CP=PC Revisited: Structural Obstructions in Implicational Logics

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Abstract

This paper addresses the *CP=PC problem*: whether the probability of a conditional formula can be identified with the corresponding conditional probability.

We show that this identification is obstructed already at the structural level. In the lattice $[C_0, S]$ of implicational logics of order, every implicational connective validates a strong inferential congruence principle (p4). Probabilistic conditioning fails this principle and therefore cannot serve as an implicational connective. This yields a structural no-go result: PC=CP is not merely false for particular connectives, but incompatible with the inferential role of implication as such.

We further show that even if this incompatibility is ignored and PC=CP is forcibly imposed on an implicational connective, then under natural semantic assumptions for order models the addition of global symmetry leads to a collapse of the positive-probability fragment. This collapse is presented as a reductio illustrating the pathology of identifying implication with conditional probability.

The positive lesson is a separation of roles: the connective $-$ governs purely inferential behavior, while a distinct internal conditional $(B \mid A)$ is interpreted semantically within a classical probability space so that its probability coincides with $\Pr(B \mid A)$. This reframes Stalnaker's program by locating CP=PC in the semantics of an internal conditional rather than in the implicational fragment.

Keywords: CP=PC problem, conditional probability, implicational logic, order logics, structural no-go, collapse theorem, internal conditional, Stalnaker's Thesis.

1 Introduction and Background

The *Probability of Conditionals versus Conditional Probability* (**PC=CP**) problem asks whether the probability of a conditional formula can be identified with the corresponding conditional probability. Formally, for formulas A, B with $\Pr(A) > 0$,

$$\Pr(A \to B) \stackrel{?}{=} \Pr(B \mid A) = \frac{\Pr(A \wedge B)}{\Pr(A)}.$$

This identity, often called *Stalnaker's Thesis* [Sta70], is attractive because it links the inferential reading of a conditional to probabilistic reasoning. However, it is well known that PC=CP fails for the material conditional and, more generally, that attempts to identify implication with conditional probability lead to triviality or collapse under natural strengthening assumptions [Fra76; Háj98].

Classical Event-Based Formulation. In the classical literature on PC=CP (van Fraassen 1976; Hájek 1998), formulas are identified with events, and the conditional is modeled as a set-theoretic operation. To preserve logical regularities, additional algebraic constraints are imposed on the event assignment E:

(a') **Probabilistic identification:** $\Pr(E(A - B)) = \Pr(E(B) \mid E(A))$ whenever $\Pr(E(A)) > 0$.
(b') **Reflexivity of events:** $E(A - A) = W$.
(c') **Modus ponens for events:** $E(A) \cap E(A - B) = E(A) \cap E(B)$.
(d') **Transitivity for intersections:** $E(A - C) \cap E(A - B) = E(A - (C \cap B))$.
(e') **Transitivity for unions:** $E(A - C) \cup E(A - B) = E(A - (C \cup B))$.

These conditions (a′)–(e′) ensure that the conditional behaves well semantically as an event-forming operation. Without such additional structure, the identification of an inferential connective with conditional probability is not even structurally well-typed.

Our Approach. In contrast, we do *not impose* these algebraic constraints. The conditional is treated purely as a *primitive inferential* connective $-$ of a logic of order, while probability is introduced externally via a separate semantic assignment E. This allows us to investigate the CP=PC thesis at two distinct levels:

- *Structural level:* we show that probabilistic conditioning cannot satisfy the inferential congruence principles (in particular (p4)) that characterize implicational logics in $[C_0, S]$. This yields a structural no-go result: PC=CP is incompatible with the inferential role of implication, independently of any probabilistic semantics.
- *Counterfactual semantic level:* even if this incompatibility is ignored and PC=CP is forcibly imposed on an implicational connective, then under natural assumptions for order-probability models the addition of global symmetry leads to collapse of the positive-probability fragment. This collapse functions as a reductio of the identification.

Conceptual Remark. This approach clarifies the division of roles: the connective $-$ encodes logical inference, while an internal conditional $(B \mid A)$ controls conditional probabilities. No attempt is made to interpret the inferential connective as a probabilistic operator, and no classical event-based constraints (a′)–(e′) are assumed in the present framework. This separation is essential to avoid triviality or collapse while allowing a meaningful probabilistic semantics for conditionals. This separation is not merely methodologically convenient but structurally necessary: without it, implication loses its inferential character, while conditional probability fails to compose.

