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СТАНДАРТ ДОКАЗУВАННЯ В ЗАГАЛЬНОМУ ПРАВІ: МАТЕМАТИЧНЕ ОБҐРУНТУВАННЯ І ДОКАЗОВЕ ЗНАЧЕННЯ СТАТИСТИЧНИХ ДАНИХ

Анотація. Унаслідок нещодавніх змін до процесуального законодавства України в судовій практиці спостерігається тенденція до диференціації стандартів доказування залежно від виду судочинства. Так, у ході цивільного судочинства застосовується так званий стандарт «баланс ймовірностей», тоді як у кримінальному провадженні – застосовується стандарт «поза розумним сумнівом». Мета статті – знайти раціональне обґрунтування диференціації стандартів доказування, що застосовуються у цивільних (господарських) і кримінальних справах, та пояснити, як може бути, що один і той же факт вважається доведеним для цілей цивільного судочинства, але водночас недоведеним для цілей кримінального обвинувачення. В основу дослідження покладено методологію Байєсівської теорії рішень. Стаття демонструє, як принципи теорії рішень Байєса можуть бути застосовані до судового встановлення фактів. Згідно з теорією Байєса, застосовуваний стандарт доказування залежить від відношення шкідливості хибно ствердних помилок до шкідливості хибно заперечних помилок. Оскільки в цивільному судочинстві обидва типи помилок мають однакові наслідки, порогове значення засудження становить 50+ відсотків. Натомість у кримінальній справі шкідливість хибно ствердних помилок істотно перевищує шкідливість хибно заперечних помилок, а отже, порогове значення переконаності має бути набагато вищим, і становить 90 відсотків. Байєсівська теорія рішень базується на ймовірнісних оцінках. І оскільки поняття ймовірності має ряд різних значень, результати застосування Байєсівської теорії до судового встановлення фактів можуть трактуватися по-різному. Маючи справу зі статистичними доказами, слід розрізняти суб'єктивну та об'єктивну ймовірність. Статистичні дані вказують на об'єктивну ймовірність, тоді як стандарт доказування стосується суб'єктивної ймовірності. Проте в деяких випадках, особливо коли статистичні дані є єдиними доступними доказами, суб'єктивна ймовірність може дорівнювати об'єктивній ймовірності. У таких випадках статистичні дані не можна ігнорувати

Ключові слова: стандарт доказування, Байєсівська теорія рішень, стандарт «поза розумним сумнівом», стандарт «баланс ймовірностей», гола статистика

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STANDARD OF PROOF IN COMMON LAW: MATHEMATICAL EXPLICATION AND PROBATIVE VALUE OF STATISTICAL DATA

Abstract. *As a result of recent amendments to the procedural legislation of Ukraine, one may observe a tendency in judicial practice to differentiate the standards of proof depending on the type of litigation. Thus, in commercial litigation the so-called standard of “probability of evidence” applies, while in criminal proceedings – “beyond a reasonable doubt” standard applies. The purpose of this study was to find the rational justification for the differentiation of the standards of proof applied in civil (commercial) and criminal cases and to explain how the same fact is considered proven for the purposes of civil lawsuit and not proven for the purposes of criminal charge. The study is based on the methodology of Bayesian decision theory. The paper demonstrated how the principles of Bayesian decision theory can be applied to judicial fact-finding. According to Bayesian theory, the standard of proof applied depends on the ratio of the false positive error disutility to false negative error disutility. Since both types of error have the same disutility in a civil litigation, the threshold value of conviction is 50+ percent. In a criminal case, on the other hand, the disutility of false positive error considerably exceeds the disutility of the false negative one, and therefore the threshold value of conviction shall be much higher, amounting to 90 percent. Bayesian decision theory is premised on probabilistic assessments. And since the concept of probability has many meanings, the results of the application of Bayesian theory to judicial fact-finding can be interpreted in a variety of ways. When dealing with statistical evidence, it is crucial to distinguish between subjective and objective probability. Statistics indicate objective probability, while the standard of proof refers to subjective probability. Yet, in some cases, especially when statistical data is the only available evidence, the subjective probability may be roughly equivalent to the objective probability. In such cases, statistics cannot be ignored*

Keywords: *standard of proof; Bayesian decision theory; beyond reasonable doubt; balance of probabilities; naked statistics*

INTRODUCTION

To prove a statement in court means to persuade the court or the jury (together referred to as “the fact-finder”) that the statement is true. But persuasion is a gradable concept, which means that the fact-finder may be more or less persuaded. Therefore, it is crucial to specify what degree of persuasion is sufficient for the fact-finder to hold that a statement is true, and the judgment can be based on it. In other words, if we express persuasion in percentage terms (supposing that one may be 100 per cent persuaded or 90 per cent persuaded etc.) then what is the threshold value necessary to adjudicate a case? Is 100 per cent persuasion the only acceptable threshold to serve justice? Is it ever achievable?

