NL with probability $1-l$) so as to maximize the expected value of her/his own payoff:

$$E^P = \begin{pmatrix} l & 1-l \end{pmatrix} G^P \begin{pmatrix} d \\ 1-d \end{pmatrix} \tag{5}$$

given the probabilities d and $1-d$ with which the patient expects the physician will play the strategies D and ND, respectively.

One easily checks that the expected values (4) and (5) may be written in the form:

$$E^{PH} = d\,\Sigma(l) + M(l) \tag{6}$$

$$E^P = l\,\Omega(d) + N(d) \tag{7}$$

where:

$$\Sigma(l) := B_D - B_{ND} - PRl = B - PRl \tag{8}$$

$$\Omega(d) := -q_{ND}(C_L - p_{ND}R) + [(q_{ND} - q_D)C_L + PR]d \tag{9}$$

$$M(l) := (B_{ND} - q_{ND}p_{ND}R)l + B_{ND}(1-l) \tag{10}$$

$$N(d) := \tilde{B}_D d + \tilde{B}_{ND}(1-d). \tag{11}$$

Being (6) and (7) respectively linear in d and l, the functions E^{PH} and E^P are respectively maximized by:

$$d^o = \begin{cases} 0, & if\ \Sigma(l) < 0 \\ d^*, & if\ \Sigma(l) = 0 \\ 1, & if\ \Sigma(l) > 0, \end{cases} \qquad l^o = \begin{cases} 0, & if\ \Omega(d) < 0 \\ l^*, & if\ \Omega(d) = 0 \\ 1, & if\ \Omega(d) > 0, \end{cases} \tag{12}$$

where

$$l^* = \frac{B}{PR}; \quad d^* = \frac{q_{ND}(C_L - p_{ND}R)}{(q_{ND} - q_D)C_L + PR}. \tag{13}$$

From equations (8) and (9), it is easy to check that:

$$\Sigma(l) > 0 \text{ for } \begin{cases} l > l^*, \text{ if } C_1 \text{ holds} \\ l < l^*, \text{ if } C_2 \text{ holds} \end{cases} \quad ; \quad \Sigma(l) < 0 \text{ for } \begin{cases} l > l^*, \text{ if } C_2 \text{ holds} \\ l < l^*, \text{ if } C_1 \text{ holds,} \end{cases} \tag{14}$$

and

$$\Omega(d) > 0 \text{ for } \begin{cases} d > d^*, \text{ if } C_3 \text{ holds} \\ d < d^*, \text{ if } C_4 \text{ holds} \end{cases} \quad ; \quad \Omega(d) < 0 \text{ for } \begin{cases} d > d^*, \text{ if } C_4 \text{ holds} \\ d < d^*, \text{ if } C_3 \text{ holds,} \end{cases} \tag{15}$$

where the conditions C_i, $i = 1 \dots 4$, are defined in the table below:

C_1	C_2	C_3	C_4
$PR < B < 0$	$PR > B > 0$	$p_{ND}R < C_L < p_D R$	$p_{ND}R > C_L > p_D R$

Table 1

Combining (12), (14) and (15) we can draw the following scenarios:

- *Scenario (a)*

$$C_1 \text{ and } C_3 \text{ hold.} \tag{16}$$

- *Scenario (b)*

$$C_1 \text{ and } C_4 \text{ hold.} \tag{17}$$

- *Scenario (c)*

$$C_2 \text{ and } C_3 \text{ hold.} \tag{18}$$

- *Scenario (d)*

$$C_2 \text{ and } C_4 \text{ hold.} \tag{19}$$

Notice that, in each of the above scenarios, no strategy dominates the other in both populations of players. These are all and only the cases where this happens; see the Appendix for a characterization of the dominance conditions.

We can characterize the non-dominance requirements for the four scenarios as follows. In scenario (a), the combination of conditions C_1 and C_3 implies the following. From C_3, we know that here $p_D > p_{ND}$, that is, courts are more inclined to penalize defensive physicians than non-defensive ones. Being also $P < 0$ from C_1, it follows that $q_{ND} > q_D$, that is, the better treatment also implies higher clinical risk. Moreover, being $B < 0$ again from C_1, there is no moral hazard for physicians. On the patient's side, from C_3 it turns out that it is convenient to sue a physician if they expect s/he to be defensive, but not if they expect s/he to be non-defensive (given the level of judiciary coverage offered by the court to non-defensive physicians). However, the differential in clinical risk between the better and the inferior treatment is such that, despite the court's tendency to favor non-defensive physicians, they end up being found liable more often than defensive ones. Therefore, this is a scenario where there is an incentive for physicians to practice defensive medicine and for patients to sue them. Moreover, being clinical risk higher for the better treatment, we face here a situation of negative defensive medicine. To sum up, this is a scenario of high clinical risk for effective treatments, that favors the emergence of negative defensive medicine and incentivizes patients to sue. The clinically and socially inefficient outcome here is basically brought about by the exceedingly high risks of the better treatment, despite that courts tend to favorably regard physicians who embrace it. Note that, in the absence of moral hazard for physicians, there would be no incentive for them to embrace defensive medicine, were it not for the high clinical risks related to the better treatment. We can therefore define this scenario as "negative defensive medicine induced by high clinical risk".

