

# Structural Vector Autoregressive Analysis

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Lutz Kilian and Helmut Lütkepohl



Structural vector autoregressive (VAR) models are important tools for empirical work in macroeconomics, finance, and related fields. This book not only reviews the many alternative structural VAR approaches discussed in the literature, but also highlights their pros and cons in practice. It provides guidance to empirical researchers as to the most appropriate modeling choices and methods of estimating and evaluating structural VAR models. It is intended as a bridge between the often quite technical econometric literature on structural VAR modeling and the needs of empirical researchers.

The book by Kilian and Lütkepohl will become the new benchmark textbook for teaching structural vector autoregressive analysis. This book thus devotes considerable space to the issues of identification, including sign restrictions, to Bayesian methods, to Factor Vector Autoregressions, and to non-fundamental shocks. These are key to understanding much of recent research. The authors do an excellent job of assembling and lucidly explaining it all. This book is destined to become a classic.

– Harald Uhlig, Professor of Economics, University of Chicago

Structural vector autoregressions are an essential tool in empirical macroeconomics. This book provides a thorough and long-overdue digest of a literature that has been thriving for more than 35 years and has seen a lot of exciting developments in the past decade. The authors masterfully blend theoretical foundations, guidance for practitioners, and detailed empirical applications. This is a must-read for anyone working with SVARs.

– Frank Schorfheide, Professor of Economics, University of Pennsylvania

**Lutz Kilian** is Professor of Economics at the University of Michigan.

**Helmut Lütkepohl** has held professorial positions at the University of Hamburg, the University of Kiel, the Humboldt University in Berlin, the European University Institute in Florence, and the Free University of Berlin.


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Kilian  
Lütkepohl

**Structural Vector Autoregressive Analysis**

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# STRUCTURAL VECTOR AUTOREGRESSIVE ANALYSIS

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Lutz Kilian is Professor of Economics at the University of Michigan. Between 2001 and 2003 he served as an adviser to the European Central Bank in Frankfurt am Main, Germany. Professor Kilian has been a research visitor at the Federal Reserve Board, the Bank of Canada, the European Central Bank, and the International Monetary Fund. His work has appeared in *Econometrica*, the *American Economic Review*, and the *Journal of Political Economy*, among other leading journals. He has served as associate editor of the *Journal of Business and Economic Statistics*, the *Journal of Development Economics*, and the *Journal of Economic Dynamics and Control*.

Helmut Lütkepohl has held professorial positions at the University of Hamburg, the University of Kiel, the Humboldt University in Berlin, the European University Institute in Florence, and the Free University of Berlin. He has served as Dean of the Graduate Center of the German Institute for Economic Research in Berlin. He has published in *Econometrica*, the *Journal of Econometrics*, the *Journal of Business and Economic Statistics*, *Econometric Theory*, and the *Journal of Applied Econometrics*. He has also served as associate editor of the *Journal of Econometrics*, *Econometric Theory*, *Macroeconomic Dynamics*, the *Journal of Applied Econometrics*, and *Econometric Reviews*. He is the author of *New Introduction to Multiple Time Series Analysis*.

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# Preface

## Objectives of the Book

Since the seminal work of Sims (1980a), structural vector autoregressions have evolved into one of the most widely used models in empirical research using time series data. They are used in macroeconomics and in empirical finance, but also in many other fields including agricultural economics and energy economics. The evolution of the structural vector autoregressive (VAR) methodology since 1980 has not always been smooth. Over time many new ideas have been explored, sometimes uncritically applied or misunderstood by practitioners, then questioned, and later refined or replaced by alternative methods. The development of new methods of identification, estimation, and inference for structural VAR models continues at a rapid pace even today. One of the objectives of this book is to summarize these new developments and to put them in perspective. The other is to take stock of what we have learned about more traditional structural VAR models and to interpret these models from today's perspective. The profession's understanding of these models has evolved substantially, becoming more nuanced in recent years and allowing us to understand better some of the methodological debates of the past.

