How to be Humean about idealisation laws

If one has Humean inclinations, what account should one provide for idealisation laws? In §1 I introduce the most currently popular Humean approach to laws of nature: the best system account, along with some basic requirements for how to be the Humean. In §2 I show why idealisation laws are unlikely to be accommodated within this account of laws. In §3 I offer an alternative approach, which takes idealisation laws to be meta-laws, placing requirements on the theorems of the best system.

1 Some background

1.1 Grounding laws in the mosaic's regularities

A Humean mosaic comprises only worldly on-goings which are not intrinsically causal. Maybe it will contain occurrences intrinsically describable as 'charge x is instantiated at spacetime point p', 'mass x is spatiotemporally proximate to mass y'. But it won't contain any occurrences which cannot be intrinsically typed by non-causal, non-modal language (Lewis 1986, 1994). To be a Humean, one need not believe some or other mosaic is all there is—although this is typical—but one should at least take it as a *methodological principle* that any empirically motivated claim (e.g. in science or metaphysics) should be *in principle* translateable into terms which commit the claimant to no more worldly entities than those in the mosaic.

Having taken that on board, Humeans may diverge over how many mosaics there are. The view given to us by Lewis, the progenitor of modern-day Humeanism, was that there is one mosaic per world and it is carved at the joints of a single set of perfectly objective natural properties. Subsequent Humeans have demured, either over the objective nature of the properties or their uniqueness (e.g. Loewer 1996, Earman 1986). Cohen and Callender (2009) suggest we oppose both constraints. More specifically, they invite Humeans to consider mosaics which carve the world according to different classes of properties correspondent with the kind terms of different sciences (e.g. thermodynamics, statistical mechanics, fluid dynamics, evolutionary biology, etc.). Presumably there are composition relations between the various tiles in different mosaics, and we needn't suppose that the composed mosaics (arguably those of the special sciences) have the same coverage as the uncomposed mosaics (arguably that of fundamental physics).

Callander and Cohen's view has significant appeal, since it no longer requires Humeans to be committed to a single and entirely language-independent individuation of the world. It also facilitates informative inter-relations among the sciences, since there need be no expectation of reduction of the entitites in one mosaic to another, and yet we can reasonably explore the compositional dependencies which hold (cf Schrenk 2017). From hereon, I take it that this 'science-relativised' view of the world's mosaics is the preferable picture for the Humeans to adopt.

Laws of nature are prominent features of scientific theorising across the sciences and any empirically motivated methodology should be able to make sense of that. Consequently, the mosaical grounds Humeans propose for laws of nature will need to satisfy a number of requirements. I'll stress three throughout this discussion. First, the proposed grounds (some or other Humean mosaic) should metaphysically explain, or 'ground', the laws. While we might wonder what exactly metaphysical explanation amounts to one plausible condition in the case of grounding is that the existence of the grounds should be at least sufficient for the existence of what is grounded. Second, laws' grounds should render them empirically accessible, such that given those grounds we can see how it is possible that laws are discovered in a non-trivial manner (Hicks 2018). It cannot be, for instance, that the laws are derived from *a priori* or logical truths, or that their grounds are all so rare and unpredictable that we could never hope to discover any of the laws which are grounded in them. A proposal of grounds need not incorporate an account about the process of laws' discovery, but it should remain consistent with the evident fact that we do come to learn them in a non-trivial way. Third, any proposal about laws' grounds should show why laws have the explanatory relevance they have. It seems evident (and I'll elaborate more on this in §2.2) that laws have an explanatory relevance beyond the mere epistemic crutches they provide for understanding the world. Something about laws makes them good explainers regardless of what we happen to know. Despite eschewing notions of laws' governance or fundamentality, even a Humean account of laws' grounds should have something to say about why this is.

I will not say anything more about the nature of mosaics' grounding of laws. Suffice it to say that whatever solution is proposed had better satisfy the three considerations just described, viz. metaphysical sufficiency, empirical accessibility, explanatory power. Obviously, Humeans should also not offer grounds which contradict their own methodological principle. As a consequence, Humeans tend to propose regularities in the mosaic as laws' grounds. For although it is coherent to hold onto a regularity-based analysis of laws of nature if one doesn't restrict the regularities to those in keeping with the Humean mosaic (see Demarest 2017, Tahko 2015), if one does make such a restriction then regularities seem to be about the only worldly resource one can go on.

1.2 Best Systems Account

Given that regularities ground the laws, the obvious follow-up question is 'which regularities?' To answer this, the current trend is a so-called 'best system account' (BSA), which determines the laws of some mosaic as those generalisations which are theorems in that deductive system which best captures the mosaic's content according to a balance of certain desiderata including, at the very least, simplicity, comprehensiveness (or 'strength') and, in order to accommodate probabilistic laws, 'fit' with the facts (Lewis 1973, 1983, 1994, Loewer 1996, Schrenk 2007, 2014, Cohen and Callender 2009, Callender and Cohen 2010). Since the content of the discussion which follows is not so concerned with issues surrounding chance, I will mostly ignore the latter constraint.

The notion of strength is invariably cashed out in terms of deducibility of content about a Humean mosaic: laws are theorems of a deductive system, originally at least, a 'deductively closed, axiomatisable set of true sentences' (Lewis 1973, 73). A system is stronger if it entails more information about the mosaic.

The strength of a system is to be moderated by its simplicity. A world (arguably, *our* world) may not be such that the strongest system is achievable without a grotesquely large set of deterministic axioms. If that's the case, considerations of simplicity may demand that some axioms—hence some laws according to BSA—be indeterministic (see Earman 1986, 89). More importantly, some generalisations will be left out altogether, relegated to the 'merely accidental'.

