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Published in:
Journal of Economic Methodology

DOI:
[10.1080/13501780601048733](https://doi.org/10.1080/13501780601048733)

IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.

Document Version
Publisher's PDF, also known as Version of record

Publication date:
2006

[Link to publication in University of Groningen/UMCG research database](#)

Citation for published version (APA):

Hindriks, F. A. (2006). Tractability Assumptions and the Musgrave-Mäki Typology. *Journal of Economic Methodology*, 13, 401-423. <https://doi.org/10.1080/13501780601048733>

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To cite this article: Frank A. Hindriks (2006) Tractability assumptions and the Musgrave–Mäki typology, Journal of Economic Methodology, 13:4, 401–423, DOI: [10.1080/13501780601048733](https://doi.org/10.1080/13501780601048733)

To link to this article: <https://doi.org/10.1080/13501780601048733>

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Tractability assumptions and the Musgrave–Mäki typology

Frank A. Hindriks

Abstract Musgrave (1981) proposed a typology of assumptions, developed further by Mäki (2000), to defend the idea that the truth of assumptions is often important when evaluating economic theories against those economists who consider only predictive success to be relevant for this purpose. In this paper I propose a new framework for this typology that sheds further light on the issue. The framework consists of a distinction between first-order assumptions that state the absence or lack of effect of some factor *F*, and second-order assumptions that explicate the purposes for which or the reasons why particular first-order assumptions are imposed. Given this distinction, Musgrave's main contention can be reformulated as the claim that, even though the falsity of first-order assumptions is often unproblematic, it is important that the second-order assumptions be true. I go on to introduce the notion of a tractability assumption, which is a second-order assumption according to which a first-order assumption is imposed in order to make a particular problem tractable. It is argued that a realist will want to relax a first-order assumption imposed for reasons of tractability as such assumptions are not even approximately true. These amendments to the Musgrave–Mäki typology are suggested in order to improve our understanding of what moves scientists when they choose particular first-order assumptions, many of which are false, and in order to argue that the practice of doing so can be supported from a realist perspective of science.

Keywords: applicability assumption, negligibility assumption, tractability assumption, heuristic assumption, early-step assumption, Musgrave–Mäki typology, F-twist, truth, instrumentalism, realism

1 INTRODUCTION

Economic theories are often criticized for being unrealistic. A common version of this objection is simply that some of their assumptions are false. Friedman (1953) has famously claimed that a theory should not be criticized for containing unrealistic assumptions. In his view, only faulty predictions provide a legitimate basis for criticizing a theory. For this reason, Friedman has often been regarded as an instrumentalist (see Lagueux 1994 and references therein). Musgrave (1981) presented a powerful critique of this methodological view. His main contention was that we should carefully

consider the roles assumptions are meant to play. Once we appreciate the different roles of assumptions, we shall find more truth in economic theories than when we fail to consider that dimension. When an economist assumes that the government's budget is balanced, to use Musgrave's main economic example, she might mean that the effect that an imbalance has on the phenomenon under investigation is negligible. Or she might mean that the theory of which this assumption forms part only applies when the government's budget is balanced. And, since they reveal the deeper considerations that move economists, the truth of these claims matters.

On the basis of these considerations, Musgrave (1981) proposed a typology of assumptions. One of the kinds of assumptions he distinguished is that of a negligibility assumption. Musgrave's name for the second kind was 'domain assumption'. Mäki (2000) convincingly argued that the label 'applicability assumption' is more suitable, as the assumptions involved concern the applicability of a theory (to particular domains). Because I accept most of the amendments Mäki proposed and add some of my own, I call the typology to be presented 'the amended Musgrave-Mäki typology'. One problem with the typology as proposed by Musgrave is that the identity of the assumptions he has in mind is often unclear. As Mäki points out, when discussing negligibility assumptions Musgrave is concerned with paraphrases of the assumptions economists formulate, such as 'the existence of a government has negligible effects on the phenomenon under investigation'. Such paraphrases bring out the role the assumptions play. When discussing the second kind of assumptions, however, he is primarily concerned with the statement that the government's budget is balanced, which is a statement about a domain in economic reality rather than a claim about the role of such statements. Even though Mäki's amendments and improvements of the typology go a long way to resolving this problem, I do not think they go far enough. Because of this, I present a new framework for the typology (Section 3.1).

At the heart of this framework lies a distinction between first-order assumptions, such as 'the government's budget is balanced', and second-order assumptions, such as 'the theory only applies to domains in which the government's budget is (approximately) balanced'. A second-order assumption explicates the purpose for which or the reason why an assumption is imposed, which might concern, *inter alia*, negligibility or applicability. Such assumptions elucidate the roles that particular first-order assumptions play. First-order assumptions are directly relevant to the models that are constructed on the basis of the relevant theories. A consequence of the first-order assumption mentioned might be, for instance, that the model contains no variable related to the government's budget at all. This framework allows Musgrave's main point to be reformulated as the claim that, even though the falsity of first-order assumptions is often unproblematic, the truth of second-order assumptions is important.

In addition to a new framework, I introduce the notion of a tractability assumption (Section 4). I have defended the usefulness of the notion of a tractability assumption in particular and that of the framework more generally in Hindriks (2005), where I apply the typology to a series of theories concerning the measurement of productivity growth and the mark-up of price over marginal cost. Here I am concerned with providing a defense from a more theoretical perspective. I explain in more detail what tractability is and I elucidate the distinction between theoretical and empirical tractability. Tractability assumptions form the third kind of assumptions of the amended typology. Currently, as conceived by Musgrave, it consists of heuristic assumptions instead, while Mäki proposed replacing the notion of a heuristic assumption with that of an early-step assumption. In Section 5 I argue that the notion of a tractability assumption is to be preferred to that of a heuristic assumption as well as that of an early-step assumption. As I argue in Sections 3.2 and 4, the proximate aim that is facilitated both by the new framework for the typology and by the notion of a tractability assumption is to improve our understanding of why economic theories frequently include assumptions that are (considered to be) false. The ultimate aim, which is discussed in Section 6, is to argue that the practice of doing so can be supported from a realist perspective on science.