In civil law countries, these issues are not paid sufficient attention [1, p. 253-255, 258; 2, p. 1593]. Ukraine is no exception. Until recently, the very concept of the standard of proof was unknown to Ukrainian jurisprudence. As Justice of the Supreme Court Konstantin Pilkov notes, the courts started to apply it not earlier than 2018-2019 [3]. In accordance with the tradition of civil law countries, the procedural legislation of Ukraine stipulates that a judge shall assess evidence according to his/her inner conviction¹. This provision is supplemented by the rule that no evidence has a pre-established probative value for the court². Along with this, among the criteria for evaluating

1. Civil Procedural Code of Ukraine, Paragraph 1, Article 89. (2004, March). Retrieved from <https://zakon.rada.gov.ua/laws/show/1618-15/ed20040318#Text>; Criminal Procedural Code of Ukraine, Paragraph 1, Article 94. (2010, April). Retrieved from <https://zakon.rada.gov.ua/laws/show/4651-17/ed20100418#Text>; Commercial Procedural Code of Ukraine, Paragraph 2, Article 79. (2003, January). Retrieved from <https://zakon.rada.gov.ua/laws/show/436-15/ed20030116#Text>; Administrative Procedural Code of Ukraine, Paragraph 2, Article 76. (2005, July). Retrieved from <https://zakon.rada.gov.ua/laws/show/2747-15#Text>.

2. Civil Procedural Code of Ukraine, Paragraph 2, Article 89. (2004, March). Retrieved from <https://zakon.rada.gov.ua/laws/show/1618-15/ed20040318#Text>; Criminal Procedural Code of Ukraine, Paragraph 2, Article 94. (2010, April). Retrieved from <https://zakon.rada.gov.ua/laws/show/4651-17/ed20100418#Text>; Commercial Procedural Code of Ukraine, Paragraph 2, Article 86. (2003, January). Retrieved from <https://zakon.rada.gov.ua/laws/show/436-15/ed20030116#Text>; Administrative Procedural Code of Ukraine, Paragraph 2, Article 90. (2005, July). Retrieved from <https://zakon.rada.gov.ua/laws/show/2747-15#Text>.

evidence, procedural codes mention sufficiency and reliability¹. However, the above provisions of the law do not allow understanding when a judge can “diagnose” themselves as having necessary inner conviction, which would allow him to recognize the evidence as sufficient and reliable.

Furthermore, until recently, it was tacitly accepted that the standard of proof in civil and criminal cases is the same. However, under the influence of the case law of the European Court of Human Rights and as a result of changes in the procedural law², there is now a tendency to distinguish between the standard of proof in criminal proceedings (where “beyond reasonable doubt” standard applies) and the standard in commercial proceedings (where the so-called standard of “probability of evidence” applies). Notably, amendments pertaining to the standard of proof were introduced into the Commercial Procedural Code³, while the Civil Procedural Code remains unchanged in this regard⁴.

The tendency to differentiate the standards of proof is new for Ukrainian courts and therefore for doctrinal justification. Academicians can help clarify the reasons for the existence of distinct standards of proof for different types of proceedings. Second, comparative law studies can predict vexed questions Ukrainian courts will have to cope with in the future. In this vein, it is helpful to resort to the doctrine of common law, where the tradition of distinguishing between the standards of proof has been the subject of thorough scholarly analysis. In common law countries, there are two different standards of proof – one for criminal cases and one for civil cases. The former is known as ‘beyond reasonable doubt’ standard (BRD), the latter is known as ‘balance of probabilities’ (in the United Kingdom) or ‘preponderance of the evidence’ (in the United States) (BoP) [4, p. 280; 5, p. 80; 6, p. 1-2].

In criminal cases, the threshold value of persuasion is much higher than in civil cases. Under the BRD-standard, the fact-finder has to be almost certain that the statement is true. In numbers BRD-standard amounts to 90 per cent conviction [7, p. 1; 8, p. 561]. On the contrary, in civil cases a much lower degree of conviction is sufficient: the fact-finder has merely to find the trueness of the statement more probable than its falseness. In numbers, it amounts to 50+ percent conviction [9, p. 168; 10, p.1076-1077; 11, p. 384-386]. It means that one and the same fact may be considered proven for the purposes of civil litigation, but at the same time unproven for the purposes of criminal charge. A bright example is the famous O.J. Simpson case [12].

The standard of proof issue was addressed by many writers, which include J. Chalmers [13], E.K. Cheng [14],

K.M. Clermont [1; 15-18], C. Engel [19], J. Kaplan [20], D.H. Kaye [7; 21; 22], J. Leubsdorf [2], B. Luppi, F. Parisi, D. Pi [23], M. Schweizer [6], G. Tuzet [24], R.W. Wright [5] and other.

