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Interaction and Structural Representation in Calibration of Economic Models

ABSTRACT. The paper discusses a version of empiricist structuralism with regard to general macroeconomic equilibrium models as instantiated by the initial RBC model. It argues that calibration, which is used to derive empirically substantiated answers to quantified questions in DSGE, explicitly represents interactions with how the model user conceptualizes the problem at hand and thus extends Bas van Fraassen's theory of representation, claiming that in the case of economic models the indexicality of the representation applies not only to the relationship between reality and the empirical model, but – as argued – pertains also to the relationship between the empirical and the theoretical model. Hence, the argument further undermines the simplistic views of the relationship between the theoretical model and reality, and in the case of economy, which involves intentional actions of economic agents, it demonstrates that even theoretical representation constitutively involves the user's indexical judgment.

KEY WORDS: empiricism, structuralism, DSGE, economic methodology, indexicality

1. Introduction

The paper advances a version of structuralist account of representation with regard to an important class of economic models. It builds on a general empiricist structuralism with regard to scientific representation propounded by B. van Fraassen [2008; 2014], which is outlined in Section 2. below. He conceives of scientific representation as inherently pragmatic [Frisch, 2014, p. 4] as it constitutively depends on the user indexical judgement. Taking for granted the use of calibration in economic models, as presented in Section 4., I argue that indexicality pertains not only, as would follow from the original van Fraassen's theory of representation, to the reality–data relation, but it also applies to theoretical economic models. The upshot of the argument is that an evaluation of the theoretical model necessarily involves the initial research question of the model's user. The general argument supporting this modified 'interactive' version of the structuralist viewpoint is presented in Section 3 and applied to the account of representation of the DSGE economic models in Section 4.

2. Empiricist structuralism and model representation

In general, structuralist accounts of scientific representation have been motivated by the advances in mathematics toward the end of the 19^{th} century [Bokulich, Bokulich, 2011, p. ix; van Fraassen, 2008, p. 191]. In particular, the developments in geometry and axiomatic definition of space proved especially influential with regard to propagating structuralist accounts among philosophers [Kawalec, 2003; 2011; Suppes, 2002; Bokulich, Bokulich, 2011; French, 2014]. Their thorough entrenchment in the philosophy of science was largely due to the fundamental claim that the Aristotelian account of concepts in terms of subject-predicate relations had to be replaced – given the then recent advances in physics and geometry – by functional notions, whose reference is based on relational structures rather than the traditional ontology of substances and their attributes [see esp. Klein, 1998, pp. 12–14; also Cassirer, 1953, p. 231; van Fraassen, 2008, p. 195]. Thus, scientific representations refer to individual objects and their properties, for instance as measured data, only insofar as they instantiate universal relations (laws) holding for a given range of values. R. Carnap strengthened the epistemological rationale behind structuralism. In his characteristically neo-Kantian solution to the problem of how the objectivity of scientific knowledge is constituted, despite the fact that it originates from purely subjective epistemic experience, he claimed that only definite descriptions referring to formal properties of relational structures of the subjective experience can successfully solve the problem [Kawalec, 2011]. To use a simplified version of Carnap's original example, suppose there is a very simple railway system in a given country with just two lines West–East and South–North, which cross at the central station. In the traditional Aristotelian framework we could represent the railway system using the proper names of the railway stations and describing their attributes, including their connections (and other relational properties). Instead, Carnap proposed that we take for granted a primitive relation, such as the relation of neighbouring between two stations, and use only the formal properties of this relation (e.g. being symmetrical, intransitive or anti-reflexive) to define all the stations. Thus, for instance, the central station can be defined by the unique definite description as the only one neighbouring four other stations. And because the definitions would be derived as purely structural definite descriptions, without any reference to individual epistemic acquaintance with them (e.g. their proper names), they can be claimed to be purely objectively determined without any reference to subjective phenomenal experience.

Structuralist accounts of scientific representation have recently been revived in the philosophy of science [Suppes, 2002; Ladyman, 2009; Ross, 2008; French, 2014; Landry and Rickles, 2012; Iranzo, 2014; Okruhlik, 2014; Thomson-Jones, 2011; Frisch, 2014; Alrøe and Noe, 2014]. In general, they can be divided between realistic and empiricist varieties.

