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A model to "make decisions and take actions": Leif Johansen's multi-sector growth model, computerized macroeconomic planning, and resilient infrastructures for policy-making

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# A MODEL TO “MAKE DECISIONS AND TAKE ACTIONS”

BY

VERENA HALSMAYER

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CENTER FOR THE  
HISTORY OF POLITICAL ECONOMY  
AT DUKE UNIVERSITY

## A model to “make decisions and take actions”

Leif Johansen’s multi-sector growth model, computerized macroeconomic planning, and resilient infrastructures for policy-making\*

### *Abstract*

The 1960s were the glorious age of large-scale, ‘economy-wide’ macroeconometric models, which enabled forecasts and simulations of the quantitative effects of certain policy changes within systems of simultaneous equations. This paper is concerned (1) with the form and character of the kind of knowledge these models brought about; and (2) with the ways in which these models shaped the practices, objects, and the very notion of macroeconomic planning. The concepts of *bricolage* and *infrastructure* help to account for the continuous reciprocal shaping of mathematical techniques, empirical data, bits of economic theory, institutional arrangements, the aims and hopes of economic planning, images and visions of ‘the economy’, and the practical requirements and affordances of computing technologies. The paper traces the movements and changes of the multi-sector growth model, constructed by the Norwegian economist and communist Leif Johansen, from its publication in 1960 to its implementation in national macroeconomic planning and its wider circulation from the mid-1970s on. In Norway, it became one component of a “system of models,” which, far from simply being a passive “tool for decision making,” structured bureaucratic procedures, and formatted the basic concepts of policies. Both in and outside Norway, it showed a certain resilience: when Keynesian macroeconometric models encountered widespread criticism, the multi-sector growth model was further remodeled, adapted to new scenarios, and built into easily applicable software packages. Its basic design, however, remained compact and consolidated economic key assumptions. Under the label of “computable general equilibrium models, it prepares the ground for a whole variety of policies until today—regardless of their political frameworks.

*Key Words:* macroeconometric modeling, economic planning, multi-sector growth model, Leif Johansen, Norwegian economics, computational general-equilibrium models, history of applied economics, computing in economics, historical epistemology, the economy.

*JEL codes:* B22, B23, B41, O21, O41

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At the end of the 1960s, alongside a growing cultural critique of consumerism, the advertising industry, and, more fundamentally, the disasters of industrial capitalism, the American economics profession came under attack for being politically irrelevant and conservative. Alongside popular utterances and John K. Galbraith's widely-read criticism of the disciplinary standard of equilibrium analysis, Robert Heilbroner excoriated economists in a contribution to a series by the *Public Interest* on "Capitalism and the Economists" for not being able to say anything about the Vietnam War, about poverty, racial discrimination, or the power of large corporations.<sup>1</sup> Some of the issues Heilbroner mentioned were put on the table only a few years later under the label of "applied economics"—though they were hardly handled in the way the critic had imagined. Rather, it seemed the mathematical and statistical apparatuses that economists had developed since the 1930s were extended, redesigned, and transformed to cast an ever-increasing set of questions in terms of clear-cut problems manageable in the form of systems of simultaneous equations. Everything that could not be formulated this way was not being problematized and at danger to be excluded from accepted as 'economic' inquiry. In addition to other contributions to the present volume, which situate "applied economics" within the rise of 'applied science' in the second half of the twentieth century, and look at entanglements of the economics profession and policy-making since the 1970s, this paper explores the form and character of the knowledge, which was believed to be useful for governance. The subsequent pages are concerned with the construction, transformations, and effects of so-called "applied models" as they actively shaped not only economic research but also the practices, objects, and the very notion of macroeconomic planning. Adaptable to new contexts, remodeled, and reinterpreted, these artifacts showed a certain resilience and remained in place over the decades, changing sceneries and political ideologies notwithstanding.

As part of a broader movement towards science-based policy-making, planning 'the economy' was one of the dominant discourses in what has been called late capitalism, organized capitalism, industrial society, or Fordism.<sup>2</sup> Leif Johansen, the Norwegian economist and communist, who is central in the following exposition, for instance, argued the very "necessity of applying economic theory" in his internationally influential textbook on *Public Economics* (1965). Given the unprecedented and ever-increasing size of the public sector, he contended, it was imperative that

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<sup>1</sup> Heilbroner (1970). On economics losing prestige in the context of civil rights, antiwar, environmental, and feminist movements, see Mata (2010). On an exchange between Galbraith and Robert Solow on the politics of method in industrial society in the *Public Interest*, see Halmayer and Hounshell (forthcoming).

<sup>2</sup> On the establishment of the "social sciences" through stabilizing as the main source of knowledge for social planning, policy analysis, and the organization of decision-making processes, see, for instance, the contributions to Porter and Ross (2003, Part IV), in particular Wagner (2003), and Porter (2006). On an update of the concept of the "scientization of the social" ("Verwissenschaftlichung des Sozialen"), see Raphael (2012). On the rise of the label "technical" in the sciences, see Porter (2009). On economics as a "science in the mold of engineering," see Morgan (2003) and Armatte (2010). On the figure of the economist as a public expert, convinced of being able to provide understanding and blueprints for social control, see Mata and Medema (2013). On the transformation of the role of the academic economist, see Furner and Supple (1990) and Fourcade (2009). On technical Keynesianism, in particular in the person of Paul Samuelson, see Maas (2014) and Backhouse (2015).

government kept track of the changing relations between the parts of a national economy.<sup>3</sup> Irrespective of different narratives of ‘the market’ and ‘the state’, planning became an organizational necessity that crucially depended on a vast ensemble of statistical and mathematical models. National accounts, national budgets, macroeconomic and input–output models presented the economy as an ordered system of components that balanced each other out in one way or another and provided a basis for intervention that sought to achieve and sustain such a state of balance. Much more than passive tools, they visualized the very object to be governed as a quantitative entity that could be modeled, measured, computed, and acted upon. They established a way of seeing national economies as separate from the political, the social, and the cultural, with their own needs and interests.<sup>4</sup> The 1960s were the glorious age of large-scale, ‘economy-wide’ macroeconomic models, which enabled forecasts and simulations of the quantitative effects of certain policy changes within systems of simultaneous equations of economic aggregates.<sup>5</sup> The “multi-sector growth model,” first published by Johansen in *A Multi-Sectoral Study of Economic Growth* (1960), fits neatly into this set of models and the ways in which they framed a specific way of economic reasoning. Developed and ‘applied’ in the context of Norwegian macroeconomic planning, it is referred to as a pioneer-contribution to the techniques operating today under the name of “computable general equilibrium” (CGE) modeling.<sup>6</sup> Even the main protagonists of new classical macroeconomics and real business cycle theory (commonly portrayed as *the* opposing theoretical school to so-called Keynesian economics) include the multi-sector growth model as part of their pedigree.<sup>7</sup> In contrast to stories of big theoretical breaks and shifts in economic ideas, it is well suited for exploring the continuities of ‘applied models’, which were constructed in the postwar period based on prewar visualizations of the economy, and which remain active until today. The paper traces the movements and changes of the multi-sector growth model from the *Multi-Sectoral Study* to its implementation in Norwegian macroeconomic planning to contemporary CGE modeling in order to reflect on the resilience of models via two interrelated themes:

*Bricolage.* While part of a historical configuration of discourses and practices that separated and stabilized two distinct domains of knowledge, the clear-cut lines between ‘pure’ mathematical

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<sup>3</sup> Johansen (1965, 5). On economic planning as a realm of rational organization based on econometrics, see, for instance, Dütte and Weintraub (2014, 467).

