INDEX

A
Abraham, B., 336, 498
ACF. See autocorrelation function (ACF)
Additive outliers (AO), 488
Adjustment (control) charts
  for discrete proportional-integral schemes, 575–78
  metallic thickness example, 567–68
Adler, J., 18
Ahn, S.K., 545, 547, 549, 551
Akaike, H., 190, 192, 193, 517, 518, 530, 537, 543
Akaike’s information criterion (AIC), 187, 190, 193, 360, 515, 517–8, 519, 522, 544, 558
Ali, M.M., 518
Andersen, T.G., 377
Anderson, A.P., 378
Anderson, B.D.O., 161, 498
Anderson, R.L., 185, 287
Anderson, T.W., 190, 340, 550
Anscombe, F.J., 284
Ansley, C.F., 158, 160, 217, 243, 262, 496, 497, 498, 532
AR model. See autoregressive (AR) model
ARCH model, 362–366
ARIMA model. See autoregressive integrated moving average (ARIMA) model
ARMA model. See autoregressive-moving average (ARMA) model
Aström, K.J., 3, 581
Asymptotic distribution
  of least square estimator in AR model, 274–76
  of maximum likelihood estimator in ARMA model, 222
  of ARMA process, 77
  of ARMA(1, 1) process, 78–80
  of AR process, 56–57
  of AR(1) process, 58–59
  of AR(2) process, 59–64
  of MA process, 69
  of MA(1) process, 70
  of MA(2) process, 71–72
  of residuals, 287–89
  role in identifying ARIMA model, 180–83
  Autocovariance coefficient, 24
  Autocovariance function defined, 24, 29
  estimation, 30
  standard errors, 31–32
  general linear process, 50
  general model with added correlated noise, 125–26
  and spectral density function, 40–43

AIC, 187, 190, 193, 360, 515, 517–8, 519, 522, 544, 558
Athanasopoulos, G., 531
Autocorrelation coefficient, 25
Autocorrelation function (ACF). See also partial autocorrelation function (PACF)
  defined, 25, 29–30
  expected behavior for nonstationary processes, 180–81, 206–07
  estimated, standard errors and variance, 31–34, 183–85
  estimated vs. theoretical, 183–84
  of AR process, 56–57
  of AR(1) process, 58–59
  of AR(2) process, 59–64
  of MA process, 69
  of MA(1) process, 70
  of MA(2) process, 71–72
  of residuals, 287–89
  role in identifying ARIMA model, 180–83


Autocovariance function (Continued)
linking estimate with sample spectrum, 43–44
and spectrum, 38–39
Autocovariance generating function, 50, 82–84
Automatic process control (APC), 5, 561
Autoregressive conditional heteroscedasticity (ARCH)
ARCH model, 362–66
example, weekly S&P 500 Index, 370–73
Exponential GARCH (EGARCH) model, 374
GARCH model, 366–67
GARCH-M model, 376
GJR and Threshold GARCH models, 374–75
IGARCH and FIGARCH models, 376
Model building, ARCH and GARCH, 367–70
Nonlinear smooth transition models, 375–76
testing for, 367–68
Autoregressive integrated moving average (ARIMA) model
ARIMA(\(p, d, q\)) model, 88–105
deterministic trends, 95, 121–22
difference equation form, 97
differencing, 90–92
effect of added noise, 122–26
identification, 180–83
integrated MA (IMA) processes, 106–16
inverted form, 103–05
minimum mean square error forecasts, 131–32
random shock form, 98–103
unit roots, unit root testing, 90–92, 353–61
Autoregressive (AR) model
AR(\(p\)) model, 8, 52
AR(1) model, 58–59
AR(2) model, 59–64
autocorrelation function, 56–57
asymptotic distribution of estimators, 274–76
duality with moving average process, 71, 74–5
forecasting, 150–52
likelihood function, exact, 266–68
partial autocorrelation function, 64–68
recursive calculation of Yule--Walker estimates, 66, 84–86
spectrum, 57, 58, 63
stationarity conditions, 54–55
unit root testing, 353–61
Autoregressive-moving average (ARMA) model
ARMA(\(p, q\)) model, 10, 53, 75–78
ARMA(1, 1) model, 78–81
autocorrelation function and spectrum, 77–78
fractionally integrated, 385–92
likelihood function, exact, 259–65
missing values, 497
model checking, 284–301
partial autocorrelation function, 78, 80–81
relationship between \(\psi\) and \(\pi\) weights, 48–50
stationarity and invertibility, 75–77
B
Bachelier, L., 174
Backward difference operator, 7
Backward shift operator, 7, 8, 48
Bagshaw, M., 599
Baillie, R.T., 343, 365
Barnard, G.A., 5, 210, 256, 572
Bartlett, M.S., 31–32, 47, 185, 210, 298, 433
Basu, S., 500
Bayes' theorem, 245
Bayesian estimation of parameters, 247–51
Bayesian HPD regions, 248–249
Bayesian information criterion (BIC), 190, 193, 515, 517–18, 519, 522, 532
Bell, W.R., 336, 339, 343, 362
Bera, J., 386, 389, 391
Bergh, L.G., 581
Berndt, E.K., 369
Bhargava, A., 358
BHHH algorithm, 369
Billingsley, P., 276, 354
Birnbaum, A., 210
Bivariate stochastic process, 429
Bloomfield, P., 36, 553
Bollerslev, T., 362, 363, 365, 366, 367, 368, 369, 370, 376
Bounded adjustment scheme
for fixed adjustment cost, 583–84
indirect approach, 584–585
Box-Cox transformation, 96, 331
Box-Pierce statistic, 289
Bray, J., 639
Briggs, P.A.N., 429
Brockwell, P.J., 46, 84, 161, 243, 379, 386, 533
Brown, R.G., 2, 7, 171, 172–74, 305
Brownian motion, 353, 354
Brubacher, S.R., 498
Bruce, A.G., 488, 499
Bucy, R.S., 92