In the remainder of this Section I will present the main tenets of van Fraassen's empiricist structuralism. He succinctly formulates the background assumptions of this position thus:

> The two poles of scientific understanding, for the empiricist, are the observable phenomena on the one hand and the theoretical models on the other. The former are the target of scientific representation and the latter its vehicle. But those theoretical models are abstract structures, even in the case of the practical sciences such as materials science, geology, and biology – let alone in the advanced forms of physics. All abstract structures are mathematical structures, in the contemporary sense of "mathematical", which is not restricted to the traditional number oriented forms. And mathematical structures, as Weyl so emphatically pointed out, are not distinguished beyond isomorphism – to know the structure of a mathematical object is to know all there is to know. [van Fraassen, 2008, p. 238]

Empiricist structuralism is a position, which systematically articulates the intuitive statement that "All we know is structure". In consequence, this view, characteristically, implies that any phenomenal experience of a given object, its intuitive understanding, or otherwise subjectively acquired data is irrelevant for scientific representation. Two claims are critical for the position [van Fraassen 2008, p. 238], namely: "Science represents the empirical phenomena as embeddable in certain *abstract structures* (theoretical models)" and "Those abstract structures are describable only up to structural isomorphism". As a general view of scientific representation empiricist structuralism endorses the view that "all scientific representation is at heart mathematical" [2008, p. 239].

However, as an empiricist position, it recognizes the inherent limitation of scientific knowledge: "all we know *through science* is structure" [2008, p. 238]. So, given van Fraassen's broad understanding of experience [2002], our artistic or religious experiences, for example, give rise to some other – admittedly, non-scientific – forms of knowledge.

The fundamental problem for the first claim, following H. Reichenbach, can be formulated as follows. The mathematical objects of knowledge, as purely conceptual, are determined uniquely by mathematical definitions and axioms, but physical (empirical) objects cannot be so determined, even if they are described by mathematical equations and definitions. In responding to this problem, van Fraassen distinguishes two kinds of 'the matching' relation: (i) one that holds between the theoretical model (an abstract representation) and the data model (the mathematical representation of phenomena) and (ii) the other between the data model and the phenomena. The relation (i) between the theoretical model and the data model is a relation of embedding one mathematical structure into another, and it is considered not to be problematic in the sense that it is a feasible task to study it by considering only the properties of both abstract representations [Suppes, 2002].

On van Fraassen's account the relation (ii), between the abstract mathematical representation and the phenomena, cannot be resolved by using conceptual analysis alone. To identify a data model as representing particular phenomena a user is necessary in order to make the indexical judgement that the former pertains to the latter: "Representation is a relation between the abstract structure and the phenomena constituted by the user. Nothing represents anything except in the sense of being used or taken to do that job or play that role for us” [van Fraassen, 2008, p. 253]. On this account, then, representation is *indexical* as it requires the user to establish whether this relation actually holds between the particular data model and the phenomena at hand. And this question can only be settled in this pragmatic, i.e. user-involving and contextual manner, and not simply by a purely syntactic or semantic analysis of the properties of the relata in question. As it is a consequence, according to van Fraassen, of Reichenbach’s problem outlined above.

Schematically, van Fraassen’s solution of this fundamental problem posed for structuralism, can be depicted as the claim that “in the chain [*theory*]–[*data model*]–[*reality*] the last link is one that is expressed in indexical judgements” [2008, p. 257] of the user of the representation who identifies a data model as representing the phenomenon observed or measured. Therefore, empiricist structuralism rejects the realist account, and in particular its foundational claim that beside the represented structure there supposedly is also an underlying ‘structure in reality’, which would then be matched by the data model. Van Fraassen’s argument against the realistic account concludes that it presumes a version of Moore’s paradox. The realist would claim that for the relation of representation to hold between the data model and the phenomena it is necessary – beyond the indexical judgement of the user – that there be an additional ‘structure in reality’. This realist requirement, van Fraassen argues, would force the user to form the paradoxical attitude towards her own data model: “It is so, but I do not believe that it is” [2008, pp. 255–258].