<sup>4</sup> On the interrelation between the making of new artifacts, creating new concepts, and establishing tools for governance, see Morgan (2012) and Boumans (2005). The past decade has seen a variety of works dealing with the making of the economy. Whether from the point of view of global history, critical theory, economic sociology, or science studies, these contributions deal with the entities and techniques inscribing the economy and concurrent phenomena like growth or global inequality in governmental routines, business procedures, and everyday practices. See, for instance, Mitchell (1998, 2005, 2014), Desrosières (2002, 2003), Breslau (2003), and Speich Chassé (2013).

<sup>5</sup> One of these was the 20-equation-model of Lawrence Klein and R. Goldberger built in 1955, which, by the 1970s, had been extended to several hundred variables and equations. The 1936 model by Jan Tinbergen is usually presented as the first macroeconomic model in the history of economics (Boumans 2004, 261). For a survey of macroeconomic modeling, see Bodkin et al. (1991); for an analysis of different kinds of macroeconomic models, see Valadkhani (2004).

<sup>6</sup> For appreciations of Johansen’s work, see Sandmo (1983) and Solow (1983). Most recently, the *Journal of Policy Modeling* published a special issue commemorating Johansen (1960): Bjerholt et al. (2016). With regard to computable and applied general equilibrium modeling, Ballard and Johnson, this volume, differentiate between highly formal general equilibrium frameworks, which were used to investigate the “welfare effects of stylized policies” on the one hand, and models, which measured sectoral changes in employment, prices, and incomes on the other. The latter, closely related to national accounting and input–output work, relied on Johansen’s design and are treated in the last section.

<sup>7</sup> Kydland and Prescott (1991, 168).

theory and its ‘applications’ get blurry when we look at modeling as the making of new artifacts.<sup>8</sup> The multi-sector growth model hereby becomes the object of the reciprocal shaping of mathematical techniques, empirical data, bits of economic theory, institutional arrangements, the aims and hopes of economic planning, images and visions of ‘the economy’, and the practical requirements and affordances of computing technologies. The first two sections of this paper focus on its build-up, inner workings, and local character in order to explore the kind of reasoning such an applied model nurtured. As a rather peculiar combination of input–output tables, macroeconomic accounting frameworks, and neoclassical modeling work, it visualized the economy on new dimensional and temporal scales, which in turn provided long-term perspectives for planning. Sections three and four follow the transformations of the model when being integrated in a computerized “system of models” for Norwegian macroeconomic planning by the end of the 1960s.

*Infrastructures of Planning.* The Norwegian “system of models” was a central component of an institutionalized infrastructure for planning, which further obscured the simple dichotomies between theory and data, between modeling work and practices of governance.<sup>9</sup> This infrastructure decisively molded the daily procedures of decision-making, framed the goals of economic policy, and created the whole sphere as an applied field of economics. Bringing together models, computers, data, people, and institutions, it , brought about specific kinds of expertise, urged changes in office space, and forged governance as a matter of rational organization. In this framework, the multi-sector growth model became the standard device for forecasting. Open to continuous remodeling and reinterpretation, its basic set-up remained resilient and its epistemic authority persisted independently of which Norwegian parties were in power.

The story of the multi-sector growth model not only fits with an account of policy-making in the Norwegian welfare state, but also contributes to a more general history of the technologisation of governance. Due to its specific features the model’s architecture circulated outside Norway from the mid-1970s on—the very time when large-scale Keynesian macroeconomic models encountered widespread criticism. Moving from the context of macroeconomic planning and detailed data-work

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<sup>8</sup> Lévi-Strauss’ concept of “bricolage” refers to the features of knowledge-making as a practice that does not follow a specific order but is shaped by the material it engages (1966). Using the concept for the realm of financial economics, MacKenzie (2003). On economic modeling as trial-and-error recipe-making, in which the economist mixes together various ingredients and uses a mathematical formalism as a homogenizer, see Boumans (2005). On economic models as artifacts, which are created from existing material, prompt new concepts, and afford certain kinds of reasoning, see Morgan (2012). For akin perspectives on the active potentials of models in the sciences and the arts, see, for instance, Knuuttila (2005) and Wendler (2013).

<sup>9</sup> In the present paper, “infrastructure” relates to the sociotechnical, both physical and conceptual, basis of macroeconomic planning akin to the way the term is used in Bowker and Star (1999), who investigate the fundamental basis of infrastructures such as classification schemes, and Edwards (2003), who presents the study of sociotechnical infrastructures such as telephone services and computer networks as a way of linking the study of practices on a micro-level with the analytical macro-level of modernity theory. On a discussion of the use of the term infrastructure with regard to economic policies, see Hirschman and Berman (2014). They describe economists’ policy devices parallel to the literature on the performativity of market devices, which “bring together people, knowledge, and material things in ways that turn the messy, endlessly complex world into a formal, calculative order that can be used productively” (18). See also Berman (this volume) investigating how the discipline became part of the “cognitive infrastructure” of policy-making. An earlier contribution to the literature on economic models as policy devices, which builds on the view of models as mediators, is Den Butter and Morgan (2000). They interpret empirical models as bridges “between the positive and normative domains of economics.”

into easily applicable software packages used by international organizations, government agencies, the private sector, and academy, the following pages illustrate the triumph of ‘applied economics’ by way of the transformations of a model that prevailed.

## 1. Design and architecture of an ‘applied model’

Johansen’s published dissertation presented an ‘applied model’, intended to help “to make decisions and take actions” in the pragmatic organization of macroeconomic planning.<sup>10</sup> In pages full of equations, descriptions of the model architecture, and huge fold-out tables of numbers, the *Multi-Sectoral Study* laid out ‘the Norwegian economy’ as a system of simultaneous equations with an input–output core and argued for the trustworthiness of the knowledge it provided. What were the questions such an ‘applied model’ afforded, the actions it provoked, the visions it nurtured, and the kind of reasoning it forbade? As is common in the presentation of ready-made knowledge artifacts, the book averted from the meanderings, failed intentions, and surprising moments of model construction. However, its narrative structure still offers an exposition of the various layers of the model: the first layer was a rather scarce mathematical design, which presented the very basic equations along which the model worked and made explicit the assumptions necessary for it to work. The more complex model architecture presented the full-scale artifact and hinted at the many intricate steps, and the role of conventions and judgments that bringing together mathematics, data, computers, and visions of planning necessitated.