In scenario (b), the non-dominance requirement calls for conditions C_1 and C_4 to hold simultaneously. From C_4, we have that it is convenient for patients to sue physicians if they expect them to be non-defensive and that courts tend to favor defensive over non-defensive physicians ($p_{ND} > p_D$). Here too, there is absence of moral hazard being $B < 0$ from C_1. On the other hand, being $P < 0$ from C_1, we may both have cases where $q_D > q_{ND}$, as well as cases where the opposite holds. Therefore, in scenario (b) there is an incentive for physicians to embrace defensive medicine of either type, depending on circumstances, and there will be no incentive for patients to sue them if they expect physicians to be defensive, irrespectively of clinical risk, due to the court's orientation in favor of defensive practices. This scenario can be termed as "defensive medicine induced by favorable court orientation".

In scenario (c), from condition C_2 we have that there is both moral hazard for physicians, who have a clear incentive to adopt defense medicine practices, and $P > 0$, that is, it is more likely to be found liable overall when practicing defensive medicine. On the other hand, from C_3 it follows that it is convenient for patients to sue physicians if they expect them to be defensive and $p_D > p_{ND}$. Here again, $P > 0$ is compatible with both treatments having a higher clinical risk than the other, so that both types of defensive medicine are possible. Now, although there is an objective benefit for physicians to embrace defensive medicine, both the high propensity of patients to litigate with physicians who are expected to be defensive and the negative attitude of the court against defensive physicians, combined with the relatively moderate level of additional critical risk of the better treatment in the worst case, all conjure up against defensive medicine. This scenario can be termed as "dis-incentivization of defensive medicine driven by hostile court orientation".

Finally, in scenario (d), we have again from C_2 that there is moral hazard for physicians and that, being $P > 0$, defensive physicians are found liable more often than non-defensive ones. However, it is now more convenient for patients to sue physicians if they expect them to be non-defensive. It follows that $p_{ND} > p_D$ and therefore, from $P > 0$ due to C_2 it follows that $q_D > q_{ND}$, that is, the clinical risk of the inferior treatment is higher than that of the better one and therefore defensive medicine practices are here of the positive type. In this scenario, there is an objective convenience for physicians to practice defensive medicine and patients are not inclined to sue if they expect physicians to be defensive. Nevertheless, courts are hostile to defensive physicians and they end up being found liable more often than non-defensive physicians due to the higher clinical risk associated to defensive medicine practices. We can therefore denote this scenario as "positive defensive medicine deterred by high clinical risk".

Clearly, other scenarios in which conditions align – for instance, there is moral hazard, courts tend to favor defensive medicine and patients find it convenient to litigate with physicians if they expect them to be non-defensive – are obvious instances of scenarios where one strategy dominates the other. This is why, in the four scenarios described above, there is always some form of tradeoff between the relative benefits of defensive vs. non-defensive medicine.

Notice that conditions (18) and (19), concerning scenarios with moral hazard, require (ceteris paribus) a high enough $P > 0$; that is, the selective punishment of physicians who provided the inferior treatment D must be efficient enough. The opposite holds for conditions (16) and (17), concerning scenarios without moral hazard, which require a low enough $P < 0$.

Figures 1(a)-1(d) illustrate the choices of d^o and l^o, in scenarios (a)-(d), respectively. The red line represents the best reply d^o (see formula (16)) by the physician, as a function of the probability l that strategy L is chosen by the patient. Note that, for $l = l^*$, any choice of probability d^o by the physician yields the same expected payoff (the horizontal branch of the red line). The blue line represents the best reply l^o (see formula (17)) by the patient, as a function of the probability d that the physician chooses strategy D. Note that, for $d = d^*$, any choice of the probability l^o by the patient yields the same expected payoff (the vertical branch of the blue line).

4. Equilibrium choices

We study the solutions of the game in terms of Nash equilibria, in the context in which no player has a dominant strategy. In such a context, the outcome of the game is not defined in terms of pure strategies but of mixed strategies, obviously unlike the case where at least one player has a dominant strategy, so that the opponent will simply play the best response to the dominant strategy.