Our Setting. We begin by reviewing the foundational notions underlying logics of order. Let S be a standard propositional language, built from a countably infinite set of propositional variables using a single primitive binary connective $-$. The set of formulas of S forms an absolutely free algebra over these variables.

A logic is an ordered pair $L = (S, C)$, where C is a structural consequence operation on subsets of S, satisfying reflexivity, monotonicity, idempotence, and structurality. If

$$C(X) = \bigcup \{C(X_f) : X_f \subseteq X \text{ finite}\}$$

for all $X \subseteq S$, then C is called finitary (or standard). When the language S is clear from context, we identify the logic (S, C) with its consequence operation C. The set $C(\emptyset)$ is called the set of theses of C.

In the language defining our class of order logics, we employ a **single primitive connective** $-$. Formulas are constructed from propositional variables using this single two-argument connective, yielding a standard sentential language with exactly one primitive binary connective. The connective $-$ is not assigned a fixed semantics; its behavior is determined inferentially by the rules governing its use.

The minimal structural consequence operation C_0 is defined by the following schemata of inference rules:[1]

(p1) $\vdash A - A$

(p2) $A - B,\ B - C \vdash A - C$

(p3) $A,\ A - B \vdash B$

(p4) $A - B,\ B - A,\ C - D,\ D - C \vdash (A - C) - (B - D)$

The complete lattice of structural consequence operations

$$[C_0, S] = \{\, C \mid C_0 \leq C \leq S \,\}$$

provides the natural setting for logics of order, where S denotes the maximal (trivial) consequence operation.

Definition 1. A **logic of order** is any structural consequence operation $C \in [C_0, S]$ satisfying *(p1)–(p4)*.

Some logics in $[C_0, S]$ are *implicational* (i.e. belong to the class Impl and satisfy the oddity property), while others are non-implicational and may remain consistent under symmetry.

Definition 2 ([CO22, p. 1427])**.** Let (S, C) be a logic of order. The logic C is called a **logic of implication** if the logic obtained from C by adjoining the symmetry rule (Sym),

$$A - B \vdash B - A,$$

is inconsistent. In this case, the connective $-$ is called an **implication** in C.

We use the terms *logic of implication* and *implicational logic* interchangeably, and denote the class of all implicational logics in $[C_0, S]$ by Impl.

[1] Each schema represents an infinite family of rules obtained by uniform substitution.

Proposition 3 ([CO22, p. 1430, Prop. 3.8])**.** *There is no implicational logic C whose set of theses $C(\emptyset)$ contains only formulas in which each variable occurs an even number of times. In particular, the set $\{A - A : A \in S\}$ cannot be the set of all theses of any implicational logic.*

Definition 4 ([CO22, p. 1431])**.** A rule of inference $A_1, \ldots, A_n \vdash B$ has the **parity property** (PP) if, for every instance of the rule, whenever each variable occurs an even number of times in each premise A_i, it also occurs an even number of times in the conclusion B.

Definition 5 (PP property for order logics)**.** A logic $C \in [C_0, S]$ has the PP property if and only if every defining rule of C (including axioms, treated as zero-premise rules) has the parity property.

Theorem 6 (Characterization of PP logics in the consequence lattice)**.** *Let $C_{\Leftrightarrow}$ be the maximal logic in $[C_0, S]$ preserving the parity property. For any logic $C \in [C_0, S]$,*

$$C \text{ preserves PP} \iff C \leq C_{\Leftrightarrow}.$$

Semantic and probabilistic interpretations are introduced in the next section.

Heuristic Collapse Principle. The following statement summarizes a *counterfactual phenomenon*: even if one were to ignore the structural incompatibility established later and hypothetically impose PC=CP on an implicational connective, then, under natural semantic conditions for order models, the addition of global symmetry would force the collapse of the positive-probability fragment. This principle is not a formal theorem but a heuristic summary of the collapse phenomena established rigorously in Section 2.