Looking back on a long and rich history of state-led data collection, Norwegian concepts and practices of economic governance in the postwar period primarily related to the coordination of the national budget as the main “tool for decision making” and “the design of policy.”<sup>11</sup> Established by the Labor government after the country’s liberation in 1945, it was part of a broader set of social planning endeavors in reconstructing the economy and creating a welfare state. As an appendix to the Central Government Budget, its format enabled to estimate alternative scenarios for the quantitative analysis of concrete policy situations in terms of the national accounts (national aggregates of production, consumption, and investment, the balance of payments, and, a Norwegian particularity, input–output tables) hereby providing the very basis for planning.<sup>12</sup> Directly located at the Norwegian Ministry of Finance—which, in contrast to other countries, not only looked after the fiscal budget but also had a supervisory role in economic governance—the Central Bureau of Statistics (CBS) created and updated the national budget and the models and measurements that would supplement it. The work

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<sup>10</sup> Johansen (1960, 3).

<sup>11</sup> These are the words of one of the economists, who were central in establishing this form of macroeconomic planning, Bjerve (1959, 24).

<sup>12</sup> The first national budget of 1945, for instance, presented different means for achieving the goal of rapid reconstruction (Bjerve 1970, 1). See Lie (2002) on the history of data collection and planning in Norway in the late nineteenth century. On the history of national accounting in Norway, see Bjerkholt (1995), and more recently, Lie (2007), who contrasts the Norwegian system of accounts with the “Anglo-American approach,” which was adopted as the international standard in the early 1950s. Vanoli (2005) elaborates on the differences between national accounting procedures in Norway and Sweden and international standard based on Richard Stone’s framework.

was mostly done by economists from the Institute of Economics at the University of Oslo, founded by Ragnar Frisch at the beginning of the 1930s.<sup>13</sup> Frisch, a key figure in the history of economic quantification and modeling and co-founder of the *Econometric Society*, is generally credited for initiating work on Norwegian national accounts and for providing the main conceptualizations of Norwegian planning as the “co-ordination of decisions taken within a large administrative system.”<sup>14</sup> Here, planning referred to the processes of decision-making, which, so Frisch’s conviction, was to be based on a scientific economic basis.<sup>15</sup> One of the Institute’s graduates was Leif Johansen. As a research assistant for both Frisch and Trygve Haavelmo, another major contributor to the foundations of econometrics, he was steeped in a style of economic reasoning that thoroughly interrelated planning with linear programming, input–output analysis, econometric techniques, and economic statistics.<sup>16</sup> Eventually, in 1960, his dissertation, which contained the multi-sector growth model, was published as one of the renowned North-Holland’s *Contributions* edited by another pioneer econometrician and first managing director of the Dutch Centraal Planbureau, Jan Tinbergen. The model, in its constructor’s words, “describe[d] simultaneously the relative production growth rates of the various sectors, the allocation and reallocation between sectors of basic resources, changes in sectoral terms of trade and changes in the composition of consumption during a process of economic growth.”<sup>17</sup>

The starting point of the *Multi-Sectoral Study* was the exposition of a “one-sector model,” which might be called a ‘theoretical model’. However, as Johansen somewhat apologetically noted, the model could not keep up with the mathematical sophistication that the contemporary economic literature on growth had to offer. It was “unsatisfactory when judged from a purely theoretical point of view.”<sup>18</sup> Since the 1930s, related to the idea of national economic manageability, a variety of growth models had been developed to ‘explain’ the “long-term trends” visualized in empirical studies based on national accounts.<sup>19</sup> Johansen referred to the highly formal systems of proposition and proof, which resulted from merging the wartime techniques of activity analysis and linear programming with what was seen as conventional neoclassical economics. These accounts formulated and proved the mathematical existence of a “uniform” or “balanced growth path” of systems of sectors in a long-run

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<sup>13</sup> On the specificities of theory and practice of Norwegian economic planning, see Van den Bogaard (1998), who compares the Norwegian and French with the Dutch “planning package” before World War II, meaning the intricate combination of models, measurements, and institutional procedures. For an example of Norwegian social engineering, see Lezaun (2011) on experimental programmes for establishing democratic structures in the organization of production.

<sup>14</sup> See Bjerkholt (1998, 318). On Ragnar Frisch’s conceptualization of national accounts, see Dupont-Kieffer (2012a).

<sup>15</sup> On Frisch’s views on the combination of “theory and observations in economics” as the basis for social engineering (as opposed to institutional and historical approaches), see Frisch (2010 [1930]); on his concepts for (indirect) macroeconomic planning on a ‘scientific basis’, see Dupont-Kieffer (2012b).

<sup>16</sup> Johansen (1930–1982) also spent the academic year 1958/59 at two of the most prestigious sites of macroeconomic planning, the Netherlands School of Economics and the Department of Applied Economics at Cambridge University. The latter would soon house the Cambridge Growth Project, developing a computable model of economic growth akin to Johansen’s (Stone 1964). On Johansen’s early research work with Frisch and Haavelmo, see Bjerkholt (2009, 107–111).

<sup>17</sup> Johansen (1960, 3–4).

<sup>18</sup> Johansen (1960, 1). For a more detailed account of Johansen’s treatment of growth theory, see Bjerkholt (2009, section 4).

<sup>19</sup> Economists developed models with two or three sectors to investigate the different development of these industries during a ‘growth process.’



equilibrium.<sup>20</sup> In contrast to their mathematical rigor, Johansen's construction was intended to contribute to the arsenal of technologies used for economic governance and therefore had to have the right shape to fit the available data from the Norwegian national accounts as well as local computing capacities. In this sense, the simple one-sector model of the first chapter of Johansen's book provided a mathematical design for the larger construction rather than an independent 'theoretical' growth model. Scaled down to one sector (instead of the several industries of the full model build-up), it laid out the basic workings of the model and made explicit the assumptions and the binding rules according to which the larger-scale system would work.<sup>21</sup>

This mathematical design was based on modeling and accounting conventions. Among its most important rules was a macroeconomic accounting balance, meaning that, just as in the national accounts, the amounts produced, consumed, and distributed in the whole system had to agree. Moreover, the equations for production were specified along the lines of the so-called "neoclassical growth model."<sup>22</sup> Based on the assumptions of perfect competition and full employment, the model featured a long-run self-sustaining growth equilibrium: if the growth rate of capital increased, then the growth rate of output initially increased as well, but in the long run returned to its equilibrium value.<sup>23</sup> Regarding the temporal scale, all the variables making up the design-economy were written down as functions in "time"—Johansen's scare quotes pointed the reader to the somewhat 'timeless' character of his differential equations excluding all kinds of contingencies, instabilities, and frictions from analysis.<sup>24</sup> The one-sector design served several purposes. Since it established the correct relations between the variables, Johansen investigated it as a didactic device in order to demonstrate the very basic workings of the model. The design also provided a kind of benchmark. Deviations between the numerical simulations results and the mathematical design were part of the interaction between modeler and the artifact. In the course of the book, the author came back to this first chapter several times, both to make some of the complexities of the larger-scale construction more intelligible and to assure the reader of the proper 'behavior' of the larger-scale model. When the larger-scale model did not behave as expected from the design, this motivated inquiries into the database and further scrutiny of the architecture of the larger-scale model.

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<sup>20</sup> Von Neumann ([1937] 1945–46) presented a complete linear input–output model of an expanding economy; Malinvaud (1953) worked on the formulation of a dynamic general equilibrium; Dorfman, Solow and Samuelson (1958) showed how to select the "balanced growth path," which would maximize "the economy's" growth rate. For an insightful analysis of time discounting in growth models, see Duarte (2016).