Van Fraassen concludes his own account with a general observation: “representation is best thought of not as a two-place relation between a representation and its target but rather as a multi-place relation, which includes a place for the user of the representation and for its context, aim, or purpose: a is *a* representation of *b* exactly if there is some context, *c*, in which a user, *u*, uses *a* to represent *b*” [Frisch, 2014, p. 3]. In this sense, then, representation is inherently pragmatic, not just semantic, as the user’s judgement is constitutive of the relation between the data model and the phenomena.

3. Representation in the case of economic models – a modified structuralist account

The indexicality – identified by van Fraassen as binding data model to reality – extends in the case of economic models, as I shall argue in the remainder of this paper, also to the relationship between theory and the data model. The argument may not, however, undermine van Fraassen's original standpoint – in particular, given its more recent exposition [van Fraassen, 2014] – as the kinds of models discussed represent relations between economic agents, which are themselves inherently intentional, and not just physical.

On a naïve view there is a simple mutual relation between theory and the data model, or – as the examples used here refer to economic research practice – hereafter I will respectively refer to 'theoretical model' and 'empirical model'. The theoretical model is estimated on the basis (of a part) of the empirical model, and then it is tested against (a different part) of it. While the result of the estimation does not meet expectations, it may lead to a modification of the initial theoretical model, or its rejection altogether. On this naïve view, the relation between theoretical and empirical models could be investigated in semantic terms, in particular van Fraassen's embedding between abstract mathematical structures.

However, this naïve view is untenable for at least two principled reasons. Firstly, the abstract theoretical model taken literarily is admittedly false. Secondly, in order for it to be confronted with the empirical model, it needs further elaboration, as the example in the next Section makes clear. The transformation of the theoretical model leads to a formulation of a '*hypothetical model*', which – after calibration using empirical data – can be put to use in order to answer a research question. The questions could consider either the behaviour of the theoretical model, when some additional aspects of the empirical model are taken into account, or the predicted results of policy-maker intervention on the economic system. The hypothetical model, in order to deliver the answers, has to be *calibrated* with the empirical data and only then can it simulate the plausible answers implied by the assumed theoretical model.

Thus, neither the theoretical model nor the empirical model yield *prêt-à-porter* enduring structures, which then could be matched against each other, as a proponent of the naïve view might have it. Rather, as claimed in this paper, they are transformed in a way, which corresponds to the user's perspective as manifested in the way she casts the research question at hand. It is only after the transformation that the obtained results may be confronted in the form of embedding described by van Fraassen. But along the way the structures integral to both models have nonetheless been framed by the context-related transformations of both models. So, the fundamental structuralist belief that "the content of representations … is purely structural" is retained, but at the same time appended with the view that "the structural content and the target of a representational structure is fixed by a context of use" [Frisch, 2014, p. 4].

The kind of indexicality involved here, though, is different than the one identified by van Fraassen. While the user identifies the empirical model as representing reality, she is positioning herself towards it as an observer (including the cases, when she takes measurements of the pertinent phenomena). This I would refer to as an *externalist* indexicality, characterized in detail by van Fraassen [2008; 2014] as establishing the relation of the representation between the phenomena and the empirical model. In contrast, in the case of the relation between the theoretical and empirical models the indexicality involved is *internalist*. For the user's judgement that the relation of representation holds between a given theoretical (hypothetical) model and the empirical model depends constitutively on how the user poses her initial research question. This is so because it is the latter [Morgan 2012, pp. 401–405] that guides the interactive transformation of the theoretical and empirical models to formulate the hypothetical model, since only those parts of the models are considered, which pertain to the user's question. In other words, the theoretical model becomes relevant, and indeed identified, as a representation of something else only when it serves the user to answer her initial question. So here, the indexicality depends on the user's own actual conceptualization of the research problem, and not, as in the case discussed in the previous Section, on the externally determined phenomena. A more detailed discussion, using the example of DSGE economic models, is relegated to the next Section.

To further substantiate the distinction between externalist and internalist indexicality we can refer to the theoretical (hypothetical) and empirical models as extensions of the user's internal cognitive apparatus [Giere, 2010]. Thus, while the user poses the initial research question using her own cognitive apparatus, she extends the latter by constructing the theoretical and empirical models, and then interacts with them in order to derive the answer.