Positive Lesson. The collapse analysis reinforces the structural no-go result: PC=CP is not a law of the implicational connective. Even when imposed only counterfactually, its global identification with $-$ leads to degeneracy of the positive-probability fragment.

A non-degenerate treatment therefore requires a separation of roles: the connective $-$ governs inference, while an internal conditional $(B \mid A)$, interpreted within a classical probability space as defined above, controls conditional probabilities without affecting the syntactic properties of $-$.

Contributions.

- We prove a structural no-go theorem showing that no implicational connective in $[C_0, S]$ can be interpreted as probabilistic conditioning.
- We identify symmetry principles in order logics that collapse the positive-probability fragment under PC=CP.
- We propose a principled separation between inferential conditionals and internal probabilistic conditionals.

Order-Probability Model. We fix an *order-probability model*

$$(W, \Sigma, \mu, E, (\cdot \mid \cdot)),$$

where:

- W is a non-empty set of possible worlds (finite or countably infinite),
- Σ is a σ-algebra of subsets of W containing all events corresponding to formulas,
- $\mu : \Sigma \to [0, 1]$ is a probability measure with $\mu(W) = 1$,
- $E : \text{Form}_{-} \to \Sigma$ maps each formula of the implicational language to an event,
- $(\cdot \mid \cdot)$ is an internal conditional operator, assigning to each pair of formulas $(B \mid A)$ a formula representing the conditional event.

The assignment E does not impose any semantic interpretation on the inferential connective $-$. All inferential properties of $-$ (reflexivity, transitivity, structurality) are purely syntactic and determined by the chosen logic of order. Conditional probability is defined classically via the internal conditional whenever $\mu(E(A)) > 0$:

$$\mu(E(B \mid A)) := \mu(E(A) \cap E(B))/\mu(E(A)).$$

Remark on conjunction. Although the object language is purely implicational, we freely use the notation $A \wedge B$ at the semantic level to denote the meet of corresponding events:

$$E(A \wedge B) := E(A) \cap E(B).$$

No syntactic conjunctive connective is assumed; this is purely a *semantic convenience*.

PC=CP Assumption. For the main theorem, we hypothetically consider the identification of the inferential connective with the internal conditional:

$$\mu(E(A - B)) = \mu(E(B \mid A)) \quad \text{for all } A, B \text{ with } \mu(E(A)) > 0,$$

which, as we will show, leads to the collapse phenomenon.

2 Main Result: Non-Iterability of Probabilistic Conditioning

The central obstruction identified in this paper is not symmetry per se, but the *non-iterability of probabilistic conditioning* under the structural congruence principles characteristic of implicational logics. Probabilistic conditioning is inherently directional and context-sensitive, whereas implicational logics of order enforce uniform substitution and congruence across nested contexts. This mismatch is the source of all subsequent impossibility results.

Symmetry as a First Obstruction

We work in the lattice $[C_0, S]$ of structural consequence operations on the implicational language Form_{-} with a single primitive connective $-$. Let (W, Σ, μ, E) be a probabilistic model.

Theorem 7 (Incompatibility for Symmetric PP Logics)**.** *Let $C \in \mathrm{PP}$ be a logic in which the primitive connective $-$ satisfies the symmetry rule*

$$\text{(Sym)} \quad A - B \vdash B - A.$$

Suppose, counterfactually, that

$$\Pr(A - B) = \Pr(B \mid A) \quad \textit{whenever } \Pr(A) > 0.$$

Then the identification $- \equiv |$ is impossible: the positive-probability fragment cannot consistently validate both the symmetry of $-$ and the asymmetry of conditional probability.

Proof sketch. Symmetry yields $\Pr(A - B) = \Pr(B - A)$. Under the identification hypothesis this implies $\Pr(B \mid A) = \Pr(A \mid B)$ for all A, B with positive probability. Since there exist events A, B with $\Pr(A), \Pr(B) > 0$ and $\Pr(B \mid A) \neq \Pr(A \mid B)$ in every non-degenerate probability space, the identification fails. The obstruction is structural and does not rely on conjunction, disjunction, or modus ponens. □

Beyond Symmetry: OP$\setminus$Impl and Minimal PP Logics

Let $C \in \mathrm{OP} \setminus \mathrm{Impl}$ or $C \in \mathrm{PP}$ such that adding symmetry does not collapse C to the maximal logic S. Let $C_{+(\mathrm{Sym})}$ denote its symmetric extension.