2 NEGLIGIBILITY ASSUMPTIONS AND APPLICABILITY ASSUMPTIONS

Musgrave uses an example from physics to introduce the notion of a negligibility assumption. In his investigations of the motion of falling bodies, Galileo relied on the assumption that there is no air resistance. This assumption is almost always false. However, Musgrave argues that it would be silly to object to Galileo's use of the assumption for this reason. According to him, Galileo does not deny that the objects in his experiments fall through air and thus meet with air resistance, but he is 'rather asserting that the effect of air-resistance is negligible' (Musgrave 1981: 379). Similarly, it would often be silly to object to an economic theory because it contains an assumption that is false. Musgrave argues that an economist who uses the assumption that there is no government might in fact mean that 'the existence of the government has negligible effects on the phenomena he is investigating' (*ibid.*). Musgrave proposes calling assumptions such as these 'negligibility assumptions'. Mäki provides an explicit definition of the notion of a negligibility assumption: 'A negligibility assumption is the hypothesis that some factor F that might be expected to affect the phenomenon under investigation actually has an effect upon it small enough to be neglected relative to a given purpose' (2000: 322; emphasis removed).

Mäki argues that whether or not an effect is small enough to be neglected depends on the purpose espoused by the scientists involved. Neither Mäki

nor Musgrave mentions the purposes involved in their economic examples, while Mäki says little else about the purposes that might be involved than that they 'can be discussed in cost-benefit terms' (*ibid.*: 321). Considering a particular assumption in the context of a concrete theory will help to say more about these issues. Robert Hall (1986) proposed a model for measuring the mark-up of price over marginal cost in which it is assumed that productivity growth is constant over time. Virtually all economists will regard this assumption as false. So does Hall himself, in fact. He imposes the assumption because it enables him to measure the mark-up and because he regards the effect of the actual variation in productivity growth as negligible. Let me elaborate.

Aggregate demand obviously changes over time. If productivity growth is indeed constant, it should not be correlated with aggregate demand. Hall states that his work 'proceeds on the assumption that the correlation is small enough to be ignored' (Hall 1986: 291). This does not mean, however, that productivity growth is constant and hence that there is no correlation at all. It becomes clear later that Hall believes there is some correlation, but that it is not very important in explaining fluctuations in aggregate demand (*ibid.*: 322). All this suggests that Hall regards the variability of productivity growth as negligible for the purpose of his investigation. In order to substantiate this, we need to know what this purpose was.

Hall measures the mark-up in order to determine whether or not industries in the US are competitive. The mark-up ratio equals 1 when the firms operate in a perfectly competitive market. On the basis of his estimates, Hall concludes that most of the industries 'show signs of market power, and in a significant part of the economy, market power is substantial' (*ibid.*: 297). His main concern is not the accuracy of the mark-up estimates per se. In the context of his theory it would not be very credible to say that the variability of productivity growth is negligible for this purpose. Instead, Hall's argument is that it is negligible for estimates of the mark-up that are reliable enough to assess whether or not industries deviate (substantially) from full competition. What we see is that, by placing the example of Hall's assumption of constant productivity growth in context, it is possible to determine his purpose, which allows us to conclude that the assumption is indeed a negligibility assumption.

Having introduced the notion of a negligibility assumption, Musgrave goes on to argue that one and the same assumption can play different roles. It might be, for instance, that the existence of a government often does have a significant effect on the phenomenon under investigation. Once this is discovered, economists may still want to hold on to the assumption that there is no government, but assign a different role to it. Changing the example from 'there is no government' to 'the government does not have a budget imbalance', Musgrave writes:

An economist who says ‘assume the government has a balanced budget’ may mean that any actual budget imbalance can be ignored because its effects on the phenomena he is investigating are negligible. But he may *also* mean precisely the opposite: that budget imbalance would have significant effects, so that his theory will only *apply* where such an imbalance does not exist. (Musgrave 1981: 381; emphases in original)

What is at issue here is an assumption that is often false, but not always. Musgrave adds that, for the sake of testability, ‘we must hope that [such assumptions] are true of as many actual situations as possible’ (*ibid.*: 382). But when false, the imbalance of the government’s budget has significant or at least non-negligible effects. Because of this, the theory can only be applied if the assumption is true.

The role played by this kind of assumption concerns the applicability of a particular theory. Because of this, Mäki (2000) has suggested using the term ‘applicability assumption’ rather than Musgrave’s term ‘domain assumption’. An applicability assumption is a statement that a theory *T* applies only if some factor *F* is absent or has negligible effects on the phenomenon under investigation (*ibid.*: 323–4). Both negligibility and applicability assumptions concern the role played by a claim that some factor *F* is absent or has negligible effects. One problem with considering that the two kinds of assumptions are similar in this respect is, as Mäki points out, that some of Musgrave’s claims, including his statement that the relevant assumption is often false, but not always, do not hold for applicability assumptions thus defined. Consider, for instance, the claim that a particular theory applies only if the government’s budget is balanced. This claim is either true or false. The assumption with a variable truth-value is the assumption that the government has a balanced budget. This assumption is true of the domains to which the theory applies, and false for other domains. Presumably this is why Musgrave called the second kind of assumption ‘domain assumptions’.

What we need to appreciate in order to resolve this problem is that there are two assumptions in play: the assumption that the government’s budget is balanced, and the assumption that the theory to which the claim that the government’s budget is balanced belongs applies only if that claim is true. The latter assumption explicates the role played by the former. As that role concerns the applicability of the theory, it is called ‘an applicability assumption’. Applicability assumptions belong to the typology as amended by Mäki.

Mäki does not claim that Musgrave’s term ‘domain assumption’ is completely useless. Rather he claims that the term is suitable for describing the assumption that the government’s budget is balanced. On his view, domain assumptions are statements concerning some factor *F*, including statements according to which factor *F* is absent. Even though Mäki believes that some assumptions are domain assumptions, he does not seem to grant

domain assumptions a status in the typology. In the next section I argue that, even though Mäki is right in including applicability assumptions in the typology and in claiming that the considerations of negligibility and applicability are in some sense on a par, assumptions such as ‘the government has a balanced budget’ should be accorded a place in the typology, too. To this end, I present a new framework for the typology.

Before doing this, let me illustrate how Hall’s assumption of constant productivity growth might play a role in relation to an applicability assumption. Consider the members of the ‘real business cycle’ school. They believe that variations in productivity growth are significant in explaining the development of aggregate demand. It would make sense for such a person to turn to applicability rather than negligibility in order to justify using Hall’s method of measuring the mark-up. The idea would be that the method only applies to domains in which the assumption that productivity growth is constant (or in which deviations from constancy are negligible) is true. Whether or not this idea could be applied in practice is another matter, as it will be difficult to obtain independent information about productivity growth in a particular domain. As used here, the example illustrates the idea that one and the same assumption – in this case the claim that productivity growth is constant – can in principle play a role in relation both to a negligibility assumption and to an applicability one. This idea is central to the Musgrave–Mäki typology. It reveals forcefully that assumptions do not wear their roles on their sleeve.