<sup>21</sup> The notion of simple mathematical models as tools for constructing larger-scale models can be found at different places in the contemporary econometrics literature. "The study of the simpler models is protected from the reproach of unreality," Tjalling Koopmans had noted a few years earlier in *Three Essays on the State of Economic Science*, "by the consideration that these models may be prototypes of more realistic but also more complicated subsequent models" (Koopmans 1957, 142–143).

<sup>22</sup> Johansen (1970, 71), see also Johansen (1977, 267).

<sup>23</sup> Solow (1956). On the construction and uses of Solow's model, see Halsmayer (2014). Johansen complemented the production-side of the neoclassical design model with a demand-side comprised of variables denoting private and government consumption, exports and imports of "the rest of the world" (Johansen 1960, 24). Solow's model did not incorporate trade.

<sup>24</sup> Johansen (1960, 24).

The subsequent chapter of the book contained the “formal structure,” that is, the complete architecture of the multi-sector growth model. Here, the narrow design was further adapted to the local conditions of macroeconomic planning. In fact, the very innovation of Johansen’s growth model—that it consisted of several sectors instead of only one, two, or three sectors as common in growth models at the time—was afforded by the Norwegian administrative specificity that input–output tables were integrated in the national accounts long before they became part of the international UN standard in 1968.<sup>25</sup> Input–output data was an important basis for economic planning. While national accounts were essentially concerned with over-all figures (i.e., the production of so-called ‘final goods’), input–output tables visualized ‘the economy’ on a smaller scale as a system of interrelated sectors, which produced goods and used ‘intermediate goods’ in production. Input–output tables equally built on an accounting balance, portraying the national economy as a system of production flows: all inputs were used for production and all outputs either went into production as inputs or were sold. Freed from their material shape, capital expressed in value terms moved freely between various industries, households, and the government sector.<sup>26</sup> The full build-up of the multi-sector growth model replaced the one sector of the design with a system of 22 production functions—manufacturing industries, agriculture, fishing, construction, etc. As common for input–output analysis, the sectors were connected through fixed coefficients, i.e., that the relations between inputs and outputs were determined by the data points in the tables and were not part of a mathematical optimization problem. Apart from the input–output extension, the rest of the model kept the structure of the neoclassical design: other than intermediate capital and labor inputs were perfectly substitutable, so that each sector maximized profit; demands were guided by utility maximization.<sup>27</sup> The model architecture consisted of a table with 86 *linear* equations, because existing computing techniques required the linearization of equations in growth rates of prices and quantities. Following the design’s accounting rule, total output of the production system had to equal total investment plus total consumption, the values of which were assumed to be determined exogenously.<sup>28</sup> As in the design model, the system included differential equations; inserting the relevant parameters resulted in relative growth rates for all variables.

This economy functioned like a perfectly organized firm. Capable of producing various mixes of final goods while efficiently allocating capital and labor between sectors, the productive system smoothly adapted to changes in exogenous factors. The growth of the system was equally frictionless:

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<sup>25</sup> About a decade before Johansen worked on his model, the “national income calculation”-division at the CBS had introduced input–output relations in the national accounts; the first input–output table was published for the year 1948, see Bjerkholt (1995, 323-325). See also Lie (2007).

<sup>26</sup> Essential for input–output-based planning models is Wassily Leontief’s open model (1944). On the making of the first fully developed input–output tables at the Harvard Economic Research Project under Wassily W. Leontief, see Kohli (2001); on Leontief’s earlier work on input–output, see Bjerkholt and Kurz (2006); on input–output as “applied economics,” see Biddle and Hamermesh (this volume).

<sup>27</sup> Demand was modeled according to Frisch’s “complete scheme.” For more comprehensive accounts of the model architecture, see Bjerkholt (2009, section 5).

<sup>28</sup> The production side of the model consisted of 86 endogenous variables, including investment, employment changes, changes in the total production for each sector, and changes in relative prices or terms of trade between sectors. The demand side consisted of 46 exogenous factors, i.e. the total demand including total investment, population growth, productivity changes, and changes in exogenous demand.

while the 22 sectors of Norwegian input–output tables did not grow in proportion but according to the way their structural characteristics were modeled, the economy *as a whole* developed along a stable “development path.”<sup>29</sup> It featured the same comparative statics as the neoclassical growth model and, with the structure of the input–output system fixed, “disregard[ed] systematic changes over time in tastes, in income distribution and in the social stratification of the population.”<sup>30</sup> Following the book’s narrative, once the “model as a whole” was established, it could accommodate data from the Norwegian national accounts.<sup>31</sup>

## 2. Implementing the model: numbers, computers, and institutions

Using the model architecture for conducting simulations, arguing for the trustworthiness of the numerical results, and pondering the possibility of making the Norwegian economy more akin to the model, the *Multi-Sectoral Study* provides an example for the ways in which models serve both as numerical visualizations and governmental visions. The tedious work necessary to arrive at the clean figures of the book and to contend their representative value can only be guessed from some minor notes in the pages. For one, “numerically implementing” the model might sound like a straightforward procedure, but required further forging of both model and numbers, involved practical obstacles to the intentions of the modeler, and drew on subjective deliberation. Filling the production system with data from input–output tables required the choice of a specific year from which multi-sector simulations started to run.<sup>32</sup> The *Multi-Sectoral Study* fixed the “middle of 1950” as a base point in time, which somewhat lent itself to the model, since that year offered the most comprehensive collection of input–output data. Nevertheless, Johansen also argued for the analytical appropriateness of using these figures and hereby for the representative legitimacy of his model: 1950 “might be regarded as a normal year, post-war reconstruction being more than fulfilled in most branches, the most important scarcities being removed and yet by 1950 no considerable unemployment had occurred.”<sup>33</sup> Apart from *reinterpreting* 1950 as a balanced state, ‘material’ adaptations were necessary to fabricate a fully-functioning numerical model. With a view on the capabilities and restrictions of later computational work, the scale of the system had to be reduced and Johansen aggregated some of the sectors. Moreover, the available data sets, the “observed value[s],” as the modeler introduced them, posed problems. For estimating exogenous variables, given national account data had to be edited in order to be filled into a matrix that fitted the form of input–output figures.<sup>34</sup> “[T]he ideal data would be two or more input–output tables,” Johansen bemoaned the practical limitations of his modeling work,

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<sup>29</sup> Johansen (1960, 172). That sectors were allowed to develop differently was the decisive feature differentiating Johansen’s from contemporary growth models.

<sup>30</sup> Johansen (1960, 21).

<sup>31</sup> Johansen (1960, 51).

<sup>32</sup> For more analytic accounts of simulations, see Gramelsberger (2011) and Morgan (2012, chapter 8). The following reflections developed in exchange with Decker (2013) on modeling and simulations in climate science.

<sup>33</sup> All: Johansen (1960, 60).

<sup>34</sup> Johansen (1960, 55).