C
Campbell, S.D., 363
Cao, C.Q., 366
Canonical correlations, 190–92, 530–31, 539, 541, 543–44, 557
Chan, K.-S., 17
Chan, N.H., 354
Chang, I., 488, 491
Characteristic equation, defined, 55
Chatfield, C., 190
Cheang, W.K., 344, 345, 390
Chen, C., 488, 489, 491, 492
Chen, R., 380
Cholesky decomposition, 244, 510
Chu, Y.-J., 339
Cleveland, W.S., 190, 339
Coherency spectrum, 472, 552–53
Cointegration, 547–51
Conditional heteroscedasticity, 361–76
Conditional least squares estimates, 211, 217, 232, 236–37, 270–71
Conditional likelihood, 210–12
Conditional sum-of-squares function, 211–12
Confidence regions, 220, 223–26, 257–58
Constrained control schemes, 581–82
Controller, defined, 13–14
Cooper, D.M., 190, 192, 344, 530, 543
Covariance matrix
for ARMA process zeros, 234–36
in asymptotic distribution of LSE in AR model, 273–74
in asymptotic distribution of MLE in ARMA model, 222–23, 233–34, 238
large-sample information matrices, 233–36
of errors in Kalman filtering, 157–58, 159, 160, 538
of LS estimates in linear regression model, 257
of AR and MA parameter estimates, 234, 236–38
Cox, D.R., 96, 331
Crawley, M.J., 18
Cross-covariance function, 431, 506–7, 526
Cross-covariance generating function, 471
Cross-correlation function
in bivariate stochastic processes, 429–31
estimated, approximate standard errors, 433–35
estimation, 431–33
role in identifying transfer function-noise model, 435–41
vector process, 506–07, 513–15, 526
Cross-spectral analysis, 471–72, 552–53
Cumulative periodogram, 284, 297–300, 324–25
Cuscore charts, 562, 568, 599–600
Cum charts, 562, 568

D
Damsleth, E., 498
Daniel, C., 285
Data series
Series A, Chemical process concentration readings, 201, 219–20, 231, 241, 292, 360, 391–92, 625
Series B, IBM common stock closing price, 201, 214–16, 231, 292, 294–95, 626
Series E, Wölfer sunspot numbers, 201, 231–33, 292, 394, 630
Series F, Yields from batch chemical process, 22, 66–68, 201, 231, 292, 630
Series K, Simulated dynamic data with two inputs, 459–61, 634
Series L, Pilot scheme data, 635–37
Series M, Sales data with leading indicator, 468–70, 479, 638
Series N, Mink fur sales data of Hudson’s Bay Company, 87, 639
Series P, Unemployment and GDP data in UK, 208, 479, 639
Series Q, U.S. hog price data, 208, 503, 640
Series R, Ozone in downtown Los Angeles, 351, 502, 640
Data series (Continued)