3 A NEW FRAMEWORK

3.1 First-order and second-order assumptions

I fully agree with Musgrave and Mäki that it is very important to appreciate the role played by certain claims that economists make, and that for this reason the notion of a negligibility assumption and that of an applicability assumption are indispensable. Even though this appreciation is very important, we should not lose sight of the significance of the original formulations of assumptions, e.g. ‘the government has a balanced budget’ and ‘productivity growth is constant’. The main reason why these statements are important is that these are the assumptions that have a direct impact on the models that are developed on the basis of the relevant theories. As we shall see, especially in Section 6, a justification is needed for imposing such assumptions if they are (often) false, given the aim of saving realism for economics.

The claims that I want to defend here are that these assumptions pertain to a different level and that they can and should be integrated in the typology. For reasons to be explained shortly, I call such assumptions ‘first-order assumptions’. A first-order assumption is *a statement according to*

which some factor F is absent or has no effect on the phenomenon under investigation. In other words, first-order assumptions (can be made to) fit the following schema, [F]:

[F] Factor F is absent or has no effect on the phenomenon under investigation.

Clearly, the two assumptions mentioned can be reformulated so as to fit this schema. We might, for instance, phrase them as ‘there is no government budget imbalance’, while the assumption used by Hall (1986) can be reformulated as ‘there is no variability in productivity growth over time’.

To be sure, such reformulations can appear somewhat unnatural. Consider, for instance, the assumption of perfect competition on which Solow (1957) relies in his method for measuring productivity growth (see Hindriks 2005 for a discussion). This would have to be reformulated, somewhat artificially, as ‘imperfect competition is absent or has no effect on the phenomenon under investigation’. The main point, then, is not to find reformulations that fit this schema, but instead to appreciate that a large number of assumptions can legitimately be regarded as first-order assumptions. Such assumptions concern the phenomena under investigation and involve idealizations about them. Those idealizations have direct consequences for model construction. Hall (1986: 289–90), for instance, models productivity growth as a constant (with random deviations). Alternatively, a consequence of a first-order assumption could be that a factor F , such as productivity growth or the government’s budget, does not occur in the model at all.

Assumptions such as negligibility and applicability assumptions are second-order assumptions. They explicate the purposes for which or the reasons why first-order assumptions are imposed, and, as such, they concern a different, higher level. This fits with the fact that, as we have seen several times now, Musgrave is concerned with what economists *mean* when they make a particular assumption. Negligibility assumptions have the following form, [N]:

[N] The factor F mentioned in first-order assumption A has a negligible effect on the phenomenon under investigation relative to the purpose for which the theory is used.

First-order assumption A is, of course, an assumption that (can be made to) fit(s) schema [F], and is part of the theory referred to. The claim that an assumption is imposed for reasons related to negligibility can now be more adequately formulated as the claim that A is imposed because factor F only exerts a negligible influence on the phenomenon under investigation. The schema that I propose for applicability assumptions is [A]:

[A] Theory T only applies to domains of which first-order assumption A is (approximately) true.

The claim that an assumption is imposed due to applicability considerations can now be reformulated as the claim that A is imposed because it is (approximately) true of the domains under investigation and the theory of which it is part only applies to domains of which A is (approximately) true. Note that, because of the reference to *approximate* truth in the second-order assumption, the term ‘negligibility’ does not need to occur in the first-order assumption relevant to applicability assumptions – which it does in Mäki’s proposal.

Negligibility and applicability assumptions are second-order assumptions, which are meta-statements that concern other assumptions. As these other assumptions are not meta-statements, they have been called ‘first-order assumptions’. First-order assumptions such as ‘productivity growth is constant over time’ do not pertain to the actual world. Instead, they concern the model world. To support the claim that a first-order assumption has indeed been imposed due to negligibility or applicability, certain presuppositions about the real world have to be satisfied. The whole idea on which the typology under discussion is based is that we need a framework for understanding why economists impose assumptions that are often regarded as false when they are interpreted as pertaining to the real world. In the case of negligibility assumptions, the presupposition concerning the real world is [N_p]: Factor F has some effect on the phenomenon under investigation. In the case of applicability assumptions, the presupposition is [A_p]: In several but not all domains, factor F has a non-negligible effect on the phenomenon under investigation. These presuppositions concern the actual world rather than the model world. If both were to concern the real world, first-order assumptions and presuppositions would be in conflict with one another. Note that, as it explicates the reason why or the purpose for which a first-order assumption is imposed, a second-order assumption reveals why the first-order assumption diverges from the presupposition made concerning the actual world.

Given that, in my conception of them, the second-order assumptions of the Musgrave–Mäki typology of assumptions concern the reasons the economists involved actually had for imposing them or the purposes for which they were actually imposed, what is relevant for classifying an assumption as, for instance, a negligibility or an applicability assumption is what these economists believed to be the case, rather than what actually is the case. Now, the reader may want to object to my proposal for interpreting the second-order assumptions of the typology as statements concerning reasons or purposes, arguing that we cannot know why economists imposed particular first-order assumptions. I would state two things in response. First, this objection only points to a practical obstacle to

classifying assumptions and fails to establish that the underlying ideas cannot be useful for understanding the role truth might play in economic theorizing – which is the topic of the next section. Second, in practice it is often possible to determine what reasons motivated economists or what purposes they had in mind. Economists often comment on why they make certain assumptions, as we saw above in Hall's case (see Hindriks 2005 for more examples). In addition, contextual information is often available that allows us to make an informed choice when classifying an assumption in one way or another. The fact that Hall does not belong to the 'real business cycle' school, for instance, provides indirect support for the interpretation of his constant productivity growth assumption discussed in the previous section.