Admittedly, these considerations prove difficult to provide a precise account for, and one might wonder whether, for instance, considerations of simplicity actually always *compete* with strength (Roberts 2008, Woodward 2014). But that *some* balancing acts between them (or perhaps other desiderata as well) are required seems to be agreed upon. Arguably, there must also be some constraint on which generalisations are laws. If it is a theorem that energy is conserved, then it is a theorem that energy is conserved or it's not, but the disjunctive claim is surely not a law! There are various criteria for how this restriction might go (no disjunctions, no quantification over non-natural classes or properties, etc.). One option which seems plausible to me is to restrict the form of the law. In the quantified sciences, at least, we might propose that laws should have the schematic form,

$$(x)(\mathrm{S}(x) \rightarrow \mathcal{F}(x)), \qquad \text{(Sch.1)}$$

where S is a 'system-type' correspondent with the basic properties and kinds of the scientific domain being systematised (e.g. comprising two masses, comprising a particle in an infinite potential well, comprising predator and prey populations in a habitat, etc.) and $\mathcal{F}$ is some functional behaviour relating variable-properties of the system. This formulation of (first-order) quantitative laws has been defended by Friend (2016) on the grounds that equations alone cannot be interpreted as the full content of laws: they must be *conditioned* on the class of systems to which the equation is explicitly or implicitly taken to be applicable. Adopting the schema provides a plausible restriction on which theorems in the best system are laws, and it seems to accurately capture the content of our most prized quantitative laws, e.g. the following.

$$(x)(\text{Two-masses}(x) \rightarrow F(x) = G\tfrac{m_1(x)m_2(x)}{r^2(x)})$$

$$(x)(\text{Electrical-component}(x) \rightarrow \mathbf{J}(x) = \sigma(x)\mathbf{E}(x)).$$

In what follows I'll assume Sch.1 (or something near enough) is the most transparent form of the laws which appear in the best system. What will remain in question is whether or not idealisation laws should fit that schema too.

Implicit in most presentations of the BSA account is that whatever ends up counting as a 'best' deductive system will be one which is *true*. However, Braddon-Mitchell (2001) has suggested that the Best-System approach may be much improved by weighing truth *against* the other desiderata of strength and simplicity. The BSA renders laws analogous to the algorithms of data compression, and compressions can be greatly improved by permitting some degree of loss to the information compressed. As Braddon-Mitchell emphasises,

> such an acount of laws is [...] thoroughly in keeping with the Humean tradition. If, as a Humean, you think that laws are just pervasive regularities in the universe, then you shouldn't be obsessed with exceptionlessness. Surely that is something which, as a conceptual requirement, comes with accounts that involve necessitation. (267)

A BSA which trades truth, in the sense of counting systems' regularities' precision and/or proportion of exceptions to count as currency alongside strength and simplicity, is therefore perfectly consistent with the Humean idea that laws are grounded in their instances, viz. regularities, albeit potentially exception-ridden or imprecise ones.

One key benefit of permitting a trade-off between truth and other desiderata is that it makes it more plausible that 'special science' laws of the macroscopic world (which are widely thought to have exceptions) get included within the best system.In particular, the statistical nature of the second law of thermodynamics arguably *demands* that exception-permitting laws be taken into account (Fenton-Glynn 2016). For it is perfectly consistent with fundamental physical laws that some closed system fails to obey the second law. Since much of the macroscopic world functions only so long as its systems are entropic (i.e. second-law obeying), it is natural to demand that any plausible account of macroscopic laws permit exceptions.

In what follows, I'll assume that BSA trades in truth as well as strength, simplicity and fit. That's not to say, however, that we should tolerate radical departures from truth. One point I'll be emphasising later on, for instance, is that idealisation laws themselves appear to be too divergent from the truth to be plausible axioms in even a lossy best system. It remains the case, however, that the Humean need not accept the BSA at all, and the approach has certainly come into question from within the Humean camp (Hall 2015, Hicks 2018). Nevertheless, my proposal for how the Humean might deal with idealisation laws takes BSA as the point of departure. If the approach turns out to need overhaul, so will what follows.

1.3 Satisfying the Humean requirements

On the face of it, BSA seems in keeping with the Humean agenda whilst at the same time looking promising when it comes to the previously mentioned requirements on laws' grounds. Presumably the local matters of fact which comprise any of the world's mosaics can't be alone sufficient to ground the best system (Shumener 2019). What is needed in addition is a *totality fact* that the sum of local mosaical on-goings exhaust the mosaic of that scientific domain. Of course, totality facts are notorious for having no uncontroversial grounds, but I take it that the Humean engages in no unique problem by relying on them.[1] In conjunction with such a totality fact, the mosaical on-goings are metaphysically sufficient for all the theorems of the best system. Moreover, the mosaical on-goings are exemplary candidates for empirical accessibility. True some may be far away or require impressive devices to observe, but it is the very foundation of Humean motivation for basing science on mosaical facts that it is superlative in empirical accessibility.

What of laws' explanatory power? The expectation of most Humeans is that laws' explanatory power comes from unification. Loewer writes that the 'L-laws', i.e. theorems of the BSA,

[1] I'm therefore choosing, as I presume most Humeans will, to reject Schumener's (2019) first premise and conclusion that Humeanism is false because (i) laws are intrinsic, and (ii) reliance on totality facts makes laws extrinsic.

> do explain. They explain by unifying. To say that a regularity is an L-law is to say that it *can* be derived from the best system of the world. But this entails that it can be unified by connecting it to the other regularities implied by the best system. (1996, 113)

From this passage alone, one might wonder why the explanatory unifying power of laws is explained by the fact they themselves are unified. But what BSA theorists like Loewer intend to say is that the unifying structure which confers upon laws their explanatory power is provided by the rules of logical consequence and those propositions from which the whole system is derived, i.e. the axioms. Hence, Callender and Cohen remark that,

> Recognizing in science the attempt to produce small sets of basic principles as a result of balancing simplicity and informativeness is the central and powerful insight that motivates MRL [read 'BSA'] (and also, we believe, the unificationist theory of explanation). (2009, 3)

So, for the BSA theorist, laws explain because they are a feature in the unifying best system, ultimately entailed by the axioms from which the rest of the system follows. As explainers, therefore, the axioms reign supreme.