Weekly Standard & Poor’s 500 Index, 370–73
U.S. fixed investment and change in business inventories, 519–24
Davies, N., 289, 381
Davis, R.A., 46, 84, 161, 243, 386, 533
Deistler, M., 446, 529, 530, 533, 534, 539, 540, 542
Degiannakis, S., 362
Deming, W.E., 562, 564, 567
Dent, W., 217
Deterministic components, 22, 95, 331–33, 335–36
Diagnostic checking
autocorrelation check, 287–89
cross-correlation check, 522–23
diagnostic checking example, airline data, 324–25
diagnostic checking example, gas furnace data, 453–57
overfitting, 285–87
periodogram check, 297–300, 324–25
portmanteau tests, 289–94, 324, 518–19, 522–24
residual autocorrelation checks, 287–94
role of residuals in transfer function-noise model, 449–53
score (LM) test, 295–97, 519
seasonal multiplicative model, 324–25
vector models, 518–19, 522–24, 533
Dickey, D.A., 353, 354, 356, 358
Dickey-Fuller test, 353–56, 359–60
Diebold, F.X., 362, 363
Difference equations
and ARIMA model, 97, 116–17
calculating forecasts, 133, 134–35
complementary function evaluation, 117–19
difference equations for forecasting airline model, 311
general solution, 117
IMA(0, 1, 1) process, 107
IMA(0, 2, 2) process, 110
IMA process of order (0, d, q), 114
Differencing operator, 91
Discrete control systems
choosing sampling interval, 609–13
models for discrete control systems, 13–14
Discrete transfer function, 398–400
Duality between AR and MA processes, 75
Dudding, B.P., 5
Dunsmuir, W., 533
Durbin, J., 66, 155, 210, 288, 332, 339
E
EGARCH model, 374
Elliott, G., 358
Engineering process control (EPC)
average adjustments, 5–6
definition, 561
process adjustment in, 562, 564–66
Engle, R.F., 362, 365, 368, 369, 370, 376, 547
Estimation. See also nonlinear estimation;
Yule-Walker equations
airline data and multiplicative model, 320–23
ARCH and GARCH parameters, 368–70
autocorrelation function, 30–31
Bayes’s Theorem, 245
cross-correlation function, 431–33
partial autocorrelation function, 66, 67–8
spectrum, 39–40
time series missing values, 498–500
Exact likelihood function
for AR process, 260–68
based on innovations form, 243–45, 532–33
based on state-space model form, 242–43
for MA and ARMA processes, 259–65
for VARMA process, 532–33
with missing values, 496–7
F
Fan, J., 378, 380, 381
Fearn, T., 575
Feedback adjustment charts, 567–68
Feedback control
advantages and disadvantages, 596–97
classifying appropriate disturbance models with variograms, 570–71
complementary roles of monitoring and adjustment, 578–79
constrained control, 581–82
vs. feedforward control, 596–97
general MMSE schemes, 573–75
inclusion of monitoring cost, 585–88
manual adjustment for discrete
proportional-integral schemes, 575–78
need for excessive adjustment, 580–82
with restricted adjustment variance, 600–09
simple models for disturbances and dynamics, 570–73
and transfer function-noise model, 597–99
Feedforward control
vs. feedback control, 596–97
fitting transfer function-noise model, 597–99
minimizing mean square error at output, 588–91
multiple inputs, 593–94
Feedforward-feedback control, 594–96
Fisher, R.A., 210, 222
Fisher, T.J., 294, 370
Fixed-interval smoothing algorithm, 160–61
Forecast errors
calculating probability limits at any lead time, 137–39
correlation, same origin with different lead times 132, 165–66
one-step-ahead, 132
Forecast function
and forecast weights, 140–44
eventual, for ARIMA model, 140–50
eventual, for seasonal ARIMA model, 307–08, 329–31
role of autoregressive operator, 140
role of moving average operator, 140–41
upgrading, 136, 144–50
Forecasting
airline data, multiplicative seasonal model, 311–18
autoregressive process, 150–52
calculating forecasts, 135–39
fractionally integrated ARMA process, 390–91
lead time, 130, 131, 132
regression models with time series errors, 342–43