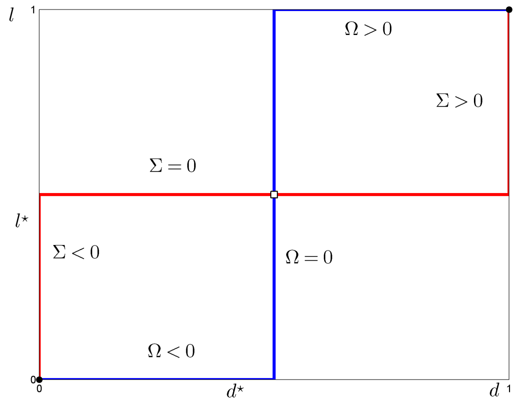
When no dominant strategies exist (i.e. if one among the conditions (16)-(19) is satisfied), only the strategic contexts illustrated in Figures 1(a)-1(d) can occur, which correspond to the respective scenarios (i.e. Figure 1(a) is for scenario (a), and so on). According to the analysis developed in Section 4, in each of these cases, a mixed-strategy Nash equilibrium exists:

$$(d^*, l^*) = \left(\frac{q_{ND}(C_L - p_{ND}R)}{(q_{ND} - q_D)C_L + PR}, \ \frac{B}{PR} \right)$$

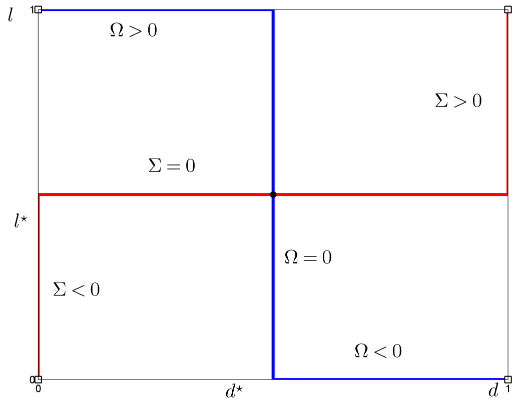
in which the physician plays strategy D with probability d^* (and ND with probability $1 - d^*$), while the patient plays strategy L with probability l^* (and NL with probability $1 - l^*$).

In scenario (a), in addition to the mixed-strategy Nash equilibrium, we have two pure-strategy equilibria: (D, L) and (ND, NL). In this scenario, where defensive medicine practices have an unambiguous negative character, the prevailing element is the high clinical risk associated to the non-defensive choice. As conditions C_1 and C_3 hold, we have that patients find it convenient to litigate a defensive physician, whereas physicians, in the case of litigation, prefer to embrace defensive practices due to the high risk of the non-defensive alternative. Therefore (D, L) is a Nash equilibrium. However, if patients are not willing to litigate the physician, physicians prefer to opt for the non-defensive treatment, as in this scenario there is absence of moral hazard and defensive practices do not offer an inherent positive benefit to the physician. Therefore, also (ND, NL) is a Nash equilibrium. We have therefore a pure-strategy litigating equilibrium with negative defensive medicine, a non-litigating equilibrium without defensive medicine, and a mixed strategy equilibrium. See Figure 1(a) for an illustration. Notice how, in this scenario, a litigating attitude in patients favors the diffusion of (negative) defensive medicine practices by penalizing the superior non-defensive treatment in view of its high clinical risk. If conversely patients tend not to litigate, there is space for experimenting with the better treatment and a more effective therapeutic approach can prevail.

In scenario (d), in addition to the mixed-strategy equilibrium, we have again two pure-strategy Nash equilibria: (D, NL) and (ND, L). In this scenario, defensive medicine practices have an unambiguous positive character, and the inferior treatment is characterized by higher clinical risk. Here, conditions C_2 and C_4 hold, and physicians face moral hazard as the defensive medicine practice is inherently beneficial for the physician. Patients find it convenient to litigate a non-defensive physician but not a defensive one. On the other hand, provided that the patient is litigating, for physicians it is preferable to adopt the non-defensive treatment due to the higher clinical risk of the defensive one. Therefore, (ND, L) is a Nash equilibrium. Conversely, if the patient is not litigating, it is convenient for the physician to adopt the defensive treatment which is inherently beneficial for him/her. Therefore, (D, NL) is a Nash equilibrium. See Figure 1(d) for an illustration. Here, contrary to the



(a) Scenario (a)



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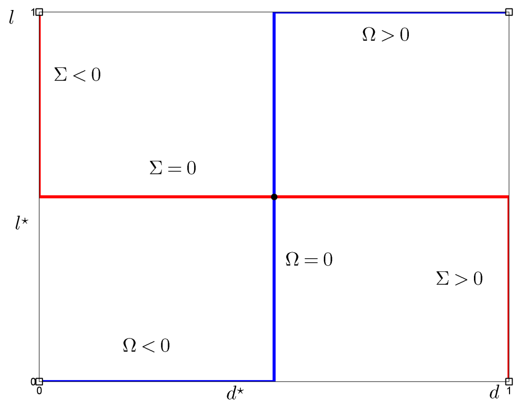
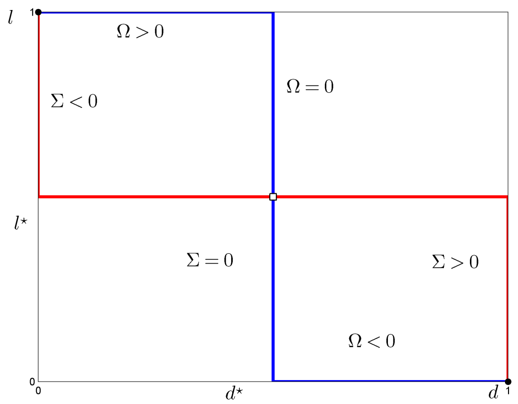