3.2 Should negligibility and applicability assumptions be true?

As stated in the introduction, Musgrave used his typology as a means for criticizing Friedman's claim that the only legitimate bases for criticizing a theory are faulty predictions, and his concomitant claim that a theory should not be criticized for containing false assumptions. Friedman made these claims in his famous 1953 essay 'The methodology of positive economics'. In that essay he also claimed that 'the more significant the theory, the more unrealistic the assumptions' (Friedman 1953: 14).¹ Paul Samuelson (1963) coined the term 'F-twist' for these claims, which Mäki (2000: 317) summarily characterizes as 'the thesis that the truth of assumptions is irrelevant to the acceptability of a theory, provided its predictions succeed'. Musgrave's (1981) main contention is that the F-twist is based on a failure to distinguish between different roles assumptions can play in a theory. The new framework for the typology presented in the previous section provides a useful vantage point for discussing Musgrave's critique.

Let us consider in some more detail what Musgrave says about Galileo's assumption of a vacuum, the example we touched on at the beginning of Section 2. We saw that Musgrave thought it silly to object to that assumption on the basis of its falsity. Now, note that the vacuum assumption is a first-order assumption. It states that there is no air resistance, it concerns the model world, and it fits [F]. In effect, then, Musgrave claims that it is silly to object to the falsity of this particular first-order assumption. He goes on to argue that 'Galileo's assumption that air resistance was negligible for the phenomena he investigated was a true statement about reality' (Musgrave 1981: 380). Here Musgrave claims that Galileo made another assumption according to which the effect of air resistance – the factor that is mentioned in the first-order assumption – is negligible. This assumption is what I have called 'a second-order assumption'. Musgrave comments that this second-order assumption is

true (even though, as Mäki notes, it is a statement about the world *and its relation to the purposes of scientists*).

Musgrave agrees with Friedman that the falsity of assumptions is often unproblematic. He resists, however, the thought that the truth of assumptions is never important. According to Mäki, Musgrave's point is that, paraphrased in terms of considerations such as negligibility, '*assumptions had better be true*' (Mäki 2000: 319, emphasis in original). Using the distinction between first-order and second-order assumptions, Musgrave's main contention can now be reformulated as the claim that, *even though the falsity of first-order assumptions is often unproblematic, it is important that the second-order assumptions be true*. The question that remains is why their truth is important. The answer Musgrave would give to this question can be uncovered by investigating his analysis of Galileo's vacuum assumption in more detail.

According to Musgrave, it is silly to object to Galileo's vacuum assumption because Galileo did not consider it to be true. In contrast, however, it might make sense to criticize the claim that the effects of air-resistance are negligible for Galileo's purposes because he was actually committed to the claim that they are negligible. Musgrave's key claim about the vacuum assumption, then, is this: '[P]roperly understood, Galileo is not denying [the effect of air resistance], but rather asserting that the effect of air-resistance is negligible' (Musgrave 1981: 379). In effect, Musgrave claims that Friedman and his allies focus on the wrong set of assumptions. He agrees with Friedman that a theory can be significant even though it contains false assumptions. The mistake that Friedman makes, according to Musgrave, is that he takes this to imply that we should not be concerned with the truth of assumptions at all. Musgrave argues that, instead, it means that we should be concerned with the truth of the second-order assumptions. His reason for claiming this is that scientists are often only committed to the truth of second-order assumptions, as we just saw in the case of Galileo. They frequently impose first-order assumptions, not because they take them to be true, but rather only for pragmatic reasons, including negligibility, applicability and tractability.

Musgrave believes that by drawing our attention to the roles first-order assumptions play in scientific theories in the way he does, he has untwisted the F-twist (the subtitle of his paper is: 'The F-twist untwisted'). The idea is that, in contrast to what Friedman maintains, the truth of assumptions is important to the acceptability of a theory, at least as far as second-order assumptions are concerned. This seems plausible in the case of negligibility and applicability assumptions. The truth of a negligibility assumption is important, because, if it is false, the effects of the factor *F* to which it pertains are non-negligible for the purposes of the investigation (recall presupposition $[N_P]$). In other words, a false negligibility assumption is likely to undermine the purposes the scientist envisages for his theory.

Whatever the exact meaning of ‘the acceptability of a theory’ may be – an issue that is discussed in Section 6 – it will be uncontroversial that a theory that is unable to serve the purposes for which it is to be used is unacceptable. A similar line of reasoning is available for applicability assumptions. If an applicability assumption is false, theory *T* does not apply at all (cf. [A_P]). Moreover, surely, a precondition of the acceptability of a theory is that there are domains to which it applies (for instance, because it provides an adequate basis for reliable predictions).

Whether or not similar considerations apply to the third kind of assumptions of the typology can only be discussed after I have introduced the notion of a tractability assumption as well as its rivals, the notion of a heuristic assumption and that of an early-step assumption. I postpone the discussion of this issue to Section 6. What I would like to emphasize here is that whether or not a second-order assumption is true is irrelevant to the question whether identifying it as such is useful for *understanding* the reasons economists have for imposing first-order assumptions, many of which are false. The only thing that matters for that purpose is whether or not they thought the second-order assumptions were true. The most basic use of the typology as developed here is for improving our understanding of why economists impose the assumptions they do. If the relevant consideration is negligibility, first-order assumption *A* is imposed because factor *F* only exerts a negligible influence on the phenomenon under investigation. And if applicability is the issue, first-order assumption *A* is imposed because it is (approximately) true of the domain under investigation and the theory of which it is part only applies to domains of which *A* is (approximately) true. In Section 6 we shall see that the typology can also be used for purposes of justification.

4 TRACTABILITY ASSUMPTIONS

In the previous section I presented a new framework for the typology and discussed the insights we can gain from it. In this section I introduce the notion of a tractability assumption. My proposal is to regard tractability assumptions as the third kind of assumptions of the typology. In the next section I argue that the typology is best served by replacing Musgrave’s notion of a heuristic assumption and Mäki’s notion of an early-step assumption with that of a tractability assumption. This section, in contrast, is merely concerned with explicating what tractability assumptions might be. The notion of a tractability assumption can usefully be illustrated by another example Musgrave uses. For the purpose of determining the movements of the planets in the solar system, 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. The question we need to ask is why Newton made

this single-planet assumption. Musgrave argues that the reason was not that he regarded the effects of other planets as negligible. Furthermore, Newton did not maintain that his theory only applied to solar systems that contain only one planet. Thus, Musgrave rules out the idea that considerations of negligibility or applicability moved Newton in making this assumption.

