Non-Humean laws of nature without spacetime

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Abstract

Recent approaches in quantum gravity suggest that spacetime may not be a fundamental aspect of reality, but rather an emergent phenomenon arising from a more fundamental substratum. This raises a significant challenge for traditional accounts of laws of nature, which are typically grounded in spatiotemporal concepts. This paper discusses two non-Humean strategies for formulating laws of nature in the absence of spacetime: the 'non-temporal evolution' approach and the 'global constraints' approach. The argument begins by showing that the latter permits a more naturalistic stance than the former. A tentative defence is then provided against the objection that laws as global constraints are too thin to provide genuine metaphysical intelligibility and explanatory power.

Contents

1 Introduction

Novel constraints for the conception of laws of nature emerge from recent progress in theoretical physics, in particular from the development of a quantum description of space and time (i.e. a theory of quantum gravity (QG)). Most influential approaches towards QG strongly suggest that spacetime might not be fundamental, but instead emerging (in some sense to be elucidated) from a more fundamental substratum. Such a feature of reality is expected to challenge the traditional accounts of laws, which are more or less explicitly anchored on fundamental spatiotemporal concepts. Insofar as a future theory of QG is expected to provide a fundamental scientific theory of the world, it is intriguing to explore whether the concept of laws of nature remains applicable in that context. Depending on the outcome, this study could reveal insights about the nature of laws, including their most suitable metaphysical commitments.

On the one hand, the prospects of applying traditional accounts of laws (in particular, non-Humean approaches) in the context of QG have been explicitly discussed by Lam & Wüthrich (2023) and Lam & Oriti (2024). They list the obstacles faced by their current formulation, and explore the notion of *non-temporal* nomic production of the world to circumvent them. On the other hand, recent developments in the literature have introduced alternative non-Humean accounts of laws, which arguably do not need to posit a fundamental spacetime. The idea is to replace laws as producing/governing the world's facts over time, by laws that constrain

what the world must be like in a global fashion, i.e. at the level of the world as a whole. These proposals encompass Adlam (2022*b*)'s account of laws as constraints, Chen & Goldstein (2022)'s minimal primitivism and Meacham (2025)'s nomic likelihood account.

This paper will investigate two main questions. First, it will be studied whether, and to what extent, the 'global constraints' framework for non-Humean laws of nature fares better than the nomic production route regarding a range of issues faced by the latter and identified in the earlier works of Lam & Wüthrich (2023) and Lam & Oriti (2024)[1]. Second, it will examine the metaphysical underpinnings of the global constraints and assess the explanatory power of laws so-conceived. The goal will be to bring into clearer focus the strengths and limitations of the alternative approach that conceives laws as constraints, which is a question only sparsely addressed in the literature so far. This, in turn, will hopefully shed light on the broader prospects for understanding laws of nature within quantum gravity, assuming the hypothesis of spacetime emergence is accepted.

The paper is structured as follows. Section 2 will review the challenges faced by traditional accounts of laws in quantum gravity, with an emphasis on non-Humean approaches. Section 3 will present in turn the (non-)temporal nomic production approach to laws, and the global constraints one, with exemplifications from case studies in Loop Quantum Gravity. Section 4 will examine the strengths and weaknesses of both approaches from various perspectives, including their inherent conceptual requirements and their congruence with physical models, their metaphysical underpinnings, and their broader explanatory power. Section 5 will conclude by comparing the prospects of both approaches and outlining the open questions that must be addressed in the future to achieve a comprehensive understanding of laws in regimes where spacetime may not exist.

2 Non-Humean laws of physics and spacetime

In non-Humean accounts of laws of nature, the regularities among local events in the world are no accident, but are imposed by nature (see Hildebrand (2020) for a review of non-Humeanism about laws). There are various ways to ground this natural necessity in reality and to tie it to laws of nature. Two prominent ways to do so are primitivism and dispositionalism. According

[1]This paper will not discuss the Humean strategies to account for laws in QG, as the challenges faced by those approaches consist in articulating a non-spatiotemporal supervenience basis without any necessary connections to glue to world together, irrespectively of whether a (non-)temporal evolution strategy or global constraints approach are to be followed.

to primitivism, laws are primitives that govern the world "from the outside" (Maudlin 2007). In dispositionalism, objects have modally-laden properties, called dispositions, powers, propensities, capacities, or potencies. The behaviour of objects is then not imposed by laws 'from the outside', but follows from the very nature of these properties. A dispositionalist account of laws must specify how the concept of dispositions is to be interpreted, their method of individuation (i.e. how their essential nature is determined), and explain how laws are *derived* from them. Different variants of dispositionalism have been proposed to answer these questions (see, e.g., (Mumford 2004, Bird 2007, Vetter 2013)).

