Introduction 9

The Keynesian macroeconomic theory developed in the 1930s and 1940s, in particular its representation in terms of IS- and LM-diagram, opened a new area in the application of statistical methods to economics. Based on the path breaking work by Tinbergen (1939) and Klein (1950) this research gave rise to simultaneous equation systems which should capture all relevant aspect of an economy. The goal was to establish an empirically grounded tool which would enable the politicians to analyze the consequences of their policies and thereby fine tune the economy to overcome or at least mitigate major business cycle fluctuations. This development was enhanced by the systematic compilation of national accounting data and by the advances in computer sciences.[1] These systems were typically built by putting together single equations such as consumption, investment, money demand, export- and import, Phillips-curve equations to an overall model. The Klein–Goldberger model for the United States was a first successful attempt in this direction (Klein and Goldberger 1955). Shocked by disturbances, Adelman and Adelman (1959) showed that these type of models exhibited cycles with properties similar to those found for the United States Economy.

As the model became more and detailed over time, they could, in the end, well account for several hundreds or even thousands of equations. The climax of this development was the project LINK which linked the different national models to a world model by accounting for their interrelation through trade flows (Klein 1985). Although this research program brought many insights and spurred the development of econometrics as a separate field, by the mid 1970s one had to admit that the idea to use large and very detailed models for forecasting and policy analysis was overly optimistic. In particular, the inability to forecast and cope with the oil crisis of the beginning 1970s raised doubts about the viability of this research strategy. In addition, more and more economist had concerns about the theoretical foundations of these models.

[1] See Epstein (1987) for an historical overview.

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The critique had several facets. First, it was argued that the bottom-up strategy of building a system from single equations is not compatible with general equilibrium theory which stresses the interdependence of economic activities. This insight was even reinforced by the advent of the theory of rational expectations. This theory postulated that expectations should be formed on the basis of all available information and not just by mechanically extrapolating from the past. This implies that developments in every part of the economy, in particular in the realm of economic policy making, should in principle be taken into account and shape the expectation formation. As expectations are omnipresent in almost every economic decision, all aspects of economic activities (consumption capital accumulation, investment, etc.) are inherently linked. Thus the strategy of using zero restrictions—which meant that certain variables were omitted from a particular equation—to identify the parameters in a simultaneous equation system was considered to be flawed. Second, the theory of rational expectations implied that the typical behavioral equations underlying these models are not invariant to changes in policies because economic agents would take into account systematic changes in the economic environment in their decision making. This so-called Lucas-critique (Lucas 1976) undermined the basis for the existence of large simultaneous equation models. Third, simple univariate ARMA models proved to be as good in forecasting as the sophisticated large simultaneous models. Thus it was argued that the effort or at least part of the effort devoted to these models was wasted.

In 1980 Sims (1980b) and proposed an alternative modeling strategy. This strategy concentrates the modeling activity to only a few core variables, but places no restrictions what so ever on the dynamic interrelation among them. Thus every variable is considered to be endogenous and, in principle, dependent on all other variables of the model. In the linear context, the class of vector autoregressive (VAR) models has proven to be most convenient to capture this modeling strategy. They are easy to implement and to analyze. In contrast to the simultaneous equation approach, however, it is no longer possible to perform comparative static exercises and to analyze the effect of one variable on another one because every variable is endogenous a priori. Instead, one tries to identify and quantify the effect of shocks over time. These shocks are usually given some economic content, like demand or supply disturbances. However, these shocks are not directly observed, but are disguised behind the residuals from the VAR. Thus, the VAR approach also faces a fundamental identification problem. Since the seminal contribution by Sims, the literature has proposed several alternative identification schemes which will be discussed in Chap. 15 under the header of structural vector autoregressive (SVAR) models. The effects of these shocks are then further analyzed by computing impulse responses and forecast error variance decompositions.[2]

The reliance on shocks can be seen as a substitute for the lack of experiments in macroeconomics. The approach can be interpreted as a statistical analogue to the identification of specific episodes where some unforseen event (shock)

[2]Watson (1994) and Kilian (2013) provide a general introduction to this topic.

impinges on and propagates throughout the economy. Singling-out these episodes of quasi "natural experiments" as in Friedman and Schwartz (1963) convinced many economist of the role and effects of monetary policy.

Many concepts which have been introduced in the univariate context carry over in a straightforward manner to the multivariate context. However there are some new aspects. First, we will analyze the interaction among several variables. This can be done in a nonparametric way by examining the cross-correlations between time series or by building an explicit model. We will restrict ourself to the class of VAR models as they are easy to handle and are overwhelmingly used in practice. Second, we will discuss several alternative approaches to identify the structural shocks from VAR models. After analyzing the identification problem in general, we describe short-run, long-run, and sign restrictions as possible remedies. Third, we will discuss the modeling of integrated variables in a more systematic way. In particular, we will extend the concept of cointegration to more than two variables. Finally, we will provide an introduction to the state space models as a general modeling approach. State space models are becoming increasingly popular in economics as they can be more directly linked to theoretical economic models.