“covering a time interval of, say, ten years or more, in which there was full employment and no idle capacity.”<sup>35</sup> Norwegian planning models did not pursue such a long-term perspective; the figures were not available and, because the purpose of the operation was to provide knowledge for macroeconomic planning, Johansen had to give up his initial aims, settled for the existing data, and remodeled the system accordingly. He admitted that for some model parameters for which it was too laborious to create estimates, or for which no numerical material was available, values were assigned based on the modeler’s personal judgment. “For these we have to rely on intuition.” The book does not give any hints how values were assigned to these parameters, what knowledge or experience were involved, which colleagues Johansen deliberated with, which other data sets he consulted, whether there were certain rules of thumb or conventions considered; “intuitive judgement,” however, was essential.<sup>36</sup>

With the base-year data shaped and the matrices filled, the system of numerical production and demand functions could be solved. The “solution matrix” provided 3,956 entries, the growth rates of all endogenous variables in terms of the growth rates of the exogenous variables. This means that the matrix showed how relations between sectors changed in the case of exogenous changes. Taken as a whole, Johansen interpreted these figures “as indication of the directions of the trends in a ‘moving equilibrium’.”<sup>37</sup> The purpose of such an equilibrium was to ‘shock’ it and to observe what happened—in the comparative-static form of snapshots. After changing the value of one of the exogenous variables, the simulation traced the repercussions of such a shock via the elasticities given in the solution matrix. For the end of the 1950s, such simulations required rather advanced computing capacities; their realization depended on the affordances and restrictions that came with the available computing machines. The solution of Johansen’s dissertation model included inverting an 86 x 86 matrix—“probably the largest matrix which had been inverted in Norway by that time,” as the modeler recounted almost two decades later.<sup>38</sup> While the *Multi-Sectoral Study* not once mentions the necessary transformations of the model into an algorithm, it is mentioned that the computations were performed on the recently installed “computer FREDERIC,” a “Ferranti Ltd. Computer of the Mercury type” belonging to the Norwegian Forsvarets Forskningsinstitutt.<sup>39</sup> It was the only computer in Norway at the time, and had been given to the ministry of finance (where Johansen was employed) by the Norwegian Defense Research Establishment.<sup>40</sup> The use of the computer not only framed the model’s shape (restricting its dimension and requiring linearization) but also involved other people and made Johansen’s modeling project a collective endeavor rather than the solitary work of an individual researcher.

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<sup>35</sup> Johansen (1960, 131).

<sup>36</sup> Both: Johansen (1960, 60). On the role of expert judgment in measurement, see Boumans (2015).

<sup>37</sup> Johansen (1960, 53).

<sup>38</sup> Johansen (1977, 31).

<sup>39</sup> Johansen (1960, 122).

<sup>40</sup> See Bjerkholt (2009, 119n1). The University of Oslo, however, seems to have been rather up-to-date regarding the most recent computing machines. Before World War II, when the Massachusetts Institute of Technology sold copies of Vannevar Bush’s differential analyzer, one went to Oslo; see Campbell-Kelly et al. (2014, 49).

The disparity between the fictional character of the smoothly running model and the desire to prescribe policy measures became evident as Johansen strove to bring his own critique of the simple shape of his model into harmony with the argument that its forecasts were trustworthy. Comparing the numerical simulations results with the mathematical relations given in the design model should foster the model's "ability to explain and forecast the changing sectoral composition of an economy under a growth process." Checking simulation outcomes "with reality," to use Johansen's words, served the same purpose.<sup>41</sup> This reality consisted in another kind of visualization of economic growth, namely, already existing growth-, productivity-, capital-, and employment trends based on the national accounts. Such comparison entangled different temporal horizons—a supposedly well-described past with a calculable future—building on the assumption that the structure of "the economy" remained constant. To a certain extent, the time trends relied on the same assumptions as the model—a macroeconomic accounting balance, measuring in market values and hereby assuming marginal conditions. Hence, the comparison between simulation numbers and measured values effectively tested the conformity of the model with measurements. Whether the check was deemed positive, i.e., which margin of error was acceptable, relied, again, on conventions and deliberations. In the course of the book, Johansen's many arguments for and against the use of the model as a tool for planning resulted in the view that as long as its flaws were taken into account, the model's (conditional) forecasts would be "reasonably good."<sup>42</sup> In the end, in spite of the model's limitations, he cautiously recommended his dissertation model as a suitable means for political decision-making: "the data and the quantitative analysis do serve the purpose of illustrating the method and the model. But, at the same time, [...] I would (in the absence of more reliable results, and without doing more work) rely to a great extent on the data and the results."<sup>43</sup>

The so-created reliability of the model opened a discussion of the status and the political possibility of implementing the solution it presented. In contrast to general equilibrium frameworks, the accounting balance of the model did not describe an optimal expansion pattern *per se*. However, and this refers to the imaginary power of models, it visualized a possible world of full employment, which could be established and maintained if only the right policies were implemented. "I do see no reason why man should not be able to provide institutional conditions which would secure a continuous and balanced growth process with full employment of both labour and capital equipment."<sup>44</sup> The life-long, card-carrying member of the Norwegian Communist Party argued that "the experiment" in the USSR provided proof that such a growth process could be created. Reorganizing the national economy, in turn, affected the significance of the economic modeling

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<sup>41</sup> Both: Johansen (1960, 131).

<sup>42</sup> Johansen (1960, 170).

<sup>43</sup> Johansen (1960, 3).

<sup>44</sup> Johansen (1960, 19).

project: once the right institutions were established and the world made more like the artifact, the multi-sector growth model would have stronger forecasting power.<sup>45</sup>

Within a few years, the ambition of the politically active and technically gifted doctoral student to provide an ‘instrument’ that would create the knowledge necessary to make decisions and take actions in economic planning would be realized, though not as a straightforward application but rather in another process of shaping and reshaping.<sup>46</sup> In this process, the visionary world of Johansen’s growth model stabilized in administrative practices, and macroeconomic planning itself was conceptualized as ‘applied economics.’

### 3. A computerized ‘system of models’ for planning

Change of scenery. Labeled as the “MSG model,” Johansen’s artifact became one of the ‘applied models’ that made “Norwegian planning” somewhat of a trademark. Based on the close cooperation of several government offices and economics departments, Norwegian planning practices were characterized by a computerized system of models that thoroughly permeated “actual economic-political decision processes.”<sup>47</sup> Incorporating the model into this infrastructure of decision-making necessitated further modeling work, shaping both the MSG, the other components as well as the institutional setting. The starting point was set at the beginning of the 1960s, when the Norwegian Ministry of Finance appointed a “Modelling Committee” with the purpose to establish, as the former Norwegian Minister of Finance Petter Jakob Bjerve put it, a “system of several numerical models for carrying out macroeconomic planning.”<sup>48</sup> Embedded in the regular administrative and policy-making activities, this formation of big-letter-acronym-models coordinated the national budget, essentially structured policy-making, and required serious efforts by different actors from bureaucratic offices, research departments, and various interest groups to make the system work smoothly.<sup>49</sup> The “MSG-2F” provided the first estimates of production growth rates of the various sectors in 1968; in the course of the following decades, several versions of the model developed.<sup>50</sup> The MSG effectively integrated long-term planning perspectives into traditional four-year programs. At this point, contemporary and retroactive statements of practitioners (instead of a detailed study of commission minutes, programming codes, and policy papers) need to suffice as pointers as to the ways in which the model-

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<sup>45</sup> Johansen (1960, 169–170).