1. MATERIALS AND METHODS

The methodology employed was determined by the purpose of this study, which is to find a rational explanation of why the standard of proof in civil and criminal proceedings should be different, and, accordingly, how the same fact can be considered proven in a civil case and unproven – in a criminal case. The methodological framework of the study is Bayesian decision theory. This theory is based on Bayes' theorem and offers an algorithm to make a rational decision under uncertainty, when the real state of affairs is unknown and only the probability values are available. According to this theory, a rational decision is one that will result in the maximum value of the expected utility under the given conditions. Therefore, it calls for determining the expected utility value of each of the possible decisions and considering the probability that such a decision can appear to be wrong.

Through the use of mathematical modelling, the principles of Bayesian decision theory are applied to judicial fact-finding process in civil and criminal proceedings. The publications of D. Kaye and J. Kaplan constitute the theoretical basis of this exercise. The utility maximisation function is replaced by the equivalent disutility minimisation function, and it is assumed that a correct decision on the issue of fact does not have any disutility. The article mentions the methodology of behaviourism in the context of the discussion of whether the actor's perceptions should be considered when determining the utility value brought by a particular decision.

Since Bayesian decision theory is premised on probabilistic judgments, it is necessary to explain what is meant by probability in the context of the judicial fact-finding. According to D. Kaye probability has at least seven different meanings (mathematical probability, informal probability, classical probability, frequentist probability, logical probability, personal probability and propensity theory) [22, p. 164-166]. That is why the second part of the article addressed the problem where different interpretations of probability are most evident. It is the problem of using statistical data as evidence in court proceedings, or the so-called “naked statistics” problem. This problem most often manifests in tort cases, where the plaintiff claims that the damage to his or her health was caused by a toxic substance (for example,

1. Civil Procedural Code of Ukraine, Articles 78, 79. (2004, March). Retrieved from <https://zakon.rada.gov.ua/laws/show/1618-15/ed20040318#Text>; Administrative Procedural Code of Ukraine, Articles 75, 76. (2005, July). Retrieved from <https://zakon.rada.gov.ua/laws/show/2747-15#Text>.

2. Commercial Procedural Code of Ukraine, Article 79. (2003, January). Retrieved from <https://zakon.rada.gov.ua/laws/show/436-15/ed20030116#Text>.

3. *Ibidem*, 2003.

4. Civil Procedural Code of Ukraine, Articles 77-80. (2004, March). Retrieved from <https://zakon.rada.gov.ua/laws/show/1618-15/ed20040318#Text>.

asbestos-containing dust). In this part of the study, the methods of statistical analysis were used. Furthermore, the authors employed the epidemiological concept of relative risk. In particular, it is explained how the concept of relative risk in epidemiology is related to the standard of proof and the problem of establishing causation in some personal injury cases.

Particular attention was paid to the analysis of the hypothetical Blue Taxi case, which is widely discussed in the literature. In this context, the methodology of law and economics was also used with reference to one of its founders – R. Posner. The empirical framework of this study included the case law of American courts in cases where they had to decide on the probative value of statistics. Those are, in particular, the case of *Herskovits v. Group Health Cooperative of Puget Sound* [25] and *Sargent v. Massachusetts Accident Co.* [26].

Although the article does not directly compare the doctrine of common law with the law of Ukraine, it nevertheless has a comparative context, as the authors sought to emphasise the universalism of the idea of rational decision-making and its applicability regardless of whether the jurisdiction belongs to common law or to civil law family. After the amendments to the Commercial Procedural Code of Ukraine and the introduction of the standard of “probability of evidence” in Ukrainian law, courts gradually begin to differentiate the standards of proof depending on the type of proceedings. This study offers a take at the achievements of the doctrine of common law to develop a more profound understanding of this differentiation, which will allow judges to approach the problem of proof more carefully and consistently, avoiding hasty manoeuvres on a new path.

2. RESULTS AND DISCUSSIONS

2.1 Bayesian decision theory as a rationalisation of the two standards of proof

Bayesian decision theory offers an algorithm of how to make a rational decision under uncertainty [8, p. 558-559].

Table 1. Fact-finder's findings

	The fact took place	The fact did not take place
Found that the fact took place	a1	a0
Found that the fact did not take place	n0	n1

However, operating under uncertainty, one cannot calculate the real disutility; only the expected disutility value can be known [7, p. 10]. The latter is defined as the real disutility of the incorrect decision (L_{a0} or L_{n0}) multiplied by the probability factor that the decision will appear to be incorrect. If the probability that the fact really took place is p , and the probability that the fact did not really take place is $1 - p$, then the expected disutility of a false positive decision is $L_{a0} \times (1 - p)$, and the expected disutility of the false negative decision is $L_{n0} \times p$.

