The Razor and the Laser[1]

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1. The Razor says: do not multiply entities without necessity! The Laser says: do not multiply *fundamental* entities without necessity! Behind the Laser lies a deep insight. This is a distinction between the costs and the commitments of a theory. According to the Razor, every commitment is a cost. Not so according to the Laser. According to the Laser, derivative entities are an ontological free lunch: that is, they are a commitment without a cost. Jonathan Schaffer (2015) has argued that the Laser should replace the Razor.

The structure of the paper is as follows. In Sections 2-4 we shall discuss and argue against Schaffer's arguments for replacing the Razor with the Laser. Schaffer considers several objections to his views, and in Sections 5-7 we shall argue that Schaffer does not deal successfully with two of them. In Section 8 we shall present a probabilistic argument for the Laser. However, the argument has a limitation and does not support the replacement of the Razor with the Laser. Indeed, it supports only the claim that, given certain assumptions, the multiplication of explanatorily relevant derivative entities does not matter; but, as we argue in the same section, there is an argument that multiplying explanatorily superfluous derivative entities does makes a theory less rationally acceptable. Section 9 is a brief conclusion.

Before we start, let us explain and justify a conspicuous absence from this paper. Often philosophers distinguish between qualitative and quantitative economy (Lewis 1973: 87). Qualitative economy refers to economy of kinds or types of entities, while quantitative economy refers to economy of token entities. This distinction thus delivers two versions of the Razor: (a) do not multiply types of entities without necessity (the qualitative Razor) and (b) do not multiply token entities without necessity (the quantitative Razor), and two versions of the Laser: (c) do not multiply fundamental types of entities without necessity (the qualitative Laser) and (d) do not multiply fundamental token entities without necessity (the quantitative Laser). But since Schaffer himself ignores the distinction (2015: 646), and the points in this paper apply equally well to the qualitative and quantitative versions of each of the Razor and the Laser, we shall not distinguish the qualitative and quantitative versions of the Razor and the Laser and shall instead interpret the Razor as commanding not to multiply entities (whether types of entities or token entities) without necessity and the Laser as commanding not to multiply fundamental entities (whether types of entities or token entities) without necessity.

[1] We thank the members of audiences at Hamburg and Leeds where this paper was read and, especially, Jonathan Schaffer, who present at the Leeds event.

2. Schaffer gives three arguments for the Laser. The first consists in an imaginary case that is supposed to show that the Laser, not the Razor, is what really accounts for certain theories being better than others. The case is as follows. Physicist Esther posits a fundamental theory with 100 types of fundamental particle. The theory is predictively excellent and is adopted by the scientific community. Then Feng comes along and builds on Esther's work to discover a deeper fundamental theory with 10 types of fundamental strings, which in varying combinations make up Esther's 100 types of particle. Schaffer describes this as 'a paradigm case of scientific progress in which a deeper, more unified, and more elegant theory ought to replace a shallower, less unified, and less elegant theory (Schaffer 2015: 648).

Schaffer thinks this example shows that what accounts for the superiority of Feng's theory is the Laser, not the Razor. For Esther's total ontology is a subset of Feng's (both token-wise and type-wise) and so according to the Razor, Esther's theory should be superior to Feng's. But, Schaffer says, the Laser gets things right. For Feng posits fewer fundamental types of entities than Esther. Thus, Feng incurs more commitments than Esther (he postulates the strings, which are not postulated by Esther), but at a lower total cost (Schaffer 2015: 648-9). Thus, when comparing how economical theories are, one should compare how many fundamental entities they posit, not how many entities are posited overall. The Laser thus wins over the Razor, according to Schaffer.

Although Schaffer sets up his example in terms of two theories that differ with respect to the number of fundamental *types* of entities they posit, nothing in his conclusion depends on this and it is clear that his conclusion is the more general one that what matters is economy of fundamental entities, both of fundamental types of entities and fundamental token entities. Although we shall understand Schaffer's argument in this way, most of what we are going to say about it would be valid even if Schaffer's conclusion were meant to be only that what matters is economy of fundamental *types* of entities. In particular, our assessment of Schaffer's argument as fallacious would still stand if the conclusion of Schaffer's argument were restricted to economy of fundamental *types* of entities.

Schaffer's argument is fallacious. Grant that Feng's theory is better than Esther's due to its positing fewer fundamental entities. Let us assume that this shows that theories positing fewer fundamental entities are preferable, all else being equal, to theories positing more. If so, this shows that the Laser is the correct rule for choosing between theories which differ with respect to the size of their fundamental ontologies but not with respect to the size of their derivative ontologies. Does it follow that the Laser should replace the Razor? No. If the Laser replaces the Razor, then *only* fundamental entities matter to ontological economy. To establish this, one must show not only that theories are better off for minimising fundamental entities, but that they are no *worse* off for multiplying *derivative* entities. But nothing in the Esther and Feng case shows that multiplying derivative entities does not decrease simplicity in a way that makes theories defective. That is, the case of Esther and Feng does not show

that we should prefer a theory T1 to a theory T2 if T1 posits both fewer fundamental entities and more derivative entities than T2. So Schaffer's case of Esther and Feng does nothing to support his thesis that the Laser should replace the Razor.