Newton never relaxed the single-planet assumption. It appears he felt uncomfortable making the assumption (cf. Musgrave 1981: note 10). He knew it was false and he appears to have believed that the presence of multiple planets in our solar system had non-negligible effects on planetary movements. It seems plausible that the only reason he made the assumption was that he could not do otherwise. Calculations of the movements of planets that take interplanetary gravitational effects into account were made only some time after he had died, and the reason for this is simple: the mathematics needed to take account of the gravitational effects of other planets was only developed some time after Newton's death. So Newton was not even in a position to do without the single-planet assumption. This means, I suggest, that the problem of determining the movements of a planet in relation to the sun was intractable for Newton without the single-planet assumption.

A tractability assumption, as I define the notion, is a statement about the tractability of a problem. The idea is that a problem would be intractable if it were not for a particular first-order assumption. On the supposition that tractability can be a matter of degree, this formulation can be generalized into [T]:

[T] First-order assumption *A* makes the problem under investigation (more) tractable.

A tractability assumption concerns a first-order assumption or model assumption in which a factor *F* figures, the effects of which are in fact non-negligible. In other words, the presupposition of tractability assumptions concerning the actual world is [T_P]: The factor *F* mentioned in first-order assumption *A* has a non-negligible effect on the phenomenon under investigation. Because of this, one would prefer to avoid relying on it, if it were not for the fact that it makes the problem under investigation (more) tractable. The fact that (one believes that) one cannot avoid imposing a particular first-order assumption is often an indication that tractability was the reason for imposing it. The statement that a particular first-order assumption makes a certain problem (more) tractable is a tractability assumption, which is a second-order assumption that, just as negligibility and applicability assumptions, explicates the reason why or the purpose for which the first-order assumption was made. Recall that in order for a second-order assumption to explicate such a reason, it need not be true. What needs to be true instead is the claim that first-order assumption

A is imposed because it makes the problem under investigation (more) tractable.

Of course, more needs to be said about tractability in order to give substance to the proposal made here. The term ‘tractability’ has a well-defined meaning in computer science. In that context, tractability is a property of functions. A function f is tractable or computable exactly if a Turing machine can provide an output for each input within a certain number of steps. The maximum allowable number of steps is some polynomial function of the number of bits of the input. In less formal terms, tractability concerns the time a Turing machine needs for solving a function. If the time needed cannot be described by a polynomial function of the length of the input, it tends to go to infinity. If this is the case, the function is intractable. On this definition of tractability, imposing a tractability assumption is a matter of simplifying a function in such a way that it becomes tractable or more tractable than it would be without that simplification.

In the context of empirical sciences such as the natural sciences and economics, the term ‘tractability’ is often used in a wider sense than this. As said earlier, I take tractability to be a property of problems (with providing outputs for a function given certain inputs as a special case). If a problem cannot be solved without imposing a simplifying assumption, the assumption that makes it manageable is imposed for reasons of tractability. If it is easier to solve a problem if some assumption is imposed, it is more tractable with than without that assumption. Tractability is often relative to developments in science. Given the level of sophistication of mathematics in Newton’s era, the problem of determining the orbit of a planet in relation to the sun while taking account of the mutual gravitational effects of planets was intractable. This problem became tractable later on. Whether a problem is tractable or not in the wider sense used in empirical science often depends on exogenous constraints, i.e. on constraints that one has to take as given when solving a certain problem.

Within the class of tractability assumptions, a distinction can be made between theoretical and empirical tractability assumptions. Whether tractability is theoretical or empirical depends on the nature of the problem at issue. Imposing an assumption in order to simplify the logical development of a theory or in order to ease the understanding of a theory is a matter of theoretical tractability. The level of sophistication of contemporary mathematics is an exogenous constraint that may provide a reason for imposing a simplifying assumption that should also be classified as a theoretical tractability assumption. Hence, Newton’s assumption of one-planet solar systems was a theoretical tractability assumption. Imposing an assumption in order to be able to apply a theory to an actual situation because of the data needed to apply the theory without the assumption is a matter of empirical tractability.

A large number of considerations fall under the heading ‘tractability’. In the case of theoretical tractability, relevant considerations include the level of sophistication of the mathematics available at the time, the cognitive capacities of scientists or students, more especially the puzzle-solving capacities of scientists, and ‘auxiliary’ theories in neighboring fields of inquiry. In case of empirical tractability, relevant considerations are the level of sophistication of statistics or econometrics available at the time, unobservability, the kinds of data that are collected by data collecting agencies, the rules such agencies set concerning the use of their data, changes in data collection over time, the ways in which data are constructed, the resources available, and the sophistication of the instruments available.²

One might regard the fact that the notion of tractability as analyzed here covers so many different considerations as a disadvantage. The objection would be that the notion is too broad to be useful. The first thing to note in response is that it is not so broad as to be vacuous. Tractability assumptions are, for instance, clearly distinct from negligibility and applicability assumptions. In contrast to applicability assumptions, the first-order assumptions to which they pertain are believed to be false in general. In contrast to negligibility assumptions, the effects of imposing the relevant first-order assumptions are non-negligible for the purpose at hand. The second thing to note is that the notion of a tractability assumption is not an undifferentiated one. I have already distinguished between theoretical and empirical tractability assumptions, and I suppose more valuable distinctions can be drawn. Finally, I do not claim that the typology presented here is exhaustive.

To complete this discussion of the notion of a tractability assumption, let us return once again to Hall’s assumption of constant productivity growth. If it were not for textual evidence to the contrary, that assumption could plausibly be regarded as a first-order assumption made for reasons of tractability. Without it, Hall’s measurement method does not work. In other words, the mark-up cannot be measured if the first-order assumption of constant productivity growth is not imposed. In this respect, the case is similar to the example concerning planetary orbits discussed earlier. The parallel is in fact striking. As in Newton’s case, a theoretical invention was needed to develop a measurement method that could do without the constancy assumption. (As described in Hindriks 2005, the invention concerned the application of duality theory to Solow’s 1957 method for measuring productivity growth.) So the alternative method that was developed about a decade later depends on a theoretical result that was not available to Hall, at least not initially. This means that the problem of measuring the mark-up along the lines of Hall’s method was intractable without the assumption of constant productivity growth.