role of constant term, 152, 164
transfer function-noise model, 461–69
upgrading forecasts, 136, 144–47
vector ARMA process, 534–36
weighted average of previous observations, 131, 133, 146, 148
weighted sum of past observations, 163
Forecasts, minimum mean square error (MMSE)
derivation, 131–32
as infinite weighted sum, 130–31
in integrated form, 133
in terms of difference equation, 133, 134–35
with transfer function-noise model, 461–65
Forward shift operator, 7, 48
Fox, A.J., 488
Fractionally integrated ARMA model
definition, 385
estimation of parameters, 389
forecasting, 390
Francq, C., 362, 363, 370
Fuller, W.A., 84, 353–59
G
Gabr, M.M., 197, 378, 381, 385
Gallagher, C.M., 294, 370
GARCH model, 366–72
GARCH-M model, 376
Gardner, G., 159, 242, 243
Gaussian process, 28
Generalized least squares (GLS), 339–40
Gersch, W., 332, 339
Geweke, J., 389
Ghysels, E., 339
Glosten, L.R., 374
González-Rivera, G., 375
Godfrey, L.G., 295, 296, 297
Granger, C.W.J., 378, 386, 547
Gray, H.L., 190
Grenander, U., 47, 84, 210
H
Hagerud, G.E., 375
Haggan, V., 379, 385
Haldrup, N., 353, 359
Hall, A.D., 532
Hall, P., 354
Hamilton, J.D., 353, 357
Hannan, E.J., 47, 193, 210, 222, 446, 517, 529, 530, 531, 532, 533, 534, 539, 540, 542, 553
Hanssens, D.M., 437
Harris, T.J., 581
Harrison, P.J., 2
Harvey, A.C., 159, 243, 244, 332, 334, 336, 339, 343, 377, 496, 498
Harvey, D.I, 358
Harville, D.A, 345
Haugh, L.D., 444
Hauser, M.A., 390
He, C., 367, 370
Heyde, C.C., 354
Higgins, M., 362
Hillmer, S.C., 217, 332, 339, 343, 532
Hinich, M.J., 381
Hipel, K.W., 385
Holt, C.C., 2, 7
Hosking, J.R.M., 386, 387, 389, 518
Hougen, J.O., 428
Hunter, W.G., 15
Hurst, H., 385
Hutchinson, A.W., 3, 429
I
Identification, See Model selection
IGARCH model, 376
Information matrix, 222, 233–36. See also
covariance matrix
Initial estimates, method of moments, 194–202
Innovational outliers, 488
Innovations
likelihood function calculations, 243–45
in state-space model, 159, 243–45
sticky, 572–73
Intervention analysis
example, 484–85
models, 481–84
nature of maximum likelihood estimator,
485–88
useful response patterns, 483–84
Invertibility
ARMA process, 75–7
ARMA(1, 1) process, 78
linear processes, 51–2
MA process, 68–9
MA(1) process, 70
MA(2) process, 71–2
Ishikawa, K., 562
J
Jacquier, E., 377
Jarque-Bera test, 372
Jeffreys, H., 246
Jenkins, G.M., 30, 36–39, 46, 51, 92, 246, 429,
431, 457, 472, 473, 485, 553, 567, 577,
581, 583, 584
Jennet, W.J., 5
Johansen, S., 547, 549, 551
Johnson, R.A., 516, 599
Jones, R.H., 159, 242, 243, 244, 496, 497
Joyeux, R., 386
Juselius, K., 549
K
Kendall, M.G., 47
Kitagawa, G., 332, 339
Kohn, R., 160, 496, 497, 498, 532
Kolmogoroff, A., 131
Kolmogorov-Smirnov test, 299, 324
Koopman, S.J., 155, 332, 339
Koopmans, L.H., 48
Kotnour, K.D., 438
Kramer, T., 562, 584, 585
Kronecker index, 530–532, 539–44,
546, 557
L
Lag window, 39
Lanne, M., 375
Le, N.D., 294
Least squares estimates
conditional, unconditional, 211, 213
linear least squares theory; review, 256–58
in transfer function-noise model, 446–47
in vector AR model, 516–17
Ledolter, J., 380
Levinson-Durbin recursion algorithm, 66,
84–86, 196, 387
Lewis, P.A.W., 380
Leybourne, S.J., 336
Li, W.K., 294, 362, 367–68, 370, 381, 389, 518
Likelihood function
AR model, 266–74
ARMA model, 262–65
ARIMA model, 210–11
based on state-space model, 242–45
care in interpreting, 221
conditional, 210–12
MA model, 259–62
unconditional, 213–17
vector ARMA model, 532–33
Likelihood principle, 210
Lim, K.S., 197, 380
Linear stationary processes
autocorrelation function, 56–57
autocovariance generating function, 50,
82–84
autoregressive (AR), 52, 54–68
general process, 47–54
invertibility, 51–52
mixed ARMA, 53–54, 75–82
moving average (MA), 53, 68–75
spectrum, 51
stationarity, 51, 84
Ling, S., 367, 370
Liu, J., 379
INDEX