In contrast to van Fraassen's theory of representation, I claim that there has to be the interaction between the theoretical and empirical model guided by the research question in order for the former to *represent* the latter. As without the interaction of the user's own conceptualization of the problem and the models she uses to answer the question, it may be possible that the relevant parts of the data will not be considered in delivering the ultimate answer and the thus derived answer will beg the original question. And, in consequence, the transformation needed to account for the data not initially included in the empirical model may not correspond with the user's initial problem, but rather follow a different conceptualization, for instance the one which is widespread within the research community. This problem is well illustrated with the historical example of the 19th century research on cholera [Kawalec, 2014], where the parliamentary commission arrived at an apparently wrong answer entailed by the initially upheld miasma theory, failing to take into account (interact) with the upcoming pieces of evidence, thus begging the question concerning the cause of cholera outbreaks in London. A parallel investigation by an individual physician John Snow led him to actually discover the cause of the disease, while he continually updated the initial conceptualization of the problem against the theoretical and empirical models of the disease.

4. Calibration and interactions

A pertinent illustration of the indexical interaction between the user's conceptualization and theoretical and empirical models was forcefully advanced in economics by F. Kydland and E. Prescott [1982; 1991a;

1991b; 1996] in their *real business cycle* (RBC hereafter) model. My exposition here follows [DeJong, Dave, 2007] and focuses on the original RBC version of the path-breaking model of Kydland and Prescott as an instance of a more general and widely used DSGE class of models.[1]

The model is directly motivated by the following question: "how much variation in aggregate economic activity would have remained if technology shocks were the only source of variation" [Kydland, Prescott 1991b, p. 169]. The theoretical model used to answer this question consists of the following system of difference equations.

$$\left(\frac{1-\varphi}{\varphi}\right)\frac{c_t}{l_t} = (1-\alpha)z_t\left(\frac{k_t}{n_t}\right)^{\alpha} \tag{1}$$

$$c_t^{\kappa} l_t^{\lambda} = \beta E_t\left\{c_{t+1}^{\kappa} l_{t+1}^{\lambda}\left[\alpha z_{t+1}\left(\frac{n_{t+1}}{k_{t+1}}\right)^{1-\alpha} + (1-\delta)\right]\right\} \tag{2}$$

$$y_t = z_t k_t^{\alpha} n_t^{1-\alpha} \tag{3}$$

$$y_t = c_t + i_t \tag{4}$$

$$k_{t+1} = i_t + (1-\delta)k_t \tag{5}$$

$$1 = n_t + l_t \tag{6}$$

$$\log z_t = (1-\rho)\log(\bar{z}) + \rho\log z_{t-1} + \varepsilon_t, \tag{7}$$

where $\kappa = \varphi(1-\varphi) - 1$ and $\lambda = (1-\varphi)(1-\varphi)$.

The basic rationale behind the model is that a typical household within the aggregated economic activity maximizes its utility – with relative risk aversion – over its consumption c_t and leisure l_t, while being equipped with a production technology for producing a single good y_t with its physical capital k_t and labour n_t under technology shocks z_t. The household is constrained to divide a unit of time between labour and leisure (equation (6)), and to consume or invest its output (equation (4)), while its stock of physi-

[1] My argument presented in the paper is indifferent to the economic debate concerning a strategy in framing the theoretical underpinnings of a particular instantiation of the DSGE model. For a systematic exposition of the differences between neo-classical and neo-Keynesian versions of DSGE models see e.g. Cooley, 1995; Woodford, 2003; Galí, 2008.

cal capital evolves (equation (5)). The functional form of the model assumes a balanced growth, constant marginal productivity of capital and labour and no tendency for long-term growth in labour and leisure [DeJong and Dave 2007, p. 90].

