Burdens of Persuasion and Standards of Proof in Structured Argumentation

Burdens of Persuasion and Standards of Proof in Structured Argumentation*

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Abstract. In this paper we provide an account of the burden of persuasion, in the context of structured argumentation. First, burdens of proof in legal proceedings are discussed in general, distinguishing the burdens of production and the burdens of persuasion. Then, we focus on burdens of persuasion, illustrating their role in civil and criminal law.
A formal model for the burden of persuasion is then defined, discussed, and used to capture the role of the burden of persuasion in adjudicating conflicts between conflicting arguments and in determining the dialectical status of arguments. We consider how our model can also capture adversarial burdens of proof, namely, those cases in which failure to establish an argument for a proposition burdened with persuasion entails establishing the complementary proposition.
Finally, we examine how burdens of proofs can be integrated with standards of proof defining the extent to which an argument for a proposition burdened with persuasion has to be stronger than arguments to the contrary, in order to meet the burden.

Keywords: burden of persuasion, argumentation, legal reasoning, standard of proof

1 Introduction

The burden of proof is a central feature of many dialectical contexts. It is particularly relevant in those domains, such as legal disputations or political debates, in which controversial issues are discussed in order to adopt a decision (see [23] on burdens of proof in different dialogue types).

Generally speaking, we can say that burdens of proof distribute dialectical responsibilities between the parties in a dialogue. In other words, when a party has a burden of proof of type b relative to a claim ϕ, then, unless the party provides the kinds of arguments or evidence that is required by that type of burden, the party will lose on ϕ. Losing on the burdened claim means that, for the purpose of the dialectic interaction at stake, it will be assumed that ϕ has not been established, not even as a relevant possibility.

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Burdens of proof complement the analysis of dialectical frameworks that are provided by argumentation systems. In particular, they are important in adversarial contexts: they facilitate the process of reaching a single outcome in contexts of doubt and lack of information. This is obtained, we shall argue, by ruling out (considering as unacceptable) those arguments which fail to meet any applicable burden.

Research in AI & law has devoted a number of contributions to the formal analysis of burdens of proof: models of defeasible legal reasoning have been criticised for not taking burdens of proof into account [11], the distinction between different standards of proof has been addressed [5], formal accounts of burdens of proof have been developed within models for formal argumentation [19, 8, 2]. However, it seems to us that a comprehensive model of burdens of proof in legal reasoning is still missing.

In the legal domain, two types of burdens can be distinguished: the *burden of production* (also called burden of providing evidence, or 'evidential' burden), and the *burden of persuasion* [19]. This terminology is used in common law systems [24], but the distinction is also recognised in civil law jurisdiction, possibly using a different terminology [10]. The focus of this paper is on the burden of persuasion. We will show how an allocation of the burden of persuasion may induce single outcomes in contexts in which the assessment of conflicting arguments would, without such an allocation, remain undecided.

Our model builds upon approach introduced in Prakken and Sartor [19, 9, 20], i.e., upon the view that burdens of persuasion complement argument priorities in deciding conflicts between arguments raising incompatible claims: unless priorities provide for a different outcome, the argument for a claim burdened with persuasion loses. This approach, however, does not address the cases in which the burden of persuasion concerns the conclusion of a multistep argument, which is subject to undecided challenges against earlier inference steps. We shall argue that in such cases too, the argument has to be rejected: uncertainty upon non-final steps also entails failing to be persuasive.

The idea is related to the Carneades' approach [7, 8], according to which the dialectical status of an argument determines whether a burden of persuasion is satisfied. This approach uses different types of premises (ordinary premises, assumptions, and exceptions) and information about the dialectical status of statements (stated, questioned, accepted, or rejected) to allocate burdens of proof and assess whether they have been met.

Hence our analysis combines Prakken and Sartor's [17, 19] model with the insight from Carneades' [7], and takes into account the fact that the persuasiveness of an argument, in a dialectical context, is determined not only by the internal strength of the argument, as determined by the strength of the inference rules used for building the argument (according, for instance, to the last link criterion), but also by the applicable counterarguments.

Our model originates from legal considerations and is applied to legal examples. However, the issue of the burden of proof has a significance that goes beyond the legal domain involving other domains – such as public discourse,

risk management, etc. – in which evidence and arguments are needed, and corresponding responsibilities are allocated, according to types of dialogues and dialectical or organisational roles [22, 23].

The novelty of this contribution consists of a new definition of defeat relations involving arguments burdened with persuasion, a corresponding definition of the criteria for labelling such argument, and a formalisation of the concept of standards of proof.

2 Burdens of production and burdens of persuasion

Following the account in Prakken and Sartor [19], we distinguish the burden of production from the burden of persuasion. A party burdened with production needs to provide some support for the claim he or she is advancing. More exactly, we can say that the party has the burden of production for ϕ if the following is the case: unless relevant support for ϕ is provided – i.e., unless an argument for ϕ is presented that deserves to be taken into consideration – then ϕ will not be established (even in the absence of arguments against ϕ). When knowledge is represented through a set of rules and exceptions, the party interested in establishing the conclusion of a rule has the burden of production relative to the elements in the rule's antecedent, while the other party (who is interested in preventing the derivation of the rule's consequent) has the burden of production relative to the exceptions to the rule (as provided in a separate exception clause or in an unless-exception within the rule).

Meeting the burden of production for a claim ϕ is only a *necessary* condition, and not a sufficient one, for establishing ϕ, since the produced arguments may be defeated by counterarguments. This aspect is addressed by the burden of persuasion: the party looking to establish a claim burdened with persuasion needs to provide a 'convincing' argument for it—that is, an argument that prevails over arguments to the contrary to an extent that is determined by the applicable standard of proof. If there is a burden of persuasion on a proposition ϕ, and all arguments for ϕ fail to prevail over their counterarguments, then the party concerned will lose on ϕ.

Let us illustrate the way in which the burden of persuasion works through two examples, one from criminal law and one from civil law.