(c) Scenario (c)



(d) Scenario (d)

Figure 1: Figure 1. Choices of d^0, l^0 in the four respective scenarios: (a) Negative defensive medicine induced by high clinical risk; (b) Defensive medicine induced by favorable court orientation; (c) Dis-incentivization of defensive medicine driven by hostile court orientation; (d) Positive defensive medicine deterred by high clinical risk.

previous scenario, a litigating attitude from patients discourages the adoption of (positive) defensive medicine practices due to their higher clinical risk, favoring the prevalence of better, non-defensive treatments despite the inherent benefit of defensive practices for physicians. Therefore, litigating attitudes do not have unambiguous effects on patients' welfare: it basically depends on the prevailing scenario, and in particular on the relative clinical risk of the available treatments.

In scenarios (b) and (c), instead, no pure-strategy Nash equilibria are found, and the mixed-strategy equilibrium (d^*, l^*) is the unique Nash equilibrium of the game. The equilibrium choices of the physician and the patient are therefore uniquely characterized by the probabilities d^* and l^*, respectively. These are also the scenarios where both types of defensive medicine can be observed depending on model parameters. See Figures 1(b-c) for an illustration.

5. Effects of Liability Reforms

Now that we have characterized the structure of the equilibria of the model, we are able to study the effects of changes in legal parameters on the threshold values d^* and l^* (see (13)).

When d crosses d^*, the patient's choice l^o switches from the value $l^o = 1$ to the value $l^o = 0$. Analogously, when l crosses l^*, the physician's choice d^o switches from the value $d^o = 1$ to the value $d^o = 0$. When both d^o and l^o coincide with the threshold values d^* and l^*, then players have no incentive to modify their choices, and the mixed-strategy Nash equilibrium (d^*, l^*) prevails. On the other hand, in scenarios where multiple Nash equilibria exist, the mixed-strategy equilibrium probabilities can be interpreted as threshold values as to the expectations of players about the choices of their opponents, that consequently lead to the selection of one of the two pure-strategy Nash equilibria. For instance, in a scenario with multiple Nash equilibria such as (a), if players' expectations d and l are such that $d > d^*$ and $l > l^*$, the two players will select the equilibrium (D, L); conversely, they will select the equilibrium (ND, NL) if $d < d^*$ and $l < l^*$. Therefore, given the expectations, a shift in threshold values d^* and l^* will favor players' coordination on one of the pure strategy equilibria at the expense of the other, depending on the direction of the shift of each threshold value. Likewise, for scenario (d), the (ND, L) pure-strategy equilibrium will be selected if $d < d^*$ and $l > l^*$, whereas the equilibrium (D, NL) will be selected if $d > d^*$ and $l < l^*$. When multiple Nash equilibria exist, the mixed-strategy equilibrium should be meant more as a "separatrix" between the two pure strategy Nash equilibria than as an attainable outcome, because for expectation levels above or below the mixed-equilibrium probabilities, players have an incentive to select the pure strategy equilibrium (as it could be easily checked in terms of limit outcomes of a best-response dynamics). When only one Nash equilibrium in mixed strategies exists, we can interpret its probabilities as the limit frequencies of the respective strategies when the game is played sufficiently many times.

Let us now consider more systematically the legal parameters of the model: the cost of litigation C_L, the malpractice compensation R, and the physician's liability probabilities p_D and p_{ND}. We can assess the effects of these parameters on the equilibrium outcomes by means of the partial derivatives of the equilibrium values d^* and l^*, in the scenarios (a)-(d), under the non-dominance conditions (16)-(19). Specifically, the sign of the partial derivative determines whether a parameter has a positive or negative effect on the players' mixed-equilibrium probabilities d^* and l^*. The results are summarized in Table 2.

The effects of changes in legal parameters, as summarized in Table 2, form a complex pattern, but with some interesting regularities. The first is that changes in liability probabilities p_D, p_{ND} have opposite effects on both probabilities d^* and l^* in the scenarios with *positive* vs. *negative* defensive medicine, and in the two mixed scenarios where both types of defensive medicine coexist. However, the effects of the malpractice compensation R and of the cost of litigation C_L are instead the same for scenarios (a) and (c), and (b) and (d), respectively.