Non-Humean approaches to laws of nature often conceive the world as produced from an earlier state to the next, upon the existence of natural necessity relations. In particular, Lam & Wüthrich (2023) have made explicit how non-Humean accounts traditionally work with some form of 'Newtonian time evolution laws', in which an initial state is evolved forward in time. A fundamental notion of time, along with a time direction, are needed in order to *generate* or *produce* the spatial distribution of facts from earlier states (whether in a governing sense or as the result of dispositions).

One sees that these conceptions of laws would become problematic in theories where there might be no fundamental notion of time (direction). This is, in a nutshell, the challenge to be met by non-Humean accounts of laws in the context of quantum gravity. Indeed, major research programmes in quantum gravity feature our four-dimensional spacetime as emergent from a non-spatiotemporal substratum (Oriti 2021, Wüthrich et al. 2021). The precise meaning of this claim depends on the particular approach to quantum gravity (e.g. causal set theory, loop quantum gravity, string theory), its interpretation (i.e. the type of realist commitment to specific formal features, see e.g. (Norton 2020)), what is taken to be our classical spacetime (e.g. a manifold, a metric field, or spatiotemporal quantities such as temporal intervals or spatial distances (Oriti 2021)), and what 'non-fundamental' is supposed to mean (see e.g. (Salimkhani 2023)). The interplay of these variables results in varying 'levels' of spacetime emergence (Oriti 2021), encompassing scenarios that range from a commitment to a quantum counterpart of classical spacetime to a framework in which the fundamental entities are inherently non-spatiotemporal. While the more radical ways in which spacetime disappears from the fundamental description of reality are straightforwardly problematic for non-Humean accounts of laws of nature, even the more moderate cases of spacetime emergence are worrying. There is a sense in which general relativity is already in tension with a picture in which the

world would be nomically produced according to some temporal evolution (Lam & Wüthrich 2023). one needs to restrict the space of solutions to globally hyperbolic spacetimes to ensure a well-defined initial value formulation of the theory and avoid closed timelike curves, which are two necessary conditions to articulate the idea of laws producing the world over time (Lam & Wüthrich 2023). When moving to the quantum context, the above issues worsen (even when considering moderate levels of spacetime disappearance) as spatiotemporal observables will be affected by quantum indefiniteness. Depending on the interpretation one assigns to the later (e.g. metaphysical indeterminacy of some spatiotemporal aspects), this could further hinder the articulation of a world production over time.

3 Non-Humean laws of nature without spacetime

Two main routes to meet the challenge faced by non-Humean laws of nature in the face of modern physics will be discussed: : the *non-temporal* nomic production approach and the 'laws as constraints' approach.

3.1 The non-temporal nomic production view

Lam & Wüthrich (2023) suggested to adapt the non-Humean accounts of laws to theories featuring a non-fundamental spacetime by articulating a notion of *non-temporal* nomic production of the world. The idea is to:

> "[...] exploits the distinction between the kinematical and dynamical parts of these theories: the latter being ontologically grounded or nomically produced (in some non-temporal way) by the former, which is either endowed with irreducible dispositions or accompanied by some primitive laws." Lam & Wüthrich (2023)

This strategy can accommodate, in principle, the different variants of non-Humeanism about laws, such as dispositionalism or primitivism. The corresponding worldview aligns with the concept of a *growing block universe* (though it could also accommodate a presentist view). By contrast, the *block universe* model, where past, present, and future coexist, seems at odds with the emphasis on an ontic process that produces the world over time.