To be sure, many have queried if this unification is sufficient to confer adequate explanatory power to the laws. It has been repeatedly objected that Humean laws would be involved in a problematic explanatory circle by virtue of being grounded in the mosaic which they are also supposed to explain (Armstrong 1983, Maudlin 2007, Lange 2013, 2018). This is no doubt a serious issue for which there has already been much in the way of response on behalf of the Humean (Loewer 2012, Hicks and van Elswyk 2015, Marshall 2015, Miller 2015). I'll mostly bypass this debate, resting my Humean account of idealisation laws implicitly on the success of some or other Humean response. However, it's worth making the following two points (which will also be helpful for the account of idealisation laws developed below). First, once sold on Humeanism in general, one should generally be content to dispel the need for laws to have any ontic explanatory power over the mosaic about which they generalise. Humeans don't believe there are any such real explanatory relations and it would not be reasonably immanent to critique the Humean's specific account of *laws* for not positing such a relation. Second, it is clear that the theorems of the best system for a mosaic do go beyond the mosaic in some sense, since they involve a totality fact which is presumably not part of any mosaic itself—at least it is not one of the local matters of fact. Therefore, there cannot be a complete circle of explanation, since no mosaic is solely responsible for grounding its laws. Laws tell us something more than we can learn by surveying the local matters of the mosaic: they tell us that that is all there is to the mosaic!

In sum, the BSA seems to have the facility *in principle* to fulfill the Humean ideals regarding laws' grounds. But difficulties may arise when we look at particular kinds of law. It is just such an issue which idealisation laws present.

2 The problem: idealisation laws

When we come across a complex situation for which a perfectly accurate law is either beyond our knowledge, our ability to solve, or our practical requirements, then we can often idealise the situation. We do this either by abstracting away from the effects of certain causally incidental influences or else by fixing variables to some appropriate value (Weisberg 2007, Elgin 2004, Strevens 2008, Potochnik 2017). The result of such idealisation is a model, e.g. an equation, which is used to describe, predict or explain real world behaviour despite not being entirely accurate. For instance, the Newtonian constitutive equation for incompressible fluids is represented as,

$$\tau = -\mu \frac{\partial u}{\partial y} \quad \text{(Eq.1)}$$

where τ is shear stress of the fluid, μ is the steady-shear viscosity and $\frac{du}{dy}$ is the velocity variation across the y direction transverse to direction of flow. The equation is a powerful tool for thermodynamic and engineering pedagogy, explanation, prediction and control; any Humean should want to account for this. Even so, there are no truly incompressible fluids. Real fluids vary in density with changes in pressure. The constitutive equation is used to *idealise* real fluids. It need not give an entirely accurate description of a fluid-dynamical system, but operates on the assumption that starting with facts which abstract away from the complexity of the real-world is a good way to explain those systems.

There has been a surge of interest in idealisation (e.g. Elgin 2004, Weisberg 2013, Potochnik 2017), and it's easy to see why. Idealisation is everywhere in science. Many idealisations are characterised by the use of known idealisation laws. Examples include Gresham's law and the laws of supply and demand (from economics), Farr's law (from epidemiology), Werner's law (from geology), Wallace's law (from evolutionary biology), the Ideal Gas law (from thermodynamics), the logistic and Lotka-Volterra equations (from ecology), Snell's law (from optics), and (more controversially) component-force laws (from mechanics). But despite their ubiquity, idealisations and their associated laws are not like a traditional philosopher's conception of laws of nature, as (e.g.) strict, true, deterministic and widely-instanced generalisations. In particular, we'll see that idealisation laws present a particular problem for orthodox Humean thinking.

Following on from §1.2, I take it that equations like Eq.1 are not themselves laws but rather specifications of some behavioural characteristic predicable of certain sorts of system. As we saw, it is reasonable to think that laws which emerge from the best system *condition* that behaviour on some or other system-type (as per Sch.1). It is just this fact which makes it sensible to talk of laws as representing (or just being, under some ways of talking) regularities in the world. The question, however, is whether idealisation laws can be understood in these terms. In the rest of this section I'll discuss two seemingly exhaustive options for fitting idealisation laws into the schematic form of Sch.1. These include 'going broad', where the system-type is understood to have plenty of instances, and 'going narrow', where the system type is understood to have very few if any. We'll see that there are serious difficulties with either option.

2.1 Going broad

If we are to fit the idealisation law corresponding to the idealising equation Eq.1 into the form of Sch.1 one option is to 'go broad' and consider the relevant system type *being any real fluid* (RF), providing the following generalisation.

$$(x)\left(\mathrm{RF}(x) \rightarrow \tau(x) = -\mu(x)\frac{\partial u(x)}{\partial y(x)}\right) \qquad \text{(Gen.1)}$$

Gen.1 has plenty of instances (i.e. systems which satisfy the antecedent), but the consequent will be invariably falsely predict most if not all of them. Following the suggestion of Braddon-Mitchell's the Humean might feel relaxed about this due to the fact that the best deductive system is permitted to be somewhat *lossy* (see §1.2). But there is a good reason why it is implausible to assume that the trade-off between truth with strength and simplicity can account for the imputed inaccuracy of idealisation laws.

Idealisation laws invariably correspond with more precise generalisations which condition behaviour on just the same broad class of system. For instance, all real fluids in general will be much better approximated by the Newtonian constitutive equation for *compressible* fluids.

$$\tau = -\mu\frac{\partial u}{\partial y} + \big(\frac{2}{3}\mu - \kappa\big)(\nabla \cdot v)I. \qquad \text{(Eq.2)}$$

The additional variables to those in Eq.1 are for bulk viscosity (κ) and bulk flow velocity (v) (I is the identity tensor). This more precise behavioural equation has the idealising equation Eq.1 as a special case. As Morrison points out in her *Introduction to Fluid Mechanics*,

> for incompressible fluids, $\nabla \cdot v = 0$ and Eq.2 reduces to Eq.1. (2013, 867)

The same goes for other cases of idealisation. For example, the idealising Rayleigh-Jeans formula for black-body radiation at low frequency can be obtained from the equation in Planck's law by putting the Planck constant to zero; the idealised dynamical behaviour of an undampened oscillator can be obtained by putting viscosity of non-Hookean springs to zero; the ideal gas equation can be obtained from Van der Waals equation by putting the values for intermolecular force and size to zero; the Malthusian growth equation can be obtained from the Lotka-Volterra equations by setting the predatory population to zero. In each case, the derived equation (often preferred in practice) can be considered a special case of the more complex equation, obtained when appropriate terms are set to a constant (often zero). In each case, the more complex and precise equation is applied in practice to a set of systems which includes that to which the original simpler equation applies to. Indeed, one might reasonably suspect that the existence of a mathematical relationship with a more accurate equation is the *mark* of idealisation, since idealising equations are always idealisations from some less-idealising model.