Therefore, it is rational to

opt for decision a whenever $L_{a0} \times (1 - p) < L_{n0} \times p$; and
opt for decision n whenever $L_{a0} \times (1 - p) \geq L_{n0} \times p$.

Next, if one takes an equilibrium point when the

Thus, the first step in its application is to acknowledge that the court and the jury operate under uncertainty. In this context, it is determined that a fact-finder cannot gain absolute knowledge of the facts under investigation [4, p. 275, 282; 9, p. 167; 19, p. 436], and therefore has to decide proceeding from incomplete knowledge, relying only on the greater or lesser probability of the relative facts (*The unattainable nature of absolute truth (absolute certainty) is emphasised even in the description of the criminal standard of proof*).

A rational decision is one that results in the maximum possible value of utility under the set conditions (utility maximisation) or, what is the same, minimum possible value of disutility under the set conditions (disutility minimisation) [1, p. 252-253; 6, p. 8; 7, p. 1-2; 21, p. 55; 20]. The fact-finding process can be analysed in terms of either function, but the analysis through the prism of disutility minimisation is somewhat more convenient and therefore prevail in the literature.

Regarding a particular fact, the fact-finder can make only one of two decisions: either that this fact really took place (true) or that it did not really take place (false). Both the first and the second decision can be either correct or incorrect. Thus, there are four possible scenarios: the fact-finder concludes that the fact took place, and it really did (a1); the fact-finder concludes that the fact took place, although it really did not (a0); the fact-finder concludes that the fact did not take place, and it really did not (n1); the fact-finder concludes that the fact did not take place, although it really did (n0) (Table 1). Scenarios a0 and n0 are called false positive and false negative errors, respectively, (or “alpha error” and “beta error” [19, c. 444-445]).

Of the two alternative decisions, it is rational to choose the one which results in less disutility. Assuming that the correct decisions do not result in any disutility, then it is rational to opt for positive decision whenever the disutility of false positive error (L_{a0}) is less than the disutility of false negative error (L_{n0}).

expected disutilities of false positive and false negative errors are equal, that is, $L_{a0} \times (1 - p) = L_{n0} \times p$, then, having solved the obtained equation, one can find the threshold value p^* , i.e., fact's probability value, below which it is rational to act as if the fact did not take place, and above which – it is rational to act as if the fact did take place. This threshold value p^* is calculated as follows:

$$p^* = \frac{L_{a0}}{L_{a0} + L_{n0}} \quad (1)$$

In Figure 1 (after [7, p. 12-14]) the descending line from the vertex L_{a0} denotes the expected disutility of the false positive error: it decreases with the increase in probability that the fact really took place (p). Instead, the ascending line to the vertex L_{n0} denotes the expected disutility of the false

negative error: contrariwise, it increases with the decrease in the probability that the fact really took place (However, it is more precise to represent the expected disutility function via the normal distribution curve (Gaussian distribution), the vertex of which corresponds to $p = 0$ (for the expected

disutility of a false positive error) or $p = 1$ (for the expected disutility of the false negative error)). Sought-for threshold value p^* is the probability value at the point of intersection of these two lines.

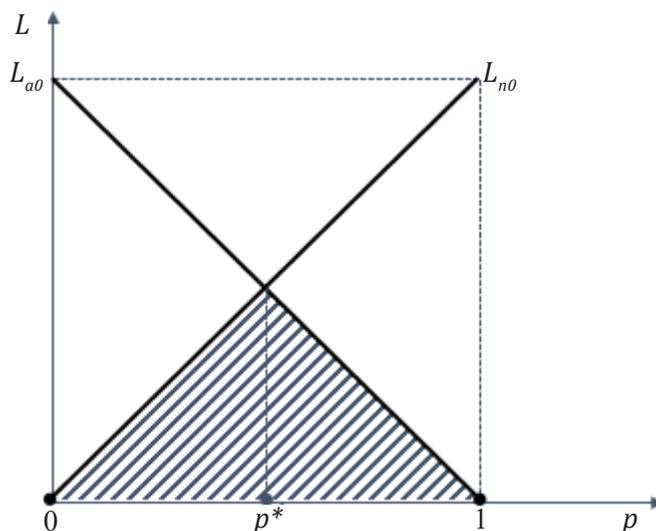


Figure 1. Threshold value of probability (p^*) where disutility of false positive error (L_{a0}) equals disutility of false negative error (L_{n0})

If up to this point one opts for the negative decision, and after it – for the positive decision, one gets the minimum amount of expected disutility possible resulting from one's decisions (Figure 1 demonstrates this amount as the shaded triangle). In this way, the goal of minimising disutility is achieved, and thus the decision-making strategy can be considered as rationally justified, despite the incompleteness of knowledge available.