The way in which this strategy can be instantiated more concretely in quantum gravity has been discussed in the recent work of Lam & Oriti (2024). They took the example of Loop

Quantum Gravity (LQG), in which spin networks (quantum states of the gravitational field) are defined. There are various ways to develop a specific model within the LQG approach, but in all cases (whether the approach is canonical or covariant), one can define 'histories' of fundamental entities, yielding what is called spin foams. 'Transition amplitudes' between spin network states can be computed within a given model, obtained by summing over spin foam configurations. To the extent that these transition amplitudes between spin networks states are *ordered* (i.e. they are sensitive to the direction of the transition), we can link them to some (non-temporal) evolution process between one boundary state to the other. Such a transition is not temporal in any sense, but rather 'proto-causal', in the sense of instantiating a bare ordering between elements.

This approach relying on a non-temporal evolution of the fundamental world necessitates an interpretation of the nature of the fundamental entities to provide a complete picture of how the laws generate the world from an initial set of entities. This, in turn, requires an interpretation of the spin networks themselves, a task that is vast and lies beyond the scope of this paper.

3.2 The global constraints view

Several authors, namely (Adlam 2022*b*, Chen & Goldstein 2022, Adlam 2022*a*, Meacham 2025), departed from the notion of dynamical laws altogether, and embraced a constraint-based account of laws. In a nutshell, the idea is to replace laws as *producing or generating* the world's facts over time, by laws that *constrain* what the world must be like in a global fashion, i.e. at the level of the world as a whole. This paper will focus on Adlam's account, due to the simplicity of its formal apparatus and (as we will discuss in section 4.4) its flexibility with respect to the underlying metaphysics of constraints. (Adlam 2022*b*)'s account appeals to the following ingredients:

- **Mosaic:** a (spatiotemporal) distribution of categorical properties. The exact content depends on the ontology assigned to a given theory (e.g. point-like objects localised in spacetime, and characterised by certain properties).

- **Constraint:** any set of mosaics defines a unique constraint. Imposing a constraint means 'to necessitate that the actual mosaic belong to its corresponding set of mosaics'. In other words, a constraint metaphysically necessitates that the actual mosaic should have certain features.

- **Laws:** functions that assign to constraints an objective chance that the actual mosaic belongs to their set of mosaics.

According to this account, laws are primitives that govern by virtue of assigning probabilities to global constraints necessitating that the actual mosaic belongs to a specific set of possible mosaics[2]. These probabilities are not determined by anything over and above themselves. The fact that laws constraint an entire mosaic 'all-at-once' makes it possible to have global/holistic laws (although it remains possible for laws to select mosaics with locally delineated patterns). This world picture is in line with the idea of a *block universe*. In contrast, a *growing block universe* picture (or a presentist view) conflicts with the notion of natural necessity operating globally, encompassing the past, present, and future.

If we take the example of LQG to illustrate the above, one way to specify the various ingredients of the account would be the following:

- **Laws**: assignment of a probability distribution (according to a given spin foam model) over transitions between spin network states.
- **Constraint**: the set of mosaics containing specific transitions between boundary spin network states.
- **Mosaic**: specifies an ontology, hence, depends on a specific interpretation of the theory (here, the spin networks).

We can be as specific (or unspecific) as we wish regarding the choice of ontology, by adding (or not) further constraints on the detailed content of the mosaic. One could adopt an ontology of fundamental entities as developed within the 'non-temporal nomic production' framework, but with histories determined 'all-at-once'. Alternatively, one could embrace an entirely new interpretational route based on a realist interpretation of the sums over spin foams themselves, in some analogy with the realist readings of the Feynman path integral (see, e.g., (Wharton 2016)). As mentioned in the previous section, the task of providing an ontology to quantum gravity models is vast and complex, and lies outside the scope of this paper.

Various advantages of laws as global constraints over traditional accounts have been identified in the literature. First, they are compatible with the hypothesis of changing evolution

[2]A distinctive feature of this account is its identification of metaphysical and physical (nomic) modality: the *nomic* constraints are taken to express *metaphysical* necessity.

patterns[3]. Second, 'all-at-once' models have the ability to circumvent the above mentioned tensions between general relativity and traditional accounts of laws (Dorst n.d., Maghsoudi & Taheri Khorramabadi 2024). Finally, such models are said to provide foundational insights about nonlocality, retrocausality, and the objectivity of entanglement (Wharton & Liu 2023). In this paper, we will comment on whether the global constraints approach to laws overcome the difficulties faced by the nomic production view *in the possible absence of spacetime*. Perhaps more importantly, we will discuss to what extent the global constraint approach can meet recent challenges that have been raised regarding their metaphysical intelligibility and explanatory power.