Burden of persuasion in criminal law In criminal law, the burden of production is distributed between prosecution and defence, while the burden of persuasion (in most legal systems) is always on prosecution. More exactly, in criminal law, the burden of production falls on the prosecution relative to the two constitutive elements of crime, namely, the criminal act (*actus reus*) and the required mental state (*mens rea*), be it intention/recklessness or negligence), while it falls to the defendant relative to justifications or exculpatory defences (e.g., self-defence, state of necessity, etc.). In other words, if both actus reus and mens rea are established, but no exculpatory evidence is provided, the decision should be criminal conviction. On the other hand, the burden of persuasion falls on the

prosecution for all determinants of criminal responsibility, including not only for the constitutive elements of a crime but also for the absence of justifications of exculpatory defences.

Example 1 (Criminal law example). Let us consider a case in which a woman, Hellen, has shot and killed an intruder in her home. The applicable law consists of *(a)* the rule according to which intentional killing constitutes murder, and *(b)* the exception according to which there is no murder if the victim was killed in self-defence. Assume that it has been established with certainty that Hellen shot the intruder and that she did so intentionally. However, it remains uncertain whether the intruder was threatening Hellen with a gun, as claimed by the defence, or had turned back and was running away on having been discovered, as claimed by prosecution. The burden of persuasion is on prosecution, who needs to provide a convincing argument for murder. Since, in this case, it remains uncertain whether there was self-defence, prosecution has failed to provide such an argument. Therefore, the legally correct solution is that there should be no conviction: Hellen needs to be acquitted.

Burden of persuasion in civil law In civil law, burdens of production and burdens of persuasion may be allocated in different ways. The general principle is that the plaintiff only has the burden of proof (both of production and persuasion) relatively to the operative facts that ground its claim, while the defendant has the burden of proof relative to those exceptions which may prevent the operative facts from delivering their usual outcomes, such as justifications with regard to torts, or incapability and vices of consent in contracts. However, derogations from this principle may be established by the law, in order to take into account various factors, such as the presumed ability of each party to provide evidence in favour of his or her claim, the need to protect weaker parties against abuses, etc.

In matters of civil liability, for example, it is usually the case that the plaintiff, who asks for compensation, has to prove both that the defendant caused him harm, and that this was done intentionally or negligently. However, in certain cases, the law establishes an inversion of the burden of proof for negligence (both the burden of production and the burden of persuasion). This means that in order to obtain compensation, the plaintiff only has to prove that he was harmed by the defendant. This will be sufficient to win the case unless the defendant provides a convincing argument that she was diligent (not negligent).

Example 2 (Civil law example). Let us consider a case in which a doctor caused harm to a patient by misdiagnosing his case. Assume that there is no doubt that the doctor harmed the patient: she failed to diagnose cancer, which consequently spread and became incurable. However, it is uncertain whether or not the doctor followed the guidelines governing this case: it is unclear whether she prescribed all the tests that were required by the guidelines, or whether she failed to prescribe some tests that would have enabled cancer to be detected. Assume that, under the applicable law, doctors are liable for any harm suffered by their patients, but they can avoid liability if they show that they were diligent (not negligent)

in treating the patient, i.e., that they exercised due care. Thus, rather than the patient having the burden of proving that doctors have been negligent (as it should be the case according to the general principles), doctors have the burden of providing their diligence. Let us assume that the law also says that doctors are considered to be diligent if they followed the medical guidelines that govern the case. In this case, given that the doctor has the burden of persuasion on her diligence, and that she failed to provide a convincing argument for it, the legally correct solution is that she should be ordered to compensate the patient.

These two examples share a common feature. In both, uncertainty remains concerning a decisive issue, namely, the existence of self-defence in the first example and the doctor's diligence in the second. However, this uncertainty does not preclude the law from prescribing a single legal outcome in each case. This outcome can be achieved by discarding the arguments that fail to meet the required burden of persuasion, i.e., the prosecution's argument for murder and the doctor's argument for her diligence, respectively.

3 Argumentation Framework

We introduce a structured argumentation framework relying on a lightweight ASPIC$^+$-like argumentation system [14]. For the sake of simplicity, we assume that arguments only consist of defeasible rules, to the exclusion of strict rules, and of some constituents of a knowledge base—such as axioms, ordinary premises, assumptions, and issues that can be found in the complete model [14]. A framework based on defeasible rules is sufficient for our purposes and can be extended as needed with further structures. In this section, we introduce arguments, their preferences, and defeat relations between them.

3.1 Defeasible theories

As usual, by a literal we mean an atomic proposition or its negation.

Notation 31 *For any literal ϕ, its complement is denoted by $\bar{\phi}$. That is, if ϕ is atom p, then $\bar{\phi} = \neg p$, while if ϕ is $\neg p$, then $\bar{\phi}$ is p.*

Literals are brought into relation through defeasible rules.

Definition 1 (Defeasible rule). *A **defeasible rule** r has the form: $\rho : \phi_1, ..., \phi_n, \sim \phi'_1, ..., \sim \phi'_m \Rightarrow \psi$ with $0 \leq n$ and $0 \leq m$, and where*

- *ρ, an atom, is the unique identifier for r, denoted by $\mathsf{N}(r)$;*
- *each $\phi_1, \ldots \phi_n, \phi'_1, ..., \phi'_m, \psi$ is a literal;*
- *$\phi_1, \ldots \phi_n, \sim \phi'_1, ..., \sim \phi'_m$ are denoted by $Antecedent(r)$ and ψ by $Consequent(r)$;*
- *$\sim \phi$ denotes the weak negation (negation by failure) of ϕ: ϕ is an exception that would block the application of the rule whose antecedent includes $\sim \phi$.*

The name of a rule can be used to specify that the named rule is applicable, and its negation correspondingly to specify that the rule is inapplicable [13].

A superiority relation $\succ$ is defined over rules: $s \succ r$ states that rule s prevails over rule r.

Definition 2 (Superiority relation). *A* ***superiority relation*** $\succ$ *over a set of rules Rules is an antireflexive and antisymmetric binary relation over Rules, i.e.,* $\succ \subseteq Rules \times Rules$.

A defeasible theory consists of a set of rules and a superiority relation over the rules.

Definition 3 (Defeasible theory). *A* ***defeasible theory*** *is a tuple* $\langle Rules, \succ \rangle$ *where Rules is a set of rules, and* $\succ$ *is a superiority relation over Rules.*

Given a defeasible theory, by chaining rules from the theory we can construct arguments, as specified in the following definition; cf. [3, 13, 21].

