Models and the Requirement to De-Idealize

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ABSTRACT: It is commonly accepted that scientific models include many misrepresentations of their real-world target. One type of misrepresentation is that of an "idealizing assumption". An idealizing assumption is a modeling assumption that omits some factor of the real-world target that is known or presumed of being causally relevant to the phenomenon of interest. Some find the inclusion of idealizing assumptions to render a model unable to count as evidence for hypotheses about the real-world target. To resolve this, it is held that a model must be completely de-idealized. I consider two challenges to this requirement to de-idealize. One argues that the requirement to de-idealize is committed to an unsavory account of model fidelity known as the Perfect Model Model. I argue that the requirement to de-idealize is not committed to any troubling version of the Perfect Model Model. The other is that, since models are never de-idealized, and models play a central role in science, too much science needs to be given up to satisfy the requirement to de-idealize. It should, therefore, be rejected. In response I argue that this turns on a lack of clarity about what it is to de-idealize a model.

KEYWORDS: philosophy of science, modeling, idealizations, de-idealization

1. Introduction

It is commonly accepted that models often include a variety of misrepresentations (Levins 1966, Kuorikoski, Lehtinen, and Marchioni 2012). Certainly, in the early stages of developing a novel model, much of the real-world target will be omitted, simplified, abstracted, and other ways misrepresented, potentially to be corrected or filled in as understanding and modeling improve. The impact of these misrepresentations has been a focus of much debate. There are some who hold that the inclusion of misrepresentations, or at least certain types of misrepresentations, undercut the value of a model. In particular, some argue that the inclusion of misrepresentations introduces such significant epistemic concerns that they need to be specifically dealt with before a model can be used to tell us about the world (Odenbaugh 2011, Odenbaugh and Alexandrova 2011, Harris 2021). Others, however, hold that the inclusion of misrepresentations, at least some, is of no great concern. Rather, they are just common aspects of scientific models, included for a variety of reasons.

In this paper, I provide a light defense of the view that models must be brought in-line with their real-world target or must accurately represent their target. In particular, I consider a concern regarding the inclusion of "idealizing assumptions", a particular type of misrepresentation where some causal feature of the real-world target is omitted from the model.[1] The concern is that, by including idealizing assumptions, the causal conditions in the model differ from the real-world target in a way that means the model cannot inform us about the real-world target. The basic claim is that, unless a model is completely de-idealized, it cannot be used to tell us about the world. I call this the requirement to de-idealize.

This requirement to de-idealize models has faced some pushback, and in this paper, I attempt to refute two arguments against the requirement to de-idealize. The first argues that the requirement to de-idealize is committed to an overly strict requirement for the fit between models and their targets known as the "Perfect Model Model". In response, I argue that the requirement to de-idealize is not committed to the Perfect Model Model, but rather this stems from a confusion about what an idealizing assumption is.

I then consider a second criticism of the requirement to de-idealize that focuses on what must be given up if the requirement to de-idealize is accepted. The criticism holds that, given the common inclusion of idealizing assumptions, and the prominent role that models play in science, accepting the requirement to de-idealize would require giving up much science that is taken to be well-established. Ultimately, it is argued that this is too drastic a bullet to bite. In response, I argue that this concern turns on a common issue in the debate of idealization and de-idealization which holds that de-idealizing a model is only carried out through manipulation of the mathematics in the model itself. Rather, I argue that there are other methods for checking the idealizations of models that are overlooked. Given this, I argue that a key premise in the drastic bullet criticism is not clearly well-founded.

The outcome of this discussion is twofold. The first is that I look to promote the idea that complete de-idealization might be a basic epistemic requirement for using models to gain insight about real-world targets. As the criticisms I consider suggest, this is typically seen to be a rather extreme, potentially unreasonable,

[1] As a note, my use of the term "idealizing" assumption is somewhat idiosyncratic. I will explain how I use this term in a bit more detail below, however, it is useful to keep in mind that my usage diverges from the use of, say, Michael Weisberg who defines idealization as "the intentional introduction of distortion into scientific theories" (2007, 639). As I will discuss in more detail, my understanding of what counts as an idealizing assumption does not include *all* intentional distortions.

position to hold. However, the second outcome is to promote a broader notion of what it is to de-idealize that I believe is generally missing from much of the work in this area. This can reinvigorate an evaluation of the epistemic requirements for models as well as expand the debate on what it is to de-idealize a model.

My paper will proceed as follows. In section 2 I elaborate on how I understand "idealizing assumption". In section 3 I briefly present arguments in favor of the requirement to de-idealize. In section 4 I consider and respond to the Perfect Model Model criticism of the requirement to de-idealize. In section 5 I consider and respond to the Drastic Bulle criticism. In section 6 I conclude the paper.