4 Discussion

4.1 The appeal to the kinematic/dynamic distinction

The non-temporal nomic production approach to laws arguably relies, at least in its current form (Lam & Wüthrich 2023), on a distinction between a kinematical space (i.e. a space of physical states within a theory) and a dynamical space (i.e. a space of physical states obeying specific dynamical evolutions). Yet, this distinction is somewhat arbitrary, to the extent that there are different ways to combine a kinematic and dynamical structure to form a theory with specific empirical predictions (Spekkens 2015). The distinct, yet empirically equivalent, variants of quantum mechanics provide such an example. In the context of quantum gravity, this distinction appears all the more artificial in the absence of a time evolution underlying the dynamical processes. This issue seems to evaporate when adopting the global constraint approach of laws. Instead of relying on a kinematical/dynamical distinction, the laws constraint the world 'all-at-once'. However, a subtle point needs to be made.

First, it is not entirely clear whether the dynamical/kinematical distinction is necessary to articulate a non-temporal nomic production. One might want to identify a subset of the world, along with a set of relations of production for the rest of the world, conceived in a sense far

[3]When laws are understood as producing the world over time, the idea of changing laws is not easily accounted for, as discussed in (Sartenaer et al. 2021). When laws are understood as global constraints, one can imagine constraints applying to certain spacetime regions and selecting patterns and regularities distinct from the other constraints applying to other regions of the whole world. The actual mosaic belongs to the set formed by the intersections of these various constraints. (It is noteworthy to acknowledge that Adlam's account currently lacks a description of how different constraints' probabilities are combined. This criticism has been discussed in (Meacham 2025)). Since the question of whether evolution laws are changing over time is arguably an open question so far, this is a noticeable advantage of the global constraint account over its nomic production opponent.

broader than the dynamics typically specified by a theory [4].

Contrary to the case of non-temporal production processes, the global constraint approach would still have an advantage, as it does not need to posit a privileged orientation and direction for the relevant relations between entities (see section 4.3). Relatedly, these relations among objects need not be understood as forming a process, subject to further requirements (such as the absence of closed causal loops, see section 4.2).

However, when it comes solely to the charge of increased arbitrariness, the supposed advantage of the global constraint approach on the non-temporal evolution one is not as striking. Since a constraint in Adlam's account *applies* to some content of the world, it still amounts to positing some relations among some objects. Both approaches ultimately require positing an ontology, along with relations between its various elements, regardless of whether these relations are characterized as non-temporal evolution. As a result, a form of arbitrariness remains present in the global constraints approach to laws, to the extent that the empirical data alone does not suffice to infer a unique (and sufficiently detailed) ontology for reality.

In sum, the conditions under which the global constraints account of laws may have a meaningful advantage over the non-temporal nomic production approach regarding the arbitrariness of the dynamical/kinematical distinction appear to be as follows: (i) it should be implemented such that it refrains from any epistemic commitment to a modal structure that is not uniquely inferred from empirical observations, or (ii) it is implemented along with the posited claim that the objective modal structure of reality is restricted to the realm of empirical data. The former attitude, however, would restrict the scope of the explanations provided by laws of nature. The latter attitude would be hardly justified (restricting modal structure to the empirical realm seems arbitrarily anthropocentric).

4.2 The threat of causal pathologies

It was discussed in Lam & Oriti (2024) that the non-temporal nomic production approach to laws implies additional constraints on our physical models, which need to be free from causal loops to support a production of the world step by step without conceptual difficulties. By contrast, Ridley & Adlam (2025) recently argued that atemporal physical models (based on an 'all-at-once' determination of the world with both past and future boundary conditions) dissolve the conceptual challenges faced by empirically equivalent retrocausal models that de-

[4] I am thankful to Christian Wüthrich and Baptiste Le Bihan for bringing this counter-objection to my attention.

scribe unfolding processes along a temporal direction. A similar resolution can be expected in non-spatiotemporal (yet causal) contexts. Overall, this suggests that the threat of paradoxes does not arise within the global constraints approach to laws, since the world is determined holistically rather than sequentially.