Theorem 8 (Incompatibility for OP$\setminus$Impl)**.** *Assume the identification $\Pr(A - B) = \Pr(B \mid A)$. Then no logic in $\mathrm{OP} \setminus \mathrm{Impl}$ admits an interpretation of $-$ as probabilistic conditioning.*

Proof sketch. In $C_{+(\mathrm{Sym})}$ the connective $-$ satisfies symmetry, forcing $\Pr(A - B) = \Pr(B - A)$. Under PC=CP this again yields $\Pr(B \mid A) = \Pr(A \mid B)$, contradicting the directional character of conditioning. The failure is structural, not probabilistic. □

Ontological diagnosis. The conflict is not merely technical but conceptual. Conditional probability is essentially directional: $P(B \mid A)$ and $P(A \mid B)$ encode distinct informational updates unless A and B are measure-theoretically equivalent. By contrast, symmetry principles in order logics erase this directionality by identifying antecedent and succedent positions up to mutual derivability. The resulting mismatch is unavoidable.

Structural No-Go via Congruence

Let $L \in \mathrm{Impl}$ be an implicational logic in the lattice $[C_0, S]$. Every such logic validates the structural congruence rule

$$\text{(p4)} \qquad A - B,\ B - A,\ C - D,\ D - C \ \vdash\ (A - C) - (B - D),$$

where $A \leftrightarrow^* B$ abbreviates mutual derivability and is not a connective of the object language.

Rule *(p4)* may be seen as a weakened form of extensionality: mutual derivability licenses substitution into both antecedent and succedent positions. Probabilistic conditioning, however, is non-extensional: the value of $P(B \mid A)$ depends on the measure of $A \cap B$, not merely on the extensions of A and B.

Theorem 9 (Structural No-Go)**.** *No connective admitting a probabilistic-conditioning interpretation can satisfy* (p4)*. Consequently, the inferential connective of any logic $L \in [C_0, S]$ cannot be interpreted as conditional probability.*

Proof. Fix a probability space (W, Σ, P) and a compositional assignment $E : \mathrm{Form}_{-} \to \Sigma$ satisfying the PC truth condition above.

Consider the finite space $W = \{1, 2, 3, 4\}$ with the uniform measure $P(\{i\}) = \frac{1}{4}$. Let

$$E(A) = \{1, 2\}, \qquad E(B) = \{1, 2\}, \qquad E(C) = \{1, 3\}, \qquad E(D) = \{1, 3\}.$$

Then $P(E(A)) = P(E(B)) = \frac{1}{2}$ and $P(E(C)) = P(E(D)) = \frac{1}{2}$.

All four premises of *(p4)* are satisfied:

$$P(E(B) \mid E(A)) = 1 = P(E(A) \mid E(B)) \quad \text{and} \quad P(E(D) \mid E(C)) = 1 = P(E(C) \mid E(D)),$$

since $E(A) = E(B)$ and $E(C) = E(D)$.

If *(p4)* were valid under this semantics, we would have that the conclusion $(A - C) - (B - D)$ is satisfied in the same model, hence (by the PC truth condition)

$$P\Big(E(B - D) \mid E(A - C)\Big) = 1 \qquad \text{whenever } P(E(A - C)) > 0. \tag{$*$}$$

Now observe that the PC truth condition determines only whether $A - C$ and $B - D$ are satisfied, i.e. whether $P(E(C) \mid E(A)) = 1$ and $P(E(D) \mid E(B)) = 1$. It does not fix the representing events $E(A - C)$ and $E(B - D)$ in Σ. In particular, distinct assignments E may agree on the truth of all premises of *(p4)* while differing on the conditional probabilities $P(E(B - D) \mid E(A - C))$. Thus, by choosing an assignment E with $P(E(A - C)) > 0$ but $P(E(B - D) \cap E(A - C)) < P(E(A - C))$, one obtains a model in which all four premises of *(p4)* are satisfied while the conclusion fails.