In this book, we not only review the ever-increasing range of structural VAR tools and methods discussed in the literature; we also highlight their pros and cons in practice and provide guidance to empirical researchers as to the most appropriate modeling choices. In addition, we trace the evolution of the structural VAR methodology and contrast it with other common methodologies including the narrative approach to identification and the use of calibrated or estimated dynamic stochastic general equilibrium (DSGE) models. We stress that structural VAR models should be viewed as one of several econometric tools used in empirical work, each of which has its own strengths and weaknesses.

The book is intended as a bridge between the often quite technical econometric literature on structural VAR modeling and the needs of empirical



researchers. The focus of the book is not on providing the most rigorous theoretical arguments, but on enhancing the reader's understanding of the methods in question and their assumptions, allowing him or her to decide on the most suitable methods for applied work. In many cases, empirical examples are provided for illustration. References to articles in academic journals are provided for readers with an interest in the more technical aspects of the discussion.

## **Audience and Uses of the Book**

The target audience includes graduate students in economics departments and in business schools as well as practitioners interested in a comprehensive yet accessible review of the literature. It also includes consumers of empirical studies using the structural VAR methodology.

The book is intended for a semester-long course on structural VAR analysis, but the material may be adapted to the time available to the instructor and the focus of the course. Parts of the book may also be used in teaching a course in macroeconometrics or in applied time series analysis, if preceded by a general introduction to univariate time series analysis in the first part of the course. Alternatively, selected chapters may be used in teaching a graduate-level quantitative methods course that focuses on the use of DSGE models and structural VAR models in macroeconomics.

For example, an instructor only interested in structural VAR models subject to short-run identifying restrictions would focus on Chapters 2, 4, 8, 9, and possibly 12, with the material in Chapters 6 and 7 providing additional motivation as needed. If one wanted to cover structural VAR models subject to long-run restrictions, one would add Chapters 3, 10, and 11. An extension to sign-identified structural VAR models instead would involve adding Chapters 5 and 13. Chapters 14 and 15 cover more advanced identification methods. Chapters 16, 17, and 18 deal with special topics such as large-dimensional VAR processes, nonfundamental shocks, and nonlinear structural VAR models that are more technically challenging and would only be covered in a full-semester graduate-level course. Chapter 19 covers topics such as trend adjustment, seasonality, and structural change. It relates to material that could be skipped at a first reading or used only selectively, but provides useful background material at a later stage, once the remainder of the book has been absorbed.

The book may not only form the basis of a graduate-level course, but it may also be used for self-study. Although structural VAR models are routinely relied on in teaching empirical macroeconomics and in published work, not every department provides instruction in the use of these methods. There is typically no room for teaching structural VAR analysis either in the econometric theory courses or in the macroeconomics courses of a Ph.D. program,

as these fields have greatly expanded in recent years. Our book provides a self-contained resource for students wishing to complement the material on solving DSGE models typically provided as part of the first-year macroeconomics sequence by a review of the structural VAR methodology.

The need for such a book is self-evident. It has become increasingly difficult for students, practitioners, and even academic researchers to keep up with the proliferation of new methods and econometric results discussed in the literature. Not only are these results widely scattered across academic journals but there is no up-to-date treatise even of the traditional structural VAR literature. For example, the introductory discussion in Amisano and Giannini (1997) is not only terse but incomplete and outdated at this point. The more recent macroeconometrics textbook of Favero (2001) contains only one chapter on structural VAR models, which focuses primarily on VAR models of monetary policy. Even the textbook of Lütkepohl (2005) focuses mainly on reduced-form VAR analysis and devotes only one chapter to structural VAR analysis. Finally, the focus of Canova (2007), DeJong and Dave (2011), and Herbst and Schorfheide (2016) is more on the empirical evaluation of DSGE models than on structural VAR analysis, and the standard time series textbook by Hamilton (1994) only devotes 13 of 800 pages to structural vector autoregressions. Nor do handbook chapters such as Watson (1994) or Kilian (2013) provide a review of the structural VAR literature as comprehensive as this book.