With that said, the additional requirements imposed on the causal structure of a theory may not constitute a meaningful weakness for the non-temporal nomic production picture, unless future developments in physics significantly favour causal pathologies.

4.3 The asymmetry of the nomic production process

The non-temporal nomic production approach to laws is grounded in an inherently asymmetric process, namely that of nomic production itself. The question is then whether this asymmetry can be grounded in the features of a future theory of QG Lam & Wüthrich (2023). Lam & Oriti (2024) emphasise that, so far, all the most developed spin foam models yield orientation-symmetric transition amplitudes. They worry that, while orientation-asymmetric spin foams models can be constructed, these are obtained via rather *ad hoc* modifications of the orientation-symmetric ones.

Now, even if strong support were found for models with orientation-asymmetric transition amplitudes, they might still require the addition of a posited *direction* for the transition. At the very least, it seems highly non-trivial whether this direction can be derived from the formalism itself or must instead be introduced as an additional assumption.

Leaving this last point aside, the challenge of grounding asymmetric processes in a future theory of QG led Lam & Oriti (2024) to conclude that "some sort of 'weakening' of the notion of law maybe is a lesson that needs be drawn from QG". They propose to deny any ontological grounds for laws of nature. Instead of conceiving laws as 'out there' in the world, they suggest to embrace a purely epistemic perspective, and to view laws of nature as located in the mind of epistemic agents.

However, this form of antirealism about laws would lack an explanation of why the nomic production view of laws survives in quantum gravity merely as an epistemic narrative. By contrast, the global constraints strategy may offer an ontologically grounded account of laws, whose 'all-at-once' modal structure could provide an answer to this question.

4.4 The metaphysical status of global constraints

While the previous sections discussed some difficulties faced by the non-temporal evolution approach to laws, the global constraints one faces its own challenges, as pointed out in (Lam & Oriti 2024):

> "It can be argued that the notion of constraint is very general and thus the understanding and explanatory power this conception of laws provides are actually very thin."

So we will now turn to the following questions: What are the metaphysical underpinnings of global constraints, and what explanatory role do they really achieve? Let us start with the former question.

4.4.1 Primitivist picture

In Adlam (2022*b*)'s account, a primitivist picture is adopted. Laws govern by virtue of metaphysically necessitating certain features for the world, by assigning probabilities to global constraints. These probabilities are not determined by anything over and above themselves. In Adlam's words:

> 'In the constraint-based picture, the laws of nature select a set of constraints, which single out a set of 'allowed' mosaics, and then the actual Humean mosaic is selected from this set.'

In that picture, the governing role of laws is simply equivalent to relations of metaphysical necessitation, and laws are reduced to modal structure. In more detail, a physical phenomenon is necessary if it features in a mosaic that is the sole element of a set of mosaics assigned a unit probability. A physical phenomenon is possible if it features in a mosaic that either belongs to a set of mosaics assigned both non-zero probabilities, or belongs to a set of more than one mosaic assigned probability 1.

According to Adlam (2022*b*), one epistemic motivation in favour of reducing laws to modal structure (instead of committing oneself to some further underpinnings of laws) is that we know about the former from their effects on the physical world mediated by the latter. As she explains, one could even go a step further, and posit that modal structure is all there is to know about laws, following a similar move as in ontic structural realism.

However, one might object that this current primitivist reading lacks metaphysical intelligibility unless the nature of the modal structure is clarified and explicitly grounded in reality[5]. The chosen metaphysics of modality must accommodate the fact that the constraints (namely, the sets of possible mosaics) and their assigned probabilities are primitive, meaning they are ontologically independent of the actual mosaic.