But Schaffer's case of Esther and Feng cannot even show that the Laser is the correct rule for choosing between theories which differ with respect to the size of their fundamental ontologies but not with respect to the size of their derivative ontologies. For Esther's and Feng's theories differ also with respect to the size of their derivative ontologies: Feng's has more derivative entities than Esther's, since all the derivative entities of Esther's theory, plus its fundamental ones, are derivative entities in Feng's theory.

Furthermore, Schaffer's case does not even show that Feng's theory is better than Esther's due to having a more parsimonious fundamental ontology. As Baron and Tallant (2016: 4) also observe, nothing excludes the possibility that Feng's theory is better for other reasons, such as being deeper, more unified, or more elegant. Specifically, we submit that the reason Feng's theory is better than Esther's is that it explains everything Esther's theory explains and more, i.e., Feng's theory explanatorily subsumes Esther's theory. As we have just noted, the fundamental entities postulated by Esther are derivative entities in Feng's theory. So Feng's theory explains what Esther's does not, and does not leave unexplained anything that Esther's theory explains. Thus, the fact that Feng's theory posits fewer fundamental entities is not needed to explain why his theory is better than Esther's.

A more relevant case to test the Laser would be either (i) one in which the fundamental entities of neither theory are the derivative entities of the other, or (ii) one in which the fundamental entities of either theory are the derivative entities of the other. This would control for the possibility that one theory is better than the other due to explanatory subsumption, rather than due to the size of its fundamental ontology.

Consider, then, two theories, T1 and T2, which postulate exactly the same particulars and the same properties. T1 grounds properties in particulars. According to T1, particulars are fundamental, properties are derivative. Theory T2 grounds particulars in their properties. According to T2, properties are fundamental, particulars are derivative. Suppose, furthermore, that both theories posit more particulars than properties. In this case T1 has more fundamental entities than T2 but fewer derivative ones, and T2 has more derivative entities than T1 but fewer fundamental ones. Imagine that the theories are otherwise equally good. Irrespective of the total number of entities, the Laser tells us to go for T2, while the Razor remains silent.

Is there any reason to prefer T2 on the basis that it postulates fewer fundamental entities? Yes, for fundamental entities are unexplained ones. Thus, a theory with fewer fundamental entities leaves fewer things unexplained. And surely this is a virtue of theories (although, of course, since there are other virtues, having this virtue does not guarantee that the theory is better than the alternatives). Thus, there is an

argument for the Laser, but it has nothing to do with the Esther and Feng case. (The same argument applies if we consider a case of two theories in which the fundamental entities of neither theory are the derivative entities of the other.)

But this argument still doesn't show that the Laser should replace the Razor. All it shows is that a theory postulating fewer fundamental entities is preferable to a theory postulating more fundamental entities, *other things being equal*. Indeed, imagine two theories, T1 and T2, such that T1 postulates 10 fundamental entities and no derivatives, and T2 postulates 9 fundamental entities that, together, ground 1000 derivatives. If this is the only difference between the theories— if they are equally explanatory, and so on— it seems clear that T1 is the better theory, since T2 is unnecessarily profligate (but in Section 8 we shall give an argument that, under certain assumptions, one should prefer T2 in such a case). In this case, what explains the superiority of T1 is its better adherence to the Razor.[2]

3. Schaffer's second argument for the Laser is an argument by analogy. Distinguish the Conceptual Razor and the Conceptual Laser (Schaffer 2015: 649):

> Conceptual Razor: Do not invoke concepts without necessity!
>
> Conceptual Laser: Do not invoke primitive concepts without necessity!

Schaffer argues that the Conceptual Laser is preferable to the Conceptual Razor and so, by analogy, the Ontological Laser is preferable to the Ontological Razor.

Schaffer supports his claim that the Conceptual Laser is preferable to the Conceptual Razor by means of a conceptual analogue of the case of Esther and Feng. Georg has developed a regimentation of set theory in which, by means of 10 primitive concepts, he defines 40 other useful set-theoretic concepts. Hamsa builds on Georg's work to discover an axiomatisation with just one single primitive notion. With her single primitive, Hamsa can define 99 other useful set-theoretic concepts, including Georg's 40 set-theoretic concepts (Schaffer 2015: 649).

Hamsa's theory, Schaffer says, is methodologically preferable to Georg's. Yet Georg's total ideology of 50 concepts is a subset of Hamsa's total ideology of 100 concepts. Thus, the Conceptual Razor gets the case backwards (Schaffer 2015: 649-50). Schaffer claims that in the conceptual domain it is only *primitive* concepts that count against the conceptual economy of the theory. Defined concepts are available for free. Given the analogy between conceptual and ontological economy, Schaffer infers that the Laser is preferable to the Razor (2015: 650-51).

The thought is roughly this:

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[2] This is similar to Baron and Tallant's Charlie and Zibeon case (2016: 4). But in their case, the theory postulating fewer entities overall is also the one that displays greater explanatory unity. This prevents Baron and Tallant from being able to say that what explains the superiority of Zibeon's theory is its better adherence to the Razor.

Defined concepts are not costly to conceptual economy.

Defined concepts are to ideology what derivative entities are to ontology.[3]

So derivative entities are not costly to ontological economy.

But compare:

Simmering doesn't change the colour of tomato soup.

Simmering is to tomato soup what grilling is to steak.

So grilling doesn't change the colour of steak.

