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ARTICLE

How Narratives Can Deidealize Models

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Abstract

Tarja Knuuttila and Mary Morgan recently challenged the widespread understanding that deidealization is no more than a simple process of relaxing assumptions to build increasingly more realistic models. They submit that, in practice, processes of model deidealization are diverse and complex and thus warrant more explicit scrutiny. Drawing on a case from economics, I extend their proposal by showing how narratives, as additional representational forms, can assume a crucial role in deidealizing mathematical models. I thereby propose to consider that processes of model deidealization are not necessarily exhausted by processes in which one mathematical model is replaced with another one.

1. Introduction

How do scientists *de*idealize their models? Whereas much philosophical attention has been paid to the role that idealization plays in scientific modeling, deidealization has attracted little explicit scrutiny. Unlike "idealization," which philosophers of science have made conceptually more precise by distinguishing, for example, between idealization and abstraction, deidealization is usually, though often implicitly, simply understood as a process in which scientists relax assumptions to make a model more realistic.

Tarja Knuuttila and Mary Morgan (2019) have recently suggested that this treatment of model deidealization be reconsidered. Their proposal is unlike many others primarily because in their plea to take model deidealization more seriously, they suggest that rather than assuming that model deidealization is no more than a simple reversal process aiming to make a model more realistic, they recommend examining how deidealization occurs in practice. In practice, they submit, "scientists are engaged in a variety of constructive activities" (2019, 646), which they suspect give rise to complex and multifaceted processes of model deidealization.

In this article, I elaborate and extend their proposal. First, I elaborate their invitation to reconceptualize model deidealization by making explicit some of the important ways in which Knuuttila and Morgan's proposal improves on the standard view of model deidealization. Then, I extend their proposal by focusing on one particular implication, namely that processes of model deidealization might not be exhausted by processes that replace one theoretical mathematical model with another theoretical mathematical model. This builds on Knuuttila and Morgan's suggestion that scientists might decide to change "representational modes" (2019, 650) when deidealizing models. As I discuss in the following, such changes of representational modes are especially important to consider given recent attempts to treat model deidealization as a comparative concept only. Yet, while Knuuttila and Morgan raise this as a possibility they do not develop this idea fully. In this article, I develop their suggestion further by examining how narratives, as additional representational forms, can play a crucial role in processes of model deidealization. By analyzing a case of model deidealization in economics, I consider how scientists might not only deidealize theoretical mathematical models by replacing them with other theoretical mathematical models but also by the use of narratives. Such an analysis, in turn, builds on recent work on narratives in science that has observed how narratives often seem to complement mathematical models by mediating between models and their target systems (e.g., Hartmann 1999; Morgan 2001, 2012; Morgan and Wise 2017; Wise 2011, 2017, 2022). Thus, by examining how narratives can contribute to the deidealization of mathematical models I also further explore one way in which narratives can complement mathematical models.

2. The standard view of model deidealization and its limitations

Although there is substantial disagreement regarding the need for model deidealization, there is some consensus on what deidealization amounts to, or at least would amount to if it were needed. Commonly, model deidealization is understood as a process in which scientists successively relax assumptions to build increasingly more realistic models.[1] Moreover, often, such a process is understood primarily as a process of adding (back) causal factors that have initially been omitted. At the same time, explicit definitions of deidealization are rare. Peruzzi and Cevolani (2022, 28) have recently characterized model deidealization in a way that I think tracks a widespread view that often remains implicit: "Roughly, de-idealizing a theory or model means removing one of its idealized assumptions and replacing it with a new one that it [*sic*] is less idealized, that is, more realistic in being closer to the actual phenomena."

While widespread this view of model deidealization has also attracted considerable criticism.[2] For one, philosophers have disputed the feasibility of model deidealization so conceived. For example, some critics argue that because of the way in which models are constructed, their assumptions cannot usually be relaxed one by one (e.g., Alexandrova 2008; Carrillo and Knuuttila 2022; Reiss 2012; Rice 2019). Scientific

[1] The notion is often traced back to McMullin (1985) and Nowak (1989, 1994, 2000). Nowak called this process "concretization" (see, e.g., also Cools et al. 1994, Kuipers 1985, and De Donato Rodríguez and Zamora Bonilla 2009 for such use of concretization). More casual and recent mentions of deidealization can, e.g., be found in Batterman (2009), Mäki (2020), and Potochnik (2017). Wajzer (2024, 2) has recently presented model deidealization more explicitly as "the gradual removal of successive idealising assumptions" and as the "process of gradual approximation of a theory to empirical reality."

[2] Given that definitions of model deidealization are not always made explicit, deidealization constitutes a moving target for criticism. I focus here on three major lines of criticism disregarding more detailed issues that will differ depending on the details of the definition presupposed.

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models are usually intricate constructions that must hold together so that "it is not normally possible to tinker with individual assumptions that are deemed 'too highly idealized for the purpose at hand' while leaving others fully intact when building a new, less idealized model" (Reiss 2012, 379). Rice (2019) has indirectly reinforced this criticism. If models are usually "holistically distorted representations" (2019, 196) that cannot be decomposed into accurate and inaccurate parts, then it is not possible, as the standard view requires, to "remove or replace the idealizations within our scientific models while leaving the contributions of the isolated accurate components intact" (2019, 189).