5 AGAINST HEURISTIC AND EARLY-STEP ASSUMPTIONS

5.1 Tractability assumptions versus heuristic assumptions

As conceived of by Musgrave, the third kind of assumptions of the typology consisted of heuristic assumptions. Heuristic assumptions are heuristic devices, which presumably means that they (are believed to) have heuristic value. They come into view when an assumption, such as ‘the government’s budget is balanced’, is never true and the effect of an imbalance is non-negligible (Musgrave 1981: 382). Musgrave maintains that in such cases a scientist may want to develop a theory in two stages: ‘[I]n the first stage he takes no account of factor F , or “assumes” that it is negligible; in the second stage he takes account of it and says what difference it makes to his results’ (*ibid.*: 383). Furthermore, he claims that heuristic assumptions are important for ‘developing any theory whose logico-mathematical machinery is so complicated that a *method of successive approximation* has to be used’ (*ibid.*: emphasis in original). Finally, he argues that Newton’s single-planet assumption is a heuristic one, and portrays the adoption of this assumption as a step in a process towards a theory that yields precise predictions.

The level of precision of the predictions was related to the complexity of the mathematical structure of the theory. Given that scientists usually prefer simpler theories to more complex ones, it is reasonable to expect that these features tend to go together in the following way: presumably they will regard greater predictive precision as an overriding reason for introducing more complexity. Taking this into account, it seems plausible to state that an assumption has heuristic value, according to Musgrave, if imposing it is conducive to developing a theory with a complex logico-mathematical structure that leads to more precise predictions.

The main problem I have with the notion of a heuristic assumption is that calling an assumption a ‘heuristic assumption’ can easily give the impression that one is rationalizing a choice after the fact. Whether or not an assumption has heuristic value can only be established with hindsight. Musgrave’s notion that a scientist might initiate a two-stage process of theory development must in this context be regarded as an idealization. The process of theory development can rarely be planned this way, especially when empirical investigations play a crucial role – which is the case in all of Musgrave’s examples. These claims derive further support from the fact that in the case of both Newton and Hall the relevant first-order assumptions were relaxed by someone else quite some time later (in Newton’s case, after he had died). If we want to understand the process of theory development beyond the role that a hope for further progress in the future might play, I venture to state that it is better to focus on tractability than on heuristic value. The claim that a first-order assumption will turn out to have heuristic value can at most be an educated guess at the time it is imposed. In such cases it will often be more convincing to state that the main reason for

imposing the assumption was tractability, perhaps combined with a hope of being able to do without it one day. This hope may materialize at some point, and at that point we shall be able to state whether or not the assumption played a heuristic role in the process of developing the theory. This does not mean that the notion of heuristic value should not play any role at all with respect to the amended Musgrave–Mäki typology. In Section 6 I argue that it can be used to defend a realist perspective of science in general and economics in particular.

Recall that the framework of the typology presented in Section 3.1, which was motivated largely by claims made by Musgrave himself, gives pride of place to the reasons and purposes scientists actually have for imposing a first-order assumption. Now, it may of course well be that a scientist genuinely imposes such an assumption because of its expected heuristic value. Developing the typology in this way would, however, introduce an asymmetry between the different kinds of assumptions. Whether or not a particular factor F has negligible effects on the phenomenon under investigation depends on the facts as they are at the time the theory is formulated and applied. Similarly for the claim that a theory is applicable to those domains for which a particular first-order assumption holds is true (or false) independently of what happens after its imposition. Again, whether or not a problem is tractable at a particular time depends on how things are at that time. In contrast, only time will tell whether a particular first-order assumption will have heuristic value. Lest this should appear to be an epistemological issue, I would stress that whether or not it actually has heuristic value depends on what happens after the imposition of the assumption. All in all, when considering the relations between the notions of a heuristic assumption and a tractability assumption, the important point to appreciate is that the latter better serves the purpose of improving our understanding of the immediate reasons or purposes that motivate economists for imposing assumptions they take to be false, which is the main overarching aim of this paper.³

5.2 Tractability assumptions versus early-step assumptions

Mäki proposes replacing the notion of a heuristic assumption with that of an early-step assumption. His main reason for doing so appears to be a paraphrase of one of the examples discussed earlier, which Musgrave provides towards the end of his paper: ‘Assume for the moment that the budget is balanced (we will relax this assumption shortly)’ (1981: 386). Mäki’s proposal is clearly inspired by this formulation, as will be apparent from the following passage:

[An early-step assumption] is a performative sentence the uttering of which amounts to an illocutionary speech act of *making the assumption*

(and giving a promise about its forthcoming relaxation), not to the assumption itself. Of these two performatives – making the assumption and giving a promise – it seems the latter may be essential. Perhaps the early-step assumption in this case is meant to be a conjunction of non-paraphrased statement (B) [the government has a balanced budget] and a *meta-level promise* that (B) is going to be temporary, that it will be relaxed in due course. (Mäki 2000: 326, emphasis in original)

Mäki places promises concerning future relaxation at the center of his conception of the third kind of assumptions. He proposes that we should regard early-step assumptions as conjunctions of two statements, statement (B) and statement (E-SB), where (B) is the statement '[t]he government has a balanced budget' and (E-SB) is the statement '(B) is an element in an early formulation of the theory and will be removed as the theory is developed' (*ibid.*). Statement (B) will be (believed to be) false, since it does not make sense to promise to relax it if it is true. As he thinks promises do not have truth-values, Mäki claims that the (E-SB) part of early-step assumptions is truth-valueless.

I do not think Mäki's notion of an early-step assumption fits particularly well with Musgrave's ideas. The very idea of an assumption having heuristic value is absent from Mäki's conception of early-step assumptions and it is not replaced by a related notion. This might be due to the fact that Mäki ascribes too much importance to this particular formulation of a heuristic assumption, which appears in the concluding paragraphs of the paper. Another reason might be that at several points Musgrave suggests that the scientist who imposes the first-order assumption is the same as the one who relaxes it. As we saw above, however, this does not hold for Musgrave's main example of a heuristic assumption, Newton's single-planet assumption. And if the scientist who relaxes the assumption is someone else, the idea that the person who imposed it made a promise to relax it becomes problematic. Making a promise only makes sense if one has good reason to believe that one will be able to fulfill it.⁴

What is more important for our purposes, however, is that the notion does not fit with the framework presented in Section 3.2, where we saw that second-order assumptions explicate the reason for making a first-order assumption or the purpose that imposing it is meant to serve. Whereas there is some plausibility that an assumption is imposed for its (expected) heuristic value, it simply does not make sense to say that a first-order assumption is made so that it can be removed later. Such a claim does not provide an answer to the question why one would impose the assumption. Instead, it raises that question more forcefully: if the assumption is to be relaxed later on, why impose it in the first place? The fact that early-step assumptions involve promises (or an expectation or a hope) is of no help in this regard. The crucial point to appreciate is that the considerations concerning the

timing of an assumption involved in the notion of an early-step assumption are orthogonal to issues such as negligibility and applicability (as well as heuristic value and tractability, for that matter). As a consequence, the notion of an early-step assumption is no use in understanding why an economist might impose a false assumption. Nor does it support Musgrave's contention that truth is a major concern of economists (since the second-order assumption that is part of an early-step assumption is truth-valueless). Both of these purposes are better served by the notion of a tractability assumption.