This last requirement is not fulfilled in Lewisian modal realism (Lewis 1986). In that view, the possible worlds (i.e. the mosaics in Adlam's framework) are concrete physical worlds, ontologically on a par with our actual world. Since all mosaics would necessarily exist, and actuality would be an indexical matter, laws would not have any governing role over our actual world. Contrary to Lewisian modal realism, we need an ontological distinction between the possible worlds and the actual one, so that the primitive nomic probabilities apply only to sets of *possible* mosaics (and do not presuppose the existence of our actual world). From there, a relation of ontological dependence of the actual world on the realm of possible worlds would be structured by the laws of nature, insofar as these laws govern by metaphysically necessitating certain features of the actual world. The relation of ontological dependence could be broadly conceived, including the possible case of causal determination understood as a one-sided existential dependence (see (Tahko & Lowe 2025)).

A notable challenge lies in the fact that the governing role of global constraints typically involves non-trivial probability distributions, whereas ontological dependence is usually conceived as non-probabilistic. Furthermore, if the laws are such that there is a set of mosaics assigned probability 1 that includes *multiple* elements (our actual world among them)[6], it seems natural to say that the laws demand that, necessarily and deterministically, all of these mosaics are actualised. The 'actuality' of our world would then have an indexical component. Through a similar reasoning, should our world belong instead to a set of mosaics assigned a non-trivial probability, the laws would make it possible (though not necessary) for multiple worlds to be actualised. Avoiding this narrative would require prohibiting laws that assign probability 1 to sets of mosaics with more than one element, and enforce that only one world (whether picked out stochastically or deterministically by the laws) is actualised.

(Van Inwagen 1986), (Plantinga 1978), (Adams 1974) and (Priest 2016) propose different theories in which possible worlds are ontologically distinct from, and exist independently of,

[5]I am thankful to Baptiste Le Bihan for bringing this point to my attention.

[6]In (Adlam 2022*a*), this scenario corresponds to the world displaying only *weak holistic determinism*. No objective chance would be involved in the laws, yet some arbitrariness would remain regarding which world they select as actual.

the actual world. However, these accounts do not posit any ontological dependence between the structure of possible worlds and our actual world. As such, they offer no support for a form of nomic governance of the actualization of the world grounded in the structure of possible worlds. A possibly more successful metaphysics can be found in (Pruss 2002). This view combines a Leibnitzian reading of possible worlds with the existence of an Aristotelian first cause. It conceives possible worlds as 'maximally specific consistent thoughts in God's mind of a way for the world to be', while God is endowed with the causal power to actualize one of them. This approach would be compatible with a primitivist reading of laws as constraints. The possible mosaics conceived as God's thoughts would be ontologically prior to his act of actualising one of them. The nomic probabilities would be objective chances in God's mind for one thought (i.e. a possible mosaic) to be selected over another. These probabilities would be independent from, and over and above, the actual world. Laws would exert their governance by metaphysically necessitating that God actualize a particular mosaic, whether deterministically or stochastically.

Now, an alternative might be preferred to this theological take on laws of nature. I leave it as an open question whether other conceptions of possible worlds can be developed in agreement with the requirements that (i) they are ontologically prior to the actual world, and (ii) they support with the latter a relation of ontological dependence in which laws, construed as constraints, play a governing role. A motivation to further explore a primitivist interpretation of laws as constraints arises from its improved answer to the well-known governing problem, captured by the question "how do [governing] laws 'tell' properties what to do?" (Ioannidis et al. 2021, p. 11)).

As stated in (Ioannidis et al. 2021), primitivism about laws approaches the governing problem by positing that the modal force of laws is a brute fact of nature, which the authors find unilluminating. A related way to express this worry can be found in (Jaag 2021), who objects that positing a 'primitive governing relation' is ontologically less parsimonious since a further 'explanatory nexus' is posited to connect the primitive laws to their instances in the world. This problem remains untouched in the global constraint approach to laws, as we still need to posit a relation of nomic governance acting on the relation of ontological dependence between the realm of possible worlds and the actual world. However, primitive laws as constraints alleviate a second worry affecting the relation of nomic governance. As explained by Jaag (2021), in traditional primitivist accounts, if one holds that a worldly fact is explained by the relevant laws

together with their antecedent states from which they causally evolve, the question arises: how does the primitive governing relation between the laws and the facts to be explained interact with the causal relation between these facts and their antecedents to provide a consistent explanation? This challenge does not arise in the framework of laws as constraints, where the global aspect eliminates any need for asynchronic causal evolution within the mosaic as part of the nomic explanation.