Others have argued that even if deidealizing models in this way were feasible, it might not be desirable. For example, both Michael Weisberg (2007) and Robert Batterman (2009) have argued that often we do not want to deidealize our models (see also Potochnik 2017). It is simply wrong to assume that the more complex, detailed, and realistic a model is, the better. Idealizations can play productive roles, and therefore, whether idealizations need to be deidealized depends on the kind of idealizations used in model construction. Idealizations can, for example, increase the explanatory power of a model and, therefore, deidealizing a model is counterproductive in such cases.

Moreover, the standard view of model deidealization is also put under pressure by conceptual difficulties that appear within an ambiguity about deidealization's aim. Critics of model deidealization often seem to assume that model deidealization is a process that is geared toward bringing about a convergence between a model and its target phenomenon so that a "fully realistic" model emerges. For example, Batterman (2002, 2009) describes what he calls the "traditional view" as one that requires a "convergence between model and reality" (Batterman 2002, 21) and that "aims for the most exact and detailed representation of the phenomenon of interest" (2009, 429). If that were the case, the standard view would run into serious difficulties because, as Cassini (2021) has forcefully argued, this requirement is too strong. Most strikingly, this ideal is incompatible with most accounts of scientific models that are widely accepted nowadays. But one might also wonder whether a fully deidealized model, that is, one that is exact and complete, would still be considered a model.[3]

Given these criticisms, model deidealization would appear as an, at best, marginal activity in scientific modeling. However, more recent defenses of model deidealization have contested this conclusion by countering with cases in which model deidealization has, in fact, occurred. Thus, it is argued, deidealization is often both feasible and desirable (e.g., Peruzzi and Cevolani 2022; Wajzer 2024). It has also been noted explicitly that there is no need to assume that model deidealization aims at any sort of "fully realistic" model. For example, Peruzzi and Cevolani (2022) state explicitly that they are primarily interested in model deidealization as a comparative concept only. When scientists deidealize they replace idealized models with less idealized ones without the requirement that models should be deidealized fully. I agree with such proposals to the extent that writing deidealization off as unimportant is a hasty conclusion. But the positive proposal associated with these

[3] This is especially so when the difference between omissions and distortions is not made explicit. We might be able to imagine a model without deliberate distortions, but requiring a model to be complete is implausible.

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recent defenses raises its own difficulties. For example, having turned deidealization into a comparative concept only, proposals like Peruzzi and Cevolani's still seem to envision a uniform process of replacing idealized with less idealized assumptions. This is in line with many others who have discussed model deidealization primarily as a process of relaxing assumptions (e.g., Hindriks 2012; Mäki 2012), eliminating idealizations (e.g., Batterman 2010; McMullin 1985; Potochnik 2017), or adding back "details" (e.g., Batterman 2009; McMullin 1985; Weisberg 2007). However, if we look at concrete scientific practices, we might find that processes of model deidealization are much less uniform than this would suggest. Yet, we might also already suspect that processes of model deidealization are much more diverse for conceptual reasons. For example, given the now prevalent distinction between idealizations as intentional distortions and abstractions as omissions without distortion (e.g., Godfrey-Smith 2009; Jones 2005; Levy 2021), we might consider not only distinguishing between different kinds of idealization but also similarly between different kinds of deidealization.[4] Such diversity seems to be suppressed both on the original standard view and its recent revisions.

Furthermore, many explicit discussions of model deidealization conceive of model deidealization not simply as any process of relaxing assumptions to make a model more realistic but as a concept that treats relations between a succession of models formally (e.g., Kuipers 1985; Niiniluoto 2012). Peruzzi and Cevolani (2022), for example, seem to retain this approach by offering a definition of model deidealization in terms of formal relations between models that need to hold. For them, one model (model B) is a deidealized version of another model (model A) if i. both models share the same target, ii. model B has relaxed one of the assumptions of model A so that model B does not include an idealized assumption that model A included and iii. model A can be shown to be a special case of model B. The problem with this account is that it turns deidealization into an exceedingly narrow concept. If we accept Peruzzi and Cevolani's definition, it would seem that examining model deidealization primarily means treating cases in which two models are compared that differ only in a single dimension. This is because if more than one element is changed, "we would quickly find problems of incommensurability" (Cassini 2021, 99; also Jones 2005). While I do not want to deny that we might find such cases, we should expect them to be rare. In most cases, more than one element is changed as a model is deidealized.

Thus, although a view of model deidealization along the lines of Peruzzi and Cevolani (2022) can avoid the initial conceptual criticism and can counter claims that deidealization is never called for or possible, it effectively focuses on what we should expect to be a small subset of relevant deidealization processes. What it primarily targets are those processes of model deidealization in which assumptions are relaxed in a way that allows for a neat ordering of the models involved. These cases surely exist. But model deidealization is not exhausted by such cases. Moreover, such a revised standard view still does not adequately distinguish between the different processes it implicitly seems to talk about.

[4] Cassini and Redmond (2021), Jones (2005), and Weisberg (2007), e.g., hint at this when they mention both processes of adding back and processes of removing deliberate distortions.

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3. A practice view of model deidealization and its merits

To the extent that Knuuttila and Morgan (2019) argue that deidealization is a prevalent and important element of much scientific modeling, they concur with the recent defenses of model deidealization discussed in the preceding section. Yet, they also share many of the criticisms sketched—they too question the feasibility and desirability of model deidealization as envisioned by the standard view. Thus, their main concern is that despite these worries about feasibility and desirability, deidealization is still commonly understood as a simple "reversal process" (2019, 642) that does not warrant much attention.