Let us see such effects in some more detail in the four scenarios. In scenario (a), characterized by negative defensive medicine and high clinical risk for the non-defensive treatment, with three Nash equilibria and with litigation favoring defensive medicine practices at a pure equilibrium, we have that an increase in p_D causes d^* to decrease and l^* to increase, that is the "basin" of possible beliefs on d that leads to a pure equilibrium with defensive medicine is enlarged, whereas the "basin" of possible beliefs on l that leads to patient litigation is shrunk. If p_D increases, for the patient it becomes more convenient to litigate a defensive physician, and therefore s/he will be willing to sue for a broader spectrum of possible values of d. On the other hand, if for the physician the probability of being liable increases when practicing defensive medicine, there is a narrower spectrum of possible values of l for which s/he is willing to practice defensive medicine. In the case of an increase of p_{ND} in scenario (a), the spectrum of d values for which the patient is willing to litigate a defensive physician still broadens as a higher liability for non-defensive medicine makes the prevalence of defensive medicine more likely. Accordingly, for the physician the range of possible values of l for which s/he is willing to practice defensive medicine broadens as now non-defensive medicine has become more liable. As to malpractice compensation R, its increase causes litigation of a defensive physician to be relatively more convenient, and therefore the range of possible values of d for which the patient is willing to sue broadens accordingly. Finally, for litigation cost C_L, its increase causes the range of possible values of d for which the patient is willing to sue to shrink as litigation is now more costly, whereas for the physician this change has no effect as s/he is not directly affected by the cost of litigation in any way. Simply reversing the above reasonings for the various parameters provides an explanation of the mirror-like effects of changes in each parameter on the values of d^* and l^* in scenario (d).

If we consider instead scenario (b), where both types of defensive medicine can be observed and they are encouraged by a favorable court orientation, with only one Nash equilibrium, we can characterize the effect of variations in legal parameters on mixed-strategy equilibrium probabilities as follows. If p_D increases, it becomes more convenient for patients to litigate (as the court's orientation toward defensive medicine has become relatively less favorable), and therefore l^* goes up. On the other hand, if patients become more litigious, it becomes more convenient for the physician to become more defensive, and therefore d^* goes up. As to an increase in p_{ND}, this now means that the relative court orientation in favor of defensive medicine becomes even more pronounced, and this causes in turn physicians' probability to practice defensive medicine to rise. But since for patients in this scenario it is convenient to litigate non-defensive physicians but not defensive ones, this also causes a decrease in patients' equilibrium probability of litigation. Once again, simply reversing the above arguments provides an explanation of the effects of the change of legal parameters on equilibrium probabilities in the mirror-like scenario (c).

	Scenario (a)	Scenario (b)	Scenario (c)	Scenario (d)
Relationship with:	**(d^*, l^*)**			
p_D	(↓ , ↑)	(↑ , ↑)	(↓ , ↓)	(↑ , ↓)
p_{ND}	(↓ , ↓)	(↑ , ↓)	(↓ , ↑)	(↑ , ↑)
R	(↓ , ↓)	(↑ , ↓)	(↓ , ↓)	(↑ , ↓)
C_L	(↑ , ↔)	(↓ , ↔)	(↑ , ↔)	(↓ , ↔)

Table 2: Relationship between legal parameters and probabilities d^* and l^*, corresponding to the physician's probability of practicing defensive medicine and the patient's probability of being litigious, at the mixed-strategy Nash equilibrium. Parameters p_D, p_{ND}: physician's probabilities of losing a litigation when practicing defensive medicine or not; R: what a liable physician pays to the litigious patient; C_L: patient's cost of litigation. Type of relationship ↑: positive; ↓: negative; ↔: no relationship.