Next, the point p^* can move along the p -axis closer to the right ($p = 1$), or closer to the left ($p = 0$). It depends on how the vertices L_{a0} and L_{n0} relate to each other. If they

are equal (as in Figure 1), then the point p^* will lie exactly in the middle, i.e., at the value of 0.5 (or 50%) because in this case:

$$p^* = \frac{L_{a0}}{L_{a0} + L_{n0}} = \frac{1}{1 + 1} = \frac{1}{2} \quad (2)$$

But if L_{a0} is greater than L_{n0} , then the value of p^* will move closer to the right edge (as shown in Figure 2). So, for example, if $L_{a0} = 8 L_{n0}$, then we obtain:

$$p^* = \frac{L_{a0}}{L_{a0} + L_{n0}} = \frac{8}{8 + 1} = \frac{8}{9} \approx 0.9 \quad (3)$$

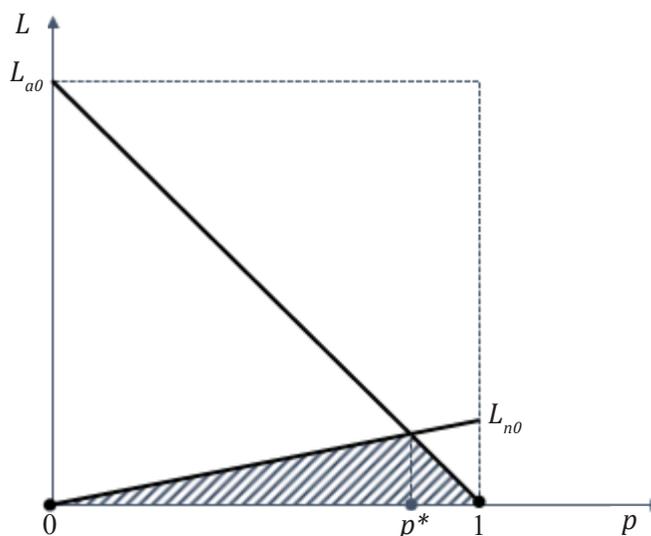


Figure 2. Threshold value of probability (p^*) where disutility of false positive error (L_{a0}) exceeds disutility of false negative error (L_{n0})

Thus, the greater the disutility of the false positive error, compared to the disutility of the false negative error, the closer to the right edge moves the threshold value p^* (and vice versa). That is, the greater the disutility from the false positive error than the disutility of the false negative error, the more confident one must be to opt for the positive decision. Therefore, if the disutility of the false positive error is eight times greater than the disutility of the false negative error, then taking a positive decision is rational only if the decision-maker is more than 90% sure that the fact on which the decision is based did really take place. On the other hand, if the disutility of the false positive error is equal to the disutility of the false negative error, it is enough to be just more than 50% sure that the fact on which the decision is based did really take place.

The above sets the scene for the justification of why the standards of proof should be different in civil and criminal cases. In a civil case, money or some other pecuniary interest is usually at stake. Upholding a claim is the positive decision and rejecting a claim – is the negative decision. Accordingly, the false positive error is when the court upholds a claim that under the complete knowledge would have been rejected. The false negative error is when the court rejects the claim, that under the complete knowledge would have been upheld.

Assuming the price of the claim is 10,000 USD, the false positive error results in defendant's losing 10,000 USD he/she should not lose; the false negative error results in plaintiff's not obtaining 10,000 USD he/she should obtain. It is generally accepted that the disutility in both cases is the same, since every dollar erroneously not received by the plaintiff has the same value as a dollar erroneously overpaid by the defendant [1, p. 252; 2, p. 1580-1581; 4, p. 280; 6, p. 3; 8, p. 559; 9, p. 171; 18, p. 469-470]. That is, $L_{a0} = L_{n0}$, which means that, according to the Bayesian formula, the probability threshold p^* is equal to 0.5, and this is precisely the threshold value set by the "balance of probability" (or "preponderance of evidence") standard [8, p. 560].

In contrast to civil cases, in criminal cases the situation is fundamentally different: under a liberal regime (*The Bayesian formula for decision-making alone does not determine the standard of proof since the respective values of the variables need to be substituted into the formula. Estimation of these values is a political decision, and it depends on the political regime. Under an authoritarian regime, the punishment of an innocent may be considered less harmful than when a guilty one goes unpunished*), convicting an innocent person (false positive error) is considered much worse than acquitting the guilty one (false negative error) [1, p. 268; 6, p. 3; 8, p. 560]. By some estimates, ten times worse [8, p. 562]. That is, $L_{a0} = 10 \times L_{n0}$. Substituting these values into the formula yields the following:

$$p^* = \frac{L_{a0}}{L_{a0} + L_{n0}} = \frac{10}{10 + 1} = \frac{10}{11} \approx 0.9 \quad (4)$$

It means that to convict a person of committing a criminal offence, the fact-finder needs to be more than 90% sure that the accused did really commit it. And this is

precisely the threshold required by the 'beyond a reasonable doubt' standard. The approach prevailing in common law, therefore, is based on three basic tenets. First, the court and the jury have to decide under uncertainty, i.e., in a situation where the absolute truth about the facts of the case is not achievable. Second, under uncertainty, the best thing to do is to make a rational decision based on the available knowledge, i.e., a decision that minimises the total amount of expected disutility. Third, in civil cases the disutility of the error favouring the plaintiff equals the disutility of the error favouring the defendant; instead, in criminal cases, a mistake favouring the prosecution is much worse than a mistake favouring the defence.