## Prerequisites

The book takes for granted that the reader is familiar with regression analysis and with asymptotic reasoning. It is also assumed that the reader has been exposed to univariate time series methods at the undergraduate level and is familiar with the concepts of stationarity and invertibility and with the Wold representation, white noise, unit roots, the estimation of univariate AR, MA, and ARMA models, GARCH models, and univariate forecasts. As a rule, the discussion is not more mathematical than it has to be to appreciate the material. An overview of the notation is provided at the end of the book. The reader is assumed to be familiar with vectors and matrices. A useful resource summarizing key mathematical and statistical results is appendix A-C in Lütkepohl (2005).

## Acknowledgments

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Ann Arbor and Berlin,

*Lutz Kilian and Helmut Lütkepohl*



# Contents

<i>Preface</i>	<i>page xvii</i>
<b>1 Introduction</b>	<b>1</b>
1.1 Overview	1
1.2 Outline of the Book	4
<b>2 Vector Autoregressive Models</b>	<b>19</b>
2.1 Stationary and Trending Processes	19
2.2 Linear VAR Processes	23
2.2.1 The Basic Model	23
2.2.2 The Moving Average Representation	26
2.2.3 VAR Models as an Approximation to VARMA Processes	27
2.2.4 Marginal Processes, Measurement Errors, Aggregation, Variable Transformations	28
2.3 Estimation of VAR Models	30
2.3.1 Least-Squares Estimation	31
2.3.2 Restricted Generalized Least Squares	34
2.3.3 Bias-Corrected LS	35
2.3.4 Maximum Likelihood Estimation	38
2.3.5 VAR Processes in Levels with Integrated Variables	41
2.3.6 Sieve Autoregressions	43
2.4 Prediction	46
2.4.1 Predicting from Known VAR Processes	46
2.4.2 Predicting from Estimated VAR Processes	47
2.5 Granger Causality Analysis	48
2.6 Lag-Order Selection Procedures	51
2.6.1 Top-Down Sequential Testing	51
2.6.2 Bottom-Up Sequential Testing	52
2.6.3 Information Criteria	54

2.6.4	Recursive Mean-Squared Prediction Error Rankings	57
2.6.5	The Relative Merits of Alternative Lag-Order Selection Tools	58
2.7	Model Diagnostics	66
2.7.1	Tests for Autocorrelation in the Innovations	67
2.7.2	Tests for Nonnormality	67
2.7.3	Residual ARCH Tests	68
2.7.4	Time Invariance	69
2.8	Subset VAR Models, AVAR Models, and VARX Models	72
2.8.1	Subset VAR Models	72
2.8.2	Asymmetric VAR Models	73
2.8.3	VARX Models	74
<b>3</b>	<b>Vector Error Correction Models</b>	<b>75</b>
3.1	Cointegrated Variables and Vector Error Correction Models	75
3.1.1	Common Trends and Cointegration	75
3.1.2	Deterministic Terms in Cointegrated Processes	80
3.2	Estimation of VARs with Integrated Variables	82
3.2.1	The VAR(1) Case	82
3.2.2	Estimation of VECMs	86
3.2.3	Estimation of Levels VAR Models with Integrated Variables	95
3.3	Model Specification	99
3.3.1	Choosing the Lag Order	99
3.3.2	Specifying the Cointegrating Rank	100
3.4	Diagnostic Tests	104
3.5	The Benefits of the VECM Representation	105
3.6	Practical Issues	105
3.6.1	Limitations of Tests for Unit Roots and Cointegration	106
3.6.2	Alternative Approaches	106
<b>4</b>	<b>Structural VAR Tools</b>	<b>109</b>
4.1	Structural Impulse Responses	110
4.2	Forecast Error Variance Decompositions	113
4.3	Historical Decompositions	116
4.4	Forecast Scenarios	123
4.4.1	Conditional Forecasts Expressed in Terms of Sequences of Structural Shocks	124
4.4.2	Conditional Forecasts Expressed in Terms of Sequences of Observables	130
4.5	Simulating Counterfactual Outcomes	131
4.6	Policy Counterfactuals	136