2. Background: Idealizing Assumptions

Models often incorporate a wide variety of misrepresentations of their real-world target. These misrepresentations come in a variety of forms, and for a variety of purposes. My focus in this paper is on a category of misrepresentation I will refer to as "idealizing assumptions". Margherita Harris states that models idealize their target, "by disregarding some variables, or ignoring or simplifying interactions amongst variables, etc." (2021, 14577). Other examples of idealizing assumptions include populations of infinite size, random mating, and perfect reasoning, among others (Odenbaugh and Alexandrova, 2011). Each of these removes some causal feature of the real-world by misrepresenting the target, such as infinite size removes the effects of the genetic drift. Given this focus in some of the literature, I will understand idealizing assumptions as those modeling assumptions that remove some causal factor that is known or expected to be causally relevant to the phenomenon of interest.[2] I give a bit of detail and clarity below.

The discussion surrounding idealizing assumptions is already full of slightly different uses of the term idealization, and many different categorizations of types of idealizations. Weisberg (2007, 639), for instance, defines "idealizations'' to be the intentional distortions introduced into a model, and provides a useful categorization of three different kinds of idealizations, galilean idealizations, minimalist idealizations, and multiple model idealizations. Kuorikoski and Lehtinen and Marchioni (2010, 547), however, introduce "galilean assumptions", following Cartwright's (2007) use of "galilean idealization", which are closer to Weisberg's minimalist idealizations, and tractability assumptions, which are modeling assumptions that are more like Weisberg's galilean idealizations. There are plenty of other categorizations of modeling assumptions and types of idealizations and, even

[2] I borrow the phrasing "known or presumed" from Kuorikoski and Lehtinen and Marchioni, (2010, 547). I discuss their position below.

having acknowledged the mix of terms in the literature, my own use of the terms "idealizing assumption" and "idealization" do not line up with how Weisberg uses the term idealization, and also cut across the different categories of assumptions found in other works, such as Kuorikoski and Lehtinen and Marchioni (2010).

With this being said, I can start to clarify what I mean by an idealizing assumption. As stated in the first paragraph of this section, I take an idealizing assumption to be any assumption of a model that removes some factor known or presumed to be causally relevant. For instance, Kuorikoski, Lehtinen, and Marchioni's (2010) category of galilean assumption discussed above provides some clear examples of idealizing. They point out, when developing a model, there may very well be "a factor known or presumed to have an effect [but] is absent in the model" (2010, 547). These are galilean assumptions, and they are assumptions regarding the omission of some known, causally relevant factor, particularly in the attempt to isolate a core set of causal relations that are of interest to the modelers.

We might look to the well-used Lotka-Volterra models as an example. Some versions of the model are a pair of coupled differential equations;

$$dV/dt = rV - (aV)P$$

$$dP/dt = b(aV)P - mP$$

In this model, V(t) stands for the size of the prey population at time *t*, and P(t) the size of the predator population at time *t*. The constants *r, m, a,* and *b* stand for the growth rate of the prey population, the death rate of the predator population, the predator attack rate, and the predator conversion efficiency respectively. Note, however, that this model fails to include causal influences on population size, such as environmental carrying capacity. Carrying capacity is the number of members of a species that can be supported by an environment, and it is the case that, for any real-world ecosystem, there will be a maximum population size it can support. In this case, the exclusion of a carrying capacity omits some causal factor that is a part of the real-world target. However, this omission may be done on purpose as it may allow modelers to better investigate the relationship between predator capture rate and prey population growth, for instance.

As stated above, how I understand "idealizing assumptions" cuts across other categorizations of modeling assumptions. For instance, Hindriks (2006) has developed the category of tractability assumption, adopted by Kuorikoski *et al.* (2010). These are misrepresentations introduced into a model, not to isolate certain causal features, but rather to make a model mathematically tractable.[3] Hindriks

[3] Hindriks' "tractability assumption" is actually more in line with Weisberg's galilean idealizations, as noted above.

discusses Newton's model of the solar system to determine the movement of the planets. As Hindriks explains, "Newton assumed that there were no interplanetary gravitational forces. Given his theory, a planet moves around the sun in an ellipse under the assumption that it is the only planet orbiting the sun" (2006, 411). However, Hindriks points out that the assumption on the lack of interplanetary gravitation forces was not because Newton thought they were causally irrelevant, but rather because the mathematics to calculate interplanetary gravitational forces did not exist at Newton's time (2006, 412).

Tractability and galilean assumption, or under Weisberg's categorization galilean and minimalist idealizations, are categorized as different types of modeling assumptions due to the purpose for which they are introduced. Tractability assumptions are introduced to make a model mathematically tractable while galilean assumptions are introduced to focus in on a core set of assumptions. However, both can create what I consider an idealizing assumption, in that they remove some factor that is presumed to be causally relevant.

My understanding of what an idealizing assumption is cuts across other categorizations of types of modeling assumptions or idealizations. However, there are a couple of important points to make. First is that not all misrepresentations or falsehoods in a model are idealizing assumptions. There are, for instance, fictional objects included in models.[4] Rather than omitting some causal factor, these introduce something into the model known not to be a part of the real-world target. These are not idealizations on my account since they are not omissions of some factor that is presumed to be causally relevant, but rather the inclusion of something that is not there. Similarly, approximations of some actual value, including the incorrect value for some factor is not an idealization. For instance, the value of some factor may be rounded off for a variety of reasons, maybe most prominently for tractability. This, however, is not an idealization on my account, as it is not the omission of some causally relevant factor, but rather the factor is included but the actual value is misrepresented. The only conditions under which an approximation of some value is considered an idealizing assumption, under my understanding, is if, by approximating the value, the causal factor is *removed* altogether from the model. So, if the value of some factor is approximated at "0", meaning it has no causal impact on the model, then it is an idealizing assumption. If the causal factor is approximated to some value that still allows it to play a causal role in the model, then it is not an idealization as I use the term here.