<sup>46</sup> Bjerkholt (1998, 331) notes that, while the model was not directly “designed for government use,” in the course of working on his dissertation Johansen was in contract with “the Ministry of Finance about the possibility of using the model for the Long-Term Programme 1962–1965.”

<sup>47</sup> The volume *Economic Planning in Norway* (Johansen and Hallaråker 1970) is witness to the international profile of “Norwegian Planning.” Two years before it had already been published as a special issue of *Economics of Planning*.

<sup>48</sup> Bjerve (1976, 6). The Committee consisted of representatives of the Ministry, the Institute of Economics at the University of Oslo, the Research Department of Statistics Norway, and in the course of the following decades added representatives of new modeling institutions, the Norwegian Central Bank, and the School of Business Administration. See Bjerkholt (1998, 334).

<sup>49</sup> Johansen (1977, 267), see also Bjerkholt (1998, 332), who notes that the interaction between model and interest groups “resulted in successive rounds of model enhancements.”

<sup>50</sup> See Bjerve (1976, 19).

based infrastructure formatted bureaucratic procedures, the basic categories of policy-making, and, after all, established and stabilized macroeconomic planning as an applied field of economics.<sup>51</sup>

Within the system of models, the MSG's task was not directly to provide knowledge for planning but to create long-term projections (capturing several decades) for short- and medium-run planning models. Its specific assumptions and sector specification therefore had to adapt to those of the central Norwegian model, the MODIS (Model of Disaggregated type), involved in preparing forecasts and simulations for the national budget since 1961.<sup>52</sup> Both MODIS and MSG were based on national accounts; both included an input–output structure, assumed exports and investments exogenously, and excluded money and credit; both presented ‘impact tables’ showing the effects of changes in exogenous variables on the input–output economy.<sup>53</sup> National account data and models interacted with each other and if one changed, the other components adjusted. For instance, when Norwegian accounts were redesigned in order to integrate the UN Standard of National Accounts of 1968, MODIS also had to be remodeled.<sup>54</sup> Equally, the construction and concepts of more detailed planning projects like projections of regional developments had to be adapted so that they could be linked with MSG projections. Institutions that took part in MSG modeling were, for instance, the Institute of Transport Economy and the National Energy Commission. Both contributed forecasts for exogenous variables and employed ready-made MSG projections in their own projects of forecasting and planning the transport system and power production, respectively.<sup>55</sup>

The stabilization and harmonization of the model system of Norwegian planning came with a change in institutional structures and the reorganization of office space. To meet and nurture the close interaction of planning technologies, the units for model construction and national accounting settled in the same department within the Central Bureau of Statistics, even on the same floor. When Odd Aukrust, at the time research director of the Central Bureau of Statistics, recounted the benefits of the reorganization, he mentioned that the immediate access to data turned the “annual updating of the model” into a “simple routine job.” Moreover, “to the national accountant it means feedback effects” for making national account data fit the models as neatly as possible. Among the advantages Aukrust listed, was also that both time series data as well as model results were readily available to “the planner or model user.”<sup>56</sup> Reminiscent of the recent boom in electronic computers and computational reasoning, the metaphoric language of ‘updating,’ ‘feedback effects,’ and ‘users’ hints at the intricate

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<sup>51</sup> The analysis of the next few pages builds on Bjerve (1959, 1976), the contributions to Johansen and Hallaråker (1970), Johansen (1977), and Aukrust (1978). See, in particular, the very comprehensive Bjerkholt (1998) on the interactions between Norwegian modelers and policy makers, republished in Den Butter and Morgan (2000).

<sup>52</sup> Bjerve (1976, 19–20).

<sup>53</sup> Johansen (1977, 213). On a detailed description of the various stages of MODIS, see Aukrust (1978). Among the other models that were integrated in the course of time were the PRIM (Price and Income Model), directed at income policies, several “taxation models,” and KRØSUS, a Central Bank model. See Johansen (1977, 214).

<sup>54</sup> See Bjerkholt (1998, 329).

<sup>55</sup> Johansen (1970, 108).

<sup>56</sup> Aukrust (1978, 76–77).

entanglement of large-scale economic modeling, the development of programming techniques and computing machines.<sup>57</sup>

At the end of the 1960s, when the first MSG forecasts were developed, computers were very large, very expensive mainframes, which, predominantly funded by state institutions, required special sites and essentially structured the daily practices of those working with numerical models. In addition to pencil-and-paper work at the desk, they prepared cards with punching equipment and electric calculating devices, operated large computing machines or, more likely, gave the stack of punched cards to computer operators, and waited for results.<sup>58</sup> MSG forecasts were calculated with a UNIVAC 1107, provided by the Norwegian Computing Centre. “[A]s the program is now,” Johansen noted, “it takes 10–20 minutes to calculate the full solution from 1963–1990 by steps of three years.”<sup>59</sup> Enthusiastically, participants celebrated the new and ever-increasing computational capabilities. Aukrust recalled how the new UNIVAC improved simulations: “[T]he planners were given an option of studying simultaneously, with moderate extra costs in terms of computer time, one master policy alternative and as many as nine partial deviations from the master plan.”<sup>60</sup> New computers, Johansen stated retrospectively, enabled “computations of scales and with speeds which would be judged as science fiction a few decades ago.”<sup>61</sup> Models rendered “the economy” a system of simultaneous equations and provided the basis for algorithms for the new computing machines to create numerical simulations and forecasts. Computerized time-stepping procedures brought the growing economy presented by the MSG model to life and showed its “development path” in ever-increasing detail, range, and complexity. More efficient computation programs afforded an extension of the scale of the models, integrating more intricate developments of exogenous variables over time, and thereby allowing the model to simulate an ever-increasing variation of policy scenarios.

Apart from the role of computing techniques in framing and strengthening a certain way of seeing the economy, they decisively shaped the process of macroeconomic planning itself. For one, a computerized model infrastructure required different personnel than earlier approaches to macroeconomic planning. Regarding the 1970 forecasting project, for instance, Johansen mentions by name “Mr. Sverre Spurkland of the Norwegian Computing Centre, who has been engaged by the Planning Division of the Ministry of Finance for this special task.”<sup>62</sup> Compared to the times when the national budget was the only policy tool of macroeconomic governance, computerized modeling not only changed the vocational composition of the administration but also required different skills in already-existing employees. Once MODIS and MSG were adapted in the standard planning process, the Ministry of Finance established courses for training its staff and the relevant personnel of other

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<sup>57</sup> For the normalization of cybernetics in the late 1960s under the guise of computation, see Kline (2015).

<sup>58</sup> See Campbell-Kelly et al. (2014, xiii).

<sup>59</sup> Johansen (1970, 109).

<sup>60</sup> Aukrust (1978, 70).

<sup>61</sup> Johansen (1977, 18).