The first tenet seems to be commonly accepted. As for the other two, there is some criticism. Thus, R. Allen insists that the goal should be to minimise the real disutility instead than expected disutility [27, p. 47; 28, p. 641; 29, p. 346]. But, as D. Kaye points out, minimising the real disutility calls for the data that is not usually available in the real world [7, p. 27]. Secondly, the more cases are considered, the more the real disutility approaches the expected disutility value [7, p. 30] (as with a coin toss: out of ten attempts, the number of heads may be other than five, but out of a thousand attempts, the number of eagles will be close to five hundred [21, p. 57]). Thus, eventually, the strategy of minimising the expected disutility leads to minimising real disutility as well.

As for the third tenet, there are two limbs of criticism. The first is based on behaviourism: there is empirical evidence showing that gaining something is perceived emotionally less intensively than losing the same [6, p. 10; 30, p. 279]. Gaining a thousand dollars brings less satisfaction than losing a thousand dollars brings frustration. From this point of view, the erroneous recovery of a thousand dollars from the defendant is emotionally experienced by the latter not in the same way as the plaintiff experiences an erroneous rejection of their claim for the same amount. However, it is debatable whether such emotional experiences should be considered when determining the rational approach to decision-making.

The second limb essentially lies in stressing that all civil or criminal cases are not the same and, thus, applying the same standard to all civil or criminal cases is effectively a "one-size-fits-all" approach [4, p. 285-286]. Indeed, if the subject of the dispute is money, then there really is a symmetry [4, p. 280]: the erroneous recovery of the money is as harmful to the defendant as its erroneous non-recovery – to the plaintiff. But in contrast, there are many civil cases in which entirely different, non-pecuniary interests are at stake: for example, cases involving deprivation of parental rights, protection of honour, dignity or business reputation, restriction of legal capacity etc. In such cases, there is no symmetry – the ratio of the two errors' disutility is other than 1:1. The same is true for the criminal cases: unlike cases involving imprisonment, there are cases of petty criminal offences where pecuniary punishment is at stake. Thus, according to K. Kotsoglou, the common view of the standards of proof is generally incoherent, since if one acknowledges

that the standard of proof is dependent on what is at stake in the trial, one should infer that the standard has to be determined for each case individually (depending on what is at stake in this particular case) rather than be fixed for all civil or all criminal cases altogether [4, p. 286].

To some extent, the third, “higher” civil standard of proof (“clear and convincing evidence”) may serve as a response to this objection. In this context, it is noteworthy that the Supreme Court of New Jersey in the case of *In re Polk License Revocation* [31] pointed out that “the clear and convincing standard has been found to be required as a matter of due process when the threatened loss resulting from civil proceedings is comparable to the consequences of a criminal proceeding in the sense that it takes away liberty or permanently deprives individuals of interests that are clearly fundamental or significant to personal welfare”. The main argument against the ‘floating’ standard of proof is, however, that it would be practically difficult to implement it [19, p. 447].

Probative value of the statistical data. For proper understanding of the standard of proof concept, it is necessary to address the issue of so-called “naked statistics”. The crux of the issue is to find out what probative value (if any) statistical data has. The issue has provoked heated debate in the academic literature and legal science. Suppose that in some city there are only two taxi services – Blue Taxi and Yellow Taxi, and the former has a fleet of vehicles three times larger than the latter. Thus, of all the taxis on the city roads, 75% are blue and 25% are yellow. Suppose further that a pedestrian was knocked down by a taxi, but he cannot recall its colour. Is it sound to hold a Blue Taxi liable for the damage proceeding solely from the fact that statistically the probability of the car being blue is greater (0.75)? It would be a hasty conclusion, even though at first glance it may seem that the threshold set by the civil standard of proof has been surmounted ($0.75 > 0.5$).