This argument by analogy doesn't work. There are respects in which simmering is to tomato soup what grilling is to steak— both are the standard cooking method relative to the foodstuff in question— but we cannot reliably infer that the analogy extends to effect on colour. Moreover, we have specific reason to doubt that the analogy holds in that respect: grilling turns steak from pink to brown due to the presence of myoglobin, which denatures into brown-reflecting hemichrome on heating; tomato soup lacks this feature. Similarly, there are respects in which defined concepts are to ideology what derivative entities are to ontology—both are the 'superstructure' relative to the 'basis' (Schaffer 2015: 649)— but we cannot reliably infer that the analogy extends to effect on parsimony. Moreover, we have specific reason to doubt that the analogy holds in that respect, as we shall now argue.

Why is it that primitive concepts incur a cost to conceptual economy, while defined concepts incur a commitment but not a cost? To find out, we must consider why conceptual economy is a virtue: what is the 'good-making' feature of conceptually economical theories, such that multiplying primitive concepts detracts from that feature, while multiplying defined concepts does not? Conceptual economy is a theoretical virtue because the more conceptually economical a theory is, the more intelligible it is. That is, assuming the primitive concepts of two theories, T1 and T2, to be equally intelligible, if T1 has more primitive concepts than T2, T2 is more intelligible than T1. Since defined concepts can be understood in terms of the primitives, multiplying defined concepts does not detract from the intelligibility of the theory. (We are assuming an ideally intelligent person— for normal people, it might be better to have more primitives, since some definitions might be hard to understand). We suggest that this is why defined concepts incur a commitment, but not a cost, to conceptual economy.

But the 'good-making' feature of ontologically economical theories is not intelligibility. By reducing the ontology of a theory—whether by the Laser or the

[3] Schaffer (2015: 649).

Razor— one does not thereby increase its intelligibility. Other things being equal, a theory positing 100 particles is not thereby more intelligible than a theory positing 101 particles; nor is a theory positing 50 fundamental particles thereby more intelligible than a theory positing 51 fundamental particles. One might point out that theories positing several different *kinds* of entity are less intelligible than theories positing fewer such kinds, especially where the entities are new or unusual. But this is an ideological matter: we need different concepts to understand different kinds of entity. Once we have the concept, *electron*, a theory positing 2 electrons is no more intelligible than a theory positing 1000.[4]

So although, in some respects, defined concepts are to ideology what derivative entities are to ontology, we have reason to doubt that the analogy extends to effect on economy. Multiplying defined concepts incurs no extra cost, because it is only by multiplying primitives that one detracts from a theory's intelligibility— the 'good-making' feature of conceptually economical features. But intelligibility is not the 'good-making' feature of ontologically economical theories. So we cannot infer from Schaffer's analogy that fundamental entities are costs to ontological economy, while derivative entities incur a commitment but not a cost.[5]

4. Schaffer's third argument turns on what he calls the *Ontological Bang for the Buck* (Schaffer 2015: 651-652). Schaffer points out that good theories are not only economical but *fruitful*; that is, they exhibit both simplicity and *strength*. On the conceptual side of things, fruitful theories are those that are able to define many further concepts from only a sparse supply of primitives: Hamsa's definition of 99 set-theoretic concepts in terms of a single primitive is fruitful, in part, because she is able to define so many further concepts (Schaffer 2015: 651-652). Thus, Schaffer proposes the following as the underlying principle that unifies the virtues of conceptual simplicity and strength:

> Conceptual Bang for the Buck: Optimally balance minimisation of primitive concepts with maximisation of defined concepts (especially useful ones).

In order to preserve the analogy with conceptual economy, Schaffer proposes an ontological analogue of this principle. Just as defined concepts are part of what makes a package of primitives useful, derivative entities are, for Schaffer, 'part of what makes a package of fundamental entities useful. They show that these fundamental

[4] What is the 'good-making' feature of ontologically economical theories? We suggest it is the likelihood of ontological adequacy, i.e. the likelihood of positing those and only those entities that are real. *Other things being equal*, and in particular if the theories are explanatorily equal, a theory positing 100 particles is more likely to be ontologically adequate than a theory positing 101 particles.

[5] See Baron and Tallant (2016: 6) for additional considerations against Schaffer's argument from analogy.

entities can be used to produce something' (2015: 652). Thus, Schaffer proposes the following as the underlying principle that unifies the virtues of *ontological* simplicity and strength:

> Ontological Bang for the Buck: Optimally balance minimisation of fundamental entities with maximisation of derivative entities (especially useful ones).

And if the single underlying virtue is the Ontological Bang for the Buck, Schaffer argues, then what it underlies is the Laser, not the Razor (2015: 653). It 'pressures one to minimise fundamental entities (that's the buck), and thus supports a specific methodological injunction not to multiply such fundamental entities where possible. It supports no methodological injunction against derivative entities, but actually *favours* the generation of derivative entities (that's the bang)' (Schaffer 2015: 653).

What shall we say about this? Firstly, the only motivation for the Ontological Bang for the Buck is to preserve the analogy with conceptual economy: since that analogy fails, the motivation for the Ontological Bang for the Buck, and therefore Schaffer's third argument for the Laser, is vitiated. However, it is worth spelling out why the analogy does not allow us to infer the Ontological Bang for the Buck from the Conceptual Bang for the Buck.