<sup>62</sup> Johansen (1970, 110). Spurkland programmed a special program, which calculated the development of various endogenous variables as a combination of linear and non-linear equations in steps of three years.



ministries in handling these models. In his report on macroeconomic planning practice, Aukrust described the model-based preparation of menus for policy-making as a division of labor among experts: “there are specialists charged with the responsibility of providing [...] up-to-date estimates of various categories of exogenous input to the model. Other staff members are trained in the operations needed to prepare the input data for the computer or in editing the output data for use in the administrative process.”<sup>63</sup> Ever more complicated models and computational routines required operators maintaining the machines, feeding data in a format that fitted the programs, and programming the simulations.

Economists were engaged in all steps of these processes and, moreover, had the important role of presenting results to policy-makers. As interpreters, they told stories in order to make intelligible what happened in the model, often with the help of neat visualizations—also enabled by the new computers—, which presented model calculations “in a more convenient way.”<sup>64</sup> In this vein, actors have described computers as a central driving force in convincing non-economists engaged in planning processes of the usefulness and necessity of model reasoning through performing most complicated calculations and illustrating them via simple graphs.<sup>65</sup> The required intelligibility of the model, in turn, affected the kinds of models chosen. Non-economists, trade unions representatives, employers’ associations, etc., for instance, abandoned MODIS II in preparing the fiscal budget in favor of a smaller and simpler model. The subsequent MODIS III, was a “more ‘user-friendly’ version,” which, in turn, motivated the Ministry of Finance to make policy-making processes “ever more model-oriented” and to adopt MODIS as the regular model for updating national budget forecasts.<sup>66</sup> Not least, economists were the ones to provide the “experience, intuition, and information not taken into account by formal models,” which, however, emphasizes the extent to which macroeconomic planning was characterized as a matter of experts, of organized decision-making on the basis of social scientific techniques.<sup>67</sup>

#### 4. Macroeconomic planning as ‘applied economics’

The establishment of an interactive computerized model infrastructure changed the procedures and the perspectives of macroeconomic planning. Its protagonists compared the system of models to the time when planning referred only to the national budget and the national accounts and deemed that quantitative planning now showed a “clearer program character.”<sup>68</sup> The model infrastructure provided a new way of conceptualizing macroeconomic planning as a process of administrative decision-making: it was not about deliberating goals and aims, but rather consisted in methods and techniques

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<sup>63</sup> Aukrust (1978, 75).

<sup>64</sup> Aukrust (1978, 70).

<sup>65</sup> On the many ways in which computers impacted on economics; see Backhouse and Cherrier (this volume).

<sup>66</sup> Aukrust (1978, 72–73).

<sup>67</sup> Johansen (1977, 35).

<sup>68</sup> See Bjerve (1970, 22), who also mentioned a stronger emphasis on the longer term (due to the implementation of the MSG) and the more comprehensive character of macroeconomic planning.

intended to visualize the consequences of pursuing various goals and aims in different ways, and was regarded as independent of the larger political setting. It could serve the interests of “a central power complex,” “one particular class of society,” or “striking a sort of balance between the different interest groups or classes.”<sup>69</sup> Planning, in this sense, was essentially an organizational task—on the level of the scientifically-based management of an economic balance but even more so on the level of the planning process itself, which, in the most rational way possible, should reach a balance between the participants. One of the figures provided Johansen’s internationally received and widely read *Lectures on Macroeconomic Planning* (1977) shows the interaction between macroeconomic medium-term plans (the “four-year programmes”), short-term plans (national budgets), and various projections and plans for individual sectors. Reminiscent of cybernetic systems, dotted lines denoted “flows of information” between the components of this “planning system.”<sup>70</sup> The rationale behind the figure seems similar to that which Johansen attributed to his growth model. Since political decision-making was hardly a rational or autonomous process (akin to the national economy being not an efficient market), formalized planning schemes (like models for the economy as a whole) provided a blueprint of what the object in question might look like once it had been improved through better organization.<sup>71</sup> Apart from technical improvements (“a large system of interconnected electronic computers”) and new modeling techniques (involving “rational behavior under uncertainty,” information and communication theory, general systems theory, etc.), an arsenal of ever more elaborate techniques in the social sciences would improve communication between planning theorists and policy-makers and organize compromise between disagreeing experts.<sup>72</sup> All these techniques and tools would improve the “at present rather weak” flows of information between the nodes of the diagram.<sup>73</sup>

Additionally to structuring planning practices and conceptualizing political decision-making as an administrative process, the system of models determined the very object to be governed, the ‘economy as a whole’ as an aggregate entity consisting of an interrelated system of industries. Accordingly, Johansen identified planning with the “development in the short and the long run of the entire economy of a country, more or less subdivided into sectors.”<sup>74</sup> In presenting the economy as a manipulable ‘what-happens-if’-system of equations and in forecasting the development of this national whole into a calculable future, these models, after all, determined the aims and values of macroeconomic planning. Based on the assumptions of the efficient utilization of resources and

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<sup>69</sup> Johansen (1977, 50).

<sup>70</sup> Johansen (1977, 215). On cybernetic ideas of economic management, see Mirowski (2002) and Tanner (2008); on Chile’s Project Cybersyn, see Medina (2011) and Pias (2005).

<sup>71</sup> This, however, did not mean that Johansen thought it was actually possible to establish a perfectly-organized policy-making procedure. Several times, both in *Public Economics* and in the *Lectures on Macroeconomic Planning*, Johansen highlighted that political processes were determined by “the social mechanism of selection of leaders of state [...], their knowledge or lack of knowledge when taking decisions” (Johansen 1965, 6–7).

<sup>72</sup> Both: Johansen (1977, 216). In the course of the book, Johansen emphasized in particular the high value of the Delphi method (Johansen 1977, 106) and game-theoretic policy models (Johansen 1977, 99, see his section 2.3). On various forms of establishing consensus between experts, including the Delphi method, see Boumans (2015, chapter six).

<sup>73</sup> Johansen (1977, 215).

<sup>74</sup> Johansen (1977, 3).

consumer sovereignty, Johansen openly noted, they promoted a kind of policy-making that gave priority to “total efficiency and the development of consumption” rather than “concerns for the income distribution, or for problems of urbanization versus preservation of rural settlements.”<sup>75</sup> Once the model system for macroeconomic planning was established, implicit assumptions consolidated and the values and goals embodied by the model were not further questioned.

## 5. The resilience of models

Once the Norwegian system of models was established, it apparently remained in place, changing political ideologies notwithstanding. “When the Labour Party surrendered power in 1965 after an unprecedented 20 years in government,” Olav Bjerkholt recounts in his portrayal of the history of Norwegian macroeconomic planning, “the transition to an anti-Socialist coalition went smoothly with practically no changes in the institutional system of economic policy making and presentation.”<sup>76</sup> While policies changed, the very model-infrastructure of macroeconomic planning and their ‘post-ideological’ aura endured. The multi-sector growth model not only survived political landslides but also critiques within the discipline. From the mid-1970s on, when stable growth gave way to the oil crisis and the recession, popular macroeconomic models came under attack for all the factors they excluded, in particular, the relationship between political steps and the actions and decisions of other time periods.<sup>77</sup> In contrast to the more fundamental critique of the economics profession for a lack of political relevance that picked up speed alongside the establishment of the New Left and the civil-rights movement, this criticism did not question modeling or model-based governance *per se*. Rather, it urged new designs and revised model architectures. Norway’s system, for instance, further increased in scale: at the end of the 1970s, MODIS incorporated 140 production sectors; and it persisted until 1993.<sup>78</sup> Versions of the MSG model are still active today; MSG6 incorporates a “detailed microsimulation model” with a system of ‘behavioral’ relationships. Decreased in scale (number of equations) but increased in dimensionality and complexity (microbehavior, dynamics), it is able to simulate the intertemporal effects of, for instance, energy policies or changing demographics.<sup>79</sup> As such, the Norwegian MSG model falls into the more recent category of CGE models.