In *Herskovits v. Group Health Cooperative of Puget Sound* [25] Justice Brachtenbach (dissenting) stated: “This fact has relevancy; it is admissible. But is it sufficient to prove the blue cab company more probably than not committed the act? No. If this were not the case, the blue cab company could be held liable for every unidentified cab accident that occurred. Thus, statistics alone should not be sufficient to prove proximate cause. What is necessary, at the minimum, is some evidence connecting the statistics to the facts of the case. Referring back to the cab example, testimony that a blue cab was seen in the vicinity of the accident before or after it occurred or evidence of a recently acquired, unaccounted for, dent in a blue cab could combine with the statistical evidence to lead a jury to believe it was more probable than not that this plaintiff was hit by a blue cab”.

The Blue Taxi case shows that there are really two different types of probability: objective and subjective. Subjective probability describes the level of confidence that some statement is true, or, in other words, the readiness to act like it were true. It is the level of our belief [4, p. 283]. Subjective probability is backward-looking: one decides

whether one believes in the facts that have taken place in the past, regarding which one does not have complete information. In contrast, objective probability is a numerically calculated concept in probability theory that describes properties of the objective world [4, p. 283]. For example, the fact that a considerable number of coin tosses show heads half of the times – it is an objective probability that describes the laws of the real world. Objective probability is forward-looking: it allows calculating the odds or chances that something will happen in the future (for example, it is the chances that one is dealing with while betting on sports).

Confusion of objective and subjective probability leads to fallacious perception of what standard of proof means [5, p. 91-95; 11, p. 379; 32]. Standard of proof sets the threshold value of subjective probability, i.e., the level of confidence the fact-finder should have to conclude that the statement is true; meanwhile 0.75 in Blue Taxi case is a value of objective probability, which indicates the odds or chances to be hit by a blue car. But when a person has already been hit, there are no odds or chances any more, it was either a blue car or not. From this point on, it becomes merely a matter of one's knowledge: one does not know which of two alternatives happened, and therefore one believes more or less in one of the versions.

In *Sargent v. Massachusetts Accident Co.* [26] J. Lummus stated: “It has been held not enough that mathematically the chances somewhat favour a proposition to be proved; for example, the fact that coloured automobiles made in the current year outnumber black ones would not warrant a finding that an unidentified automobile of the current year is coloured and not black, nor would the fact that only a minority of men die of cancer warrant a finding that a particular man did not die of cancer. ... a proposition is proved by a preponderance of the evidence if it is made to appear more likely or probable in the sense that real belief in its truth, derived from the evidence, exists in the mind or minds of the tribunal notwithstanding any doubts that may linger there”.

Thus, statistical probability and subjective probability are two indicators on two different scales. In the case of the Blue Taxi, the statistical data were not sufficient to form the necessary level of belief in the mind of the fact-finder that the victim was hit by a blue car. However, it would be wrong to claim based on Blue Taxi case that statistical probability has no probative value at all and hence it can never be used to prove causation in a particular case. Richard Posner suggests digging deeper into the reasons why exactly the statistical data in Blue Taxi case seem unconvincing [33, p. 39-42]. According to Posner, the main reason is the overall implausibility of the situation where there is absolutely no other evidence that could help identify the car apart from the naked statistics [33, p. 40].

The fact that the plaintiff failed to provide any other evidence (apart from the ratio of the number of cars belonging to two services) provokes two assumptions: either the plaintiff knows that he was hit by a yellow car, but for some reason he wants to avoid suing the Yellow Taxi (maybe, it is insolvent or has ceased to exist), or the

plaintiff poorly prepared his case and did not bother to find other evidence [33, p. 40-41]. If the first assumption is correct, admittedly, the claim is not subject to satisfaction. And the very possibility of such an assumption renders the subjective probability lower than the objective probability. If the second assumption is correct, then the hint of guilt for the plaintiff disinclines to believe in the veracity of his allegations. From law and economics perspective, “[a] court should not expend any of its scarce resources of time and effort on a case until the plaintiff has conducted a sufficient search to indicate that an expenditure of public resources is reasonably likely to yield a significant social benefit” [33, p. 41].

Instead, assuming that both parties have conducted a thorough investigation and did everything in their power, but nevertheless failed to find other evidence – in this case, a decision based on objective probability no longer seems an ill-founded [33, p. 41]. Thus, the vital question is whether evidence other than statistical data could have been obtained, and if not, was it due to the plaintiff’s fault? If no evidence other than statistical data is available, and the plaintiff is not to blame for it, the ponderance of statistics increases significantly and the subjective probability may approach the value of the objective probability indicated by the statistics [34; 35].