As an alternative, Knuuttila and Morgan propose to examine processes of model deidealization more explicitly, to consider that they are often complex and to scrutinize how scientists avail themselves of a potentially diverse set of strategies to deal with the multifaceted challenges of model deidealization. Thus, in one way, their proposal is simple: Rather than preempting that deidealization, by definition, requires adding back to make a model more realistic, Knuuttila and Morgan (2019) propose to study model deidealization by examining how scientists achieve model deidealization in practice. To this end, Knuuttila and Morgan suggest a guiding framework that differentiates between four distinct processes of deidealization: what they call "deidealizing as recomposing," "deidealizing as reformulating," "deidealizing as situating," and "deidealizing as concretizing" (2019, 642; emphases suppressed). Knuuttila and Morgan thus approach "deidealization" as a comprehensive category within which several distinct processes can be differentiated. This is important to recognize because it shows how Knuuttila and Morgan's treatment of model deidealization does not begin from the increasingly widespread distinction between abstraction and idealization (which would suggest that we reserve the term "deidealization" for those processes that deal with assumptions that distort, while "concretization" would refer to those processes that deal with assumptions that omit without distortion, i.e., abstractions). Instead, they suspect that the processes of model deidealization are much more diverse than even this distinction would suggest and retain "deidealization" as a generic term that can be used to refer to several different processes.[5]

A second novelty of Knuuttila and Morgan's proposal is their framing of model deidealization as a means to diverse ends. Rather than conceiving of model deidealization as a process that primarily aims to make a model more realistic, for them, deidealization is required "for different kinds of attempts to apply models to the world" (2019, 642). Thus, a practice view of model deidealization positions the processes of deidealization as a means for different kinds of model "applications": application designates a goal, deidealization is what a scientist might have to do to achieve this goal. It is important to recognize, however, that this covers a great deal of ground. Specifying the goal as model application that might call for model deidealization encompasses, for example, cases in which a model is used to explain a

[5] They retain idealization as a similarly generic category. Thus, on their account, abstraction is a kind of idealization process and concretization is a kind of deidealization process. As many have noted, no consistent terminology is available for "idealization" (e.g., Cassini 2021; Frigg 2023; Jones 2005; Knuuttila and Morgan 2019). See, e.g., Carillo and Knuuttila (2022) for a systematic critical discussion of idealization as distortion.

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specific phenomenon but also cases in which a model is transferred across domains to study different kinds of phenomena (2019, 653).[6] But on a practice view, we should expect that the processes of model deidealization could look very differently depending on whether a model is used for explanation or whether it is transferred into a new domain. Lastly, it is not only the case that deidealization might look differently depending on the purpose to which a model is put. It is also only required to the extent that it helps to achieve that particular purpose. This, in turn, is in line with Cassini (2021) who argues that deidealization is only required to the extent that it helps with achieving the epistemic purpose that the model is meant to serve. As a result, scientists only want to deidealize a mathematical model if it helps them with "obtaining better explanations or predictions, or more generally, improving the expediency of our models to solve the problems that originated their construction" (2021, 88).[7]

Importantly, then, Knuuttila and Morgan's practice view has the resources to overcome the weaknesses of the standard view as discussed in the previous section. Above all, their practice view makes visible and tries to conceptually account for the diversity of model deidealization processes which the standard view neglects. Moreover, Knuuttila and Morgan do not only suggest that the processes of model deidealization are diverse. They also emphasize that model deidealization is not only after "more realism" but can serve several different goals thereby reframing standard feasibility and desirability concerns. In sum, a practice view along the lines of Knuuttila and Morgan (2019) offers a new perspective and important new resources for better understanding how models are deidealized.

4. Deidealization by narrative

Generally, Knuuttila and Morgan (2019) thus redirect attention to the diversity and complexity of processes of model deidealization in scientific practice. More specifically, however, their proposal includes the suggestion that processes of model deidealization might not be exhausted by processes in which one theoretical

[6] It goes beyond the scope of the article to systematically disentangle the different senses of model application. But see, e.g., Alexandrova and Northcott (2009) for explaining with models as model application, Knuuttila and Loettgers (2023) for transferring models across domains as model application, and Alexandrova (2006) for practical interventions on the basis of models as model application. It is because of this diversity of activities covered under "model application" that a clean division of idealization as "an essential procedure in model-construction" (Cassini 2021, 94) and deidealization as an essential procedure in model application does not work at this point. E.g., as models are "applied" when they are transferred across domains, processes of model deidealization play a role in model construction.

[7] Cassini (2021) focuses his critical discussion of model deidealization on this issue of "more realism" as the primary goal of model deidealization. It should be noted that, generally, Cassini (2021) and Knuuttila and Morgan (2019) seem to have much in common. He, too, does not share what he calls a "'deficiency' conception of idealizations" (2021, 95). He emphasizes the feasibility and desirability concerns of model deidealization without thereby dismissing its importance and submits that the goal of model deidealization is not simply more realism. Scientists deidealize to the extent that it serves the purpose to which the model is put. But crucially for the purposes of this article he, unlike Knuuttila and Morgan, seems to leave the standard view intact with respect to the actual processes of deidealizing models. While at times he seems to be open to processes of model deidealization being diverse (see Cassini 2021, 96–99), in the end he seems to retain the idea that deidealization is primarily about adding (back).