Definition 4 (Argument). *An* ***argument*** *A constructed from a defeasible theory* $\langle Rules, \succ \rangle$ *is a finite construct of the form:* $A : A_1, \ldots A_n \Rightarrow_r \phi$ *with* $0 \leq n$, *where*

- *A is the argument's unique identifier;*
- $A_1, \ldots, A_n$ *are arguments constructed from the defeasible theory* $\langle Rules, \succ \rangle$*;*
- ϕ *is the* conclusion *of the argument, denoted by* $\mathsf{Conc}(A)$*;*
- $r : \mathsf{Conc}(A_1), \ldots, \mathsf{Conc}(A_n) \Rightarrow \phi$ *is the top rule of A, denoted by* $\mathsf{TopRule}(A)$.

Notation 32 *Given an argument* $A : A_1, \ldots A_n \Rightarrow_r \phi$ *as in definition 4,* $\mathsf{Sub}(A)$ *denotes the* ***set of subarguments*** *of A, i.e.,* $\mathsf{Sub}(A) = \mathsf{Sub}(A_1) \cup \ldots \cup \mathsf{Sub}(A_n) \cup \{A\}$. $\mathsf{DirectSub}(A)$ *denotes the* ***direct subarguments*** *of A, i.e.,* $\mathsf{DirectSub}(A) = \{A_1, \ldots, A_n\}$.

Preferences over arguments are defined via a last-link ordering: an argument A is preferred over another argument B if the top rule of A is stronger than the top rule of B.

Definition 5 (Preference relation). *A* ***preference relation*** $\succ$ *is a binary relation over a set of arguments* $\mathcal{A}$*: an argument A is preferred to argument B, denoted by* $A \succ B$*, iff* $\mathsf{TopRule}(A) \succ \mathsf{TopRule}(B)$.

3.2 Defeat with burdens of persuasion

Let us first identify burdens of persuasion, i.e., those literals the proof of which requires a convincing argument. We assume that such literals are consistent (it cannot be the case that there is a burden of persuasion both on ϕ and $\overline{\phi}$).

Definition 6 (Burdens of persuasion). *Let* $\mathsf{BurdPers}$*, the set of* ***burdens of persuasion****, be a set of literals such that if* $\phi \in \mathsf{BurdPers}$ *then* $\overline{\phi} \notin \mathsf{BurdPers}$*. We say that an argument A is burdened with persuasion if* $\mathsf{Conc}(A) \in \mathsf{BurdPers}$.

We now consider possible collisions between arguments, i.e., those cases in which an argument A challenges an argument B: *(a)* by contradicting the conclusion of a B' subargument (rebutting), or *(b)* by denying (the application of) the top rule of a B' subargument or by contradicting a weak negation in the body of the top rule of a B' subargument (undercutting).
Note that our notion of rebutting corresponds to the notion of successful rebutting in [14].

Definition 7 (bp-rebut). *Argument* A ***bp-rebuts*** *argument* B *iff* $\exists B' \in Sub(B)$ *such that* $\mathsf{Conc}(A) = \overline{\mathsf{Conc}(B')}$ *and*

1. $\mathsf{Conc}(A) \notin \mathsf{BurdPers}$*, and* $B' \not\succ A$*, or*
2. $\mathsf{Conc}(A) \in \mathsf{BurdPers}$ *and* $A \succ B'$*.*

According to definition 7.1, for an unburdened argument A to rebut B by contradicting the latter's subargument B', it is sufficient that B' is non-superior to A. According to 7.2 for a burdened argument A to rebut B by contradicting B', it is necessary that A is superior to B'. Thus, burdens of persuasion supplement priorities in deciding conflicts between arguments having opposed conclusions. They dictate the outcome of such conflicts when priorities do not already determine which argument is to prevail: when two arguments contradict one another, the one burdened with persuasion will fail to bp-rebut the other, while the latter will succeed in bp-rebutting the first.

Undercutting is defined as usual, including both the case in which the attacker excludes the application of the top rule of the attacked argument (by denying the rule's name) and the case in which it contradicts a weakly negated literal in the body of that rule.

Definition 8 (bp-undercut). *A* ***undercuts*** B *iff* $\exists B' \in Sub(B)$ *such that:*

1. $\mathsf{Conc}(A) = \neg\mathsf{N}(r)$ *and* $\mathsf{TopRule}(B') = r$*; or*
2. $\mathsf{Conc}(A) = \phi$ *and* $\sim \phi \in Antecedent(\mathsf{TopRule}(B'))$

Finally, we have the notions of bp-defeat and strict bp-defeat that are defined on the basis of bp-rebutting and undercutting. As you can see from the definition below the difference from the usual notion of defeat pertains to bp-defeat.

Definition 9 (bp-defeat).

1. *A* ***bp-defeats*** *B iff A bp-rebuts B or A undercuts B*
2. *A* ***strictly-bp-defeats*** *B iff A bp-defeats B and B does not bp-defeats A .*

3.3 Example

To exemplify the notions just introduced, let us formalise example 2 through a set of rules. Note that we assume that evidence is provided to establish the factual claims at issue, i.e., that the corresponding burdens of production are satisfied (facts e1, e2, e3).

Example 3 (Civil law example: rules and arguments).

e1 : ev_1	er1 : $ev_1 \Rightarrow \neg guidelines$
e2 : ev_2	er2 : $ev_2 \Rightarrow guidelines$
e3 : ev_3	$er3$: $\text{ev}_3 \Rightarrow harm$
r1 : $\neg guidelines \Rightarrow \neg dueDiligence$	r2 : $guidelines \Rightarrow dueDiligence$
r3 : $harm, \sim dueDiligence \Rightarrow liable$	

We can then build the following arguments:

A1 :$\Rightarrow ev_1$	A2 :$\Rightarrow ev_2$
A3 :$\Rightarrow ev_3$	A4 : A1 $\Rightarrow \neg guidelines$
A5 : A2 $\Rightarrow guidelines$	A6 : A3 $\Rightarrow harm$
A7 : A4 $\Rightarrow \neg dueDiligence$	A8 : A5 $\Rightarrow dueDiligence$
A9 : A6 $\Rightarrow liable$	

If were no burden of persuasion the relations would be the following:

- arguments A4 and A5 defeat one another,
- A5 defeats A7,
- A4 defeats A8,
- A7 and A8 defeat one another,
- A8 strictly defeats A9.