[4] See Bokulich (2009, 2012), Winsberg (2010), and Weiskopf (2011) for discussions of fictions in models.

A second is that not all assumptions that omit some feature of the real-world target are idealizations. Whether or not some assumption is an idealizing assumption depends on the phenomenon of interest. The omitted feature needs to be known or presumed to be causally relevant to the phenomenon of interest. There are features of any real-world system that are causally irrelevant, or at least rather negligible, to some of the phenomena in that system. For instance, if someone were to model the crashing of waves on a beach, the color of the sand probably has minimal to no effect on determining the pattern of waves.[5] Compare this to the Lotka-Volterra model and real-world ecosystems, the limitations of what can be supported by the environment will have an impact on how large a population can actually grow. Given this, not all omissions are idealizing assumptions.

For fear of complicating the terminological landscape further, my understanding of what an idealizing assumption is includes only those assumptions of a model that omit some factor that is known or presumed to be causally relevant. This account of idealization cuts across other categories of types of modeling assumptions and idealizations. Further, it is not inclusive of all types of misrepresentations. From here on, when I use the term idealization or idealizing assumption, I am referring to an assumption of a model that omits some feature of the real-world target that is presumed or known to be causally relevant.

3. The Requirement to De-Idealize

The inclusion of idealizing assumptions is seen by some to introduce some concerns about whether or not a model can count as evidence for some real-world phenomenon.[6] Since an idealizing assumption is a known deviation from the real-world target, particularly in terms of causal relations that are *known or presumed* to have a causal effect, one may question whether or not a model can be used as evidence in favor of some hypothesis about the target. I consider one version of this concern which, as an outcome, requires that models be completely de-idealized before they can count as evidence for some hypothesis about the real-world target.

We can find a concern about the inclusion of idealizing assumptions in Odenbaugh and Alexandrova (2011).[7] The focus is on when we are justified in

[5] One may press that, say, color of the sand may indicate a different composition of the sand which could then have an effect on the patterns of waves that crash. I would respond to this, however, by pointing out that what is causally relevant is the composition of the sand and not the color.

[6] There has been plenty of discussion about the role that idealizing assumptions might play in various capacities. For instance, Strevens (2008) takes the role of idealizing assumptions to indicate that some factor is explanatorily irrelevant.

[7] Both Odenbaugh and Alexandrova (2011) and Harris (2021) discuss this concern in relation to

making causal claims, and they state that, "when articulating a causal claim we need to specify the conditions in which the causal relation holds," and if idealizing assumptions are included, "we do not know what the actual conditions are which, when conjoined with the causal factor of interest, produces the predicted effect" (2011, 763). A model will have a core set of causal relations that are the focus of the model with other causal relations idealized away. Given that causally relevant features of the real-world target are omitted through idealizing assumptions, then whatever results the model may provide for the core features cannot be inferred to the real-world target. The model provides no insight into how the core causal relations behave under the actual conditions.

A similar thought is echoed in Harris (2021). Here it is stated that, for at least some idealizing assumptions, their inclusion in the model means that, for the result produced, "the theorem that we are actually trying to confirm does not seem to be a theorem about the real world in the first place; indeed, it is not clear what kind of theorem it is at all" (2021, 14593). Since the model removes some causally relevant factors found in the real-world target, discovering that some core set of causal relations in the model produces an empirically confirmed result does not tell us about the causal mechanism in the real-world target. In order to use the model as evidence that some set of causal relations produces the phenomenon in the real-world target, the model cannot include idealizing assumptions.[8]

To make this concern a bit clearer, we can return to the Lotka-Volterra model discussed above. The model is a pair of coupled differential equations;

$$dV/dt = rV - (aV)P$$

$$dP/dt = b(aV)P - mP$$

As discussed in section 2, this model fails to include causal influences on population size, such as environmental carrying capacity and influences on predation, like predator satiation. The concern is that any real-world system will have a carrying capacity, and real-world predators are subject to satiation, and so it is not clear that this model can be interpreted as being about any real-world target, since real-world targets will include these causal factors.

galilean idealizations specifically, rather than idealizing assumptions in general. This should not provide a significant concern since the epistemic concerns about galilean idealizations are the same as for my more general idealizing assumptions.

[8] As noted just before the quote from Harris above, their concern about idealizing assumptions is a bit more measured than Odenbaugh and Alexandrova, limiting the concern to "at least some" idealizing assumptions. No clear demarcation is provided between idealizing assumptions that are a concern and those that are not, and I will not try and hash this out here. I will generally treat the concern to be that *all* idealizing assumptions should be treated with suspicion.