The empirical model is a log-linear approximation of the theoretical model (equations (8–14)) at the steady state values (where $y = y_t$ and $y' = y_{t+1}$):

$$0 = \log\left(\frac{1-\varphi}{\varphi}\right) + \log c' - \log l' - \log(1-\alpha) - \log z' - \alpha\log k + \alpha \log n' \tag{8}$$

$$0 = \kappa\log c + \lambda \log l - \log\beta - \kappa \log c' - \lambda\log l'$$
$$- \log\left[\alpha\exp\,(\log z')\frac{\exp\,[(1-\alpha)\log n']}{\exp\,[(1-\alpha)\log k']} + (1-\delta)\right] \tag{9}$$

$$0 = \log y' - \log z' - \alpha\log k - (1-\alpha)\log n' \tag{10}$$

$$0 = \log y' - \log\,\{\exp[\log(c')] + \exp[\log(i')]\} \tag{11}$$

$$0 = \log k' - \log\,\{\exp[\log\,(i')] + (1-\delta)\exp[\log(k)]\} \tag{12}$$

$$0 = -\log\{\exp[\log(n')] + \exp[\log(l')]\} \tag{13}$$

$$0 = \log z' + \rho\log z. \tag{14}$$

DSGE models, like the example discussed here, differ in an important respect from the earlier structural models propounded since [Haavelmo, 1943; 1944] onwards till the 1970's. "In place of behavioral equations, DSGE models feature equations that reflect the pursuit of explicit objectives (e.g., the maximization of lifetime utility) by purposeful decision makers (e.g., representative households)" [DeJong, Dave, 2007, p. 120].[2] The model discussed here has two such equations determining the trade-offs that decision maker needs to face: one between labour and leisure and the other between consumption and investment. However, the early attempts at empirical applications of such models – or rather their reduced forms [Sims, 1972] and Hansen and Sargent [1980] – were unsatisfactory because of rejections of the parametric implementations. Kydland and

[2] For a critical assessment of the microeconomic foundations of narrowly understood DSGE models see e.g. Hartley, 1998, pp. 8–13.

Prescott address the latter problem by introducing a new procedure of *calibration.*[3] The general approach is succinctly described as follows:

> To apply general equilibrium methods to the quantitative study of business cycle fluctuations, we need methods to compute the equilibrium processes of dynamic stochastic economies, and specific methods for the stochastic growth model economy. Recursive competitive theory and the use of linear-quadratic economies are methods that have proven particularly useful. These tools make it possible to compute the equilibrium stochastic processes of a rich class of model economies. The econometric problem arises in the selection of the model economies to be studied. Without some restrictions, virtually any linear stochastic process on the variables can be rationalized as the equilibrium behavior of some model economy in this class. The key econometric problem is to use statistical observations to select the parameters for an experimental economy. [Kydland, Prescott, 1991b, p. 169]

So, the 'econometric analysis' referred to in the above quotation is characterized in detail as 'calibration'[4]. In order to address the initially posed precise quantitative question "a researcher needs some strong theory to carry out a computational experiment: that is, a researcher needs a theory that has been tested through use and found to provide reliable answers to a class of questions" [Kydland, Prescott, 1996, p. 72]. As DeJong and Dave explain [2007, p. 124]: the rationale for playing with theories 'as simplifications of reality' is that all models suffer empirical shortcomings along certain dimensions, and any procedure that enables their empirical implementation must be applied with this problem in mind. The point here is that the chosen theory must be suitably developed along the dimensions of relevance to the question at hand".[5]

As noted in the preceding Section, calibration explicitly – as evidenced by the above quotations – embraces the indexical interaction between the model's user, who poses the question, and the relevant theory, which is reframed in order to correspond with the user's initial conceptualization of

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[3] Admittedly, calibration has already been well-established in science [Dawkins et al., 2001, p. 3661] and economics [Cooley, Prescott, 1995, pp. 15–16].

[4] For alternative definitions of calibration in economics see Dawkins et al., 2001, p. 3656–3657].