If on the contrary, there is burden on the doctors' diligence ($dueDiligence \in$ BurdPers), then A8 fails to defeat A7, so that A7 strictly defeats A8.

4 A labelling semantic for burdens of persuasion

In this section, we show how arguments are linked to argumentation graphs. Then, we define a labelling semantics that takes burdens of persuasion into account.

4.1 Argumentation graphs and bp-labelling

In an argumentation graph, arguments are connected according to the defeat relation.

Definition 10 (Argumentation graph). *An **argumentation graph** constructed from a defeasible theory T is a tuple $\langle \mathcal{A}, \rightsquigarrow \rangle$, where $\mathcal{A}$ is the set of all arguments constructed from T, and $\rightsquigarrow$ is* defeat *relation over $\mathcal{A}$.*

Notation 41 *Given an argumentation graph $G = \langle \mathcal{A}, \rightsquigarrow \rangle$, we write $\mathcal{A}_G$, and $\rightsquigarrow_G$ to denote the graph's arguments and attacks respectively.*

Now, let us introduce the notion of the $\{\mathsf{IN}, \mathsf{OUT}, \mathsf{UND}\}$-labelling of an argumentation graph, where each argument in the graph is labelled IN, OUT, or UND, depending on whether it is accepted, rejected, or undecided, respectively.

Definition 11 (Labelling). *Let G be an argumentation graph. An $\{\mathsf{IN}, \mathsf{OUT}, \mathsf{UND}\}$-**labelling** L of G is a total function $\mathcal{A}_G \to \{\mathsf{IN}, \mathsf{OUT}, \mathsf{UND}\}$.*

Notation 42 *Given a labelling L, we write $\mathsf{IN}(L)$ for $\{A|L(A) = \mathsf{IN}\}$, $\mathsf{OUT}(L)$ for $\{A|L(A) = \mathsf{OUT}\}$ and $\mathsf{UND}(L)$ for $\{A|L(A) = \mathsf{UND}\}$.*

There are various ways to specify $\{\mathsf{IN}, \mathsf{OUT}, \mathsf{UND}\}$-labelling functions [1]. For example, they can be *complete* or *grounded*.

Definition 12. *A **complete** $\{\mathsf{IN}, \mathsf{OUT}, \mathsf{UND}\}$-**labelling** of an argumentation graph G is a $\{\mathsf{IN}, \mathsf{OUT}, \mathsf{UND}\}$-labelling such that $\forall A \in \mathcal{A}_G$*

1. *A is labelled IN iff all defeaters of A are labelled OUT, and*
2. *A is labelled OUT iff A has a defeater labelled IN.*

Definition 13. *A **grounded** $\{\mathsf{IN}, \mathsf{OUT}, \mathsf{UND}\}$-**labelling** of an argumentation graph G is a complete $\{\mathsf{IN}, \mathsf{OUT}, \mathsf{UND}\}$-labelling L of G such that $\mathsf{IN}(L)$ is minimal.*

Remark that any argument not labelled IN or OUT must be labelled UND, since any $\{\mathsf{IN}, \mathsf{OUT}, \mathsf{UND}\}$-labelling is a total function.

While common specifications of $\{\mathsf{IN}, \mathsf{OUT}, \mathsf{UND}\}$-labellings define reasonable positions [1], they do not cater for burdens of persuasion. We now specify the notion of bp-labelling, namely, a labelling which takes into account a set of burdens of persuasion.

We now specify the notion of **bp-labelling**, namely, a labelling which takes into account a set of burden of persuasion $\mathsf{BurdPers}$.

Definition 14 (bp-labelling). *A **bp-labelling** of an argumentation graph G, relative to a set of burdens of persuasion $\mathsf{BurdPers}$, is a $\{\mathsf{IN}, \mathsf{OUT}, \mathsf{UND}\}$-labelling s.t. $\forall A \in \mathcal{A}_G$ with $\mathsf{Conc}(A) = \phi$*

1. *$A \in \mathsf{IN}(L)$ iff $\forall B \in \mathcal{A}_G$ such that B bp-defeats $A : B \in \mathsf{OUT}(L)$*
2. *$A \in \mathsf{OUT}(L)$ iff*
   (a) *$\phi \in \mathsf{BurdPers}$ and $\exists\ B \in \mathcal{A}_G$ such that*
      - *B bp-defeats A and*
      - *$B \in \mathsf{IN}(L)$ or $B \in \mathsf{UND}(L)$*

   (b) *$\phi \notin \mathsf{BurdPers}$ and $\exists\ B \in \mathcal{A}_G$ such that*
      - *B bp-defeats A and*
      - *$B \in \mathsf{IN}(L)$*
3. *$A \in \mathsf{UND}(L)$ otherwise.*

Burdens of persuasion affect conditions for rejection, as specified in Definition 14 (2) (a). The rejection (the OUT labelling) of an argument burdened of persuasion may be determined by any counterargument B that is accepted (IN) or also is uncertain (UND). On the contrary, as specified in 14 (2) (b) the rejection of an argument that is not burdened with persuasion requires a defeating counterargument B that is IN.

Note that the semantic just described does not always deliver a single labelling. Multiple labelling may exist when arguments rebut each other, none of them being burdened with persuasion. If one of these arguments is labelled IN the other is labelled OUT and vice versa. To address such a situation, we focus on IN-minimal labelling, i.e., on the labelling where both such arguments are labelled UND. Let us call such a labelling a *grounded bp-labelling*.

Definition 15 (Grounded bp-labelling). *A* ***bp-labelling*** *L of an argumentation graph G is a* ***grounded bp-labelling*** *iff* $\mathsf{UND}(L)$ *is maximal.*

Proposition 1. *If* $\mathsf{BurdPers} = \emptyset$*, L_1 is the grounded labelling of argumentation graph G, as defined by [1] and L_2 is the grounded bp-labelling of G, then* $\mathsf{IN}(L_1) = \mathsf{IN}(L_2)$

Proof. It is easy to see that if the condition 14(1) concerning arguments burdened with persuasion is removed from definition 14, we obtain the definition of grounded labelling as characterised in [1].