But the correspondence of idealising equations with more accurate equations implies that the inaccuracy of broad idealising generalisations like Gen.1 cannot be mitigated by permitted lossiness. That's because there's always a another generalisation which is more accurate (at some small cost to its simplicity) and which is inconsistent with that broad idealising generalisation. In the fluid dynamical case, for example, we have the following generalisation.

$$(x)\left(\mathrm{RF}(x) \rightarrow \tau(x) = -\mu(x)\frac{\partial u(x)}{\partial y(x)} + \big(\frac{2}{3}\mu(x) - \kappa(x)\big)(\nabla \cdot v(x))I\right). \qquad \text{(Gen.2)}$$

Gen.2 is clearly a law of fluid dynamics if Gen.1 is. From the Humean's perspective, it is more accurate for a broader range of real fluids at a justifiable increase in complexity. From the perspective of scientific practice, Eq.2 is employed widely in fluid dynamics and we would certainly not want to preclude its involvement in a law for the sake of including the employment of the less accurate equation. However, the two broad generalisations Gen.1 and Gen.2 are inconsistent. At most *one* can be a theorem of the best system. The strategy of 'going broad' therefore seems to force us to choose between candidate laws involving equations *both* of which we would like to feature in the laws of fluid dynamics.

In sum, we'd better find some other way of rendering idealisation laws like that for constitutive flow. For the strategy of 'going broad', as we're currently conceiving it, brings the candidate idealisation laws into conflict with those candidate laws constructed in the same broad way using the inevitable and more accurate equations of which the idealising equation is a special case. The obvious response to neturalise the conflict is to narrow the scope of one or other generalisation. And if either candidate is to have its scope narrowed, it is surely not that of the more accurate law, since it is better at predicting the behaviour of that broad class of systems.[2]

2.2 Going narrow

Since we've tried 'going broad' with idealisation laws' system types, the alternative seems to be to 'go narrow' and consider the relevant system type of whatever idealisation law corresponds with Eq.1 to be more tailor-made for the particular behavioural function. The obvious choice for our central example is *being an* ***in****compressible Newtonian fluid* (IF), as in the following generalisation.

$$(x)\left(\text{IF}(x) \rightarrow \tau(x) = -\mu(x)\frac{\partial u(x)}{\partial y(x)}\right). \qquad \text{(Gen.3)}$$

At the very least, such a formulation has the merit of fitting our common parlance of the law as one 'for incompressible fluids'. In practice an incompressible fluid is any fluid with a Mach number less than 0.3, implying a change in density of less than 5%. So if IF is interpreted as being satisfied by anything with a Mach number of less than 0.3 then it will have a narrower class of instances of its system type than RF, but will still have plenty of instances. Nevertheless, it remains implausible for the Humean to interpret the idealisation law for constitutive incompressible flow law this way. Unless we also interpret RF as being satisfied only by fluids with Mach number greater than or equal to 0.3 then Gen.3 and Gen.2 will still remain inconsistent, since some of their instances will be shared but the predictions will be different. But interpreting Gen.2 as concerning *all* fluids is so much simpler and also more accurate (for fluids of any Mach number) than bifurcating the class of real fluids into a subclass described by Eq.2 and a subclass described by Eq.1 (I assume there must be a law covering the compressible fluids). Consequently, Gen.3 will not be counted a law if its instances include any fluid with change in density less than 5%.

[2]Of course, it could well be that neither are satisfactory in their broad form, if there is a *third* even more accurate equation applying to at least the same class of systems.

This kind of reasoning shows in general that the only kind of narrowing of scope of the antecedent condition of an idealisation law which has a chance of not coming into conflict with its more accurate counterparts is to narrow its system type to that class of systems for which the more accurate counterpart provides no descriptive improvement. In the fluid dynamical case, therefore, narrowing the scope of the system type would involve treating IF as satisfied by only *truly* incompressible fluids, i.e. those whose density does not change under pressure. But in that case, of course, Gen.3 turns out to be vacuous (similarly for other idealisation laws). While it is not incumbent on a Humean who adopts BSA to ground every law in the regularity it describes, i.e. not every law needs to be grounded in its own instances, it is fairly disastrous to think that the constitutive law for incompressible flow, or indeed any idealisation, is one of these. There are at least two reasons for this.

First, the issue of Gen.3's vacuity is not just that there may just happen to be no instances but that instances are *impossible* according to the laws of fluid dynamics. After all, there are laws of fluid dynamics (e.g. the total force law) which entail that all fluids are somewhat compressible under pressure. Hence it is a consequence of the laws themselves that nothing satisfies the antecedent of Gen.3. This makes Gen.3 a trivial theorem of the best system, since *any* generalisation with that antecedent condition would be a theorem.[3] Even if the Humean is willing to stomach labelling such theorems 'laws', there is surely a difference between those of value in scientific practice (e.g. idealisation laws and non-trivial axiomatic laws) and trivial theorems like 'if something is an incompressible fluid then anything goes'. Yet Humeans seem to commit to a rejection of this distinction by narrowing the scope of the system type in this way.

Note that this issue of triviality does not apply only to the fluid dynamical case. Presumably it is a law of ecology that populations always have some external pressures (predation, food sources, environmental hazards, other evolutionary pressures, etc.). But that entails that not only isn't there any system which exactly obeys the Malthusian exponential growth equation, but that there *couldn't* be. Hence any attempt to narrow the system type to which the Malthusian growth equation applies, so that it comes out true and consistent with more accurate ecological laws with a broader scope, will be trivially true. Malthusian

[3]Thanks to an anonymous referee for stressing this point to me.

growth will apply, but so will any functional behaviour, since the antecedent is unsatisfiable. I take it similar reasoning will hold for other idealisation laws, e.g., the ideal gas law, law of supply and demand, etc.