[5] This is also one of the reasons of the advantage of calibration over estimation or other statistical techniques [Dawkins et al., 2001, pp. 3663–3665; Romer, 2012, pp. 218–220].

the problem. The indexical interaction continues to the next step of calibration, where the model economy is constructed. As pointed out by Solow [1956, p. 65]: "The art of successful theorizing is to make the inevitable simplifying assumptions in such a way that the final results are not very sensitive." So, the model economy retains the minimal level of complexity needed to satisfactorily address the research question. These three steps are not specific to calibration as they would apply to most empirical determinations of theoretical models. However, what follows is the core step, which consists in the calibration of model parameters. As Kydland and Prescott [1996, p. 74] explain: "data are used to calibrate the model economy so that it mimics the world as closely as possible along a limited, but clearly specified, number of dimensions". Thus, the core step of calibration explicitly depends on the initial user's conceptualization of the problem, which then projects the "limited, but clearly specified, number of dimensions" onto the empirical model. In the final step the model economy is used to "run the experiment" and deliver the answer to the question [Kydland, Prescott, 1996].

If x_t represents the set of variables in the model (cast as deviations from steady state values), X_t the corresponding observable variables and μ the structural parameters of the model, then calibration may schematically be represented as determination of the particular elements of μ by using the 'real-world' criteria $\Omega(\{X_t\}_{t=1}^{T})$. Let X_t^M represent the model version of the data and X_t – the actual data. The calibration leads thus to:

$$\Omega(\{X_t^M\}_{t=1}^{T}) = \Omega(\{X_t\}_{t=1}^{T})^6. \tag{15}$$

As well-illustrated in [Romer, 2012, p. 219–220], calibration may be iterated to improve "its fit with the data". Apparently, its justification – and in consequence the usefulness of the model – derives from the user's judgement in picking out the relevant microeconomic evidence consistent with the model's 'central building blocks'.

[6] The subsequent exemplary calibration of the DSGE model discussed here is presented in detail in DeJong, Dave 2007, pp. 134–139.

5. Conclusion

Calibration, as illustrated in the paper with the example of the original version of the DSGE model, explicitly undermines a simplistic view of the matching relation between the theoretical and the empirical model conceived of as static and purely semantic. Rather, calibration is constituted by its interplay with the model's user, who poses the initial research question, and thus determines the relevant aspects of the theoretical model, which subsequently are used to derive the answer from the model economy.

The appeal of the interactive structuralist account, I propound, of van Fraassen's triple: [*theory*]–[*data model*]–[*reality*] may be largely entailed by the fact that the relations being modeled are intentional rather than physical. The DSGE model discussed here is considered to be an advancement over its antecedent structural models precisely because the behavioral equations have been substituted by their intentional counterparts explicitly representing (typical) agent's optimization strategies.

References

Alrøe H.F., Noe E., (2014), "Cross-disciplinary science and the structure of scientific perspectives", *Journal of Organizational Knowledge Communication* 1, 1, pp. 7––30.

Bokulich A., Bokulich P. (eds.), (2011), *Scientific Structuralism*, Dordrecht, Springer Netherlands.

Cassirer E., (1953), *Substance and Function and Einstein's Theory of Relativity*, New York, Dover Publications.

Cooley T.F. (ed.), (1995), *Frontiers of Business Cycle Research*, Princeton, N.J., Princeton University Press.

Cooley T.F., Prescott E.C., (1995), "Economic growth and business cycles", [in:] *Frontiers of Business Cycle Research*, ed. T.F. Cooley, Princeton, N.J., Princeton University Press, pp. 1–38.

Dawkins C., Srinivasan T.N., Whalley J., (2001), "Calibration", [in:] *Handbook of Econometrics* Vol. 5, eds. J.J.H. and E. Leamer, Amsterdam, Elsevier, pp. 3653––3703.

DeJong D.N., Dave C., (2007), *Structural Macroeconometrics*, Princeton, N.J., Princeton University Press.

French S., (2014), *The Structure of the World: Metaphysics and Representation*, Oxford, New York, Oxford University Press.

Frisch M., (2014), "Users, structures, and representation", *The British Journal for the Philosophy of Science*, first online 1–22, http://bjps.oxfordjournals.org/content/early/2014/03/19/bjps.axt032.

Galí J., (2008), *Monetary Policy, Inflation, and the Business Cycle: An Introduction to the New Keynesian Framework*, Princeton, N.J, Princeton University Press.

Giere R.N., (2010), *Scientific Perspectivism*, Chicago, University of Chicago Press.

Haavelmo T., (1943), "The statistical implications of a system of simultaneous equations", *Econometrica*, 11, 1, pp. 1–12.