Against the narrative of a decisive break in the 1970s, which suggests that macroeconomic models vanished together with Keynesian politics of demand management, following the traces of Johansen’s model provided an instance of the continuities in the format of ‘applied knowledge’ that

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<sup>75</sup> Johansen (1977, 51).

<sup>76</sup> Bjerkholt (1998, 323).

<sup>77</sup> Usually, these issues are ascribed to “the Lucas critique.” Lucas (1976) claimed that macroeconomic models could not account for reactions to changes in policies, i.e., adaptations of agents’ expectations and behavior regarding, for instance, a tax increase. On Lucas’ critique and reactions to it, see De Vroey (2016, part II) and Goutsmedt et al. (2015). On the new classical macroeconomics, the rational expectations movement, and microfoundations, see, for instance, Duarte and Lima (2013), and Hoover and Young (2011).

<sup>78</sup> See Bjerkholt (1998, 329).

<sup>79</sup> On the most recent version of the Norwegian MSG model, see Holmøy (2016).

economy-wide models provided.<sup>80</sup> By the end of the 1960s there were some early references to Johansen's in the context of planning outside Norway.<sup>81</sup> From the mid-1970s on, publications spoke of “a model similar to the one developed in Leif Johansen's *Multi-Sectoral Study of Economic Growth*”<sup>82</sup> or, later, even of a “Johansen-style CGE modelling.”<sup>83</sup> References and acknowledgments are utterances of credit; they do not show that Johansen's model was the ‘origin’ of a class of new models, not even that it was among the pieces of knowledge that these authors used to build their artifacts. However, if we refrain from looking for influences but rather focus on the shape of the objects used in policy-making, models such as Johansen's proliferated from the 1970s on—not despite the critique macroeconomic models encountered but accommodating the criticism.<sup>84</sup> Examples are the Australian model ORANI (later MONASH), which provided a system of simultaneous linear equations in changes of variables and the techniques to solve them in solution matrices, and the CGE models used by World Bank economists to measure the effects of policy changes in developing and transitional countries as changes in macro-balanced systems of equations based on the utility-maximizing behavior of agents.<sup>85</sup> Over time, CGE models afforded the formulation of ever more quantitative ‘what-happens-if’-questions, not only regarding diverse policy issues (such as immigration, pension funds, or mineral discoveries) but also with regard to very finely defined groups of interest.<sup>86</sup> This was enabled by the integration of new variables and by the development of new solution techniques, which in turn were related to the further increase in computing capacities. By the 1980s, these models had become quite large, getting into the million variables range, but could still be implemented on a personal computer.

The resilience of CGE is due to the various ways in which they can be extended. Sediments of earlier research, however, remained within all of these models' structures. Sharing a common design, these models portrayed the economy as a system of simultaneous equations characterizing the relations between agents (whether sectors, firms, institutions, households, etc.). Solving the system for various exogenous changes, they presented a matrix describing the response of endogenous variables.

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<sup>80</sup> De Vroey and Hoover (2005) delineate the persistence of IS-LM models see; on the continuities of macroeconomic models at the FED, see Brayton et al. (1997).

<sup>81</sup> An early reference to Johansen's model can be found in Stoléru (1968), presenting the long-term multisector model ANTOINE as “a Johansen-type model,” which was used for preparing the Sixth Plan of French macroeconomic planning. See Bodkin et al. (1991, 256n30). Bjerkholt et al. (2016, 417) provides references presenting Johansen (1960) as the first successful CGE model. See Ballard and Johnson, this volume, on the related history of “applied general equilibrium” modeling, which focused on the numerical exploration of mathematical general-equilibrium frameworks rather than the development of policy analysis.

<sup>82</sup> Taylor and Black (1974, front page) provide a “35-sector model of the Chilean economy,” which came out of research at the Harvard Development Research Group, funded by the Agency for International Development, the National Science Foundation and the Ford Foundation. The model was never numerically implemented but provided a point of departure for the CGE modeling literature.

<sup>83</sup> Dixon and Rimmer (2010, 5).

<sup>84</sup> In contrast to its more common aggregate counterparts, as Benjamin Mitra-Kahn (2008) has argued, Johansen's model was based on the assumptions of utility- and profit-maximization.

<sup>85</sup> On the history of ORANI, see Dixon et al. (2013, chapter 2) as well as Ballard and Johnson, this volume. For detailed arguments that CGE models (and even more recent AGE models) are not general equilibrium but macrobalancing models like Johansen's, see Mitra-Kahn (2008) and Taylor (2011). Akhbar et al. (2011) account for the historical relations between input–output and CGE modeling in the European context.

<sup>86</sup> Dixon et al. (2013, 27).

The model's basis, as delineated for Johansen (1960), remained compact and consolidated the key assumptions of flexible prices, clear markets, the efficient allocation of resources and some degree of consumer sovereignty. As such, the model reified specific values, which prepared the ground for a whole variety of policies assumed to belong to different ideological frameworks—from national, regional, and sectoral planning questions to monetary and fiscal policy-making, designs of greenhouse gas abatement, and deregulation policies in the context of the World Bank's Washington consensus.<sup>87</sup>

While the actors denoted models as 'tools' for decision making, the story of the multi-sector growth model illustrates the ways, in which so-called 'applied' models were much more than passive instruments. As part of infrastructures for policy design, models established the objects, procedures, and goals of economic planning. Economists' 'what-would-happen-if' devices and their glimpses into simulated futures acted upon administrative practices, impinged on ideas of governance, brought about specific forms of expertise, and urged new expectations regarding the manageability of capitalist societies. Recent history of science has argued that the "scientification" of society can neither be reduced to the distribution of ideas thought to be true nor to the spread of paper objects, books, or journals. Rather, the socio-technical infrastructures in which scientific knowledge was created had to spread simultaneously in order to equip objects of knowledge with everyday effectiveness, computability, and prognostic potential.<sup>88</sup> On this view, the resilience of economic models such as Johansen's might support an alternative narrative to the dissemination of economic ideas or the mere blackboxing of economic theories. Following the transformations, shifts, and movements of models could illustrate, how they not only symbolically created objects like the economy but propagated a quasi-material way of reasoning, seeing, and acting that substantiated the increasing power of economic concepts in the second half of the 20<sup>th</sup> century.

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<sup>87</sup> See Taylor (2011) on CGE modeling between macroeconomic planning and World Bank policies..

<sup>88</sup> See, for instance, Espahangizi and Orland (2016).

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