Hence no compositional PC-interpretation of $-$ can validate *(p4)*. □

Non-Iterability of Probabilistic Conditioning

The preceding results are manifestations of a deeper fact: probabilistic conditioning cannot be iterated in a purely implicational, structural setting.

Theorem 10 (Non-Iterability of Probabilistic Conditioning)**.** *There exists no structural, compositional semantics for the full implicational language* Form_{-} *satisfying the probabilistic clause*

$$v(A - B) = 1 \quad \Longleftrightarrow \quad P(E(B) \mid E(A)) = 1 \quad \textit{whenever } P(E(A)) > 0.$$

Consequently, probabilistic conditioning cannot serve as the inferential connective of any logic in the lattice $[C_0, S]$.

Proof. Assume, for contradiction, that there exist a probability space (W, Σ, P), a total event-assignment $E : \mathrm{Form}_{-} \to \Sigma$, and a valuation $v : \mathrm{Form}_{-} \to \{0, 1\}$ such that *(PC$_1$)* holds for all formulas and the semantics is structural (closed under uniform substitution).

Choose events $X, Y \in \Sigma$ such that

$$0 < P(Y) < 1 \quad \text{and} \quad 0 < P(X \cap Y) < P(Y).$$

Let p, q be variables with $E(p) = X$ and $E(q) = Y$. Then $P(E(q)) > 0$ and

$$P(E(p) \mid E(q)) = \frac{P(X \cap Y)}{P(Y)} \in (0, 1),$$

so by *(PC$_1$)* we have $v(p - q) = 0$.

Now consider a uniform substitution σ with $\sigma(r) = p - q$ for some variable r (and acting as the identity on all other variables). Structurality requires that $\sigma(\varphi)$ is meaningful for every formula φ, hence in particular that E assigns events to *nested* formulas in which $p - q$ occurs as a proper subformula.

At this point iterability is unavoidable: to interpret σ-instances of rules such as *(p4)*, one must assign events to contexts like $(A - C)$ and $(B - D)$ even when A, B, C, D themselves already contain occurrences of $-$. But *(PC$_1$)* fixes only the *truth-value* of $A - B$ from the numerical value $P(E(B) \mid E(A))$; classical conditional probability provides no canonical event in Σ representing the conditional statement in a way that can be fed back as an argument of $P(\cdot \mid \cdot)$ at the next level of nesting.

Hence a total, structural, compositional E satisfying *(PC$_1$)* on the whole of Form_{-} cannot exist, contradicting the assumption. Therefore probabilistic conditioning is non-iterable in the present purely implicational setting and cannot interpret the inferential connective of any logic in $[C_0, S]$. $\square$

Remark. Rule *(p4)* makes the need for iterability explicit: it forces reasoning about nested implicational contexts purely syntactically. Classical conditional probability fixes only truth values at the first level and provides no canonical objects to feed back into further conditionalization. Non-iterability is thus the fundamental obstruction underlying all collapse and no-go phenomena identified in this paper.

Appendix: One Function Doing Both (Measure and Consequence)

Remark on methodology. Throughout the main text we work with abstract order–theoretic semantics (E, μ) in the sense of Czelakowski. In the Appendix we switch to a concrete counting measure m, defined on finite model spaces, solely as a *toy model* to illustrate the semantic phenomena discussed above. No generality is claimed for this construction.

This appendix illustrates the PC=CP collapse in a purely classical setting, independently of order logics, by presenting a combinatorial framework in which a single function plays both probabilistic and inferential roles.

Motivation. Identifying $m(A \to B)$ with $m(B \mid A)$ causes degeneracy: whenever $m(A) > 0$, all formulas in the context of A collapse. We show a construction avoiding this by separating roles.

Definition of m. Let V be a finite set of propositional variables. Define

$$m(A) := \frac{|\mathrm{Mod}_V(A)|}{2^{|V|}},$$

the uniform measure over all valuations. Then

$$m(\top) = 1, \quad m(\bot) = 0, \quad m(A \vee B) = m(A) + m(B) - m(A \wedge B),$$

so m is a proper probability measure.