4.2 Examples

Let us now apply the model just introduced to some legal examples.

Example 4 (Civil law example: graphs and bp-labelling). Let us consider again the Example 2 and the corresponding rules and arguments built in Example 3. The argumentation graph and its grounded $\{\mathsf{IN}, \mathsf{OUT}, \mathsf{UND}\}$-labelling are depicted in Fig. 1 (top), in which all arguments are UND except arguments for undisputed facts.

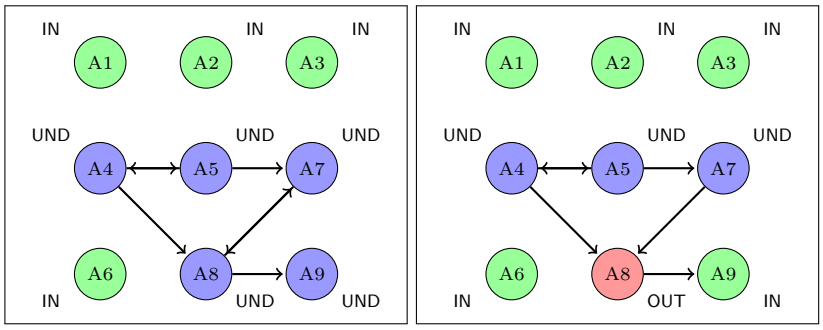

Fig. 1. Grounded $\{\mathsf{IN}, \mathsf{OUT}, \mathsf{UND}\}$-labelling of Example 2 in the absence of burdens of persuasion (top) and its bp-labelling with $\mathsf{BurdPers} = \{dueDiligence, liable\}$ (bottom).

The result is not satisfactory according to the law, since it does not take into account the applicable burdens of persuasion. The doctor should have lost the

case – i.e., be found liable – since she failed to discharge her burden of proving that she was diligent (non-negligent). The doctor's failure results from the fact that it remains uncertain whether she followed the guidelines. To capture this aspect of the argument, we need to specify the burdens of persuasion. Let us assume that (as under Italian law) we have $\mathsf{BurdPers} = \{dueDiligence, liable\}$ (i.e., the doctor has to provide a convincing argument that she was diligent, the patient has to provide a convincing argument for the doctor's liability). As the burdened doctor's argument for *dueDiligence* is OUT, her liability can be established even though it remains uncertain whether the guidelines were followed. □

This example shows how the model here presented allows us to deal with the *inversion of the burden of proof*, i.e., a situation in which one argument A is presented for a claim ϕ being burdened with persuasion, and A (or a subargument of it) is attacked by a counterargument B, of which the conclusion ψ is also burdened with persuasion. If no convincing argument for ψ can be found, then the attack fails, and the uncertainty on ψ does not affect the status of A. In the example, the argument for the doctor's due diligence fails to meet its burden of persuasion. Consequently, it fails to defeat the argument for the doctor's liability, which succeeds, meeting its burden of persuasion.

Example 5 (Criminal law example: rules, graphs and bp-labelling). According to the description in Example 1, let us consider the following rules (for simplicity's sake, we will not specify the evidence here, but we assume that all factual claims are supported by evidence):

$$\begin{array}{l}
\text{f1: } \Rightarrow killed \\
\text{f2: } \Rightarrow intention \\
\text{f3: } \Rightarrow threatWithWeapon \\
\text{f4: } \Rightarrow \neg threatWithWeapon \\
\text{r1: } threatWithWeapon \Rightarrow selfDefence \\
\text{r2: } \neg threatWithWeapon \Rightarrow \neg selfDefence \\
\text{r3: } selfDefence \Rightarrow \neg murder \\
\text{r4: } killed, intention \Rightarrow murder
\end{array}$$

with $r3 \succ r4$. We can build the following arguments:

$$\begin{array}{ll}
\text{C1} :\Rightarrow \neg threatWithWeapon & \text{C2} : \text{C1} \Rightarrow \neg selfDefence \\
\text{A1} :\Rightarrow killed & \text{B1} :\Rightarrow threatWithWeapon \\
\text{A2} :\Rightarrow intention & \text{B2} : \text{B1} \Rightarrow selfDefence \\
\text{A3} : \text{A1}, \text{A2} \Rightarrow murder & \text{B3} : \text{B2} \Rightarrow \neg murder
\end{array}$$

In the $\{\mathsf{IN}, \mathsf{OUT}, \mathsf{UND}\}$-labelling of Fig. 2 (top), all arguments are UND except for the undisputed facts. Thus, in the absence of burdens of persuasion, we do not obtain the legally correct answer, namely, acquittal. To obtain acquittal we need to introduce burdens of persuasion. Prosecution has the burden of persuasion on *murder*: it therefore falls to the prosecution to persuade the judge that there was killing, that it was intentional, and that the killer did not act in self-defence. The

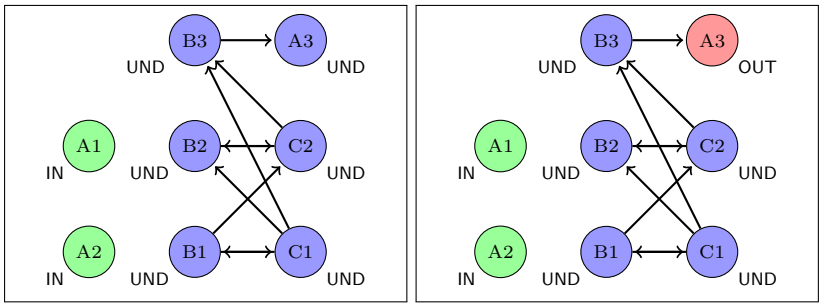

Fig. 2. Grounded {IN, OUT, UND}-labelling of Example 1 in the absence of burdens of persuasion (top) and bp-labelling with the burden of persuasion BurdPers = {*murder*} (bottom).

bp-labelling is depicted in Fig. 2 (bottom). The prosecution failed to meet its burden of proving murder, i.e., its argument is not convincing, since it remains undetermined whether there was self-defence. Therefore, murder is OUT and the presumed killer is to be acquitted. □

4.3 The problem of defeat cycles

A complexity in argumentation graphs including arguments burdened of persuasion concerns what we may call defeat cycles, i.e., cycles of arguments that defeat one another. Cycles of defeats have been extensively in argumentation theory ([6, 1, 4]). Here we just consider how the problem emerges in connection with burdens of persuasion.