Those who question the inclusion of idealizing assumptions argue that a version of the Lotka-Volterra model that excludes causally relevant features cannot be used to tell us about the causal mechanism at play in the real-world target. Suppose that a Lotka-Volterra model is used that omits some causally relevant features, but does so with the purpose to explore, say, the relationship between the growth rate of prey population and the growth of predator population. Let us say, for instance, that this version of the Lotka-Volterra model shows that an increase in prey population leads to an increase in predator population. Those who argue for de-idealization hold that we cannot infer that this result from the model will hold of real-world populations, since there are other factors on the growth rate of predator populations that are not considered in the model. The results of the influence of prey population growth rate on the growth of predator populations cannot be inferred from a model that fails to include other causally relevant factors that will be found in the real-world target.

The solution to the concern about idealizing assumptions is to de-idealize them.[9] De-idealization is the filling in of idealizing assumptions with more realistic assumptions. Given our example of the Lotka-Volterra model above, de-idealization would be to include a carrying capacity in the model.[10] However, since the concern stated above is about placing the core set of assumptions into realistic causal conditions, this requires the *complete* de-idealization of the model (Odenbaugh and Alexandrova 2011).[11] To put the core set of causal relations in conditions that reflect the real-world target, all idealizing assumptions need to be filled in with realistic assumptions *at the same time*.

We can now state the basic requirement to de-idealize. Any model that fails to be completely de-idealized cannot be used as evidence for some hypothesis about its real-world target. Put another way, complete de-idealization of models is a minimal requirement for a model to tell us about the real-world target.

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[9] There are other proposed solutions, such as robustness analysis (Kuorikoski and Lehtinen and Marchioni. 2010, 2012). However, robustness analysis typically works by exchanging false assumptions for other false assumptions. Given the general concern about idealizations, exchanging a false assumption with a different false assumption will not solve the problem. Further, both Odenbaugh and Alexandrova (2011) and Harris (2021) present their concerns in criticism of robustness analysis, so I will not consider such options in this paper.

[10] This has been done where new parameters, K_1 and K_2 are added representing the carrying capacity of predator and prey populations respectively.

[11] Odenbaugh and Alexandrova also refer to this as absolute robustness analysis.

4. The Perfect Model Model Absurdity

This requirement to de-idealize models has been called into question and I consider several criticisms in sections 4 and 5. The criticisms I consider both claim that the requirement to de-idealize involves a commitment to some principle that leads to an absurdity. Given this, as both arguments proceed, the requirement to de-idealize cannot be legitimately held. The first criticism I consider holds that the requirement to de-idealize is committed to an untenable assumption about representational requirements for models, in particular a commitment to the "Perfect Model Model" (PMM) (Teller 2001, Kuorikoski and Lehtinen and Marchioni, 2012). This commitment to the PMM implies some clear absurdities, and, given its commitment to the PMM, the requirement to de-idealize is similarly committed to these absurdities. I argue that formulations of this criticism misrepresent the requirement to de-idealize.

The PMM is a requirement for the representational fidelity of a model and is questionable for a variety of reasons (Teller, 2001). However, Kuorikoski *et al.* argue that it leads to a particular absurdity about model representation. Kuorikoski *et al.* state that the PMM requires that "every part of a model has to be true for it to be an adequate representation of anything" (2012, 897). According to the PMM, in order for a model to represent any real-world target, the model can neither include false assumptions nor omit features of the real-world target. If a model fails to live up to the PMM, then it fails to represent any real-world target, and therefore cannot be used to tell us about any real-world target. The PMM absurdity is presented in direct response to the arguments of Odenbaugh and Alexandrova (2011), and so it is intended to criticize the requirement to de-idealize as presented by Odenbaugh and Alexandrova specifically. In particular, it is pointed out by Kuorikoski *et al.* that, for Odenbaugh and Alexandrova, the epistemic import of a model hinges "on finding a true assumption to replace each and every questionable assumption," and therefore it seems that, "Odenbaugh and Alexandrova apparently endorse something like the 'perfect model model'" (2012, 897). Since the requirement to de-idealize, at least as expressed by Odenbaugh and Alexandrova, is committed to finding true assumptions for each and every questionable assumption, Kuorikoski *et al.* take this to mean that the requirement to de-idealize models is committed to the PMM as a standard for model fidelity.

However, Kuorikoski *et al.* argue that the PMM leads to some absurd consequences, which would imply that the requirement to de-idealize is committed to these absurdities. As a potential absurdity drawn from the PMM, Kuorikoski *et al.* present "that if a model uses the gravitational constant G = 6.653645×10^{-11} rather than the correct 6.67384 in representing gravitation, it does not represent a causal force at all" (2012, 897). This is an absurdity because the misrepresentation of some causal factor, like gravity, where it is given the wrong, approximated, value does not lead to it *failing to represent a causal force*. It does, after all, have a value for gravity that is meaningful within the model and representative of gravitational forces, albeit slightly different from the actual value. This absurdity is used to criticize the requirement to de-idealize because this absurdity stems from the PMM, and the requirement to de-idealize assumes the PMM, and is therefore committed to its absurdities. Given this absurdity, commitment to the requirement to de-idealize is an untenable position to hold.