6 SHOULD TRACTABILITY ASSUMPTIONS BE TRUE?

We saw in Section 3.2 that the question whether or not negligibility and applicability assumptions should be true could fruitfully be discussed without going into any detail about what it means for a theory to be acceptable – the issue which lies at the heart of the F-twist. In order to provide a satisfactory answer to the question whether tractability assumptions should be true, more needs to be said about this matter. The disagreement between Musgrave and Friedman does not concern the status of first-order assumptions. Both regard the fact that such assumptions are often false as unproblematic. Instead, their disagreement concerns what follows from this. Friedman appears to believe that, instead of the truth of assumptions, the quality of the predictions should be the criterion for evaluating the acceptability of a theory. Because of this, Musgrave regards Friedman as an instrumentalist, i.e. someone who regards theories as tools the only relevant use of which is prediction. As a scientific realist, Musgrave cannot go along with this. A core commitment of a scientific realist is that truth is of value independently of the quality of the predictions made on the basis of a theory. In Section 3.2 we saw, in effect, that Musgrave tries to accommodate this by assigning importance to the truth of second-order assumptions.

The question is whether this suffices for a realist defense of theories that contain false assumptions. The foregoing implies that an instrumentalist regards a theory as acceptable exactly if its predictions are adequate. The commitments of scientific realists, as implied by what Musgrave writes, are somewhat less clear. What can be inferred is that a necessary condition for being a scientific realist is that one deems the truth of at least some assumptions of a theory to be important. In other words, a theory is acceptable only if at least some of its assumptions are true. Musgrave claims that the adequacy of a theory depends in particular on the truth of its second-order assumptions. We saw that a provisional answer to the question whether or not negligibility and applicability assumptions should be true could be given independently of these issues. Given what was said about Musgrave's realism, that answer can now be substantiated. We

shall see that things are more problematic when it comes to tractability assumptions.

Consider negligibility assumptions first. For an instrumentalist, prediction is the purpose for which theories are used. Clearly, the effect of factor F , which is assumed to be absent or exert no influence on the phenomenon under investigation, had better be negligible for this purpose. Explanation is the primary purpose that the realist assigns to theories. Moreover, she will maintain that (approximate) truth is essential for achieving that purpose. An obvious way to accommodate this in the case of negligibility assumptions is that the first-order assumption is approximately true. What about applicability assumptions? For an instrumentalist, the applicability of a theory to a domain will turn on the question whether or not it can be used to generate adequate predictions for that domain. The realist might, instead, care about whether or not the theory is true of that domain. The idea would be that, even though there are many domains in which factor F exerts a non-negligible influence on the phenomenon under investigation, the claim that it does not have any effect is (approximately) true for particular domains. All in all, we can conclude that the truth of negligibility and applicability assumptions is a concern for both the instrumentalist and the realist. As we shall see next, this matter is not as clear-cut in the case of tractability assumptions.

Let us first consider the issue from the perspective of an instrumentalist. For him, all scientific puzzles or problems ultimately boil down to the question of how to provide adequate predictions. As a consequence, he will want the second-order statement that a particular first-order assumption makes a certain problem (more) tractable to be true. A similar line of argument can be developed for the realist. The question, however, is whether this is enough for her purposes. In order to answer this, more needs to be said about realism. A fairly minimal requirement for being a realist is that one holds that '[g]ood scientific theories are true, or close to the truth, or capable of helping us get closer to the truth' (Mäki 2004: 19). Let us examine how the notion of a tractability assumption fares in this regard. As we saw, the presupposition of tractability assumptions – as well as heuristic and early-step assumptions for that matter – is that the factors mentioned in the first-order assumptions to which they pertain commonly have non-negligible effects on the phenomena under investigation (see [T_P]). Making a problem (more) tractable as such, then, does not seem to be an answer that will fully satisfy the realist, because the theory that contains the assumption imposed for reasons of tractability is not even approximately true.

This is where the notion of heuristic value becomes relevant. Whereas appealing to the heuristic value of an assumption as a reason for imposing it is often problematic – *inter alia* because it is very difficult to judge whether imposing a first-order assumption will have heuristic value at the time it is imposed – invoking it for purposes of justification will turn out to be a

promising idea. Recall Musgrave's view that an assumption has heuristic value if imposing it is conducive to developing a theory with a complex logico-mathematical structure that leads to more precise predictions. The point to appreciate is that the theory that produces these more precise predictions will no longer contain the first-order assumption that the original theory included. The theory that superseded Newton's, for instance, did not rely on the assumption that only one planet orbits the sun. As a consequence, the theory that is ultimately developed contains fewer assumptions that are not even approximately true. As a whole, such a theory will be closer to the truth. In other words, a theory that contains a tractability assumption that turns out to have heuristic value – more accurately, a theory that contains a first-order assumption imposed for reasons of tractability, the imposition of which turns out to have heuristic value – is capable of helping us get closer to the truth.

We are now in a position to see that Musgrave's main contention falls short of achieving his purpose. The claim that, even though the falsity of first-order assumptions is often unproblematic, it is important that the second-order assumptions be true fails to secure realism. As we saw, the truth of a tractability assumption as such is insufficient for realist purposes. Furthermore, even the claim that the imposition of a particular first-order assumption has had heuristic value will be unsatisfactory to the realist, since both the theory that includes the assumption, and the model that is constructed on the basis of it, contain a statement or equation that is not even approximately true. However, the theory that will ultimately be developed if the assumption imposed turns out to have heuristic value will be closer to the truth in the sense that it will include fewer assumptions that are non-negligibly false.⁵

This discussion reveals an asymmetry between negligibility and applicability assumptions on the one hand and tractability assumptions on the other. Whereas theories that include assumptions imposed for reasons of negligibility or applicability are acceptable to the realist as they are, she will want ultimately to relax the first-order assumptions that are imposed for reasons of tractability. In other words, she will want to take the effect of factor *F* into account. As I have argued in Hindriks (2005), this is what often happens. What is more, many economists appear to regard the relaxation of a first-order assumption as a matter of achieving progress.⁶