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mathematical model is replaced with another theoretical mathematical model because they suggest that "deidealizing may involve making a choice of different representational modes" (2019, 650). This is especially important to consider given the vacancy that arises on those recent revisions of the standard view that dispense with the requirement of "full" model deidealization: As a comparative concept only, it directs attention to those processes of scientific practice in which idealized mathematical models are replaced with less idealized ones. But beyond such a comparative analysis, processes in which a highly idealized mathematical model that is deemed sufficiently realistic for a purpose at hand is put to such a purpose and the challenges of dealing with the idealized nature of such models remain beyond view. While Knuuttila and Morgan (2019) hint at the possibility that representational modes can be changed as models are deidealized, they do not develop this fully. In this section, I develop and extend their suggestion by considering narratives as one important representational mode that scientists might decide to rely on in processes of model deidealization.[8]

The general idea that narratives might play an important role in the sciences has increasingly been studied by philosophers and historians of science (e.g., Morgan and Wise 2017; Morgan 2022; Morgan et al. 2022). In this literature, a narrative is commonly understood as a representation of a connected sequence of events. The defining feature of narrative is then often marked by contrasting it with a chronicle: Both chronicles and narratives are representations of a sequence of events, but unlike chronicles that only order events in time, narratives also draw connections between events thus ordered (e.g. Morgan 2022).[9] From a narratological perspective, this is a relatively minimal definition of narratives (e.g., Fludernik and Ryan 2020). But it is in line with what Ryan (2007) has called "the most universally accepted feature of narrative" (2007, 25) namely that narratives are a representation of an "ordered sequence of events" (2007, 23). One of the points of contention important for this context is the nature of this ordering. It is often assumed that something more than temporal ordering is characteristic of a narrative—this is what distinguishes narratives from chronicles. On some definitions, these connections of the narrative have to be causal (e.g., Carroll 2001; for a discussion see Abbott 2002, Ryan 2007). While I do not assume that narratives, by definition, posit causal connections, we will see that the narratives I am concerned with in this article are of the stronger form where the connections are indeed causal.

Now, one important theme in those analyses of the role of narratives in science is the oft-observed complementarity between mathematical models and narratives (e.g., Currie and Sterelny 2017; Hartmann 1999; Miyake 2022; Morgan 2012; Rosales 2017; Wise 2011, 2017; see also Morgan 2024). More specifically, for several different fields, narratives have been observed to operate on the model-world axis in that they often seem to assist mathematical models in achieving their epistemic aims by "linking" (Morgan 2012) or "relating" (Wise 2017) a model and its target system. In the following, I will propose to analyze such a "linking" relation in terms of the activity of deidealizing models. While the epistemic aims that narratives seem to promote in

[8] Knuuttila and Morgan (2019, 650) primarily highlight changes in formal languages.

[9] Morgan (2017) proposes to amend this narratology-based definition. Unfortunately, it goes beyond the scope of this article to discuss the nature and extent of her departure.

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mathematical modeling vary somewhat, often narratives are observed to help models with achieving their explanatory aims. Thus, in the discussion that follows, the focus is on modeling practices that aim at explanation. At this point, such a focus is helpful given that, on a practice view of model deidealization, the kind of purpose to which a model is put determines both the extent to which model deidealization is called for and the kind of processes that might be required. Moreover, a focus on explanation also allows for some continuity with previous analyses which have often linked model deidealization to the issue of explanation in particular (e.g., Hindriks 2012; McMullin 1985; Niiniluoto 2018; Nowak 2000).

4.1. Case study: "The superstar firm model"

To argue that narratives can contribute to deidealizing a mathematical model, in this section, I first discuss a case study to show in concrete terms how a narrative is constructed in the process of modeling and how, in this process, subtle extensions and elisions are introduced. This should provide sufficient concrete resources to then discuss how narratives can deidealize a model—primarily by concretizing and recomposing it.[10]

The case study comes from economics and centers on what is called the "superstar firm model." Although the model has this particular name, it is a modified extension of a widely used international trade model (Autor et al. 2020; see also Melitz and Redding 2014). It explicitly builds on a model that was developed by two economists (Melitz and Ottaviano 2008), which in turn extends one of the standard models of modern international trade (Melitz 2003). The economists of the case study introduce this superstar firm model to explain a macroeconomic pattern of changes in the distribution of an economy's aggregate income, namely that the labor share has fallen in many industrialized economies in recent decades. What this means is that the proportion of the gross domestic product going to labor in the form of wages has fallen vis-à-vis the proportion of national income that goes to capital in the form of profits. This change to the labor share is of interest to economists not only because these shares have long been considered to be relatively stable—the stability of the labor share was one of the "stylized facts" of twentieth century economics—but also because a shifting labor share points to important changes in an economy's income inequality levels. While the economists of the case study assume that the fact that the labor share has fallen is well supported by the available evidence, they recognize that there is considerable disagreement about the causes behind this phenomenon. Technological innovations, international trade, social norms, and labor market institutions have all been suggested to be responsible for the fall of the labor share. So, while the superstar firm model is a typical theoretical mathematical model as commonly used in contemporary economics, its name already indicates the specific use to which this otherwise standard model is put. This specificity of the model, in turn, is needed to exemplify the processes of deidealization.