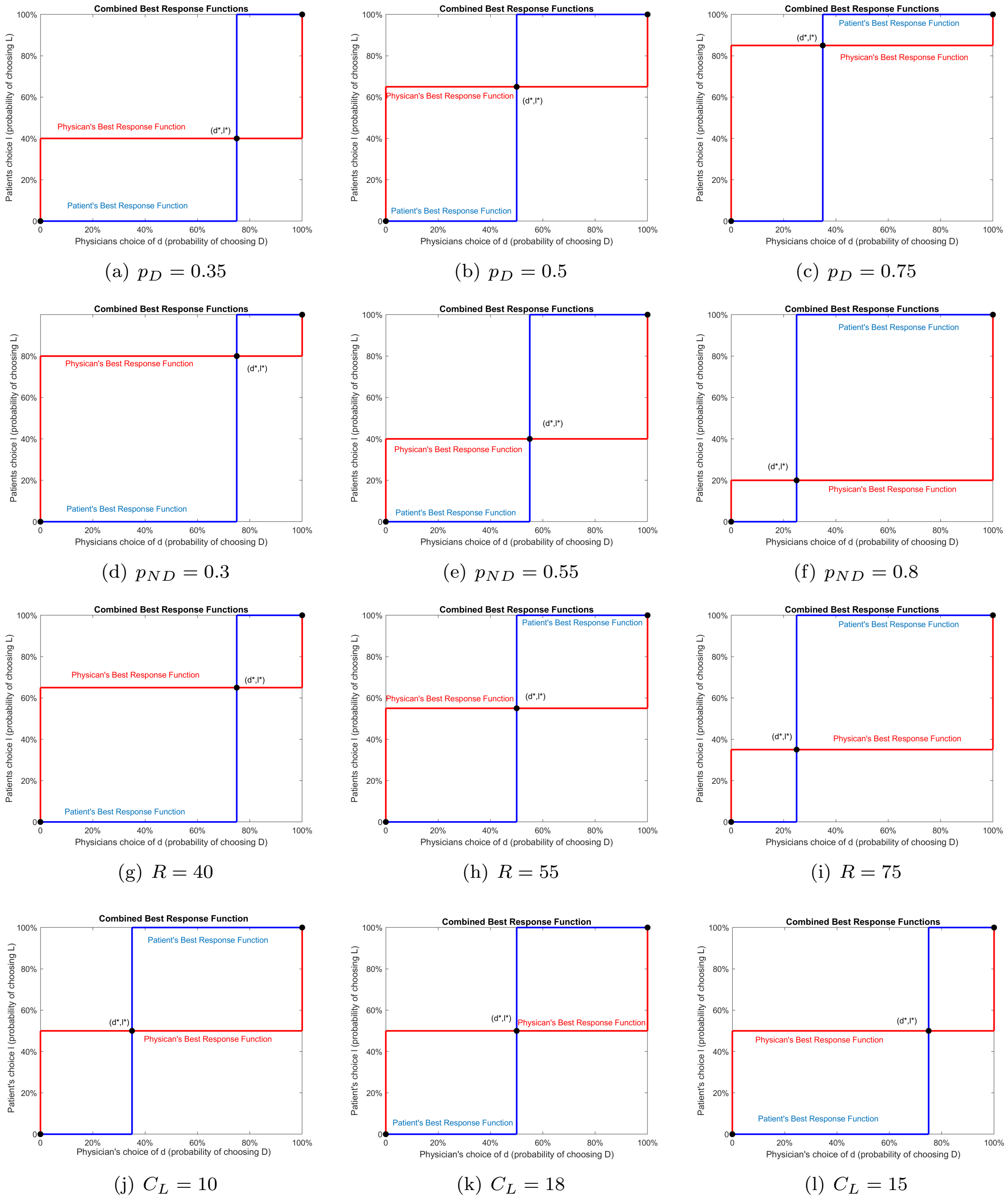
An especially interesting result of the analysis is that, in all scenarios, the patient's probability to litigate at the mixed-strategy equilibrium is always *negatively* related to the amount R of malpractice compensation. Whereas in scenarios (a) and (d) this has mainly the effect of making the emergence of one pure-strategy equilibrium over the other more likely and in an intuitively plausible way, in the case of scenarios (b) and (c) this has the effect of reducing the observed amount of litigation from strategic interaction, due to the fact that in such scenarios only the mixed-strategy Nash equilibrium exists. In scenario (b) where patients find it convenient to litigate non-defensive physicians but not defensive ones, and in which courts are generally favorable toward defensive practices, an increase in R has the effect of further discouraging physicians from engaging in non-defensive practices and this makes litigation less appealing. In scenario (c) where patients find it convenient to litigate defensive physicians but not non-defensive ones and in which courts are generally hostile to defensive practices, an increase in R makes physicians relatively more willing to engage in non-defensive practices and again this makes litigation relatively less appealing.

In Figure 3, we provide a more detailed comparative static analysis of the relevant curves for examples of legal parameter changes in scenario (b).

From Table 2, we see that an increase in p_D will cause a less likely emergence of defensive medicine practices (i.e., a narrower spectrum of values of l that support the pure-strategy equilibrium where D is played) in scenario (a), that is, in a scenario where high clinical risk plays against non-defensive medicine. An increase in p_D in scenario (a) amounts to a decrease, in relative terms, of the potential damage from liability of non-defensive medicine practices as compared to defensive ones. In scenario (d), where clinical risk is relatively higher for defensive practices, the increase in p_D causes again a less likely emergence of defensive practices in a scenario where relatively lower clinical risk plays in favor of non-defensive practices. Likewise, an increase in p_D in scenario (b) which is characterized by favorable court orientation toward defensive practices causes a more likely emergence of defensive practices through its encouragement to patients to litigate more, whereas in scenario (c) where the orientation of the court is relatively hostile to defensive practices the increase of p_D that makes the court even more hostile discourages patients from litigation and therefore reduces the appeal of defensive practices. From this cross-sectional survey of the effects of a legal parameter on defensive medicine practices in the various regimes we notice how the actual impact depends on the prevailing scenario in a relatively complex way. When we consider possible liability reforms that simultaneously involve more than one parameter, the effect may be even more complex to unscramble, again depending on the prevailing scenario. Therefore, there is no possibility to design liability reforms outside of a context-specific logic. There is no way to ensure a gain in patient welfare by unilaterally advising in favor or against increased physicians' liability or increased litigation entitlement of patients. In certain scenarios, what may seem the most intuitively appealing way to proceed may lead to perverse results. Of particular importance is the fact that defensive medicine practices may emerge also in the absence of moral hazard. The rationale behind defensive treatments is not a straightforward consequence of the direct benefit that the physician obtains from them but is the product of a complex interplay between clinical risk, court orientation *and* intrinsic benefits.