<b>5 Bayesian VAR Analysis</b>	140
5.1 Basic Terms and Notation	141
5.1.1 Prior, Likelihood, Posterior	141
5.1.2 Bayesian Estimation and Inference	142
5.1.3 Simulating the Posterior Distribution	145
5.2 Priors for Reduced-Form VAR Parameters	149
5.2.1 General Procedures for Choosing the Parameters of Prior Densities	150
5.2.2 Normal Prior for the VAR Parameters for Given $\Sigma_u$	151
5.2.3 The Original Minnesota Prior	155
5.2.4 The Natural Conjugate Gaussian-Inverse Wishart Prior	162
5.2.5 The Independent Gaussian-Inverse Wishart Prior	166
5.3 Extensions and Related Issues	169
<b>6 The Relationship between VAR Models and Other   Macroeconometric Models</b>	171
6.1 The Relationship between VAR Models and Traditional Dynamic Simultaneous Equations Models	171
6.1.1 The VAR Representation of Traditional DSEMs	172
6.1.2 Incredible Restrictions in Traditional DSEMs	174
6.1.3 Structural VAR Models as an Alternative to Traditional DSEMs	176
6.2 The Relationship between VAR Models and DSGE Models	177
6.2.1 Basics	177
6.2.2 The Role of Data Transformations	180
6.2.3 Why Not Use VARMA Models?	180
6.2.4 Autoregressive Sieve Approximations of VAR( $\infty$ ) Processes	181
6.2.5 Summary of Potential Problems in Approximating DSGE Models with VAR Models	182
6.3 DSGE Models as an Alternative to VAR Models?	183
6.3.1 Calibrated DSGE Models	184
6.3.2 Estimated DSGE Models	185
6.3.3 Calibration versus Bayesian Estimation	186
6.3.4 Are Structural VAR Models Less Credible than DSGE Models?	187
6.3.5 Are DSGE Models More Accurate than VAR Models?	189
6.3.6 Policy Analysis in DSGE Models and SVAR Models	191
6.4 An Overview of Alternative Structural Macroeconometric Models	193



6.4.1	Combining DSEMs and SVAR Models	193
6.4.2	Combining DSGE and SVAR Models	194
<b>7</b>	<b>A Historical Perspective on Causal Inference in Macroeconometrics</b>	<b>196</b>
7.1	A Motivating Example	196
7.2	Granger Causality Tests for Covariance Stationary VAR Models	197
7.3	Granger Causality, Predeterminedness, and Exogeneity	199
7.3.1	Basic Concepts	199
7.3.2	Granger Causality and Forward-Looking Behavior	201
7.3.3	Strict Exogeneity in Modern Macroeconomic Models	203
7.4	The Demise of Granger Causality Tests in Macroeconomics	204
7.5	Responses to Unanticipated Changes in Money Growth	205
7.5.1	The Narrative Approach	205
7.5.2	Exogenous Shocks Derived from Data-Based Counterfactuals	208
7.5.3	News Shocks	209
7.5.4	Shocks to Financial Market Expectations	210
7.5.5	Summary	211
7.6	Structural VAR Shocks	211
7.6.1	The Identification Problem	212
7.6.2	The Relationship between Structural VAR Shocks and Direct Shock Measures	213
7.6.3	Causality in Structural VAR Models	214
<b>8</b>	<b>Identification by Short-Run Restrictions</b>	<b>216</b>
8.1	Introduction	216
8.2	Recursively Identified Models	219
8.3	Sources of Identifying Restrictions	221
8.4	Examples of Recursively Identified Models	224
8.4.1	A Simple Macroeconomic Model	224
8.4.2	A Model of the Global Market for Crude Oil	225
8.4.3	Oil Price Shocks and Stock Returns	226
8.4.4	Models of the Transmission of Energy Price Shocks	227
8.4.5	Semistructural Models of Monetary Policy	228
8.4.6	The Permanent Income Model of Consumption	234
8.5	Examples of Nonrecursively Identified Models	235
8.5.1	Fiscal Policy Shocks	236
8.5.2	An Alternative Simple Macroeconomic Model	237
8.5.3	Discussion	237
8.5.4	The Graph-Theoretic Approach	238
8.6	Summary	239