Consequence via m. Define probabilistic consequence by certainty:

$$A \in \mathrm{Cn}_m(\Gamma) \quad \text{iff} \quad m(\Gamma \wedge \neg A) = 0.$$

Theorem 11 (Soundness and Completeness)**.** *For finite Γ and formula A over V,*

$$A \in \mathrm{Cn}_m(\Gamma) \iff \mathrm{Mod}_V(\Gamma) \subseteq \mathrm{Mod}_V(A).$$

Proof. $m(\Gamma \wedge \neg A) = 0$ iff $\mathrm{Mod}_V(\Gamma \wedge \neg A) = \varnothing$, i.e., $\mathrm{Mod}_V(\Gamma) \subseteq \mathrm{Mod}_V(A)$. □

Internal Conditional and Operatorial PC=CP. Introduce $(B \mid A)$:

$$m((B \mid A)) := \begin{cases} \dfrac{m(A \wedge B)}{m(A)}, & m(A) > 0, \\ \text{undefined or regularized}, & m(A) = 0. \end{cases}$$

Then

$$m((B \mid A)) = m(B \mid A),$$

while material implication remains inferential:

$$m(A \to B) = 1 - m(A \wedge \neg B).$$

The notation $(B \mid A)$ is not intended to denote an event in Σ. Rather, it is a semantic construct used to represent conditional probability within the object language. Formally, $(B \mid A)$ is a syntactic term whose interpretation under a measure m is given by

$$m((B \mid A)) := \frac{m(A \wedge B)}{m(A)},$$

whenever $m(A) > 0$. No algebraic structure on such terms is assumed beyond this numerical interpretation.

Regularization for zero-probability events. If $m(A) = 0$, the internal conditional $(B \mid A)$ can be defined in one of two ways to ensure totality:

$$m((B \mid A)) := m(B) \quad \text{or apply Sober's ranking-based method.}$$

This ensures $(\cdot \mid \cdot)$ is always defined, without affecting Cn_m inference.

Worked Example. Let $V = \{p, q, r\}$ and

$$A := p \wedge \neg q, \quad B := (p \equiv r),$$

then

$$m(A) = \frac{1}{4}, \quad m(B) = \frac{1}{2}, \quad m(A \wedge B) = \frac{1}{8},$$

so

$$m((B \mid A)) = \frac{1}{2}, \quad m(A \to B) = \frac{7}{8}.$$

Implication remains inferential; the internal conditional matches conditional probability.

No-collapse Lemma.

Lemma 12. *If $m(A \to B) = m(B \mid A)$ for all A, B with $m(A) > 0$, then for any A with $0 < m(A) < 1$ and any B, $m(A \wedge \neg B) = 0$. That is, all formulas in the context of A degenerate.*

Proof. Let $x = m(A \wedge B)$, $y = m(A \wedge \neg B)$, so $m(A) = x + y$. Then

$$1 - y = m(A \to B) = m(B \mid A) = \frac{x}{x + y},$$

which gives $y(1 - (x + y)) = 0$. Since $0 < m(A) < 1$, we must have $y = 0$. □

Remarks.

- *Separation of roles:* $\to$ induces inference; $(\cdot \mid \cdot)$ satisfies PC=CP.
- *Scope:* For infinite variable sets, the construction applies cylindrically to finite subsets. Regularization for $m(A) = 0$ ensures totality without affecting inference.
- *Significance:* This shows a single function can serve both roles, provided roles are sharply separated. No-collapse lemma explains why identifying $A \to B$ with $(B \mid A)$ trivializes inference.

Summary. m simultaneously:

- induces classical inference via $\to$ and Cn_m,
- defines conditional probabilities via $(\cdot \mid \cdot)$.

Role separation prevents degeneracy and ensures operatorial PC=CP.

Note on the Use of AI Assistance

In preparing and editing this article, I made use of AI-based tools and consultation. Artificial intelligence assisted in clarifying the formulation of selected technical passages, synthesizing critical perspectives on alternative notions of probability, and improving the language of the manuscript. All substantive decisions—the central ideas, the structure of the argument, and the final editorial form—are entirely my own. The role of AI is best characterized as analogous to expert consultation or editorial support. The final version fully reflects my scholarly standpoint and approach to the subject matter.

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