The risk of triviality is problem enough for the 'going narrow' approach. But a further, and perhaps even less avoidable, problem is that going narrow makes it difficult to see how idealising equations can have the explanatory relevance they have to real-world situations. The explanatory importance of idealisation laws is nicely brought out by Elgin in discussion of Snell's law, an idealisation of the contributory influence of perfect media boundaries to actual (often anisotropic) refraction phenomena.

> Sometimes it is useful to first represent a light ray as conforming to Snell's law, and later introduce 'corrections' to accommodate anisotropic media [...] [I]f we are interested in optical refraction in general, it might make sense to start with a prototypical case, and then show how anisotropy perturbs. By portraying anisotropic cases as perturbations, we point up affinities that direct comparisons [e.g. between the paths of two actual light rays] would not reveal [...] Showing how a variety of cases diverge from the prototypical case contributes valuable insights into the phenomenon we are interested in. And what makes the case prototypical is not that it usually obtains, but that it cleanly exemplifies the features we deem important. (2004, 117-8)

Elgin's example draws attention to the thought that idealisation involves abstraction from real-world cases in order to explain those very real-world behaviours. By idealising, we draw attention to the affinity that many real-world cases have which we could not do if we only used more accurate but also more complex laws. Idealisation laws, it seems, are explanatorily relevant to real world systems.

Idealisation laws also furnish an important theoretical basis for more complex laws. This point is made by Woody with reference to the ideal gas law:

> Descriptions surrounding application of the law, in textbooks and classrooms, suggest instead that idealization underwrites both its

> broad application and its explanatory status. [...] This vision [of an ideal gas] guides model construction for actual gases, and when the law poorly approximates actual gas behavior, properties are conceptualized as deviations from the ideal. In this way, the law's mathematical structure provides inferential scaffolding for the treatment of all gases, not only those for which it is a good approximation. Thus, the ideal gas law's role in practice is not essentially descriptive, but rather prescriptive; by providing selective attention to, and simplified treatment of, certain gas properties (and their relations) and ignoring other aspects of actual gas phenomena, the ideal gas law effectively instructs chemists in how to think about gases as they are characterized within chemistry. (2015, 4)

Here Woody is drawing attention to the ideal gas law's 'law's 'cognitive role in chemistry' in helping chemists understand the behaviour of real gases better. The point is that the idealisation laws aid our reasoning and understanding in a way which shows them to be explanatorily relevant, in part perhaps, by setting conceptual constraints, to what more accurate laws must be like. Notice that this is the case even if, in practice, it is known that the idealising equations are only predictively accurate in a small number of cases (if any). Idealisations have explanatory relevance even in cases when they are poor predictors.

The observation of idealising equations' wide application and explanatory relevance to real world situations heavily undermines the thought, captured in the 'going narrow' approach, that the laws in which they are involved concern antecedent system types which aren't satisfied by anything in the world (or only extreme cases). By modifying the antecedent in this way, we risk making idealisation laws irrelevant (cf Cartwright 1983, 57-8). Idealisation laws, it seems, are *about* real, non-ideal cases.[4]

In sum, the 'going narrow' strategy of rendering idealisation laws' antecedent system type is at least as undesirable as the 'going broad' strategy appeared to be. This is because there's no way to narrow the scope of the system type in a way which removes the risk of conflict with more accurate candidate laws but avoids rendering them vacuous (or applying to only some very extreme class of cases). The existence of vacuous laws might not be an issue *per se*,

[4]A non-Humean way of putting this would be to say that, for instance, the law for incompressible flow in fact governs compressible fluids.

but in the particular case of the attribution of idealising behaviour it risks (i) the resulting generalisation being a trivial theorem of the relevant deductive system (since there may be laws which preclude the existence of instances of the system type) and (ii) the resulting generalisation failing to have a system type appropriate for the kinds of practical explanatory applications to which the idealising equations in fact get applied.

2.3 Where to go from here?

The problem raised for idealisation laws is essentially a dilemma of logical form. We want to find a way to identify a system-type about which the law can be said to concern which renders the law non-trivial and non-vacuous. But we need to find a way to do so which doesn't conflict with the fact that there is clearly a more accurate law which covers at least the same systems the idealisation law covers. If we choose the same broad system type as the more accurate law then there is inconsistency in the deductive system, and the more accurate law is clearly the preferable theorem to maintain. If we choose a narrower system-type then there is hopeless triviality and loss of explanatory power.

Something like this problem has been observed in a more general assessment of Humean approaches to special science laws by Backmann and Reutlinger (2014) who identify both 'Lange's dilemma' (after Lange 1993) between laws' triviality and falsity, and 'Cartwright's dilemma' (after Cartwright 1983) between laws' vacuity and falsity. Both dilemmas, they claim, undermine the possibility of the best system's approach accommodating special science laws, which are invariably idealising or require ceteris paribus clauses. They argue, in particular, that the problems remain even granting the modifications proposed by Cohen and Callender (2009), who explicitly suggest that their science-relativisation may help avoid such troubles.[5]

Here I'm focusing on idealisation laws, thereby leaving so-called 'ceteris paribus laws', which have some or other explicit modifier (cf Fodor 1974, Pietroski and Rey 1995) to the system-type, to one side. Consequently some of the issues raised by Backmann and Reutlinger do not apply. In particular, the triviality

[5]Backmann and Reutlinger grant that the admission of lossy laws may have more luck. I certainly think such an admission is necessary but the foregoing discussion makes clear that they are also insufficient, given the existence of more accurate laws.

complaint raised in the foregoing is not quite that exposed by Lange's dilemma. Lange was concerned that ceteris paribus clauses could be used to trivialise a law by building into the antecedent the behaviour mentioned in the consequent, or else by allowing for any kind of behaviour to be consistent with the generalisation. The triviality worry raised in the present discussion, however, is rather that the laws might entail that there are no instances of an idealisation law's system-type, and so whatever behaviour it attributes to the system-type will be trivially satisfied. Nevertheless, an answer to the problem of idealisation laws' logical form will surely go some way to address the concerns raised by them.