[10] I focus on these two processes primarily to keep the discussion manageable. They most clearly draw attention to what narratives can *do* in the deidealization process. One could next explore, e.g., the extent to which narratives concretize and recompose the model by reformulating it and the extent to which narratives can contribute to situating a model.

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The superstar firm model consists of a system of equations, some of which are shown here:

$$q\left(p_\omega\right) = p_\omega^{-\sigma} d\left(\mathrm{A} p_\omega\right) \tag{1}$$

$$q\left(p_\omega\right) + \left(p_\omega - c_\omega\right) q'\left(p_\omega\right) = 0 \tag{2}$$

$$\varepsilon\left(p_\omega\right) = Ap_\omega d'(Ap_\omega)/d(Ap_\omega) - \sigma \tag{3}$$

$$m_\omega \equiv \frac{p_\omega}{c_\omega} \tag{4}$$

$$S_\omega \equiv \frac{wV}{p_\omega q_\omega} \tag{5}$$

We can interpret these equations by assigning economic meaning to the mathematical variables and parameters: $q(p_\omega)$, for example, refers to the quantity demanded for an individual good ω, p_ω refers to the price of such a good, σ is a preference parameter, $\varepsilon(p_\omega)$ is the so-called elasticity of demand, m_ω are what economists call firm markups, and c_ω are marginal costs. Thus interpreted, these equations basically tell you about the demand side (equation one), the supply side (equations two and three), the markups (equation 4), and the labor share (equation 5) in the model economy.

In practice, the economists not only interpret the model by assigning meaning in this way. They tell us much more about the model by offering further verbal descriptions that outline other features of the model in economic terms. For example, they tell us that "in the model, entrepreneurs entering an industry are ex ante uncertain of their productivity z_i. They pay a sunk entry cost κ and draw z_i from a known productivity distribution with density function $\lambda(z)$. Firms that draw a larger value of z will employ more inputs and have a higher market share" (Autor et al. 2020, 654). While this verbal description tells us more about the model, importantly, this is not where I want to suggest that we find the narrative.[11] To appreciate the role that the narrative plays in this case study, we need to pay attention to the fact that the economists not only posit the model or describe the modifications they have made to its predecessor(s). They further engage with it.[12]

One thing that the economists of the case study do with the model is that they manipulate it to mathematically derive results. These results are presented in terms of three major "propositions" (Autor et al. 2020, Appendix) establishing relationships between key variables considered in the model. The first result establishes a relationship between two variables, the size of a firm and the size of its labor share,

[11] Commonly, interpreting a model means assigning a unique meaning to the primitive nonlogical symbols (such as variables and parameters) that turns a mathematical structure into a scientific model (see, e.g., Frigg 2023 for different versions of this). In that case, such verbal descriptions are not part of an interpretation. On less orthodox notions of interpretation, one might treat such informal elucidations as "interpreting" a model. Crucially, however, I suggest that the narratives (at least those I focus on in this article) are not primarily tasked with informally describing a model in this way, but they emerge in a further engagement with the model as discussed in this section.

[12] Locating narratives in this further engagement follows Morgan (2012) who sees narratives as emerging in the processes of model manipulation (see also Wise 2011, 2017).

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and the second and third results establish a relationship between two variables conditional on a third. These latter two results thus discriminate between three cases by specifying how the average and aggregate labor share change depending on the form of the productivity distribution in an industry. But the economists do not leave it at deriving these results. They also engage with the model and its results further and in the process, I suggest, construct a narrative. I reconstruct how the narrative is developed in the economists' further engagement with the model as two steps because this allows us to see more clearly how the narrative is constructed and how exactly it differs from the model and the mathematically established results.

In the first step, the economists verbally summarize the results that they have derived in the appendix as:

> Proposition 1 of the model delivers the intuitive result that markups are higher for more productive firms. Thus, the labor share is lower for larger firms. An increase in market toughness that reallocates more output to these firms which [*sic*] will tend to reduce the aggregate labor share. However, a change in market toughness will also change the level of each individual firm's labor share. Greater toughness will tend to . . . *increase* the firm-level labor share. . . . Propositions 2 and 3 show that when the underlying productivity distribution is log convex, the reallocation effect dominates the within firm effect so that the aggregate labor share unambiguously falls even though individual firms' labor shares rise. (Autor et al. 2020, Appendix, 68; emphasis in original)[13]

Most importantly, in this first step, we can see how the economists engage with the mathematically derived results further by embedding them in a broader context. "Proposition 1" now specifies a condition at the beginning of a sequence that is initiated by an external change that induces two opposing effects, and "Propositions 2 and 3" help to establish what effect this external change has on the aggregate labor share as the variable of interest. Notably, by relating their results in this way, the economists generate an ordering that neither maps the structure of the model nor follows necessarily from the mathematical results derived in the model manipulations. Yet, importantly, this first step involves not only such ordering but also selection. For example, the economists have eliminated two of the three possible cases that they developed during their model manipulations. Having derived the results mathematically, it is not yet decided whether an increase in market toughness leads to a decrease, an increase, or a neutral effect on the aggregate labor share. Depending on the form of a productivity function, all three effects are possible. But when the economists summarize their results at the end of the appendix, they select one of these cases. They choose the case in which the labor share falls in response to market toughening.[14]

[13] "Increase in market toughness" in the model simply means that the "marginal cost cutoff" has increased so that when the market toughens, the marginal costs of some firms now lie above this marginal cost cutoff, effectively making these firms unprofitable.