On the conceptual side of things, the more concepts one can define from fewer primitives, the better: this increases intelligibility. The fewer the primitive concepts, the less it takes (for an ideally intelligent person) to understand the theory. Since defined concepts can be understood on the basis of primitives, they do not detract from a theory's intelligibility. But the more concepts one can define in terms of the primitives, the better one understands the primitives. And even if a defined concept is *eliminable*, it can still increase intelligibility. If two concepts are interdefinable, then either can be eliminated with no loss to expressive power, but one concept might render the other more intelligible. This is why the Conceptual Bang for the Buck can encourage us to maximise *especially*— rather than *exclusively*— defined concepts that are useful.

On the ontological side of things, as we've said, generating entities does not increase intelligibility—it may even have the opposite effect, if describing an entity requires new conceptual apparatus. There is therefore no relevant analogy that could allow us to infer the Ontological Bang for the Buck from the Conceptual Bang for the Buck. It is hard to see, therefore, what could justify the injunction to maximise derivative entities, *especially* useful ones— why not *only* useful ones?

This leads us to our second point. Schaffer says very little about why generating derivative entities *per se* is to be encouraged. He only says that derivative entities show that the fundamental entities can be used to produce something. But this doesn't explain why it is virtuous to generate derivative entities *per se*. And as we'll now see, it is difficult to see what the explanation could be.

Theories aim to describe and explain reality. The ideology of a theory refers to the means by which it expresses its descriptions of reality. The ontology of a theory refers to what the descriptions tell us reality is like, that is, to the objects, properties and processes they posit. Theories are ideologically virtuous, we've said, insofar as their means of expression make for more intelligible descriptions. But theories are ontologically virtuous insofar their ontological posits are real; it is difficult to see how maximising derivative entities *per se* furthers this goal. Generating derivative entities guarantees a more correct or complete description of reality only insofar as reality in fact contains the entities generated. One gets no more bang for one's ontological buck by positing derivative entities, unless there is reason to believe that those entities happen to exist.[6]

It seems, therefore, that a more plausible injunction would be to maximise derivative entities *as long as* they make for more correct descriptions of reality: surely, on the ontological side of things, this is the bang we want for our buck. But this injunction seems to comport well enough with the Razor. And it is hard to see how else we might benefit from multiplying derivative entities *per se*. To illustrate, note that the Ontological Bang for the Buck commits Schaffer to the idea that the best theories are those according to which every entity grounds at least one *other* entity. But it is difficult to see why such a theory is preferable to one which posits some entities that do not ground anything, assuming that the theories are otherwise equally good.

In sum, without the analogy with conceptual fruitfulness, there seems to be no good reason to think it is virtuous to multiply derivative entities *per se*. The only reason would seem to be if one has a prior taste for fruitful orchards (even strange orchards, in which every fruit produces another fruit). Put another way, the only reason to accept the Ontological Bang for the Buck is if one already accepts that the Laser should replace the Razor. For why should we permit the generation of derivative entities other than useful ones, unless we already think derivative entities are an ontological free lunch?[7]

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[6] Note that to say that theories are ontologically virtuous insofar their ontological posits are real is not to give a criterion by which to choose theories. One such criterion is, for instance, the Razor. The Razor presupposes that ontologically economical theories are more likely to posit only real entities, i.e. it presupposes that ontologically economical theories are more likely to be ontologically adequate and therefore ontologically virtuous. Another such criterion is the Laser, which presupposes that theories with a smaller fundamental ontology are more likely to be ontologically adequate and therefore ontologically virtuous. Similarly, to say that theories are ideologically virtuous insofar as their means of expression make for more intelligible descriptions is not to give a criterion by which to choose theories. One such criterion is, for instance, the Conceptual Razor, which presupposes that ideologically economical theories are more likely to be ideologically virtuous. Another such criterion is the Conceptual Laser, which presupposes that theories with fewer primitive concepts are more likely to be ideologically virtuous. Thanks to a referee for prompting us to clarify this point.

[7] Baron and Tallant give two counterexamples to the Ontological Bang for the Buck. The first consists of a case of two theories T1 and T2. According to T1 there exist 4 derivative entities and 1 fundamental entity, which grounds the 4 derivative ones. According to T2 there exist 3

5. Schaffer considers four objections to his views. Here we shall argue that he does not deal successfully with two of them. We have just touched on the first of these—the overgeneration objection, according to which the Bang for the Buck methodology invites us to spuriously overgenerate derivative entities. Schaffer uses the example of what he calls doubled mereology on which every sum has a counterpart with exactly the same proper parts. Doubled mereology gets double the bang for the same buck, so shouldn't this version of mereology be a better theory according to the Bang for the Buck methodology? (Schaffer 2015: 656–57).

Schaffer's first answer to this objection emphasises that, according to the Ontological Bang for the Buck, one is supposed to generate *especially* those derivative entities which are useful; but the extra sums of doubled mereology have been put to no use.

But this puts all the weight on how *useful* derivative entities are. If that is the case, the Ontological Bang for the Buck has little to recommend over and above the injunction: maximise derivative entities provided they are useful— an injunction which, as we said above, seems to comport well enough with the Razor.