3 The solution: 'going meta'

Going broad and going narrow are only exhaustive options if one assumes that idealisation laws must maintain the schematic form of Sch.1. The way out of the dilemma just posed for idealisation laws is, therefore, to break with this assumption. Evidently, if Sch.1 is a mark of laws among the theorems of the best system, as I think it is, then this way out will require us to think of idealisation laws as something *other* than laws of the best system. What I propose is that we think of them as *meta*-laws, specifically theorems of a 'meta-ised best system' with a certain schematic form. In §3.1 I give the details of this 'going meta' solution. In §3.2 I say why it improves on the previous approaches to idealisation laws. In §3.3 I say why it fits the Humean credentials in a satisfying way.

3.1 Idealisation laws as meta-laws about super laws

Following Cartwright (1983, 70), let's refer to those more accurate generalisations concerning the same broad class of systems to which idealising equations seem relevant the idealisation's corresponding 'super law'. The original idea behind the notion of a super law is that they 'take into account all the relevant interactions into which a system can enter' (Corry 2009, 166); although I will suggest later that this might be something the Humean will not want to commit to. Such laws therefore diverge from idealisation laws which only take account of some subset of interactions, as when, e.g., Eq.1 fails to include variables for bulk viscosity and bulk flow velocity on shear stress. Therefore the behavioural functions in super laws under this interpretation are *superlative* with respect to their ability to accurately predict the behaviour of physical systems, at least in comparison to any other function involved in the deductive system for the relevant domain (e.g. fluid mechanics).

Crucially, idealising equations are related to equations featuring in super laws by being *special cases* of them, i.e. being instances of the super laws' equation resulting from substituting some variables for constants (which may, e.g., be finite, complex, zero or a limit). In principle, then, there might be a sequence of idealising equations related by virtue of each in the sequence having some variable which is a constant in the preceding equations until finally reaching that full set of variables employed in a super law. Of course, it might happen that we don't precisely know a super law corresponding to some idealisation. Nevertheless, if we know a law is an idealisation, then we know that some super law is out there.

Despite being an initial cause for concern, the existence of super laws can in fact be used by Humeans to construct a plausible view of idealisation laws. Here's a first pass. Since any idealising equation E itself is a special case of some corresponding super law's behavioural function, we can attribute to the same system type S to which the super law applies the property of *being such that its instances behaviours are described by a behavioural function which has E as a special case.* It's a good start, but not going to be quite what we need, since it is trivially satisfied. Arguably *any* equation is a special case of *some* behavioural function which accurately describes some class of systems. What more is needed, I take it, is the observation that the behavioural function which has E as a special case is that of a (super) *law*. That is, for any idealising equation E explanatorily relevant to some system type S, the following sort of statement is true.

$$\text{There is a law } (x)(S(x) \to \mathcal{F}(x)), \text{ such that } \mathcal{F} \text{ has } E \text{ as a special case.} \quad \text{(Sch.2)}$$

It is *this* form I propose the Humean understands idealisation laws to have. So, for example, in the case of the Newtonian constitutive equation for incompressible flow, the corresponding idealisation law looks as follows.

There is a law $(x)(RF(x) \to \mathcal{F}(x))$, such that $\mathcal{F}$ has

$$\tau(x) = -\mu(x)\frac{\partial u(x)}{\partial y(x)} \tag{Gen.4}$$

as a special case.

Two things are of note about instances of Sch.2 (like Gen.4). First, they do not have the form of a generalised conditional. The quantifier which takes the widest scope is an *existential* quantifier not a universal quantifier. As a consequence they do not have the form of Sch.1. However, they do imply there must be laws of that form. Hence, second, instances of this schema make reference to laws and so are, in some reasonable sense, 'meta-laws'. *Both* characteristics imply that idealisation laws cannot be laws in the standard way Humeans have understood them. Strictly speaking, laws under the BSA are theorems of the best deductive system which are generalisations (Lewis 1973, 73), arguably of the form Sch.1. That means, at least, that even if idealisation laws were to feature in the best system, they couldn't be laws. However, the deductive system takes as input only facts about the mosaic, and since the Humean eschews metaphysically real views of laws no such facts will be facts about what the laws are. Hence, if idealisation laws are to have the form Sch.2 they can't even be in the best system.

If idealisation laws aren't in the best system, then where do they come from? Key to the proposal is the idea that idealisation laws can be accommodated by the Humean, not as a theorem of the best system's axioms, but as a theorem of a different but crucially related set of axioms. Take the statement Gen.4. Neither Gen.1 nor Gen.2 are logically sufficient to entail it. But the statement that either statement *is a theorem of the best system* (and hence a law) would be. For example, if—as seems the more likely of the two—Gen.2 were a theorem of the best system, then the statement that it is such a theorem would entail (under Humean Best System theory) that it is a law that Gen.2. And given that Gen.2 entails that all real fluids' shear stress (τ), steady-shear viscosity (μ) and velocity variation ($\frac{du}{dy}$) are mutually predictable according to some function which has Eq.1 as a special case, then the statement that Gen.2 is a law will entail Gen.4.

In general, then, while Humeans will want to say that the (first-order) laws for some domain of properties are the expressions of the form §Sch.1 which are theorems of the axioms of the best systematisation of the distribution of those properties, they should say something different for the idealisation laws for that domain. Under the 'going meta' proposal, *idealisation laws are expressions of the form Sch.2 which are theorems of a set of axiomatic statements which state, for each axiom L of the best system, that L is an axiom of the best system*.[6] Call this alternative deductive system the 'meta-ised best system'.[7] Notice that it will follow deductively from all the axioms of this meta-ised system that all the theorems of the best system are laws too, and that all the special cases of all the behavioural functions attributed to certain system types by theorems of the best system are special cases of functions attributed by laws about those system types. There will, therefore, be instances of Sch.2 in the meta-ised best system. According to the current proposal, all of these are idealisation laws.