[14] In this article, I do not discuss how these decisions are made. The economists in this case study, e.g., make explicit that this decision is an empirical issue (Autor et al. 2020, 655).

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Next, the economists arrive at the narrative that I want to draw attention to. This narrative tells you what the authors claim to be behind the fall of the labor share. In the main body of the text, the authors write that

> globalization, which increases effective market size, or greater competition . . . will tend to make markets tougher . . . causing low-productivity firms to shrink and exit. The reallocation of market share toward more productive firms will increase the degree of sales concentration and will be a force decreasing the labor share because a larger fraction of output is produced by more productive (superstar) firms. (Autor et al. 2020, 654–55)

Although both quotations put forward a representation of a connected sequence of events, only the connections in the second quotation are put forward as causal claims because only in the second excerpt do the authors use causal language: from describing things that "increase," "decrease," and "change" to describing things that "tend to make tougher," "cause," "shrink," and "exit." But not only do these two quotations differ with respect to causality the components that appear have also changed. For example, the element at the beginning of the sequence of events differs. Whereas the economists speak only of a "change in market toughness" in the first quotation, in the second quotation it is "globalization" that initiates the changes. Notably, "globalization" is not only more ambiguous than "increase in market toughness" as operationalized in the model but also not fully determined. In the article the authors do not commit themselves on whether "globalization" means that the effective market size has increased or whether competition has risen (Autor et al. 2020, 654). Similarly, the meaning of "firm" also has subtly changed: from firms in the model that are defined as existing in a world where there is only one factor of production and where their productivity is determined by a draw from a probability distribution to "superstar firms" such as Google, Facebook, Amazon, and Uber, with which we interact in the real economic world (2020, 650–51).[15]

In sum, this shows how in using the model for this particular epistemic purpose things happen that do not involve replacing the mathematical model with a less idealized one but nonetheless respond to the idealized nature of the model. It is also meant to exemplify how this further engagement can yield a narrative simply because it shows how the economists have constructed a representation of a causally connected sequence of events in the process. Importantly, this representation does not automatically follow from either the model or its mathematically derived results. Instead, in constructing a narrative to explain the fall of the labor share, the economists of the case study have selected elements of the model deemed relevant, changed the meaning of some of these elements, and ordered and related them to yield a representation that is meant to be able to causally account for the phenomenon.

[15] Subtle changes such as these have, e.g., also been observed and discussed by Mäki (1992, 2004). While he, in effect, focuses on how these changes figure in processes of idealization, I focus on how they are part of processes of deidealization.

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4.2. How narratives can deidealize by recomposing

The economists of the case study proceeded in a way that allowed their further engagement with the model to be reconstructed relatively cleanly in terms of these two steps. More generally, I consider the selecting, ordering, and relating that occurs in these two steps as the characteristic achievements of the narrative that I argue constitutes the basis for narrative's role in "recomposing" a model.[16]

Recomposing is the process of model deidealization that targets most directly what is often at the center of discussions of model deidealization, namely the idea of adding (back) causal factors initially omitted. This is because, on Knuuttila and Morgan's framework, recomposing is that process of model deidealization that responds specifically to a model's omissions and exclusions. Yet, in line with many of the critics of the standard view of model deidealization, Knuuttila and Morgan want to emphasize the great difficulties that can arise when a modeler wants to add (back) causal factors. The major point I take Knuuttila and Morgan to be making here is that they want to draw attention to the fact that, oftentimes, reconsidering causal factors that were initially omitted requires a constructive act because often "adding back these other causal factors will alter the existing contents of the model" (2019, 647). This is where their label of "recomposing" seems to originate from: as you want to add back to a model, you will likely have to "recompose" the model in the sense of putting it together in new ways because the addition you want to make will often destabilize the original model. Therefore, rather than just marginally changing a model by adding one element, you will often have to "reconfigure[e] … the parts of the model with respect to the causal structure of the world" (2019, 646). Importantly, given their fourfold framework one might get the impression that scientists never add back in the way that the standard view leads us to expect. Yet, more plausibly, deidealization can also involve "simple" adding. Indeed, Knuuttila and Morgan (2019, 648) seem to recognize this because they note that adding back can be relatively easy. And, of course, there are examples of relatively straightforward cases of adding (back) (e.g., Cassini 2021 for a case in physics, Peruzzi and Cevolani 2022 for a case in economics, Wajzer 2024 for a case in political science). Knuuttila and Morgan just seem to caution that we should not assume that this is always, or necessarily often, the case.

Now, when trying to grapple with a specific phenomenon that is to be explained, scientists can choose to build another less idealized mathematical model. This can involve simple adding back but, on a practice view, we would expect that it often requires recomposing. However, scientists might also decide that the *mathematical* model is "realistic enough." On the standard view of deidealization, this would mean that the processes of model deidealization have come to an end. Yet, on a practice view, the processes of model deidealization need not necessarily end here. Scientists might decide to change "representational modes" and choose a representational mode "that is more convenient for that particular use" of the model (Knuuttila and Morgan 2019, 650). I suggest that narratives constitute one such representational mode to which modelers can resort to deal with the remaining challenges that their

[16] Morgan (2017) has argued that narratives are particularly suited for such tasks. She has suggested that the distinct contribution that narratives can make in science is to provide a form of representation that selects, orders, and relates all at once what she calls their strength to "configure."