The need for admissibility of statistical evidence is particularly acute in cases of so-called toxic torts [11], where often the epidemiological data is the only evidence available that can prove a causal link between a toxic substance and a disease. In such cases, it is proffered to employ doubling the risk principle to assess causal nexus. This principle is based on the epidemiological concept of relative risk (*RR*) [36, p. 195-209; 37, p. 305-307]. Relative risk is the ratio of the incidence of a disease in a group exposed to a toxic substance to the incidence of a disease in a control group that has not been exposed to the substance [32, p. 129]. Therefore,

$$RR = \frac{\text{Risk in exposed group}}{\text{Risk in unexposed group}} \quad (5)$$

For example, if among the population not exposed to substance X the incidence of lung cancer is 1.5%, whilst among the population exposed it is 3%, then

$$RR = \frac{3}{1.5} = 2 \quad (6)$$

This means that the exposure to substance X doubles the risk of lung cancer. If $RR = 1$, it means that there is no correlation between the substance and the disease. Under doubling the risk doctrine, the causal nexus between exposure to substance and the disease shall be considered proven whenever $RR > 2$. Suppose that, in the above example, the incidence of the disease among the population exposed to substance X is 3.5% (instead of three). Thus, $RR = 2.3$. This means that for every 1,000 people exposed to substance X, 35 people contract the disease. However, 15 of them would have contracted the disease even if they had not been exposed to the substance, while 20 would not have contracted the disease but for the exposure. Therefore, statistically, the probability that a random person suffering from the disease

has contracted it because of the exposure is $20/35 = 0.57$. Such a statistical probability will always be greater than 0.5, provided that $RR > 2$. And since often in such cases objective (statistical) probability is the only knowledge available to humankind (since medical science cannot describe the aetiology of the disease in each particular case), there is no choice but to rely on this objective probability.

Against the application of doubling the risk doctrine, the following argument is submitted. Indeed, whenever $RR > 2$ among the exposed who contracted the disease, there are two categories of people: first is the people who contracted the disease as a result of exposure; second is the people whose disease was caused by some other factors. And it is correct that $RR > 2$ indicates that the first category is more numerous than the second. But it does not indicate to which of the two categories a particular plaintiff belongs [5, p. 92; 11, p. 383].

It is all about the distinction between general and individual causation [5, p. 92; 32, p. 125]. General causation answers whether some substance X is theoretically capable of causing the disease Y. Individual causation answers whether in this particular case the disease Y was caused by the substance X? [36, p. 127]. In substantiating the tort claim, the plaintiff must persuade the fact-finder that the answers to both questions are in the affirmative. The opponents of the use of statistical evidence insist that epidemiological data can only be helpful regarding the first question, and cannot clarify anything regarding the second, since epidemiology deals with populations, and not with a single case [5, p. 91-96; 11, p. 379-380, 390].

It is true that epidemiology does not solve the issue of individual causation. However, it does not follow that the plaintiffs should be denied compensation. Because, if in the given example with 35 diseased per thousand the courts deny all the claims on the ground that epidemiology does not prove individual causation, at the end of the day, the majority of court judgments (20) will turn out to be fallacious (since of all 35 people whose claims were rejected, 20 really deserved compensation); on the contrary, if the courts satisfy all the claims, recognising doubling the risk doctrine, then in a long run the number of fallacious decisions will amount to 15 and this number will be always less than the number of correct ones provided that $RR > 2$.

CONCLUSIONS

From the perspective of civil law countries, it may sound discordant that one and the same fact may be considered proven in the civil case and not proven in the criminal case. However, there is nothing irrational in it. As a starting point, one has to acknowledge that the fact-finder acts under uncertainty and conviction is a gradable concept. Once these premises are accepted, the question is how to determine the threshold value of conviction that would suffice for the specific purposes of civil litigation or criminal charge. The rational answer to this question can be found through the use of Bayesian decision theory. This theory offers an algorithm of rational decision-making under uncertainty. The decision is considered rational if it yields the

maximum possible utility value (or, which is the same, – the minimum possible disutility value). According to Bayesian decision theory, the standard of proof applicable in the proceedings depends on the ratio of false positive error disutility to false negative error disutility. Since in a civil case two types of error have equal disutility, the threshold value of conviction is 50+ percent. Instead, in a criminal case, false positive error disutility significantly exceeds false negative error disutility and therefore the threshold value of conviction is much higher – 90 percent.

Bayesian decision theory is based on probabilistic judgments. And since the concept of probability has many distinct meanings, the results of the application of Bayesian theory to judicial fact-finding can be interpreted in several ways. A bright illustration of this conflict of interpretations is the problem revolving around the probative value of statistical data.

However, it does not mean that statistics and subjective probability are out of contact with each other. In some cases, statistics (including epidemiological data) may be the only available evidence of a causal nexus between wrongdoing and harm. If the absence of any other evidence cannot be blamed on the plaintiff (or even more – can be blamed on the defendant), then the statistics may well determine the degree of subjective probability. In other words, the value of subjective probability (belief) can approach the value of the objective probability indicated by statistics. In such cases, statistics cannot be ignored.

RECOMMENDATIONS

This study may be of use for judges, lawyers, law professors, law students and everyone interested in evidence law in general and in the issue of the standard of proof in particular.

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