Liu, L.-M., 437, 488, 489, 491, 492
Ljung, G.M., 262, 289, 292, 499, 518
Ljung-Box statistic, 289–90
Loève, M., 38
Long memory time series processes
estimation of parameters, 389–90
forecasting, 390–91
fractionally integrated, 385–92
Luceño, A., 582, 586
Lundbergh, S., 370
Lütkepohl, H., 506, 510, 518, 519, 524, 530, 532
Luukkonen, R., 336, 368, 381, 382

M
MA model. See moving average (MA) model
MacGregor, J.F., 581, 598, 615
Mahdi, E., 518
Mak, T.K., 370
Mann, H.B., 222
Maravall, A., 524
Maris, P., 575
Markellos, R.N., 362, 376
Martin, R.D., 488, 499
Maximum likelihood (ML) estimates
approximate confidence regions, 223–26
for AR process, 236–38
for ARMA processes, 238–39
for MA process, 238
likelihood principle, 210
parameter redundancy, 240–42
variances and covariances, 222–23
McAleer, M., 367
McCabe, B.P.M., 336
McLeod, A.I., 367–68, 370, 381, 385, 389, 518
Melino, A., 377
Meyer, R.F., 171
Mlhøj, A., 365
Mills, T.C., 362, 376
Mikosch, T., 374
Min, A.S., 217
Minimum mean square error (MMSE) control
constrained control schemes, 581–82
excessive adjustment requirement, 580–82
feedback control schemes, 573–75
Minimum mean square error (MMSE) forecasts. See Forecasts
Missing values in ARMA model, 495–502
Model building
basic ideas and general approach, 14–17, 177–78
for ARCH and GARCH model, 367–72
for regression models, 340–42
for seasonal models, 318–29
for vector AR model, 515–24
Model selection
ARIMA model, nonseasonal, 180–83, 190–94
ARIMA model, seasonal, 318–20, 327–28
transfer function-noise model, 435–46
vector autoregressive (VAR) model, 515–18
Monti, A.C., 293
Moore, J.B., 161, 498
Moran, P.A.P., 197, 232
Moving average (MA) model
autocorrelation function and spectrum, 69
calculation of unconditional sum of squares, 214–16
duality with autoregressive process, 75
estimation of parameters, 226–30, 232, 238, 249–50, 280
invertibility conditions, 75–77
likelihood function, 259–62
MA(q), 9, 53
MA(1), 70–71
MA(2), 71–75
spectrum, 70
vector MA, 524–26
Multiplicative seasonal model, 308–11
Multivariate time series models. See vector AR, MA, and ARMA models
Muth, J.F., 7, 110