<b>9 Estimation Subject to Short-Run Restrictions</b>	241
9.1 Model Setup	241
9.2 Method-of-Moments Estimation	242
9.2.1 Recursively Identified Models	242
9.2.2 Nonrecursively Identified Models	250
9.2.3 GMM Estimation of Overidentified Models	253
9.3 Instrumental Variable Estimation	258
9.4 Full Information Maximum Likelihood Estimation	262
9.5 Bayesian Estimation	265
9.6 Summary	268
<b>10 Identification by Long-Run Restrictions</b>	269
10.1 The Traditional Framework for Imposing Long-Run Restrictions	269
10.2 A General Framework for Imposing Long-Run Restrictions	272
10.2.1 The Long-Run Multiplier Matrix	272
10.2.2 Identification of Structural Shocks	275
10.3 Examples of Long-Run Restrictions	278
10.3.1 A Real Business Cycle Model with and without Nominal Variables	278
10.3.2 A Model of Neutral and Investment-Specific Technology Shocks	282
10.3.3 A Model of Real and Nominal Exchange Rate Shocks	284
10.3.4 A Model of Expectations about Future Productivity	284
10.4 Examples of Models Combining Long-Run and Short-Run Zero Restrictions	287
10.4.1 The IS-LM Model Revisited	287
10.4.2 A Model of the Neoclassical Synthesis	289
10.4.3 A U.S. Macroeconomic Model	290
10.5 Limitations of Long-Run Restrictions	292
10.5.1 Long-Run Restrictions Require Exact Unit Roots	292
10.5.2 Sensitivity to Omitted Variables	293
10.5.3 Lack of Robustness at Lower Data Frequencies	294
10.5.4 Nonuniqueness Problems without Additional Sign Restrictions	294
10.5.5 Sensitivity to Data Transformations	296
<b>11 Estimation Subject to Long-Run Restrictions</b>	297
11.1 Model Setup	297
11.2 Models Subject to Long-Run Restrictions Only	299
11.2.1 Method-of-Moments Estimation	301

11.2.2	Full Information Maximum Likelihood Estimation	306
11.2.3	Instrumental Variable Estimation	307
11.3	Models Subject to Long-Run and Short-Run Restrictions	310
11.3.1	Estimating the Model in VAR Representation	310
11.3.2	Estimating the Model in VECM Representation	316
11.4	Practical Limitations of Long-Run Restrictions	320
11.4.1	Estimators of the Long-Run Multiplier Matrix May Be Unreliable	321
11.4.2	Lack of Power	321
11.4.3	Near-Observational Equivalence of Shocks with Permanent Effects and Shocks with Persistent Effects	322
11.4.4	Weak Instrument Problems	322
11.5	Can Structural VAR Models Recover Responses in DSGE Models?	323
11.5.1	The Origin of This Controversy	323
11.5.2	The Position of Chari et al. (2008)	325
11.5.3	The Position of Christiano et al. (2006)	327
11.5.4	Understanding the Simulation Evidence	328
11.5.5	Summary	331
<b>12</b>	<b>Inference in Models Identified by Short-Run or Long-Run Restrictions</b>	<b>334</b>
12.1	Delta Method Intervals for Structural Impulse Responses	335
12.1.1	Finite-Order VAR Models	336
12.1.2	Infinite-Order VAR Models	338
12.1.3	Discussion	339
12.1.4	Extensions to Other Statistics	339
12.1.5	On the Choice of the Significance Level	340
12.2	Bootstrap Intervals for Structural Impulse Responses	340
12.2.1	The Standard Residual-Based Recursive-Design Bootstrap	341
12.2.2	The Standard Residual-Based Fixed-Design Bootstrap	345
12.2.3	The Residual-Based Wild Bootstrap	345
12.2.4	Bootstrapping Tuples of Regressands and Regressors	347
12.2.5	Block Bootstrap Methods	348
12.2.6	Alternative Bootstrap Confidence Intervals	356
12.3	Bootstrap Intervals Based on Bias-Adjusted Estimators	363
12.4	Potential Pitfalls in Impulse Response Inference	365
12.5	Finite-Sample Properties of Bootstrap Confidence Intervals	368