3.2 Why going meta is better

Like the 'going broad' proposal considered earlier, the 'going meta' proposal keeps the relevant system-type (whose instances' behaviour the law ultimately concerns) broad. For example, the relevant system type for the idealisation law for constitutive incompressible flow concerns *all* real fluids. Similarly, the ideal gas law will concern *all* gases, the Malthusian growth equation *all* populations, and so on. In doing so, it avoids the troubles associated with narrowing the law's system type. As we learned in §2.1, however, going broad seemed doomed to render idealisation laws disastrously trivial and explanatorily vacuous, neither of which are plausible characteristics of idealisation laws. The problem with keeping the system type broad, or so it seemed, was that idealisation laws then came into conflict with their super laws. But the conflict with super laws only occurred because it was assumed that the idealisation laws and their super laws would have the same logical form (viz. that of Sch.1). The 'going meta' proposal gives up this assumption. Idealisation laws do *not* after all

[6]Of course, for the entailment to go through the theorem must be referred to in a way that makes its generalisation transparent, as in Sch.2. It wouldn't do, for instance, to *name* the theorems then refer to the theorems by their names.

[7]Not to be confused with a "meta-best system", which best systematises the theorems of the best system according to desiderata of (e.g.) simplicity and strength (cf Lange 2007, 479). The meta-ised system is not a systematisation of anything really. It is a system whose axioms are one-one correspondent with the best system's axioms.

have the same schematic form as their super laws. Rather, they have the form of meta-laws (specifically Sch.2). As such they are no longer inconsistent with their super laws. Indeed, they are partly grounded in them! Idealisation laws are theorems derived from the statement (ultimately from axioms in the meta-ised best system) that their super laws are theorems of the best system.

So, far from being inconsistent with their super laws, the 'going meta' proposal actually makes idealisation laws *reliant* on them. Can the Humean rely on the existence of the required super laws? I think so. Earlier, the Newtonian law for compressible flow Gen.2 was presented (implicitly) as a candidate super law for the idealisation of incompressible flow. As it happens, however, the constitutive equation for compressible flow involved in that law does not itself describe any fluid perfectly accurately, since no fluid is precisely Newtonian (i.e. has a viscous stress linearly proportional to the strain rate) and some fluids diverge considerably (e.g. Peanut butter and Mayonnaise). This might lead to the thought that Gen.2 cannot after all be the corresponding super law. But that is not necessarily the right inference. Recall that the Humean who takes truth to be a desideratum in choosing the best system for some domain can permit some lossiness in the best system so long as it scores well on strength and simplicity. The reason the lossiness of the initial candidate idealising generalisation Gen.1 went unmitigated was because, (a) it was *very* lossy in some cases, and (b) we could name Gen.2 as a rival candidate generalisation which would come into conflict with it. But it's not obvious that Gen.2 is problematic to the same extent. Regardless, what is crucial is that *whatever* our verdict about the status of Gen.2, there must be *some* generalisation of the form Sch.1 which appears in the best system which (a) is accurate enough such that any loss is mitigated by the overall strength and simplicity of the system to which it contributes, and (b) there is no further generalisation in that same system which concerns the same system type and attributes a functional behaviour which has its attributed behaviour as a special case.

3.3 Satisfying Humean considerations (again)

What's already been presented is enough, I think, to show that idealisation laws have the right structure to avoid the dilemma raised in §2. The solution is to reject the idea that idealisation laws are laws, in the typical Humean sense of being theorems of the best system. But it would be far from adequate to take the position that the Humean requirements on laws do not apply for that reason. Idealisation laws aren't pure imaginative constructs and must for the Humean ultimately be grounded in the mosaic somehow. Idealisation laws are also clearly empirically accessible, indeed arguably more so than their super laws. Finally, as we have seen in §2.2 idealisation laws are clearly highly explanatorily important. So if the proposal for Humean idealisation laws is to be at all plausible, it must at least cohere with the same three requirements for laws. Thankfully, it does.

Idealisation laws have often been posed as problems for the Humean on account of their lack of metaphysically sufficient grounds within the Humean mosaic (see esp. Cartwright 2009, Corry 2009, Cartwright 2017, Backmann and Reutlinger 2014). But there is no special problem of metaphysical grounds under the current view, since idealisation laws are grounded ultimately in some or other mosaic, along with certain totality facts. That's because the mosaic, plus totality fact about the extent of the mosaic, grounds the best system's generalisations; the best system's generalisations, plus totality fact about the availability of other systems, in turn grounds the meta-ised best system, of which idealisation laws are theorems. All that's needed for idealisation laws, then, is the mosaic and totality facts. As before, I take it that the commitment to totality facts provide no unique problem for the Humean.

The approach of understanding idealisation laws as meta-laws might seem at a glance to render idealisation laws too far removed from the on-goings of the mosaic to satisfy the requirement of empirical accessibility. But I think we can assuage much of this kind of concern. Note that it is not incumbent on Humeans to argue that the super laws which help ground idealisation laws must be epistemically prior to or more accessible than their corresponding idealisation laws. It is therefore not straightforwardly a problem that super laws are often only discovered much later than the derived idealisation laws, if at all. Humeans can also provide a plausible story about why the idealisation laws would be discovered sooner than, and even used to predict, their complex super laws. Idealisations' mathematical simplicity and approximation to real-world phenomena (when other factors are minimal) makes them obvious inferences from experimental data. This can happen either as a conscious effort to idealise or as a result of the discrepancies being falsely attributed to experimental error. The merit of the 'going meta' approach is that it shows why the idealisation laws are legitimate inferences from experiment on real world systems.