6. Discussion

The emergence of defensive vs. non-defensive medicine practices in realistic social environments is likely the result of a constellation of factors. In the context of multiple Nash equilibria, which in our model is also the one where defensive medicine practices take an unambiguously positive or negative character, agents' beliefs and coordination have a relevant role in equilibrium selection. Coordination tends to emerge in contexts that favor



(a) $p_D = 0.35$ (b) $p_D = 0.5$ (c) $p_D = 0.75$

(d) $p_{ND} = 0.3$ (e) $p_{ND} = 0.55$ (f) $p_{ND} = 0.8$

(g) $R = 40$ (h) $R = 55$ (i) $R = 75$

(j) $C_L = 10$ (k) $C_L = 18$ (l) $C_L = 15$

Figure 2: Graphical illustration of the comparative statics results in Table 2, concerning the Scenario (a).

altruistic behavior (Brañas-Garza et al., 2010; Rand et al., 2009; Antoci et al., 2004), or when the action of one player is knowable in advance (for example, a patient who signs a liability waiver). On the other hand, the assumption of no coordination is typical of many patient-physician relationships characterized by impersonal interactions, as well as of most contexts of asymmetric information. The latter includes medical services that can be considered credence goods (Darby and Karni, 1973; Chen et al., 2017).

In a pandemic or post-pandemic scenario, issues of defensive medicine assume an even higher relevance that what is ordinarily the case. The emergence of defensive medicine practices may severely affect the capacity of a health system to respond effectively to the crisis, and may result in a significantly, or even tragically, higher number of fatal clinical outcomes. Therefore, designing health policies that enable physicians to choose the better treatment in such circumstances is, literally, of vital importance. What our results suggest is that singleminded approaches are not helpful. Liability reforms may reveal counterproductive if there is uncertainty about the relevant scenario. More generally, the enforcement by the judiciary system as the main basis to motivate physicians to act in the interest of the patient is likely to be a socially very costly and noisy approach (Vetch, 1991). On the other hand, what the pandemic crisis has shown us is that the medical profession has often (though clearly not always) revealed to be much less calculative than one might expect. The COVID-related casualties in the medical ranks in many countries are not only linked to improper protection from viral exposure or lack of awareness of the viral threat in the early stages of the pandemic. They are also due to the fact that many physicians, including already retired, elderly ones, have spontaneously volunteered to remain or return in service much beyond their duties to be of help during such a severe crisis. In Italy, at the peak of the crisis in March 2020, nearly 8,000 physicians responded to volunteer for a call that asked for 300 (Song, 2020). This means that, for many physicians, deontological obligations still seem to be a powerful motivational force (Garrett and Davies, 2011), and this factor should not be ignored when designing a possible liability reform. In particular, the effect of internalized deontological norms may be, according to cases, that of at least partially offsetting the cost of the penalty from having been found liable when practicing non-defensive medicine, or of reducing the intrinsic benefit from practicing defensive medicine. Although this kind of effects is difficult to obtain through policy actions, it should be nonetheless advisable to reckon with them, for instance by accounting for cultural evolution processes that select certain kinds of pro-social vs. selfish traits and may also lead to the building of specific social assets (Antoci et al, 2018b).

A pandemic crisis cannot be merely resolved in terms of providing the right incentives to medical professionals or of enabling patients to sue to affirm their rights. One of the critically relevant aspects of the crisis has been the capacity of our social fabric to make people feel they mattered for others, and this cohesive dimension has had a crucial importance in the resilience of health systems in the most critical moments (Flett and Zangeneh, 2020). We therefore need to understand in much more detail how the prevalence of defensive medicine practices may not only be the effect of a badly designed incentive system and judiciary enforcement, but also of failed cultural selection of pro-social traits and attitudes. Internalizing these effects into our modeling and testing their strength in empirical research is one of the key challenges for future research in the field. This is all the truer in view of the fact that, in a post-pandemic world, we may expect pro-sociality and socio-cultural traits and attitudes leading to more responsibility and better social coordination to become increasingly important (Gunessee et al, 2018). In such a high-stakes situation, and more generally in a world where large-scale disasters may become more frequent due to the effect of long-term trends such as global climate change (which can in turn pave the way to new pandemic threats), complex societies cannot afford themselves to only rely upon suitable but fallible incentive schemes to prevent the systematic emergence and consolidation of dangerous and socially disintegrating behaviors, which could spark perverse domino effects with unpredictable long-term consequences.