Schaffer's second reply is to emphasise that ontological economy and strength are not the only methodological principles. The problem with doubled mereology seems to be that its axiomatization requires less elegant axioms than those required by

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derivative entities, and 3 fundamental ones, where each fundamental entity grounds one of the derivative ones. The Ontological Bang for the Buck tells us to select T1 over T2. But this coincides with the recommendation of the Razor. Baron and Tallant criticize the Ontological Bang for the Buck for being agnostic as to whether we are trading simplicity with respect to the total number of entities off against the number of derivative entities produced, or whether we are trading simplicity with respect to the number of fundamental entities off against the number of derivative entities produced (Baron and Tallant 2016: 7). But we see no agnosticism in the Ontological Bang for the Buck: it is clear that it tells us to trade simplicity with respect to the fundamentals off against the number of derivative entities produced. The fact that in this particular case the result is the same whether the simplicity traded is with respect to the fundamentals or with respect to the total number of entities does not mean that the Ontological Bang for the Buck is not clear about the kind of trading off it recommends. The second counterexample adduced by Baron and Tallant consists of two other theories, T1 and T2. According to T1 there exist 9 entities in total. 8 entities are derivative, 1 entity is fundamental, and the 1 fundamental entity grounds 4 derivative entities which, in turn, ground 1 further derivative entity each. According to T2 there exist 11 entities in total. 10 entities are derivative, and 1 entity is fundamental, and the 1 fundamental entity grounds 2 derivative entities which, in turn, ground 4 derivative entities each. The Ontological Bang for the Buck counsels to select T2 over T1. The selection, Baron and Tallant (2916: 7) say, is not based on any trade-off between the number of fundamentals and the number of derivative entities, but on the fact that T2 gets more Bang for the Buck in virtue of the fact that it uses *fewer* derivative entities to do *more* work. But then the Ontological Bang for the Buck seems to recommend the Razor rather than the Laser, 'since only the former can handle parsimony considerations directed at interlevel objects' (2016: 8). Again, we do not see the rationale for the criticism here. That T2 uses fewer derivarive entities to do more work might be a reason to prefer T2 over T1, but the reason why the Ontological Bang for the Buck recommends T2 is that it optimizes the balance between minimization of fundamental entities with maximization of derivative ones.

classical mereology which is, furthermore, the maximally permissive system that still obeys extensionality. Thus, for Schaffer, classical mereology strikes a further balance, namely it maximises bang for the buck and preserves extensionality (2015: 657). But since Schaffer is not in a position to show that all of the methodologically most virtuous theories are maximally permissive given certain plausible independent constraints, Schaffer offers as a last resort to withdraw the Bang for the Buck and the associated argument for the Laser, but still uphold the Laser on the basis of the other two arguments, since the Laser is compatible with the multiplication of derivative entities as purely neutral or as costly for independent reasons, but not as costly as fundamental entities, so that there is no collapse into the Razor (2015: 658).

But this line of retreat weakens the analogy between conceptual economy and ontological economy since the Conceptual Bang for the Buck is surely correct. Once the analogy is weakened, this must weaken his second argument for the Laser, since it is more difficult to see now why the analogy must hold in certain respects and not in others. Thus, this second reply to the objection has some collateral effects not noticed by Schaffer.

Thus, the first reply amounts to undermining the value of the Bang for the Buck as a reason for the Laser, and so it leads to the abandonment of the third argument for the Laser. The second reply consists in withdrawing the Bang for the Buck and its associated argument for the Laser. Both answers result in the abandonment of the third argument for the Laser. Thus in so far as the overgeneration objection was an objection against the Bang for the Buck and consequently an objection against the third of Schaffer's arguments for the Laser, the overgeneration objection has not been properly blocked.

6. We will now discuss the *special sciences* objection. Since the special sciences are not concerned with fundamental entities, the objection goes, the Laser offers no methodological guidance to theories in the special sciences. Thus, on the assumption that chemicals and organisms are not fundamental entities, the Laser offers no methodological guidance to chemists or biologists (Schaffer 2015: 661). Yet ontological economy seems to be relevant in the special sciences. The Laser fails to capture this.[8]

Schaffer's reply turns on two cases, intended to illustrate two sorts of way in which economy principles are invoked in the special sciences (2015: 661). The *Bigfoot* case runs as follows. A strong objection to the claim that Bigfoot exists is that no data has been produced which hasn't clearly been fabricated. But, says Schaffer, the objection here isn't that Bigfoot would be an extra entity; it is that the simplest overall explanation is that hoaxsters have fabricated the data.[9] This is an inference to the

[8] Baron and Tallant (2016: 8-11) present a detailed version of the special sciences objection. They do not, however, consider Schaffer's reply, which is our focus here.

[9] As a referee pointed out, it is not entirely clear here whether the Bigfoot theory is positing one extra thing or one extra type of thing. But something Schaffer says suggests that for him

simplest explanation, 'but not one involving concerns about the multiplication of entities. Neither The Razor nor The Laser is needed' (2015: 661).

Schaffer's second case—the *telekinesis* case—runs as follows. A strong objection to the claim that telekinetic powers exist is that, in order to explain how mind could act on matter without physical mediation, we seem obliged to posit some hitherto undiscovered fundamental force. Hence, 'part of the reason for rejecting telekinesis is to avoid ontological costs at the fundamental physical level. Both The Razor and The Laser suffice to capture this' (Schaffer 2015: 662).