Lastly, we come to the requirement that the 'going meta' proposal should be able to show why idealisation laws have the explanatory relevance they have. As already remarked on, idealisation laws under this proposal get to keep their breadth without coming into conflict with other laws. For example, The idealisation law for constitutive incompressible flow (Gen.4) makes a claim about all real fluids, and so makes sense of the evident fact that equations like Eq.1 are explanatorily relevant to real world systems. Insofar as they do this, idealisation laws are able to explain the on-goings of the mosaic in much the way that first-order laws are. Furthermore, by rendering idealisation laws in the form Sch.2, idealisation laws gain an extra dose of explanatory power. By attributing to the broad class of systems a behaviour which has some explicit equation as a *special case*, idealisation laws are able to draw specific attention to a subset of (perhaps particularly important) causal relationships around which more complex laws are built. This all seems to support the increased pedagogical and cognitive explanatory power of idealisation laws emphasised by Elgin and Woody.

Of course, according to the proposal the kind of explanatory relevance idealisation laws have to their more complex super laws is not one of ontological priority. For the Humean who adopts this meta-conception of idealisation laws, idealisation laws are parasitic on their super laws. Consequently, the conception will not do justice to the intuition of, e.g., Cartwright, who has long argued that,

> what unified [super] laws dictate should happen, happens *because* of the combined action of laws from separate domains [...] without these [idealisation] laws, we would miss an essential portion of the explanatory story. (1983, 70)

It's not my aim to show that idealisation laws under the proposed Humean conception satisfy *that* intuition. The Humean should not feel compelled to do justice to the thought that super laws are the way they are *because* idealisation laws are as they are, at least not in the same way they are (perhaps) compelled to make sense of the thought that the mosaic is the way it is *because* of the laws.

As we saw earlier, for the Humean first order laws explain the mosaic because they are part of a unifying systematisation of it. Idealisation laws should inherit some of that explanatory power over the mosaic too. But granting the form of explanation is unification there does not seem to be any reason from a Humean perspective to think that idealisation laws unify their super laws in any way (if anything it's the other way round: the super laws will unify a number of idealisation laws formed from different fixings of variables). However, if the charge is that the Humean should be seeking to make sense of a more weighty kind of explanatory priority for idealisation laws then the Humean can simply respond that such a demand falls into the bracket of expectations which the they eschew in general, e.g. that laws govern, that they are productive, etc. Moreover, the Humean can reject this demand without having to give up making sense of what is perhaps anyway driving the Cartwrightian intuition, that idealisation laws concern core causal features of systems which are subject to further interference in situ (Weisberg 2007, Corry 2009, Cartwright 2017). Because of the posited relationship of idealising equations being special cases of super laws' equations, any causal components described in an idealising equation for some physical system will be causal components described also in a super law's equation for that system. The Humean simply leaves it up to context-variable scientific interests to say what counts as a 'core causal component' and what counts as 'interference'.

A different kind of worry related to idealisation laws' explanatory power concerns their modal robustness. Under a traditional Humean view about nomological possibility, the content of a law is nomologically necessary but it is not nomologically necessary that such content is that of a law.[8] Consequently, claims to the effect that such and such axiom of the best system is a law will not be as modally robust as the axiom itself. The upshot for the going meta proposal is that idealisation laws will be modally weaker than the super laws from which they are derived.

How much of a problem is this? Perhaps not so much. Notice, we can still admit that whenever the super law is a law, so is the idealisation law. Moreover, in worlds where a super law of our world is true but is not a law, it's corresponding idealisation laws will still employ equations which idealise the behaviour of the systems the super law does. Nevertheless, due to their weak-

[8]Thanks to an anonymous reviewer for raising this issue.

ened modal status the proposal renders instances of Sch.2 accidental regularities, which can seem at least highly counterintuitive and potentially also inconsistent with their explanatory relevance.

I think the best response the Humean can make to this issue is one they should probably feel anyway compelled to make, and that is to assert a condition of nomic preservation (Roberts 2008, Lange 2009). Notice that it is anyway counter-intuitive to say that if I were to have done differently the laws might have been different. But that's something the Humean must accept following traditional lines. Similarly, it has been widely recognised that the counterfactuals of sparse worlds (e.g. containing a single electron) under such a view are liable to be counter-intuitive too (Carroll 1994). The Humean is not committed to the traditional line. An alternative is to say that laws remain laws under counterfactual supposition up to inconsistency with the counterfactual conditional's antecedent (see, e.g., Roberts 2008, 191). That means, roughly, that what it is for a statement of the form 'it is a law that p in w' to be true is not a matter of whether p is an axiom of the best systematisation of w, but whether it is true at w and an axiom of the best systematisation of the world of utterance.[9] As a consequence of this, laws will remain laws under consistent counterfactual supposition. Drawing the analogous move with the meta-ised best system, the Humean will assert that idealisation laws remain idealisation laws under counterfactual supposition up to inconsistency with the counterfactual conditional's antecedent. This ensures that idealisation laws' modal robustness is more equal to that of their super laws, as well as making sense of a number of other issues anyway facing Humean thinking about laws.

In sum, the proposal to take idealisation laws as meta-laws about super laws seems to fulfill it's duty of satisfying Humean basic requirements described in §1.1 whilst also capturing the more demanding explanatory intuitions motivated in §2.2. I considered a couple of objections to this proposal but found neither a significant stumbling block.

[9]The details will in fact need to be a little more complicated; see Roberts (2008, chs 5-6). A further alternative is for the Humean to adopt a notion of 'nomothetic explanation' to contrast with that of 'metaphysical explanation' (Bhogal forthcoming).

4 Conclusion

If one has Humean inclinations, what account should one provide for idealisation laws? It is tempting to find a place for them in the best system, but as I've demonstrated, this is far from easy. Either idealisation laws will come into conflict with the super laws which attribute more accurate behaviour to a wide class of real world systems, or they will be trivial and explanatorily vacuous on account of not attributing behaviour to any system. My suggestion has been to take idealisation laws *not* to be theorems of the best system, but as theorems of a specific schematic form of a meta-ised best system, which has an axiom corresponding to each axiom L of the best system which states that L is an axiom of the best system. By doing this we retain idealisation laws' relevance to the real world without coming into conflict with the super laws from which they idealise.

Declaration of interests

I have no competing interests.

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