To sum up, the above discussion proposed a primitive interpretation of Adlam's framework, presented through a suitable theory of possible worlds, expanded with a nomic governing relation that operates on the ontological dependence of the actual world on the realm of possible worlds.

4.4.2 Dispositionalist picture

Moving away from the primitivist picture, one could modify Adlam's original account to accommodate a dispositionalist grounding of laws of nature. One way to articulate this view is to posit dispositional properties possessed by the world as a whole. That is, the actual mosaic would possess global dispositions to possess certain features. The laws as global constraints would supervene on these global dispositional properties.

To spell that idea in more detail, one could follow a similar path to (Bird 2007, Borghini & Williams 2008) and see global dispositions of the actual mosaic as grounding the structure of the modal space. In other words, the actual mosaic's dispositions to possess certain features would ground the (sets of) possible mosaics displaying these features, along with their corresponding objective chance. Contrary to the original formulation of Adlam's account, the actual mosaic would be ontologically prior to the laws of nature and the sets of possible mosaics (constraints). These would be derivative of the actual global dispositions, in which would lie the source of objective modality. The sets of possible mosaics (i.e. the constraints) and their assigned probabilities (i.e. the laws as a probability distribution over global constraints) would be descriptions or representations of possible ways the actual dispositional powers could have manifested.

However, the notion of a global disposition is delicate. Traditionally, the dispositional property of an actual object causally triggers a specific manifestation in response to a particular stimulus. By contrast, the dispositional property of the actual mosaic as a whole cannot trigger

a manifestation of itself, since it is already fully actualised[7]. Moreover, any stimulus that could trigger the world's mosaic as a whole would have to exist 'outside' that mosaic.

A solution might be found in Tugby (2013)'s Platonic dispositionalism, where dispositions are conceived as transcendent universals, existing independently of their (non)-spatiotemporal instantiations. In the global constraints formalism, the possible mosaics would then be understood as global Platonic dispositions for the actual world to manifest itself in a certain way. The former inconsistency of a world's global dispositions triggering its own manifestation would be dissolved, since these global dispositions are now suitably external to the actual mosaic itself. The appeal to laws of nature can solve the second issue of global dispositions having untriggered manifestations. The actualisation (or better, instantiation) of a given 'dispositional Platonic mosaic' would be governed by the nomic probability distributions over constraints.

That said, this move would make the resulting account akin to a primitivist interpretation: the constraints and their probabilities would be independent from the actual world, and a nomic governance relation would be postulated. To the extent that such a (possibly probabilistic) governing relation ruling the actualisation of Platonic mosaics can be meaningfully articulated, this would constitute an alternative to (Pruss 2002)'s picture presented in section 4.4.1.

In conclusion of this section, the above discussion showed that it seems possible to make laws as constraints metaphysically intelligible via a primitivist interpretation specifying the nature of the possible mosaics, their ontological relation to the actual world, and the governing role of laws with respect to that relation. I leave a more advanced development and assessment of the proposed routes for future work.

4.5 The explanatory power of global constraints

Turning to the second concern raised by Lam & Wüthrich (2023), we now examine whether the global constraints approach to laws offers satisfactory explanatory power for a range of (potentially interrelated) questions typically addressed by non-Humean theories of laws. First, it is expected that non-Humean laws explain the presence of patterns and regularities in nature (Bird 2007, p. 86). More specifically, they are usually expected to explain the phenomena they apply to (Dretske 1977, p. 262). Finally, supporting counterfactual propositions is likely a crucial task for laws that explain. Woodward (2005) argued that a core feature of an explana-

[7]The idea of 'global dispositions' possessed by the entire world has been discussed, albeit somewhat indirectly, in (Bigelow et al. 1992). However, the global aspect of these dispositions involves only the spatial dimensions, as the entire world is understood as everything that exists at a given time.

tion is its ability to answers counterfactual questions. An account of nomic explanation based on counterfactual dependence has also been developed in (Jansson 2015).