Definition 16 (Defeat cycle). *A **defeat cycle** is a set of arguments $\mathcal{S}$ where $\forall$ argument $A \in S$, $\exists B \in \mathcal{S}$ such that A defeats B and A is defeated by B.*

Note that this definition includes, beyond the usual case of head-to-head rebuttals, those cases in which arguments attack each other's subarguments, or undercut one another, as in Example 6.

Example 6 (Defeat cycle example). Let us consider the following rules, with $Conc(A1) \in$ BurdPers

$$\begin{array}{lllll} Rules: & \text{r1} :\sim a \Rightarrow b & \text{r2} :\sim b \Rightarrow c & \text{r3} :\sim c \Rightarrow a \\ Args: & \text{A1} : \Rightarrow a & \text{A2} : \Rightarrow b & \text{A3} : \Rightarrow c \end{array}$$

It's easy to see that A1 undercuts A2, which undercuts A3, which undercuts A1.

Determining the status of a burdened argument included in a defeat cycle, such as $A1$ in example 6, is problematic (assuming that no argument in the cycle is defeated by external attackers). Consider for instance the case of argument $A1$ in example 6. The argument cannot be IN, since there are no reasons for

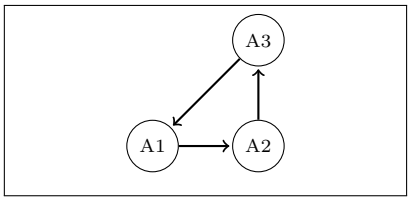

Fig. 3. Defeat cycle example

assuming that its attacker is OUT, not it can be UND because doubt should entail rejection for burdened arguments, not it can be OUT, since in such a case there would be no reason for it to be in such status, as its only attacker, $A3$ would be OUT as well. Among these three imperfect solutions, it seems that the second one may be preferable, in accordance with the idea that, in the absence of a decisive reason to accepting it, an argument burdened with persuasion should be rejected.

In conclusion, seems that we have two approaches to deal with such (vicious) cycles. One approach consists in restricting the argumentation graphs we are considering to those that do not contain defeat cycles including arguments burdened with persuasion, i.e., in making this restriction a constraint on the construction of valid argumentation graphs with burdens of persuasion. In fact, we have not been able to find reasonable legal examples that may include such cycles.

The second approach consists of assuming that all arguments burdened with persuasion, which are included in a circular bp-defeat set are OUT. More formally, let us introduce the following definition, which is meant to capture circular defeat sets such that no external argument rules out any argument in the cycle: all external defeaters of burdened arguments in the set are OUT, and all external defeaters of non-burdened arguments are OUT or UND.

Definition 17 (Protected defeat cycle). *A defeat cycle $\mathcal{S}$ is **protected** in G iff $\forall\ A \in \mathcal{S}$ holds that*

- *if $\mathsf{Conc}(A) \in \mathsf{BurdPers}$, then $\forall B \in \mathcal{A}_G \backslash \mathcal{S}$ such that B bp-defeats A: $B \in \mathsf{OUT}(L)$*
- *if $\mathsf{Conc}(B) \notin \mathsf{BurdPers}$ then $\forall B \in \mathcal{A}_G \backslash \mathcal{S}$ such that B strictly bp-defeats A: $B \in \mathsf{OUT}(L)$ or $B \in \mathsf{UND}(L)$.*

Following the idea that all burdened arguments in a protected cycle set are OUT we can then modify definition 14 as follows.

Definition 18 (bp-labelling with defeat cycles). *A **bp-labelling** of an argumentation graph G, relative to a set of burdens of persuasion $\mathsf{BurdPers}$, is an $\{\mathsf{IN}, \mathsf{OUT}, \mathsf{UND}\}$-labelling s.t. $\forall A \in \mathcal{A}_G$ with $\mathsf{Conc}(A) = \phi$*

1. *$A \in \mathsf{IN}(L)$ iff $\forall B \in \mathcal{A}_G$ such that B bp-defeats $A : B \in \mathsf{OUT}(L)$*
2. *$A \in \mathsf{OUT}(L)$ iff*

(a) $\phi \in$ *BurdPers* *and*
- $\exists\ B \in \mathcal{A}_G$ *such that bp-defeats* A *and* $B \in \mathsf{IN}(L)$ *or* $B \in \mathsf{UND}(L)$, *or*
- $A \in \mathcal{S}$ *such that* $\mathcal{S}$ *is a protected circular defeat set in* G

or

(b) $\phi \notin$ *BurdPers* *and* $\exists\ B \in \mathcal{A}_G$ *such that* B *bp-defeats* A *and* $B \in \mathsf{IN}(L)$

3. $A \in \mathsf{UND}(L)$ *otherwise.*

5 Adversarial burden of persuasion

Adversarial burden or persuasion expands a bp-labelling approach in order to capture those cases in which failure to meet a burden of persuasion on ϕ entails that $\overline{\phi}$ (*phi*'s complement) is established.

For instance, failure to show that the accused is guilty will entail that he should be found innocent. Similarly, the plaintiff's failure to provide a convincing argument that he has a right to compensation for a certain event will entail that he has no right to be compensated. Or the burden of providing a convincing argument that a genetically modified crop is not harmful may entail – according to the so-called precautionary principle – that the crop is deemed to be harmful.

Thus, an adversarial burden of persuasion on a claim ϕ entails not only that arguments for ϕ will be OUT if they are not IN, but also that failure to establish ϕ entails ϕ's complement, according to a rule "$r :\sim \phi \Rightarrow \overline{\phi}$".