N
Nelson, D.B., 366, 369, 374, 376
Nerlove, M., 362
Newbold, P., 217, 262, 297, 449
Nicholls, D.F., 377, 380, 385, 532
Ng, S., 358
Nonlinear estimation
general approach, 226–29
general least squares algorithm for
conditional model, 229–31
large-sample information matrices, 233–36
sum of squares, 226–27
in transfer function-noise model, 447–49
Nonlinear time series models
bilinear, 378
Canadian lynx example, 382
classes, 378–81
detection of nonlinearity, 381–82
exponential autoregressive, 378, 379
random coefficient, 380
threshold autoregressive, 378, 379–80
O
One-step-ahead forecast error, 132
Operators
  backward difference operator, 7, 91
  backward shift operator, 7, 48
  forward shift operator, 7, 48
Order determination. See Model selection
Osborn, D.R., 217, 339
Outliers in time series
  additive, 488–91
  analysis examples, 492–95
  detection, iterative procedure for, 491–95
  estimation of effect for known timing, 489–91
  innovational, 488–91
Overfitting, 221, 285–87
Ozaki, T., 379, 385
P
PACF. See partial autocorrelation function
  (PACF)
Page, E.S., 5
Palm, F.C., 359
Palma, W., 386
Pankratz, A., 437
Pantula, S.G., 353, 357, 358
Parameter redundancy, 240–42
Parsimony, 14–15, 47, 241, 400, 445
Partial autocorrelation function (PACF). See
  also autocorrelation function (ACF)
  autoregressive processes for deriving, 64–66
  ARMA process, 78, 83
  defined, 65
  estimated, standard errors, 66–67, 183–85
  estimation, 66–68
  ARMA(1, 1) process, 80–81
  MA(1) process, 71
  MA(2) process, 72–75
  role in identifying nonseasonal ARIMA
    model, 83,
    and Yule-Walker equations, 84–86
Peña, D., 293, 294, 368, 381, 518
Periodograms
  for analysis of variance, 35–36
  cumulative, 297–300, 324–35
  as diagnostic tool, 297–300, 324–25
  for time series, 34–35
Perron, P., 358
Petruccelli, J., 381
Phillips, G.D.A., 243, 343
Phillips, P.C.B., 353, 358, 359
PI. See proportional-integral (PI) control
Pierce, D.A., 288, 289, 448, 450, 452
Pierce, R.G., 244, 496, 498
Porter-Hudak, S., 389
Portmanteau tests, 289–94, 324, 367–68, 370,
  371–72, 381, 518–19, 522–24, 533
Poskitt, D.S., 295, 297, 453, 518, 524, 532
Power spectrum, 38, 40
Prediction. See forecasting
Prewhitening, 436, 437–41, 443, 444, 450, 471
Priestley, M.B., 131, 378, 380, 444, 553
Process adjustment
  bounded adjustment schemes, 583–88
  cost control, 582–88
  defined, 561
  introduction, 564–66
  monitoring of scheme, 599–600
  vs. process monitoring, 561–62, 568, 578–79
  role of feedback control, 566–79
Process control
  defined, 561
  introduction, 561–62
  minimum cost control, 582–88
Process monitoring
  cost control, 585–88
  defined, 561–62
  introduction, 562–64, 568
  vs. process adjustment, 561–62, 568, 578–79
  and Shewhart charts, 562–64
Process regulation. See process adjustment
Proportional-integral (PI) control, 561, 569,
  575–78, 580
Q
Q-Q plots, 290, 291, 295, 324, 372
Qu, Z., 358
Quenouille, M.H., 47, 66, 208, 210, 547, 640
Quinn, B.G., 377, 380, 385, 517, 518
R
R software, 17–18
R commands, 17, 25–26, 31, 34, 40, 42, 59, 64,
  68, 75, 81, 139, 182–83, 232–33, 286–87,
  292, 317, 320, 323, 359–60, 371, 384, 392,
  440–41, 456–57, 494–95, 514, 524, 527, 544
Ragazzini, J.R., 92
Ramírez, J., 568, 599
Ramsey, J.B., 381
Random walk, 109, 110, 125, 161, 174, 181,
  185, 306, 332, 353, 355, 357, 549
Rao, C.R., 501
Rao, J.N.K., 92
Regression models with time series errors
model building, estimation, and forecasting, 339–44
restricted maximum likelihood estimation, 344–45
Reinsel, G.C., 244, 336, 343, 344, 345, 358,
390, 446, 448, 496, 497, 500, 506, 509,
513, 514, 517, 518, 519, 529, 530, 531,
532, 533, 534, 545–46, 547, 549, 551
Residual analysis, 287–94, 301–2, 324–25,
449–57, 518–19, 522–24, 533
Restricted control schemes, 581–82
Ripley, B.D., 18, 344
Rissanen, J., 193, 531
Rivera, D.E., 581
Roberts, S.W., 5, 583
Robinson, E.A., 47
Robinson, P.M., 386
Rodríguez, J., 293, 294, 368, 381, 518
Rosenblatt, M., 47, 84, 210
Said, S.E., 356, 358
Saikkonen, P., 336, 375
Savage, L.J., 245
Scalar component model (SCM), 530–31, 539
Schmidt, P., 358
Schuster, A., 197
Schwarz, G., 190, 193
Score test, 295–97, 358, 368, 370, 381,
382, 519
Seasonal ARIMA model
airline data, 305–06, 309
choice of transformation, 331
eventual forecast functions, 329–31
model identification, 327–28
multiplicative model, 308–11
nonmultiplicative models, 325–26
parameter estimation, 320–23
Seasonal models
deterministic seasonal and trend components, 335–36
estimation of unobserved components in
structural models, 336–39
general multiplicative, 325–26
involving adaptive sines and cosines, 308–10
structural component models, 332–35
Second-order stationarity, 28, 507
Shapiro-Wilk test, 372
Shea, B.L., 532
Shelton, R.J., 3, 429
Shephard, N.G., 377
Shewhart charts, 561, 562–64, 567, 568, 579,
599
Shewhart, W.A., 5, 564
Shin, D.W., 358
Shumway, R., 36, 176
Silvey, S.D., 295
Slutsky, E., 47
Smoothing relations, in state-space model,
160–61
Solo, V., 358, 361, 530, 532
Sotiris, E, 339
Sowell, F., 389
Spectral density function
and autocorrelation function, 40–43, 58–59
and stationary multivariate processes,
552–53
theoretical, 39–42
Spectral window, 40
Spectrum
and autocovariance function, 37–39
ARMA process, 81
compared with autocorrelation function,
42–43
estimation, 39–40
for AR(1) process, 58–59
for MA(1) process, 71
for MA process, 70
for AR(2) process, 63
for MA(2) process, 72
State-space model
as basis for likelihood function, 242–45
for ARIMA process, 155–57
for exact forecasting, 158–59
estimating missing values in time series,
496–97
innovations form for time-invariant models,
159
Kalman filtering for, 157–58
smoothing relations, 160–61
for structural component time series model,
332–3, 337, 339
for vector ARMA process, 536–39
Stationarity
of ARMA process, 75–76
of AR process, 54–55
of AR(2) process, 59–60
of ARMA(1, 1) process, 78
of linear process, 51, 84
VAR(𝑝) process, 509
weak, 29, 507
Stationary models, 7–10
Stationary multivariate processes, 506–46
Statistical process control (SPC), 5, 561–64
Statistical time series vs. deterministic time series, 22
Steady-state gain, 398, 400, 402, 405
Step response, 401, 403, 406–07, 410
Stevens, J.G., 380
Sticky innovation model, 571–72
Stochastic processes
  defined, 22
  strictly stationary, 24
  weakly stationary, 28
Stochastic volatility models, 377
Stoffer, D., 36, 176
Straumann, D., 374
Strictly stationary stochastic processes, 24, 506–07
Structural component models, 331–39
Subba Rao, T., 197, 378, 381, 385
Sum of squares
  conditional, calculating, 210–12, 229–31
  and conditional likelihood, 210–11
  graphical study, 218–20
  iterative least squares procedure, 229–31
  nonlinear estimation, 226–29
  unconditional, calculation for ARMA process, 213–14, 262–65
  unconditional, calculation for MA process, 214–16, 259–62
  unconditional, general procedure for calculating, 216–18
  unconditional, introduction, 213–14