This absurdity fails to carry much bite against the requirement to de-idealize. Kuorikoski *et al.*'s (2012) example of a potential absurdity that follows from the PMM is that of approximating the value of the gravitational constant and that, due to this misrepresentation, the PMM implies that this *fails to represent* a causal force altogether. That this is supposed to be an absurdity stems from the fact that this sort of misrepresentation or approximation very clearly *does* represent a causal factor. This sort of misrepresentation, however, is not an *idealizing* assumption. As noted in section 2, idealizing assumptions are those that remove some causal factor that is known or presumed to have a causal effect. An approximated value, like the one found in is not the same as removing the causal factor. Given this, the example provided does not target something that the requirement to de-idealize is actually committed to. It is rather silent about the sorts of approximations that Kuorikoski *et al.* use, only speaking to the filling in of *omitted* causally relevant features. So, as far as this example is used to criticize the requirement to de-idealize, it fails since the absurdity stems from a misrepresentation that is not an idealization.

This sort of absurdity, drawn from the example by Kuorikoski *et al.*, does not extend to the requirement to de-idealize. The absurdity of the example presented by Kuorikoski *et al.* does not carry over to idealizing assumptions and only works with the kind of approximation or misrepresentation specific to their example. Let us pretend that the altering of the gravitational constant amounted to an idealizing assumption. This would mean that the causal factor of gravity had been *removed* from the model. However, if this were the case, then the absurdity presented by Kuorikoski *et al.* (2012), that the model fails to represent the causal force of gravity at all, is not an absurdity. It is patently true, because an idealizing assumption is defined by the omission of a causal force. So, the example provided by Kuorikoski *et al.* is not one of an idealizing assumption, and the absurdity does not carry over to idealizing assumptions.

Kuorikoski *et al.* present a second criticism of the requirement to de-idealize and its fidelity expectations. In particular, they say in response to Odenbaugh and

Alexandrova (2011), "it is not only rare that every assumption of a model is discharged or deidealised with 'some true assumption' (p. 764) [12], it is *never* the case. The only model capable of such a feat would be reality itself" (2012, 896). Ultimately, the fear is that the requirement to de-idealize is committed to an expectation of fidelity such that all aspects of a real-world target must be present, and no actual model can live up to it. This criticism of the requirement to de-idealize draws out an absurdity by arguing it is committed to a version of the PMM that makes only the real-world target itself sufficiently similar enough to be an appropriate model.

However, this concern is a bit misplaced. Remember that idealizing assumptions are those assumptions that remove causal factors *known or presumed* to have an impact. It is not the case that *all* features of some real-world target are causally relevant to the phenomenon of interest. As discussed in section 2, if one wants to model the crashing of waves on a beach, there are many features that are not causally relevant. The color of the sand, for instance, or even any particular grain of sand. In this case, individual grains of sand do not need to be modeled and so concerns about requiring too much detail can be assuaged. Most importantly, given that there are features of the real-world target that are not causally relevant, something less than the real-world target itself can be an appropriate model.

So far, I have considered two criticisms of the requirement to de-idealize from the literature. In doing so, I have argued that these criticisms misinterpret the scope of the requirement to de-idealize and therefore fail to effectively criticize the requirement to de-idealize. The criticisms of the requirement to de-idealize draw on aspects that are not central to the requirement to de-idealize. In the first criticism considered, it attempted to draw an absurdity about the requirement to de-idealize by claiming it is committed to the claim that approximating the real value of a causal factor means that the model *fails* to represent a causal factor. This absurdity does not follow from the requirement to de-idealize. The second absurdity was that the requirement to de-idealize is committed to the position that only the real-world target itself is sufficiently similar enough to qualify as a model of itself. This, once again, overstates the commitment of the requirement to de-idealize. Both of these fail to target the central claim, which is that idealizing assumptions need to be replaced with more accurate assumptions in order for a model to be able to tell us about the real-world target, and therefore we fail to have sufficient criticism of the requirement to de-idealize.

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[12] This citation is part of the Kuorikoski *et al.* quote and references a page in the Odenbaugh and Alexandrova paper.

5. Biting a Drastic Bullet

In section 5 I consider a concern about the requirement to de-idealize, which is that models are never completely de-idealized (Dethier, 2022). However, rather than arguing that the requirement to de-idealize is committed to a particular fidelity requirement for models (i.e. the PMM), the concern is that expecting models to be de-idealized in order to count as evidence would lead to rather drastic consequences for what we take to be well-established science (Dethier, 2022). The basic outline of the argument is that models are rarely, if ever, completely de-idealized, just like Kuorikoski *et al.*'s second concern above. Given this, the requirement to de-idealize is forced to give up on much of what is taken to be well-established science relies on these models. This forces an untenable outcome for defenders of the requirement to de-idealize, since much of what is taken to be well-established science needs to be given up. This concern is a rather natural extension of the second concern presented by Kuorikoski *et al.* but is not committed to the claim that the requirement to de-idealize assumes the PMM. It loosens the assumed requirement of model fidelity and simply focuses on the conflict between the requirement to de-idealize and the fact that models are rarely, if ever, de-idealized.

Dethier presents this criticism of the requirement to de-idealize while providing a defense of some other means of validating the results of a model that do not require de-idealization.[13] In doing so, Dethier includes the basic premise;

> P1. Model reports are evidence.