Example 7 (Criminal law example: adversarial bp). Let us consider again our example concerning criminal law (example 5). Let us assume that we add the rule

$$\text{abp1} :\sim murder \Rightarrow \neg murder$$

This rule enables us to develop an argument for concluding that in the criminal law example above that there is no murder. This is indeed what generally happens in criminal and other legal cases: failure to establish the prosecution's claim that a murder was committed or the plaintiff's claim that a compensation is due leads to the conclusion that there was no crime or that no compensation is due.

$$\mathrm{B}_4 = \{\} \Rightarrow \neg murder$$

The corresponding new argumentation graph is depicted in Fig. 4.

6 Standards of proof

In this section, we complement burdens of proof with standards of proof. Following the approach by [20], we model standards of proof as the required bandwidth between competing arguments, i.e., as the extent that is needed for one argument to prevail over its counterargument in order to meet the applicable burden.

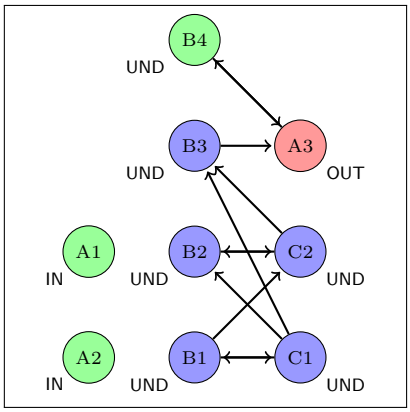

Fig. 4. Criminal law example with adversarial bp.

6.1 From priorities to bandwidths

As with priorities, we assume that bandwidths between arguments are determined by bandwidths between their top rules. Given that $r_1 \succ r_2$, we indicate the bandwidth between r_1 and r_2 rules through a positive rational number, which expresses the positive extent to which r_1 prevails over r_2, i.e., the comparative superiority of r_1 over r_2. If $r_1 \not\succ r_2$ we assign 0 to the corresponding bandwidth (this holds both when r_2 prevails over r_1 and when there is no superiority between the two rule). Accordingly, we define the bandwidth function as follows.

Definition 19 (Bandwidth function). *Let $\succ$ be a superiority relation over a set of rules Rules. A bandwidth assignment over $\succ$ is a function* BW *which assigns to every pair $(r_i, rj) \in$ Rules a number as follows:*

- *if $(r_i, rj) \in \succ$, then* $\mathsf{BW}(r_i, rj) \in \mathbb{R}_{>0}$
- *otherwise,* $\mathsf{BW}(r_i, rj) = 0$

Notation 61 *We use $r_i \succ^n r_j$ as an abbreviation for* $\mathsf{BW}(r_i, r_j) = n$*, i.e, to express that rule r_i prevails over rule r_j to the extent n.*

Note that we may want to impose some constraints over bandwidths, for instance to require that if $r_1 \succ^x r_2$ and $r_2 \succ^y r_3$ then $r_1 \succ^z r_3$ and $z \geq max(x, y)$ (or even $z = x + y$), but this is not needed for our purposes.

In our examples, for the sake of simplicity, we assume that bandwidths only take values 1, 2, or 3, denoting respectively that r_1 *barely prevails* over r_2 (as sufficient to meet the standard of preponderance of evidence), that it *significantly prevails* (as needed to meet the standard of clear and convincing evidence) and that *strongly prevails* (as needed to meet the standard of "beyond reasonable doubt"). Other ranges of possible values may however be considered, depending on the standards being modelled.

As above, the ordering over rules is transferred to the ordering over arguments: argument A is preferred to argument B to the extent x, denoted by $A \succ^x B$, iff $\mathsf{TopRule}(A) \succ^x \mathsf{TopRule}(B)$.

We are now in a condition to define the notion of rebutting with standard of proof, denoted as *bps-rebutting*. The idea is that the conflict between two arguments A and B such that A contradicts a subargument $B' \in Sub(B)$ is to be determined by the bandwidth between A and B'. We have three cases to consider:

- There is no burden of persuasion on both A and B'. Then, as usual, A bps-rebuts B, unless B' is superior to A.
- There is a burden of persuasion on A. Then A bps-rebuts B' only if it is superior to B' to an extent than at least reaches the applicable standard.
- There is a burden of persuasion on B. Then A bps-rebuts B unless B' superior to A to an extent that reaches the standard.

Definition 20 (bps-rebutting). *An argument A **bps-rebuts** an argument B relative to a standard $S \in \mathbb{R}_{>0}$ iff $\exists B' \in Sub(B)$ such that $\mathsf{Conc}(A) = \overline{\mathsf{Conc}(B')}$*

1. *$\mathsf{Conc}(A), \mathsf{Conc}(B') \notin \mathsf{BurdPers}$, and $B' \not\succ A$*
2. *$\mathsf{Conc}(A) \in \mathsf{BurdPers}$, and $\mathsf{BW}(A, B') \geq S$*
   or
3. *$\mathsf{Conc}(B') \in \mathsf{BurdPers}$ and $\mathsf{BW}(B', A) \ngeq S$*

On this basis, we get the following definition for defeat relative to a standard of proof (bps-defeat).

Definition 21 (bps-defeat).

- *A **bps-defeats** B relative to standard of proof S iff A bps-rebuts B relatively to S or A undercuts B*
- *A **strictly bps-defeats** B relative to standard of proof S iff B iff A bps-defeats B relative to standard of proof S and B does not bps-defeats B relative to standard of proof S.*

We can now define the notion of bp-labelling with a standard of persuasion, which will be denoted as bps-labelling.

Definition 22 (bps-labelling). *A **bps-labelling** of a cycle-free argumentation graph G, relative to a set of burdens of persuasion $\mathsf{BurdPers}$ and a standard of proof $S \in \mathbb{R}_{>0}$, is a $\{\mathsf{IN}, \mathsf{OUT}, \mathsf{UND}\}$-labelling s.t. $\forall A \in \mathcal{A}_G$ with $\mathsf{Conc}(A) = \phi$.*

1. *$A \in \mathsf{IN}(L)$ iff $\forall B \in \mathcal{A}_G$ such that B bps-defeats A: $B \in L(\mathsf{OUT})$*
2. *$A \in \mathsf{OUT}(L)$ iff*
   (a) $\phi \in \mathsf{BurdPers}$ and $\exists\ B \in \mathcal{A}_G$ such that B bps-defeats A: $B \notin L(\mathsf{OUT})$ or
   (b) $\phi \notin \mathsf{BurdPers}$ and $\exists\ B \in \mathcal{A}_G$ such that B bps-defeats A: $B \in L(\mathsf{IN})$
3. *$A \in \mathsf{UND}(L)$ otherwise.*

Definition 23 (Grounded bps-labelling). *A **bps-labelling** L of an argumentation graph G is a **grounded bps-labelling** iff $\mathsf{UND}(L)$ is maximal.*

6.2 Examples

Let us now consider how different standards of proof may affect the outcome of a dispute, by comparing a criminal case from a civil case for the compensation of damages resulting from a crime.