T
Tam, W.K., 336
Teräsvirta, T., 362, 367, 370, 374, 376, 378, 380, 385
Thompson, R., 344
Time series
  heteroscedastic, 361–77
  continuous vs. discrete, 21–22
  deterministic vs. statistical, 22
  estimation, missing values, 495–505
  forecasting overview, 129–44
  intervention analysis, 481–88
  long memory processes, 385–92
  multivariate, 505–51
  nonlinear models, 377–85
  nonstationary behavior, 88–116
  outlier analysis, 489–95
  as realization of stochastic process, 22–23
  regression models, model building and forecasting, 339–45
  seasonal models, 305–39
  vector models, 505–51
Tintner, G., 92
Tjøstheim, D., 380
Todd, P.H.J., 332
Tong, H., 131, 197, 294, 370, 378, 380, 382, 384–85
Transfer function-noise model
  cross-correlation function, 429–31
  conditional sum-of-squares function, 446–47
  design of optimal inputs, 469–71
  fitting and checking, 446–53
  forecasting, 461–469
  gas furnace CO₂ output forecasting, 465
  gas furnace, diagnostic checking, 453–57
  gas furnace, identifying transfer function, 438–41
  gas furnace, identifying noise model, 443
  identification, 435–46
  identifying noise model, 442–46
  identifying transfer function model, 435–41, 444–46
  model checking, 449–53
  nonlinear estimation, 447–49
  nonstationary sales data, 468–70
  single-input vs. multiple-input, 445, 472–73
Tremayne, A.R., 295, 297, 453, 518
Tsay, R.S., 190, 191, 192, 362, 369, 374, 377, 378, 380, 381–83, 488, 489, 491, 506, 510, 523, 530, 531, 539, 543, 551, 557
Tuan, P.D., 379
Tukey, J.W., 15, 284
Tunnicliffe Wilson, G., 344, 345, 498, 581
Turnbull, S.M., 377