Dethier then provides a potential paraphrasing of the requirement to de-idealize position as,

> unless we can show that the idealizations present in a model can be removed without changing its implications, we don't have good reason for increasing our confidence in a hypothesis based on the reports given by the model. Since we're rarely (if ever) in a position to remove all of the idealizations in a model, (P1) fails (2022, 2741).

Models must be completely de-idealized in order to count as evidence, but we can rarely remove all of the idealizations from a model, and so we are rarely (if ever) be in a position to take models as evidence (i.e. P1 fails). This part of the argument has one clear advantage in that it focuses on idealizing assumptions specifically and does not introduce other types of misrepresentations.

[13] Dethier presents this in defense of robustness analysis.

Dethier goes on and points out that to accept or deny P1 makes a significant difference on what sort of evidence one has access to. Much of successful science incorporates models. As Dethier points out,

> Not only are there a wide variety of results that depend explicitly on models, but… models often play crucial roles in even the most paradigmatic cases of empirical evidence (2022, 2740).

In particular, the wide variety of results depends on models *as evidence*. Similarly, it is evidence from models that plays a crucial role in paradigmatic cases of empirical evidence. For instance, Dethier points out that it is the idealized "model of the pendulum that provides us with reason for thinking that experiments involving a low-amplitude pendulum will be more accurate than ones involving a high-amplitude pendulum" (2022, 2740). Models, in all their idealized glory, play a significant role in many aspects of science. If it is the case that most, or all, models are never completely de-idealized, to deny P1 would require giving up on a significant amount of accumulated evidence, both from models and from more empirical means. However, Dethier claims that this,

> is simply not plausible because it would leave far too much of our most successful sciences unconfirmed. It's even commonly thought that all models are idealized (see, e.g., Teller 2001), which would render virtually all scientific results unconfirmed (2022, 2741).

Virtually all results of science rely, in some way, on models. Virtually all, if not all, of these models have never been completely de-idealized. Given this, potentially all results found in science are untenable, if one accepts the requirement to de-idealize. To give up on virtually all scientific results is a rather drastic bullet to bite, certainly not one that most would be willing to accept.

This concern about the requirement to de-idealize is significant and needs to be addressed. However, I think the power of this concern turns on some lack of clarity on what it means to de-idealize a model. I want to distinguish between two types of de-idealization. One I will call *mathematical de-idealization* and the other I will call *epistemic de-idealization.* Mathematical de-idealization is a method of de-idealization by completing the *mathematical* representation of the real-world target. To put this another way, this would include the filling in of all idealizing assumptions with some mathematical representation of those causal factors. In the case of Lotka-Volterra models, this would include filling in parameters for omitted causal factors, such as adding in a variable for carrying capacity. Mathematical de-idealizations, adjustments, and corrections are carried out by making the mathematical formulae more complete and complex.

Epistemic de-idealization, in comparison, includes all of the methods for de-idealizing a model. Mathematical de-idealization is one method for epistemic de-idealization, but there are other ways of de-idealizing a mode beyond manipulating the mathematical structure of the model. I will briefly discuss two such ways, through empirical evidence and "de-idealization by commentary" (Svetlova, 2013).

It is important to note that by using the terms mathematical de-idealization and epistemic de-idealization, that I do not mean to imply that there are mathematical *idealizations* and epistemic *idealizations*. All idealizations I consider here are aspects of the mathematical model that omit some causally relevant feature. However, what I intend to discuss are methods of correcting idealizations found in models, some by adding to the mathematics, and some that do not involve adding to the mathematics of the model.

The first means of non-mathematical methods of de-idealizing a model is through the consideration of empirical evidence. That empirical evidence influences how we understand and interpret models is not unheard of. For instance, models of predator/prey relations like Lotka-Volterra models, often exclude any representation of predator satiation (Harris, 2021). However, empirical evidence has come to show that predator satiety might be a significant factor in the impact of predation on prey populations (Dubey *et al.*, 2010). Whether or not satiety is a significant factor to be included in models has been debated for decades, empirical evidence can come to indicate that satiety may very well play a significant role in the causal mechanism of interest. In this case, empirical evidence plays an important role in showing which causal relations are relevant and can provide insight into the shortcomings of the model.

Another example may be Galileo's experiments on the relationship between a pendulum's period and amplitude. While there was determined to be a minor difference in the effect of amplitude on period through experimentation, it is not significant.[14] Given a result like this, it can be determined that, for instance, amplitude does not need to be accounted for in some models of pendulums.

Another non-mathematical form of de-idealization is "de-idealization by commentary" (Svetlova, 2013). As an example, Svetlova considers the Discounted Cash Flow (DCF) model, a model used in finance for option pricing. One aspect of the DCF model is that it assumes that the risk premium for emerging market equities is greater than the risk premium for markets in developed countries. Differences in the risk premium will influence valuation, and so it is often the case that the DCF implies that emerging market equities are overvalued.

[14] Empirical evidence does not just come to bear on the relative influence of idealizing assumptions, but since this is our focus, I will only consider it in relation to idealizing assumptions.