7 CONCLUSION

Musgrave (1981) argued that we should take the role assumptions play into account when considering the question whether or not the assumptions of scientific theories should be true. This insight provided the basis for the typology of assumptions he proposed that was further developed by Mäki (2000). In this paper I have presented a new framework for this typology. At

the heart of this framework lies a distinction between first-order and second-order assumptions. A first-order assumption states that a factor F is absent or has no effect on the phenomenon under investigation. A second-order assumption provides the reason why or the purpose for which a first-order assumption was made. Such reasons or purposes can relate to negligibility (the effect of factor F is negligible) and applicability (a particular theory can only be applied if it is indeed the case that factor F is absent or has no effect). Given this distinction, Musgrave's main contention can be formulated as the claim that, even though the falsity of many first-order assumptions is unproblematic, the truth of second-order assumptions is important. He takes this to imply that Friedman is wrong when he claims that the falsity of assumptions is not a legitimate criticism of a theory. I have emphasized instead that true second-order assumptions improve our understanding of what moves economists to rely on particular (first-order) assumptions, many of which are false.

In addition, I have introduced the notion of a tractability assumption. A tractability assumption is a second-order assumption that states that a particular first-order assumption is imposed in order to make a certain problem (more) tractable. A distinction has been drawn between theoretical and empirical tractability assumptions. It has been argued that the notion of a tractability assumption fits better with the typology than either Musgrave's notion of a heuristic assumption or Mäki's assumption of an early-step assumption. These two amendments to the Musgrave–Mäki typology should help us to appreciate the extent to which the truth of assumptions is important, as well as the extent to which economists in practice ascribe significance to the truth of assumptions and their presuppositions. In addition to this, they served as the backbone of an argument that the practice of imposing false assumptions derives support from a realist perspective of science.

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ACKNOWLEDGEMENTS

An earlier version of this paper was presented at the Conference on Causation and Explanation in the Natural and Social Sciences (Ghent, Belgium, 2002). I thank the participants as well as Emrah Aydinonat, Igor Douven, Roberto Lazzari, Caterina Marchionni, Roberta Muramatsu, Menno Rol and Ana Santos for insightful comments. I am particularly grateful to Uskali Mäki and two anonymous referees for providing me with extensive comments from which the paper benefited greatly.

NOTES

- 1 See Mäki (forthcoming) for a recent set of papers about Friedman's seminal contribution to economic methodology.
- 2 The reader may wonder why the level of sophistication of statistics and econometrics is regarded as a matter of empirical tractability whereas that of mathematics is seen as a matter of theoretical tractability. The reason is that statistics and econometrics are usually only relevant when a theory is applied to reality, i.e. when it is used in empirical research. Nevertheless, the matter is somewhat arbitrary, as it may be due to a lack of theoretical development of econometrics, for instance, that a certain assumption has to be imposed when used in empirical research. The distinction between theoretical and empirical tractability assumptions is not sharp.
- 3 The reader might object to my proposal by arguing that the notion of a tractability assumption cannot replace that of a heuristic assumption, because they are not similar enough to do the same work. For instance, Musgrave can be taken to suggest that a heuristic assumption has the form 'Factor F has a negligible effect on the phenomenon under investigation' (see Musgrave 1981: 382), whereas tractability assumptions pertain to first-order assumptions according to which factor F is absent or has no effect. The reason for this difference is that I take first-order assumptions to concern the model world rather than the real world, and in the model world these factors, including interplanetary gravitation as modeled by Newton, have no effect. Note that, according to Musgrave, factor F in fact has non-negligible effects. I retain this feature of his proposal, as will be clear from [Tp]. This also implies that the first-order assumption in question will always be (regarded as) false, just as is the case with heuristic assumptions. Not all tractability assumptions simplify the logical development of the theories in question, whereas on Musgrave's view all heuristic assumptions do. As a consequence of this, the notion of a tractability assumption is more encompassing than that of a heuristic assumption. Finally, in my view, the notion of heuristic value plays a significant role with respect to tractability assumptions, as I explain below in Section 6. I thank one of the referees for pressing me to explicate the relation between heuristic and tractability assumptions in more detail.
- 4 Mäki (2004) suggests that the scientist who imposes a false first-order assumption, to use my term, might expect, or hope rather than promise that the assumption will be relaxed at a later point in time. Even though allowing for expectations and hopes in addition to promises might indeed be a way of improving the notion of an early-step assumption, it does not make it more suitable to figure as a type of assumption in the Musgrave–Mäki typology for the reasons I go on to present in the main text.
- 5 In this respect, using the term 'assumption' for the statements that specify the reasons why or purposes for which first-order assumptions are imposed can be somewhat misleading. It can easily lead one to think that they are part of the relevant theories. If they were, though, Musgrave's main contention would imply that the second-order assumptions *of theories* would be true, which sounds like a promising message for a realist. Strictly speaking, these assumptions are not part of the theories, however. As a consequence, one might want to use the term 'meta-statement' instead of 'second-order assumption' (which would make the qualification 'first-order' redundant). I use the term 'second-order assumption' because it is more suitable for

reconstructing Musgrave's assertions about the truth and falsity of claims for which he uses the term 'assumption'.

- 6 Mäki (2004: 23) criticizes my proposal of a tractability assumption, which he and I have been discussing for some years now, for failing to provide an adequate justification for imposing a first-order assumption that is false. The first thing to note is that tractability can in fact constitute a partial justification, especially in cases where the relevant problem would be completely intractable without the relevant assumption. In such cases, the choice is between not being able to solve the problem at all and providing a solution that is based on a theory that contains a false assumption. Surely it is reasonable to opt for the latter. Secondly, as was argued in Section 3.1, the primary purpose of the typology is to understand why scientists impose the assumptions they use, in particular the false ones. So the immediate goal is not to provide a justification. Note furthermore that the notion of an early-step assumption provides no justification at all for imposing a false first-order assumption. It states that the assumption will be relaxed, but this does not justify its imposition. So even if Mäki's argument were to work against the notion of a tractability assumption, it fails to support his notion of an early-step assumption. Finally, as I have argued in the main text, the notion of a tractability assumption can be embedded in a dynamic perspective concerning theories and models in which heuristic value plays a role that does provide such a justification.

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