Example 8 (Criminal law example with standards of proof). Let us first provide an example by modifying our criminal law example. In example 5, the outcome was no conviction for Hellen, since a doubt remains whether she acted in self-defence, as a consequence of the doubt on whether she was threatened with a weapon. Let us now assume that the evidence against Hellen being *not* being threatened with weapons ($f4 :\Rightarrow \neg threatWithWeapon$) prevails over the evidence to the contrary ($f3 :\Rightarrow threatWithWeapon$), but only to a small extent (e.g.,1), i.e., $f4 \succ^1 f3$.

Given that the bandwidth 1 is inferior to the standard 3 for criminal law, we get that argument C1 for $\neg threatWithWeapon$ fails to strictly defeat B1 for $threatWithWeapon$. Consequently, both arguments are UND, as a consequence, also the argument B2 for self-defence is UND. Accordingly, the argument for A3 for murder is UND. Thus, the attempt to establish a conviction for murder fails. The resulting bps-labelling is depicted in Fig. 5 (top).

Let us now assume that the evidence for $\neg threatWithWeapon$ is stronger, i.e., $f4 \succ^3 f3$ and correspondingly C1 $\succ^3$ B1. It is easy to see that with this bandwidth, C1 strictly defeats B1, which is consequently OUT as also B2 and B3. As a consequence A3 is IN and conviction for murder is successfully established. The resulting bps-labelling is depicted in Fig. 5 (bottom).

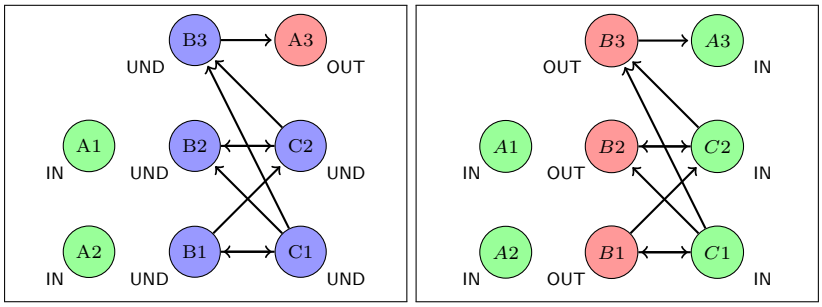

Fig. 5. bps-labelling relative to the murder case in a penal suit with $f4 \succ^1 f3$ (top) and with $f4 \succ^3 f3$ (bottom).

Example 9 (Civil law suit for damages resulting from a crime).

Assume that the issue of murder is addressed in a civil suit, where the standard of proof is 1. Moreover, let us add one further rule to our framework, namely a rule which extends the previous example with the right to compensation:

$$\text{r5} : murder \Rightarrow compensation$$

and accordingly, with the following argument:

$$\text{A4} := \text{A3} \Rightarrow \textit{compensation}$$

It is easy to see that in such a case A3 would be IN, since $f4 \succ^1 f3$ and in civil suit the bandwidth is 1, so that also compensation for murder can be granted (A4 would be IN). This is what happens in those legal systems in which criminal and civil suits can be independently started for the same facts (an in the famous O.J. Simpson case). This result is depicted in Fig. 6.

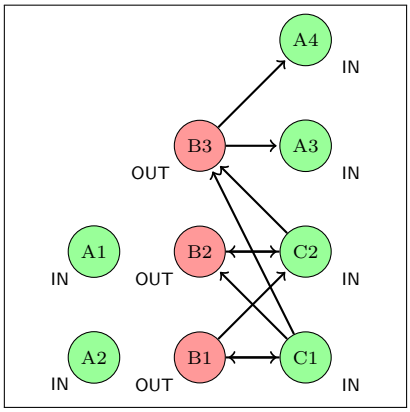

Fig. 6. bps-labelling relative to the compensation of a murder in a civil suit with $f4 \succ^1 f3$.

7 Conclusion

We have presented a formal model for the burden of persuasion. The model is based on the idea that arguments burdened with persuasion have to be rejected when there is uncertainty about them. Consequently, such arguments become irrelevant to the argumentation framework including them: not only they fail to be included in the set of the accepted arguments (the IN ones), but they also are unable to affect the status of the arguments they attack.

We have shown how an allocation of the burden of persuasion may lead to a single outcome (IN arguments) in contexts in which the assessment of conflicting arguments would otherwise remain undecided. We have also shown how our model is able to address inversions of burdens of proof, namely, those cases in which the burden shifts from one party to the other. In such cases, there is the burden of persuasion over the conclusion of a multistep argument, and at the same time a burden of persuasion over the conclusion of an attacker against a subargument of that multistep argument.

We have also modelled adversarial burdens of proofs, namely, those cases in which failure to meet a burden of proof for a claim ϕ entails the complementary claim $\overline{\phi}$.

Finally, we have shown how standards of proof can be captured in our model. This has been done by introducing the requirement that, in order to meet the applicable standard, a burdened argument must prevail at least to a certain extent (as specified by the standard) over the arguments to the contrary.

The model can be expanded in various ways, to capture further aspects of legal reasoning. For instance, it can also be supplemented with argumentation over burdens of persuasion [15, 18], in a manner similar to the way in which argumentation systems can be expanded to include argumentation about priorities (see [16, 12]). An open issue, that we plan to address in future research concerns how to deal with defeat circles including burdened arguments (see Section 4.3). More generally we plan to study the properties of our semantics and the connection of our semantics with the standard semantics for argumentation. We also plan to inquire about the way in which our model fits into legal procedures and enables a rational reconstruction of aspects of them. Connections with the handling of burdens in other formalisms, such as defeasible logic [9] have to be explored.

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