7. Conclusions

In this paper, we proposed a game-theoretic framework analyzing a typical interaction between a physician and a patient, in which the former chooses between providing two risky treatments and the latter can resort to litigation if an adverse event occurs. Clinical treatments have specific features related to their benefits and risks. Through suitable assumptions on parameter values, we defined and studied four scenarios in which medical decisions contemplate the possibility of negative or positive defensive practices, or of both, according to cases, with or without moral hazard for physicians.

Our results suggest that legal reforms, aimed at preventing defensive medical practices, may have indeterminate effects if the law does not distinguish between *positive* and *negative* forms of defensive medicine and is not able to assess the consequences of a possible reform as conditional to the specific prevailing scenario. Indeterminacy may arise, within the framework of our model, because changes in legal parameters have diverging effects on the probability of practicing defensive medicine, as measured at the mixed-strategy Nash equilibrium of the given scenario.

Furthermore, legal reforms focusing upon the accuracy with which the court adjudicates cases, may have indeterminate effects on the levels of litigation if the law fails to consider the moral hazard of physicians. This conclusion derives from comparing, in our model, the effects of changes in the probability of winning litigation on the probability that the patient is litigious, measured at the mixed-strategy Nash equilibrium. These effects are divergent in the scenarios with and without physician moral hazard, irrespective of the form of defensive medicine.

An apparently paradoxical result is that, in all the considered scenarios, the probability that the patient is litigious is *negatively* related with changes in patient's malpractice compensation. This effect is consistent with

empirical literature on reforms imposing caps on noneconomic damages: Durrance (2010) finds a negative and statistically significant relationship between these caps and claim frequency, while Ambrose and Carrol (2007) suggest that these reforms may increase the expenses of insurance companies, associated with litigated claims. Our study confirms the importance, for the success of reforms, of determining the appropriate level of damage assessment in different clinical settings (Shavell, 2014; Arlen and MacLeod, 2005; Polinsky and Shavell, 1998). This study can also help explain the ambiguous results reported in the empirical literature on the effects of tort reforms (Kessler, 2011; Kachalia and Mello, 2011), which may be due to unobserved factors related to the prevailing form of defensive medicine and to the presence of moral hazard or lack thereof. These factors should be empirically examined by accounting for differences in medical specialties and clinical settings, and by jointly considering the legal and financial incentives of physicians (as also suggested by Schutz, 2014), in addition, as suggested in the discussion, to deontological and socio-cultural ones.
The findings of this study reinforce concerns about the suitability of traditional tort reforms in achieving the dual goals of containing healthcare and litigation costs, while improving clinical outcomes. This conclusion is consistent with the empirical literature on the relation between malpractice pressure and medical errors (Iizuka, 2013; Carvell et al., 2012), and it is supported by the theoretical results obtained, using a different methodology, by Chen et al. (2017) on credence goods, and by Montanera (2016) on negative defensive medicine. The ambitious goals of improving patient care and doctors' deontological standards, while avoiding unnecessary expenses, may only be achieved through innovative policies and programs, based on an integrated approach encompassing medical, legal, economic and socio-cultural perspectives.

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Appendix A–Dominance of strategies

A strategy is strictly dominant if it yields the player a better outcome than the alternative strategy, no matter what the opponent does.
Providing the inferior treatment D is the physician's dominant strategy if it yields an additional sure benefit that exceeds its additional expected compensation (with respect to the optimal treatment); that is, if $B > 0$ and $B > P$ hold. Conversely, if $B < 0$ and $B < P$ hold, providing the optimal treatment *ND* is the physician's dominant strategy. Furthermore, strategy D is the best response: to strategy *NL*, for $B > 0$; and to strategy L, for $B > P$. Conversely, strategy *ND* is the best response: to strategy *NL*, for B < 0; and to strategy L, for $B < P$.
Litigating is the patient's dominant strategy if the cost of litigation falls below the expected compensation to the injured patient, whatever the treatment; that is, if $C_L < p_D R$ and $C_L < p_{ND} R$ hold. Conversely, if $C_L > p_D R$ and $C_L > p_{ND} R$ hold, not litigating is the patient's dominant strategy. Furthermore, strategy L is the best response: to strategy *ND*, for $C_L < p_{ND} R$; and to strategy D, for $C_L < p_D R$. Conversely, strategy *NL* is the best response: to strategy *ND*, for $C_L > p_{ND} R$; and to strategy D, for $C_L > p_D R$.
The solution of the game, when at least one player has a dominant strategy, is the unique Nash equilibrium:

- (*ND*, *NL*) if both $B < 0$ and $C_L > p_{ND} R$ hold, and either $B < P$ or $C_L > p_D R$ also holds;
- (*ND*, L) if both $B < P$ and $C_L < p_{ND} R$ hold, and either $B < 0$ or $C_L < p_D R$ also holds;
- (D, *NL*) if both $B > 0$ and $C_L > p_D R$ hold, and either $B > P$ or $C_L > p_{ND} R$ also holds;
- (D, L) if both $B > P$ and $C_L < p_D R$ hold, and either $B > 0$ or $C_L < p_{ND} R$ also holds.