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detail-poor mathematical model confronts when used for explaining a specific phenomenon. As we saw in the case study, instead of adding back causal factors to a mathematical model, modelers can use a narrative to select, order, and relate elements of a model deemed relevant so as to reconfigure "parts of the model with respect to the causal structure of the world" (2019, 646). Thus, to the extent that narratives select relevant elements of a model and put them together into a new representational form that is meant to be able to causally account for the phenomenon, I suggest that narratives can recompose a mathematical model.

4.3. How narratives can deidealize by concretizing

However, a narrative can not only deidealize a mathematical model by recomposing it. A narrative can also deidealize by concretizing a model. In fact, when it comes to how narratives can deidealize mathematical models, keeping the processes of recomposing and concretizing apart is difficult. This is primarily because to the extent that we understand a narrative as a representation of a causally connected sequence of events, narratives are implicated simultaneously in processes of recomposing and concretizing. The last section has focused on the structural changes of the form of the representation: from a mathematical model as an interpreted set of equations that yields results to a narrative as a representation of a causally connected sequence of events. Yet, in recomposing the mathematical model in this way further changes are effected that are the basis for narratives concretizing a model.

Knuuttila and Morgan characterize concretizing as that process of model deidealization that responds to the fact that mathematical models contain what they call "conceptual abstractions" (2019, 651). This highlights that models are not only idealized because they are incomplete but also because they contain theoretical concepts that are abstract. Therefore, they suggest, when you want to deidealize a model, you might have to concretize such conceptual abstractions. Knuuttila and Morgan do not elaborate in detail. One way of further developing this notion of concretizing builds on Cartwright (1999, 2012) who presents an understanding of the relation between the abstract and concrete where the relation is not simply one of more or less detail, but in which "abstract features are … multiply realizable at the concrete level" (2012, 982). One of her examples effectively illustrates this relation: While claiming that educating mothers can improve the nutritional status of children is true for India but false for Bangladesh—because in Bangladesh the mother does not make these household decisions—the more abstract claim that educating the person that makes household decisions improves the nutritional status of children is true for both countries. Because the person who makes household decisions is mothers in India but fathers and mothers-in-law in Bangladesh, choosing the right level of abstraction enables the abstract claim to apply to both countries when the concrete claims would not. But conversely, it also shows that you can concretize any abstract claim in various ways. In the preceding example, the abstract claim about educating the person that makes household decisions is concretized into educating the mother in one situation and educating the father and/or mother-in-law in the other.[17] Now, it

[17] Chang (2011) seems to exploit a similar understanding of the abstract–concrete relation. Both Cartwright and Chang, of course, thereby complicate the notion of abstraction as simple omission. It goes beyond the scope of this article to systematically discuss these different notions. But see, e.g., Mäki (1992)

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is such a relation that Knuuttila and Morgan seem to highlight when they draw attention to the processes of concretizing because just like Cartwright emphasizes how the person that makes household decisions can be concretized into mothers or fathers and mothers-in-law depending on the context, Knuuttila and Morgan emphasize how an abstract concept that is part of a mathematical model can be concretized in several different ways. For example, they note how an abstract concept like "the economy" could be concretized into "a dynamic path with cyclical oscillation" in business-cycle research, but how it could also be concretized into "a system that relates all the inputs to all the outputs of each productive sector" in input-output analyses (2019, 651).

I suggest that narratives can concretize a mathematical model just in the way highlighted by Knuuttila and Morgan. Mathematical models are versatile tools with a generic character relying on abstract concepts. In the case study, for example, one such abstract concept is "market toughness," which is represented in the model through c^*. This abstract concept can be concretized differently depending on the context in which the model is used. In fact, in the case study, the economists consider several different concretizations. One way to concretize this abstract concept is to conceive of an increase in market toughness as "globalization." However, the market could have also toughened because of growing platform competition or cost-saving technological innovations (Autor et al. 2020, 656). Thus, by using a narrative to replace the abstract concepts of a mathematical model with more concrete ones, narratives can concretize mathematical models. This is, however, not the only way in which narratives can concretize mathematical models. They can also concretize a model *in the way* that they transform mathematical equations capturing abstract conceptual relations into claims about causality. In discussing how narratives can recompose a model in the previous section, I have focused on the structural changes in which a set of mathematical equations is transformed into a representation of a causally connected sequence of events. But it is important to note that to the extent that narratives are used for such a transformation, they often use causal language that Cartwright (2007) has characterized as "thick causal concepts."[18] According to Cartwright, thick causal concepts are "content-rich causal verbs" (2007, 19) such as "compress," "attract," "discourage"—and, as in the case study, "tend to make tougher," "shrink," and "exit"—that are more concrete than the more abstract expression of "cause" (see also Godfrey-Smith 2010). Rather than considering this as "mere" renaming of features of a model, I suggest that we treat these as processes of concretizing in which the level of abstraction is changed with important evidential consequences. This is because, as Cartwright argues in her discussion of thick causal concepts, by being more concrete, thick causal concepts provide additional content:

for the distinction between what he calls horizontal and vertical (de)isolation that could be especially helpful for separating out the different underlying senses of abstraction—and concretization—in the future.

[18] Cartwright takes her cue from Anscombe (1971). Anscombe claims that specific causal concepts are semantically prior to a general causal concept. One does not need to believe in semantic priority to allow for the abstract–concrete relation between the generic "cause" and "thick causal concepts" that Cartwright describes. Thick concepts are, of course, better known in discussions in ethics, where they refer to terms that have both descriptive and evaluative components (for an overview see Väyrynen 2021).