Putting the Bigfoot and Telekinesis cases together, Schaffer draws the following conclusion:

> [T]here is a very strong methodological constraint operative in the special sciences, which is to *fit within the grounds provided by fundamental physics*. (In general, derivative entities impose an indirect cost, in terms of whatever fundamental entities serve as their grounds.) This is part of what makes telekinesis so implausible. But I am also saying that there is no further economy constraint on special science tokens or types. This is why biologists have no economy-based constraints against positing one more squirrel, or one more species of roundworm. (Schaffer 2015: 662).

Thus, Schaffer's reply to the special sciences objection consists in the two following points: (1) There is an ontological economy-based constraint on the special sciences— fit with fundamental physics— that the Laser suffices to capture; (2) This is the *only* ontological economy-based constraint on the special sciences; neither the Laser nor the Razor is needed otherwise. We will argue that neither of these claims is adequately motivated by the cases discussed.

The Bigfoot case makes the point that many apparent appeals to *ontological* economy in the special sciences may really be appeals to other sorts of economy. Perhaps, for instance, when Lavoisier repudiated phlogiston, he wasn't concerned about the multiplication of entities, but with phlogiston theory's needing 'a number of inconsistent assumptions to explain facts easily explained by his [Lavoisier's] theory' (Thagard 1978: 87). But the burden is on Schaffer to show that *no* case where economy is invoked (apart from cases involving fit with fundamental physics) turns on concerns about the multiplication of entities. For one thing, this is far stronger than the claim his opponents need to establish. For the special sciences objection to gain a foothold, it suffices that an *important class* of cases involve ontological economy; not *every* case must do so. Other cases may suffice to launch the objection even if, for instance, the above account of the repudiation of phlogiston is correct, or biologists

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it can be seen as positing either: 'But note that the objection to Bigfoot is not that Bigfoot would be an additional entity. Indeed, I take it that (…) a biologist would have no qualms whatsoever about positing one more squirrel, or one more species of roundworm' (Schaffer 2015: 661).

indeed have no qualms about multiplying species of roundworm. For another thing, several cases have been argued to support the relevance of ontological economy in the special sciences, and Schaffer doesn't discuss a single relevant one. Such cases include Baker's (2007) discussion of pre-1950s theories of biogeographical distribution, and Nolan's (1997) discussion of Avogadro's hypothesis concerning the behaviour of gases in chemical reactions. Indeed, Baron and Tallant (2016: 8-11) argue explicitly that these cases favour the Razor over the Laser. Moreover, neither of these cases seem to involve concerns about fit with fundamental physics.[10] *Pace* Schaffer (2015: 662), it is he who faces the burden of proof here, and the Bigfoot case does little to shift it.

Secondly, it is far from clear that Schaffer's own example of ontological economy at work in the special sciences is a genuine case. According to Schaffer, positing telekinesis requires some novel mental force, thereby incurring ontological costs at the fundamental level— costs the Laser can measure. But the objection here is not that this force would be an *extra entity*; it is that no such entity exists according to our best fundamental physics. We don't need an economy principle here; we only need the principle that theories should not entail claims that conflict with our best science.

Finally, Schaffer does not explain *how* the Laser captures the objection to telekinesis. He only states that '[i]n general, derivative entities impose an indirect cost, in terms of whatever fundamental entities serve as their grounds' (2015: 662). But it is unclear how Schaffer could develop this claim. It can't be that the costs are incurred by what serves as the fundamental grounds *according to what theories explicitly say*; the point of the special sciences objection is that the special sciences do not make claims about fundamental entities. The claim must be that derivative entities incur *implicit commitments* at the fundamental level, whose cost the Laser can measure. But we need an account of this. Schaffer's wording strongly suggests the following:

(A) A theory T, in positing derivative Ds, incurs an indirect cost in terms of fundamental Fs just in case Fs ground Ds.

But (A) entails that theories positing non-existent derivatives incur no costs whatsoever, even at the fundamental level. Thus, suppose telekinetic powers don't exist. Then they lack fundamental grounds. So, given (A), the Laser tells us that positing telekinetic powers incurs no ontological costs whatsoever.

Furthermore, consider Esther and Feng again. Suppose Feng's theory is true: the fundamental entities are his 10 types of strings, which ground Esther's 100 types of particles. Then (A) seems to tell us that, by the Laser's measure, Esther's ontological costs were the same as Feng's all along, since the string types are the fundamental

[10] For instance, the issue in the case of Avogadro's hypothesis was which to choose among certain hypotheses concerning the number of atoms in an elemental molecule of gas (Nolan 1997; Baron and Tallant 2016: 10).

entities serving to ground her particle types. This undermines Schaffer's claim in the Esther and Feng argument, that the Laser finds Feng's theory more economical. So here's a dilemma: If what the Laser counts are the *implicit* fundamental grounds of a theory's posits, Feng and Esther have the same ontological costs, contrary to Schaffer's claim in the Feng and Esther argument. If what the Laser counts are the entities that are fundamental *according to what theories explicitly say*, then the Laser does not apply to theories whose only posits are derivative, contrary to Schaffer's claim in the telekinesis case.

Perhaps the solution is to construe implicit costs in terms of the *required*, rather than the *actual* grounds of derivative entities. But we'd still need an account of the relevant notion of 'requirement'. There are problems, for instance, if we construe it in terms of metaphysical necessity:

(B) T, in positing Ds incurs an indirect cost in terms of Fs just in case, necessarily, if Ds exist, Fs ground Ds.