Haavelmo T., (1944), "The probability approach in econometrics", *Econometrica: Journal of the Econometric Society* 12, Supplement, pp. iii-vi, 1–115.

Hansen L.P., Sargent T.J., (1980), "Formulating and estimating dynamic linear rational expectations models", *Journal of Economic Dynamics and Control*, 2, pp. 7–46.

Hartley J.E. (ed.), (1998), *Real Business Cycles a Reader*, London, Routledge.

Iranzo V., (2014), "Models and phenomena: Bas van Fraassen's empiricist structuralism", [in:] *Bas van Fraassen's Approach to Representation and Models in Science*, ed. W.J. Gonzalez, Amsterdam, Springer Netherlands, pp. 63–76.

Kawalec P., (2003), *Structural Reliabilism: Inductive Logic as a Theory of Justification*, Dordrecht, Kluwer Academic Publishers.

Kawalec P., (2011), "Introduction" (in Polish), [in:] R. Carnap, *The Logical Structure of the World*, trans. and edited by P. Kawalec, Warszawa, Wydawnictwo Naukowe PWN, pp. xi–civ.

Kawalec P., (2014), "Is truth perspectival in science? Viability of pragmatic account of scientific truth for mixed-methods research", *Zagadnienia Naukoznawstwa*, 50, 4(202), pp. 281–290.

Kydland F.E., Prescott E.C., 1982, "Time to build and aggregate fluctuations", *Econometrica: Journal of the Econometric Society*, 50, 6, pp. 1345–1370.

Kydland F.E., Prescott E.C., (1991a), "Hours and employment variation in business cycle theory*", Economic Theory*, 1, 1, pp. 63–81.

Kydland F.E., Prescott E.C., (1991b), "The econometrics of the general equilibrium approach to business cycles", *The Scandinavian Journal of Economics*, 93, 2, pp. 161–178.

Kydland F.E., Prescott E.C., (1996), "The computational experiment: an econometric tool", *Journal of Economic Perspectives*, 10, 1, pp. 69–85.

Ladyman J., (2009), *Structural Realism*, New York, Oxford University Press.

Landry E., Rickles D. (eds.), (2012), *Structural Realism*, Vol. 77, Dordrecht, Springer Netherlands.

Morgan M.S., (2012), *The World in the Model: How Economists Work and Think*, Cambridge, New York, Cambridge University Press.

Okruhlik K., (2014), "Science, sex, and pictures: reflections on Van Fraassen's use of perspectival representations", [in:] *Scientific Explanation and Methodology of Science*, p. 156–169.

Romer D., (2012), *Advanced Macroeconomics*, New York, McGraw-Hill/Irwin.

Ross D., (2008), "Ontic structural realism and economics", *Philosophy of Science*, 75.5, pp. 732–743.
Sims C.A., (1972), "Money, income, and causality", *American Economic Review*, 62, pp. 540–552.
Solow R.M., (1965), "A contribution to the theory of economic growth", *Quarterly Journal of Economics*, 70, pp. 65–94.
Suppes P., (2002), *Representation and Invariance of Scientific Structures*, Stanford, Calif., CSLI Publications.
Thomson-Jones M., (2011), "Structuralism about scientific representation", [in:] P.J.M. Bokulich, A. Bokulich, *Scientific Structuralism*, Dordrecht, Springer, pp. 119–141.
van Fraassen B.C., (2002), *The Empirical Stance*, Yale, Yale University Press.
van Fraassen B.C., (2008), *Scientific Representation: Paradoxes of Perspective*, Oxford, New York, Clarendon Press, Oxford University Press.
van Fraassen B.C., (2014), The criterion of empirical grounding in the sciences, [in:] *Bas van Fraassen's Approach to Representation and Models in Science*, ed. W.J. Gonzalez, Dordrecht, Springer Netherlands, pp. 79–100.
Woodford M., (2003), *Interest and Prices: Foundations of a Theory of Monetary Policy*, Princeton, N.J., Woodstock, Oxfordshire [England], Princeton University Press.
Worrall J., (1989), "Structural realism: the best of both worlds?"*, *Dialectica*, 43,1–2, pp. 99–124.

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