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"If we overlook this, we will lose a vast amount of information" (2007, 20). This seems to apply not only to the content-rich causal verbs Cartwright has in mind but similarly to the concretized versions of abstract concepts more generally. Thus, by replacing the abstract concepts and relations of the model with more concrete ones in the narrative, scientists can make informationally richer claims. This ultimately matters evidentially because by concretizing a model in this way scientists tighten the empirical constraints. For example, in the case study, while the abstract claim that market toughness has increased is true for many different situations, its concretizations are only true for some situations and false for others. For example, the more concrete concept of globalization is only true to the extent that it really was globalization that has toughened the market. If indeed it was increased platform competition that has increased the toughness of the market, then having concretized an increase in market toughness into globalization would be false.

In sum, examining how narratives are built up as a mathematical model is used for explanation tracks a considerable transformation: from a mathematical model, that is, a representation consisting of an interpreted system of equations from which mathematical results can be derived to a representation of a causally connected sequence of events, a narrative. I have suggested that through this transformation narratives can deidealize mathematical models because they can be used to recompose and concretize them: They recompose them in that they reconfigure selected elements of the model in a way that yields a representation of a causally connected sequence of events that is claimed to be responsible for the phenomenon; and they can concretize them because they are used to replace abstract concepts and relations with more concrete ones.

5. Narratives as a strategy on the deidealization "menu"

Knuuttila and Morgan (2019, 646) present their framework as proposing a "menu" of deidealizing processes emphasizing that we should expect scientists to combine them in various ways depending on their goals. Thus, on a practice view, we should expect that the processes of deidealization can look differently depending on the purpose to which a model is put. In this article, I have suggested to consider narratives as one important strategy of model deidealization when such models are used for explanation. In those cases, it is narratives that, as additional representational forms, help with achieving the goal of explaining with the model by recomposing and concretizing it.

By proposing to add narratives to the menu, I have thus focused on one particular implication of Knuuttila and Morgan's proposal that widens the attention from processes of deidealization in which one theoretical mathematical model is replaced by another one to processes of deidealization that involve a change of representational mode. Importantly, however, by recognizing the role that narratives can play in deidealization we do not need to deny the importance of those processes of model deidealization in which mathematical models are replaced by other less idealized mathematical models. Rather, on a practice view, we should expect that these processes are prevalent and warrant close attention, too. Thus, examining how mathematical models can be deidealized by narratives should be thought of as an extension rather than as a replacement of such processes. Nor does recognizing the

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role that narratives can play in deidealizing models mean that narratives are always called for or that all narratives deidealize.

At the same time, there are reasons to believe that finding narratives as an important means of deidealizing mathematical models when the goal is explanation might be a more widespread phenomenon. On the one hand, there are those analyses that have discussed narratives as a close companion of mathematical models that mediate between model and target when models are used for explanation in several different sciences (e.g., Morgan 2012; Morgan and Wise 2017; Wise 2011).[19] On the other hand, one might also think that it is not only economists who build up such narratives when using models for explanation if we believe that often explaining means describing causal mechanisms (e.g., Bechtel and Abrahamsen 2005; Glennan 2002; Machamer et al. 2000). While Kaiser and Plenge (2014) sketch some of the affinities between mechanistic accounts of explanation and narrative representation, Glennan (2010, 2014) has explicitly put forward an account of mechanistic explanation that assigns narratives an important representational role. He even claims that a "mechanistic explanation characteriz[ing] entities and activities, describing how their organization in space and time gives rise to some phenomenon ... is in essence a narrative" (2014, 279). More work is required to spell out when and how narrative representation is involved in mechanistic explanation, especially in mechanistic explanations using mathematical models.[20] At the least, this would require close attention to the ways in which mechanisms are often viewed as both systems/structures and as processes (Glennan 2002, 2014) and to the complexity of mechanisms—because mechanisms not only have parts that are organized but all mechanisms have "an active element that is seen through the inter-relationship of the parts" (Crasnow 2017, 8). But at this point those affinities already observed indicate why we might expect narratives to be an especially important strategy of model deidealization when models are put to explanatory uses.

6. Conclusion

In this article, I have considered processes of model deidealization as a constructive phase in the larger modeling process that poses distinct challenges not sufficiently recognized if deidealization is primarily understood as a simple reversal process that makes a model more realistic. I have argued that we should consider narratives as one important deidealizing strategy when scientists use mathematical models for explanatory purposes. In those cases, they function as an additional representational form that can recompose and concretize a mathematical model. They thus not only draw attention to the complexity and diversity of model deidealization processes but also to the fact that processes of deidealization might not be exhausted by processes in which one mathematical model is replaced by another one.

[19] But see also, e.g., Beatty (2017) and Morgan (2017) for a discussion of the explanatory potential of narratives more generally that is discontinuous with older discussions in philosophy of history.

[20] Glennan (2014) does not explicitly discuss how his proposal goes along with the widespread view that mathematical models describe mechanisms. Furthermore, many mechanistic accounts of explanation seem to bring us back to where we started, namely the standard view of model deidealization, because they seem to presuppose that the more complete and accurate a model, the better it explains (e.g., Craver 2006; see Levy and Bechtel 2013 for a critical discussion).

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