(B) entails that theories whose posits necessarily fail to exist have no ontological costs whatsoever. Thus, suppose compositional nihilism is necessarily true. Then, given (B), the Laser tells us that no chemical or biological theory incurs any costs whatsoever, even at the fundamental level, since chemicals and organisms, on the assumption that compositional nihilism is necessarily true, necessarily fail to exist and therefore they necessarily lack fundamental grounds.[11]

We suggest that Schaffer's most promising option is to construe the implicit costs of non-fundamental theories in terms of the fundamental commitments of their *best* (most complete, rational and plausible) *extensions*. Thus, the best extension of a theory positing genes might include a series of claims about how genes are grounded in chemicals, and chemicals in microphysical particles, all in accordance with our best science. Thus the best extension of a special science theory contains both scientific and metaphysical elements, since such an extension makes grounding claims, which are metaphysical claims, about certain scientific derivative entities being grounded in other scientific entities. The relevant principle would be as follows:

(C) T, in positing Ds, incurs an indirect cost in terms of Fs just in case Fs ground Ds according to T's best extension.

(C) avoids the modal problems with (B) (subatomic particles may ground genes according to the best extension of the gene theory, even if compositional nihilism is

[11] Two points: (a) Do not be tempted to reply by arguing that compositional nihilism is false or impossible: the plausibility of a principle governing metaphysical theory choice should not depend on which metaphysical theories are true! (b) If conditionals with impossible antecedents are necessarily true, *everything* is a cost of positing chemicals, since 'Necessarily, if chemicals exist they are grounded in Fs' will be true for any F.

necessarily true). But it is still unclear how (C) copes with non-existent derivatives, like telekinetic powers. Given that telekinesis conflicts with our best science, what are the Fs, such that the most scientifically and metaphysically plausible extension of the telekinesis theory tells us that Fs are needed to ground telekinetic powers? Perhaps what matters is that the telekinesis theory *cannot* be extended in such a way that terminates in entities recognised by fundamental physics. Then the problem with telekinesis is not that it incurs implicit commitment to certain Fs, but that it is *not* implicitly committed to any Fs that are recognised by fundamental physics. But this invites the challenge mentioned above: the problem has nothing to do with *economy*, but with the fact that telekinesis entails, via its best extension, something for which our best fundamental physics cannot account.

7. At this point, we should mention that Schaffer has another strategy for dealing with the overgeneration and special sciences objections. This is to modify the Laser by introducing 'some discounted but still non-zero pricing policy for derivative entities' (2015: 658). In other words, even if derivative entities are not an ontological free lunch, economy with respect to derivative entities is less important than economy with respect to fundamental entities. We agree with Baron and Tallant (2016: 22) that this would be an interesting avenue to explore, but requires further development. What, for instance, is the pricing ratio between fundamental and derivative entities? How would we decide between a theory positing 10 fundamental entities, and 5 derivatives, and a theory positing 2 fundamental entities and 100 derivatives? We also note that such a discounted pricing policy may end up resembling the Razor more closely than the Laser, if the pricing ratio is small enough. Finally, the arguments that Schaffer gave for the Laser do not seem to support the modified Laser (the Esther/Feng case only supports the claim that theories that explanatorily subsume others are preferable to them, and the other two arguments are based on an incorrect analogy between ideology and ontology), so new arguments will have to be provided.

8. We have argued that Schaffer's arguments for the Laser fail. In this section we shall first present a different argument for the Laser and then we shall argue that the Laser cannot replace the Razor. Consider the following probabilistic justification for the Razor:

> The ontological commitments of a theory can be seen as a conjunction each of whose conjuncts asserts the existence of a certain entity. *If* the conjuncts of T and U are mutually independent, and *if* the conjuncts of T and U have the same initial probability then, in these circumstances, if T postulates fewer entities than U, T is more probable than U (Rodriguez-Pereyra 2002: 205).

The point applies only when the initial probability in question, shared by the conjuncts of T and U, is greater than 0 and lesser than 1. Now, the quote above does

not make clear what kind of probability is in question. But let us think of a situation in which different independent fundamental entities *f1*, *f2*, and *f3* have the same *epistemic* probability,[12] i.e. they are confirmed to the same degree by the available evidence, and that this epistemic probability is greater than 0 but lesser than 1. Now suppose T1 postulates only fundamental entity *f1*, and asserts that *f1* grounds 4 derivative entities *d1*, *d2*, *d3*, and *d4*; and suppose that T2 postulates only fundamental entities *f2* and *f3*, and asserts that *f2* grounds one derivative entity, *d5*, and *f3* grounds one derivative entity, *d6*. Suppose, finally, that the available evidence fails to confirm the grounding claims of both T1 and T2. Then T1's postulation of more derivative entities than T2 does not affect its epistemic probability. But although the fundamental entities of T1 and T2 have the same epistemic probability, since T2 postulates more fundamental entities than T1, the epistemic probability of the fundamental ontology of T2 is lower than that of the fundamental ontology of T1. Hence, T1 has a higher epistemic probability than T2, despite T1 having both a greater derivative ontology and a greater total ontology. Thus, in a situation like this one should choose T1 over T2. And the result generalizes: in situations like this one should choose the theory with a lesser fundamental ontology over the theory with a greater fundamental ontology, irrespective of the relative size of their derivative and total ontologies. Thus this is a probabilistic justification for the use of the Laser in certain circumstances.