However, those who use the DCF to make investment decisions do not always trust this part of the model (Svetlova, 2013). Most importantly, they evaluate whether or not to take this overvaluation of emerging market equities by considering historical aspects that are not part of the model. For instance, in an interview with someone who works with the DCF model, Svetlova is told that,

> The claim that the risk premium in the emerging markets is higher comes from history. Then history is projected into the future and one says, 'emerging markets are overvalued'. But now the discussion of a qualitative nature can begin. Is the history relevant now? Is it not? How relevant is it? (2013, 330).

The reason why this overvaluation is derived is considered and evaluations as to whether or not the historical reasons for higher premium risks is legitimate taken up. Decisions made based on the model are adjusted in light of these considerations. Most importantly, Svetlova points out that,

> neither the relaxation of assumptions nor concretization is the prevailing method of de-idealization; rather, under-constrained financial models are de-idealized by the ongoing storytelling that occurs in the form of judgment…This observation leads to the hypothesis that the more under-constrained the model is the larger the role that narrative and other pragmatic elements outside of the model play when the model is applied (2013, 336).

The work of adjusting a model, both by removing the influence of some features and de-idealizing or "concretizing" the model is done without manipulating the actual mathematics of the model. It is held the same and used to lead "commentary" regarding how to adjust and interpret the results.

It is important to note that mathematical and other forms of de-idealization do not always operate in isolation. Empirical evidence might be used in interpreting a model, and this might lead to adding more to the mathematics of the model. However, when using a model, there are strategies of de-idealizing a model that include adding to the mathematical structure, and there are methods that work in ways other than adding to the mathematical structure. This second group fleshes out what I intend to mean by epistemic de-idealization.

This gives us at least two ways in which modelers may de-idealize at least some causal factors that are not carried out through changing the mathematical structure itself. One is that the relative influence of some causal factor may be determined through empirical measures. The other is through commentary, where a parameter might be included by further background information to determine how to treat that causal factor without altering the mathematical structure of the model. Both cases are examples of de-idealization in that they allow a modeler to "fill in" some causal factor or determine that it can actually be left out without changes to the mathematical structure. A model could, potentially, be completely de-idealized with a combination of these methods, where some suspected idealizing assumptions are de-idealized by being shown to be inconsequential through empirical or commentary means, and others are de-idealized through correcting the mathematics of the model.

This gives us a framework for better understanding the concern about requiring idealization giving up too much well-established science. In particular, we can consider the claim that models are rarely, if ever, de-idealized. In terms of mathematical de-idealization, I believe that this is true. It is rare, if ever, that a model is completely mathematically de-idealized. However, if we consider the question of whether models are ever completely *epistemically* de-idealized, I believe that this is not so clear. This is not to say that I am certain that models typically are completely epistemically de-idealized, but simply that whether or not this is the case has not been well established. Most importantly, I do not believe that it has been proven that models, in general, are *rarely if ever* completely epistemically de-idealized. The discussion regarding the de-idealizing of models focuses almost exclusively, as far as I am aware, on the mathematical de-idealization of models, with little focus on how other types of evidence are incorporated into the de-idealization process.

This is problematic for the criticism of the requirement to de-idealize. The premise that models are rarely if ever de-idealized is central to establishing the claim that the requirement to de-idealize must give up on much well-established science. If it turns out to be the case that models quite often *are* completely epistemically de-idealized, then there is little to suggest this retort to the requirement to de-idealized.

The drastic bullet criticism may be saved if mathematical de-idealization is sufficient to establish its conclusion. This, however, I believe is not the case. The debate between those who require de-idealization and those who do not is one that focuses on potential epistemic shortcomings of models and their role as evidence. If the only way to resolve these epistemic concerns was through mathematical de-idealization, then all that would need to be shown is that models are rarely, if ever, mathematically de-idealized. However, insofar as there may be various methods of *resolving* these epistemic shortcomings, mathematical and empirical, then this should be the scope considered when leveling criticisms of one particular position. In this case, in order for the criticism of the requirement to de-idealize works because it requires giving up too much evidence in the form of models, *all* of the methods for establishing a model as evidence, both mathematical and empirical, need to be considered. Therefore, the scope of this debate requires taking into consideration epistemic de-idealization and not just mathematical de-idealization.

The purpose of the above discussion is to more clearly establish what is meant by de-idealization and how this factors into criticisms of the requirement to de-idealize. The criticism considered in this section works if what is meant is mathematical de-idealization. However, I believe that the criticism of the requirement to de-idealize needs to include the broader epistemic de-idealization. The literature on de-idealization is not at a state to establish that models in general are rarely, if ever, epistemically de-idealized. Given this, the criticism by drastic consequences rests on an unestablished premise. The conclusion that requiring de-idealization is unrealistic is premature.

One may respond by pointing out that those who have pressed to require de-idealization also focus on mathematical de-idealization. Odenbaugh and Alexandrova (2011), for instance, seem to only focus on examples of failure to completely mathematically de-idealize a model. Given this, is their criticism, and others who similarly argue for required de-idealization, about the need to mathematically de-idealize a model, not the need to epistemically de-idealize? Put another way, is it appropriate to consider epistemic de-idealization in the context of this debate given the focus on mathematical de-idealization.