In Adlam's account of laws as constraints, the existence of patterns and regularities in nature is due to governing laws assigning non-zero probabilities to constraints (i.e. sets of possible mosaics) containing such patterns and regularities[8]. On the constraints view, laws explain phenomena not by invoking unfolding mechanisms or processes, but by appealing to 'all-at-once' structural patterns. The question of why and how a given system evolves from initial conditions becomes obsolete, as the framework adopts an atemporal perspective on the world as a whole (a move particularly well-suited to non-spatiotemporal contexts). In this picture, the histories of physical systems are treated as epistemic constructs, echoing Lam & Oriti (2024)'s antirealist stance toward the nomic production account of laws.

Finally, how do laws as constraints support counterfactual reasoning? In the nomic production approach to laws, the truth value of counterfactuals is grounded in the (non-)temporal evolution of physical systems. A counterfactual is true if the antecedent, construed as a well-defined intervention on the initial state, leads to the consequent via the system's causal structure (see (Lam & Wüthrich 2023)). Since such causal grounding is unavailable in a constraints approach to laws, counterfactual truth must instead be evaluated through the lens of possible worlds. Lewis (2013) famously proposed that a counterfactual "If A had happened, B would have happened" is true if, in the closest possible world(s) where A holds, B also holds. This account must be adapted to fit Adlam's framework and its metaphysical commitments, as discussed in Section 4.4.

In the context of a primitivist interpretation of laws as constraints, the counterfactual "If A had happened, B would have happened" is true with probability p if, in the closest possible mosaic(s) where A is true, B is also true, and the assigned probability is p. Alternatively, the counterfactual "If A had happened, B would have happened with probability p" would be true. For trivial probability distributions for which the set of mosaics assigned probability 1 contains *only one* element (our actual world), the world could not have actualised differently, and all counterfactual statements are false. For trivial probability distributions in which the set of mosaics assigned probability 1 contains *more than one* element (among which our actual

[8]As argued in Hildebrand (2013), one may doubt whether primitive governing laws can adequately explain regularities in nature. The argument remains intact in the context of laws as primitive global constraints. This challenge lies beyond the scope of the present paper, and it will suffice for current purposes to note that primitive global constraints appeal to a similar explanatory strategy as traditional primitive accounts in addressing patterns and regularities.

world), different worlds are actualised, and some counterfactual statements may be true. Lastly, for non-trivial probability distributions, the world could have actualised differently (and might have, if one allows for the actualisation of multiple worlds), and some counterfactual statements may be true.

5 Conclusion

This paper examined three key challenges confronting the nomic production approach to laws in non-spatiotemporal contexts and assessed how these challenges are addressed within the framework of laws as global constraints. First, the purported advantage of the global constraints approach with respect to its lack of commitment to a kinematic/dynamical distinction was tempered, as the arbitrariness of this distinction partly stems from the arbitrariness involved in choosing an ontology, a challenge shared by both approaches. Second, the additional theoretical constraints on the causal structure of physical models imposed by the nomic production picture were considered a relatively minor drawback, especially given that contemporary physics has not (yet) unequivocally endorsed models with closed causal loops. Finally, the need to ground the nomic production of the world in asymmetric processes poses the most serious challenge for the approach, as it likely requires positing additional elements (at the very least, a direction for the asymmetric process), which sits uneasily with a naturalistic attitude.

While the global constraints approach to laws appears less affected—or entirely unaffected—by the challenges confronting the nomic production view, questions remain as to whether it can overcome its own criticisms, particularly concerning metaphysical clarity and explanatory power. Several interpretative paths have been outlined to further develop Adlam's original framework, which, if convincingly pursued in future work, may help clarify the metaphysical status of laws as constraints in (non)-spatiotemporal contexts. It was further argued that the shift to global constraints might even alleviate some open issues related to the long-standing governance problem. Regarding explanatory power, the approach shows promise in accounting for regularities and phenomena in nature and in supporting counterfactual claims

To sum up, given the difficulties facing the nomic production picture in quantum gravity, and the strengths of the global constraints approach, the latter stands as a compelling alternative to the antirealist retreat advocated by Lam & Oriti (2024).

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