But does the argument above show that the Laser ought to replace the Razor? In particular, does it show that it is always innocuous to multiply derivative entities? The considerations on which the argument is based support the Laser over the Razor only in cases where the fundamental ontologies of the theories in question are different. But a crucial case is where theories have the same fundamental ontology but different derivative ontologies. What to do in those cases? Is multiplication of derivative entities innocuous in that case? No. As we shall now argue, multiplying *explanatorily superfluous* entities makes theories more likely to be defective, in a way that makes no exceptions for derivative entities.

Suppose theory T1 posits 10 fundamental entities and no derivative entities. Theory T2 posits those 10 fundamental entities along with 10 derivative entities. If the Laser replaces the Razor, then the fact that T2 posits an additional 10 entities is no reason to choose T1 over T2. This should be the case even if T1 and T2 explain the evidence equally well. It is crucial to note, however, that it does not follow from 'T2 posits 10 derivative entities' and 'T2 explains the evidence' that the *10 derivative entities posited* get confirmed by the evidence. An argument adapted from Barnes (2000: 363) makes this clear.

Let E be the available evidence. Suppose that T1, positing just the 10 fundamentals, entails E and would explain E if true. Let *d* be the hypothesis, not in

[12] For a clear distinction between different kinds of probabilities, namely chances, credences, and epistemic probabilities, see Mellor (2005: 7–13).

T1, that the 10 additional derivative entities exist. Because T1 entails E, we have that the epistemic probability of *d* given T1&E equals the epistemic probability of *d* given T1. Thus, where T1 is assumed true, *d* gets no confirmation from E. Thus, consider T2, which adds to T1 the hypothesis that the 10 derivative entities exist, i.e. *d*. Even though T2 entails and explains E, *d* gets no confirmation from E. The reason for this is that, with respect to the explanation of E, the hypothesis that the 10 derivative entities exist is explanatorily superfluous, relative to T1.

This alone won't trouble friends of the Laser. The fact that *d* gets no confirmation from E does not show that T2 is *less* rationally acceptable than T1 for positing the superfluous entities. However, we can reason as follows:[13]

(1) If *d* is not confirmed by any evidence whatsoever,[14] then *d* is rationally unacceptable.
(2) The fact that *d* is not confirmed by E raises the epistemic probability that *d* is not confirmed by any evidence whatsoever.
(3) Therefore, the fact that *d* is not confirmed by E raises the epistemic probability that *d* is rationally unacceptable.

Thus, T2 is more likely to be rationally unacceptable for positing the 10 superfluous derivative entities. This is a reason to choose T1 over T2. Hence, contrary to the Laser, multiplying superfluous entities can make theories worse off, in a way that makes no exceptions for derivative entities. Consider, once again, Feng's theory, with its 10 fundamental strings, grounding 100 derivative particles. Suppose another physicist, Dave, builds on Feng's theory by positing an additional 200 particles, grounded in the strings. Even though Dave's particles are derivative, the resulting Feng-Dave theory is less rationally acceptable for superfluously positing the particles. Let E be the available evidence. Assuming that Feng's portion of the theory explains and entails the available evidence E, Dave's particles get no confirmation from E, making it more likely that there is no evidence that confirms them, thereby making it more likely that there is no reason to accept the hypothesis. The superfluous derivative particles are therefore costly to the theory. The particles might turn out to be useful for explaining some other evidence, in which case, the hypothesis escapes

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[13] The inspiration here is Barnes (2000: 369), who suggests the following schema to explain why theories are worse off for containing superfluous components:

(A) If *p* were true, there would be some evidence that requires *p* for its explanation.
(B) There is no evidence that requires *p* for its explanation.
(C) Therefore *p* is false.

('If (A) and (B) are conclusively established,' Barnes explains, 'then the falsehood of *p* is too…If (A) and (B) are established less conclusively, then *p* follows more tentatively'). But we are concerned about the verificationist overtones of (A).

[14] If a claim follows logically from compelling premises, it is rationally acceptable even if it is not confirmed by any *empirical* evidence. In premise (1), 'evidence' is to be construed broadly, including both empirical and non-empirical sources of evidence.

censure on grounds of economy. But this would have nothing to do with the particles being derivative; it would be because they've proven *useful*.

Putting the two foregoing arguments together, we can draw the following moral. Sometimes, there is more reason to believe a theory rather than another because it has a smaller fundamental ontology. But in other cases, there is more reason to believe a theory rather than another because, lacking explanatorily superfluous derivative entities, it has a smaller derivative ontology. In such cases, the less believable theory violates the Razor, because it multiplies entities without necessity, but it does not violate the Laser, since the entities multiplied without necessity are derivative ones. Thus the Laser cannot replace the Razor.

9. As we said at the outset, there is an important insight behind the Laser: a distinction between the ontological costs, and the ontological commitments of a theory. Schaffer is right to raise the question of whether all of a theory's commitments count equally towards its costs, especially given the current level of interest in grounding and fundamentality. We conclude, however, that the Laser cannot replace the Razor and that derivative entities are not an ontological free lunch.

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