I believe it is correct to point out that the requirement to de-idealize has been focused on complete mathematical de-idealization. This, however, is a confusion on the part of those pushing for required de-idealization. The reasons that they push for required de-idealization are *epistemological* reasons. Their concern is that failure to completely de-idealize a model leaves the results open to uncertainty, as the actual conditions required to produce the result are not accurately reflected in the model. They seem to be mistaken, just as with the presentation of the drastic bullet criticism, that the epistemic concerns regarding the features of models are handled exclusively through mathematical means. In this case both sides are incorrect about the focus of de-idealization.

The change in focus from mathematical de-idealization to epistemic de-idealization does not undercut the concerns of those who push for the requirement to de-idealize. Their concern, as mentioned above, is primarily epistemological. In particular, they feel that interpreting a causal claim in a model requires knowledge about the conditions under which the causal claim of interest is actually found. The problem is that they limit gaining this knowledge to mathematical de-idealization. The concern about de-idealizations can be stated in terms of epistemic de-idealization where, if we have *no way* of de-idealizing a model, through whatever mathematical or non-mathematical means, then we might fairly say that the model cannot be used to tell us about the real-world target. Put another way, the concern is that, if we lack knowledge, of any kind, about the actual conditions surrounding the core causal aspects of the model, then we cannot take the model as evidence about some hypothesis for its real-world target.

I will put this concern in yet another way. Suppose we have some model that idealizes some causally relevant factor. Given that it is causally relevant, there is the suspicion that it has an influence on the real-world phenomenon being modeled. If our model, which omits the causally relevant factor, produces some empirically confirmed result, then the modelers know that this result was produced without taking all potentially causally relevant factors into account. If there is no way to account for the influence of that causal factor, whether through mathematical or non-mathematical means, then the modeler has open questions about their model. They can see that it produced an empirically confirmed result, but what if adding in the causal factor changes the results? This may give the modeler reason to question their model, unless there is some method of answering this question about every idealization.

Ultimately, I have argued that the requirement to de-idealize does not necessarily succumb to the drastic bullet concern. If the focus is on solely mathematical de-idealization, then the drastic bullet concern carries significant bite. However, I have argued that a second option, epistemic de-idealization, is not so obviously a victim of the drastic bullet concern. I then motivated epistemic de-idealization as a reasonable interpretation of the initial requirement to de-idealize.

6. Conclusion

The inclusion of idealizations into models has long been a focus of epistemic concern. Given that idealizations are known dalliances from the real-world target, there have been concerns about whether or not the inclusion of idealizations allows for legitimate inferences to be made from results of the model to its real-world target. I started by considering a version of this concern that argued that the inclusion of any idealizations undercut the ability to use the model to make inferences about its real-world target. A model must be completely de-idealized in order for it to be able to provide a basis for inferences about the real-world target.

Next, I considered a criticism of the requirement to de-idealize which argued that the requirement to completely de-idealize is committed to the PMM. The PMM, however, was supposed to lead to some clear absurdities. In response, I argued that the example of an absurdity presented does not affect idealizing assumptions. I then argued that the requirement to de-idealize is not committed to any problematic account of the PMM.

Next, I considered a criticism that the requirement to de-idealize was too strict an epistemic requirement. Given the significant role that models play, and the rarity it is to completely de-idealize a model, If it was the case that all idealizations need to be de-idealized in order for a model to be able to provide inferences about the real-world target, then much of well-confirmed science would have to be given up. This is too drastic a bullet to bite. In response, I argued that the claim that models are rarely, if ever, completely de-idealized was not as clearly established as taken. I did so by distinguishing mathematical de-idealization from epistemic de-idealization and argued that it is unclear that epistemic de-idealization is rarely achieved. I also argued that epistemic de-idealization is the better understanding for the concern about de-idealizing models.

This paper far from settles whether or not models need to be de-idealized in order to provide evidence for their real-world targets. For instance, when it comes to epistemic de-idealization, I am unable to provide evidence that models are regularly completely epistemically de-idealized. In order to better evaluate the strength of the concern about the drastic bullet criticism, an investigation about whether or not models are regularly epistemically de-idealized needs to be carried out. This, I believe, requires a rather significant historical and sociological investigation to better determine what sorts of understanding modelers had of the various causal factors. As well, the process of developing a checking models is not carried out in an instant, but models are often validated and confirmed over time and through communities of investigators, and so a means of tracking the sorts of implicit and explicit thoughts that communities of scientists carry over times is a significant undertaking. Finally, to determine whether or not the drastic bullet criticism carries significant bite, this would need to be carried out on more than one model, or one prominently central model, to establish those wide ranging effects. If it is claimed that models are rarely, if ever, de-idealized, this process of historical and sociological evaluation would need to be carried out on many models.

A positive outcome of this paper is that, potentially, more attention will be paid to the variety of ways that models are de-idealized. De-idealization, in order to play the epistemic role it is intended to play, may not only be carried out through mathematical manipulation of the model, but might be achieved by considering what empirical evidence tells about the idealizations of the model, or might be de-idealized through commentary. Considering the various ways that a model might be de-idealized can help shed light on the pragmatic aspect of modeling, and the way that models are applied.

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