U
Unconditional sum of squares, 213–18
Unit roots, tests for, 353–60
Unstable linear filters, 92
Updating forecasts, 136, 144–55, 313–15

V
van Dijk, D., 362, 378
Variate difference method, 92
Variograms, 571–72
Vector AR (VAR) model
cross-covariance and cross-correlation matrices, 506–07, 511, 512–14
infinite MA representation, 509
model building, 515–24
model building example, 519–24
model checking, 518–19
model specification and least squares estimation, 515–18
parameter estimation, 516, 518
partial autoregression matrices, 516–17
stationarity, 506, 509–10, 512
VAR(\(p\)) model, 509–11
VAR(1) model, 511–15
Yule-Walker equations, 510–11
Vector MA (VMA) model, 524–26
Vector ARMA (VARMA) model
aspects of nonuniqueness and parameter identifiability, 528–29
calculating forecasts from difference equation, 534–36
canonical correlation analysis, 530–31, 541–43
cointegration, estimation and inferences, 549–51
covariance matrix properties, 506–07, 528
echelon canonical form, 530, 533, 539, 541–42
estimation and model checking, 532–33
forecasting, 534–36
Kronecker indices, 530, 539–43
likelihood function, 532–33
model specification, 529–32, 539–45
nonstationarity and cointegration, 546–51
partial canonical correlation analysis reduced rank structure, 545–46
relation to transfer function and ARMAX model forms, 533–34
scalar component models (SCM), 530–31, 539
state-space form, 536–39
stationary and invertibility conditions, 527–28
vector autoregressive (VAR) model, 509–24
vector autoregressive-moving average (VARMA) model, 527–35
vector moving average (VMA) model, 524–27
vector white noise process, 507–08
Vector white noise process, 507–08
Venables, W.N., 18, 344

W
Wald, A., 222
Walker, A.M., 222
Walker, G., 47, 57
Weak stationarity, 28, 507
Wei, C.Z., 354
Wei, W.W.S., 514, 517
Weiss, A.A., 363, 368, 369, 370
White noise process
added, 124–25
defined, 7–8, 28–29
effect on IMA process, 124–25
linear filter output, 47–8
vector, 507–08
Whittle, P., 131, 210, 222, 273, 581
Wichern, D.W., 206, 516
Wiener, N., 131
Wincek, M.A., 244, 343, 496
Winters, P.R., 7
Wittenmark, B., 581
Wold, H.O., 47, 48, 131, 508
Wong, H., 370
Wood, E.F., 190, 192, 530, 543
Woodward, W.A., 190
Wooldridge, J.M., 370

X
Xiao, Z., 353
Xekalaki, E., 362

Y
Yaglom, A.M., 92
Yamamoto, T., 343
Yao, Q., 378, 380, 381
Yap, S.F., 358
Yohai, V.J., 488
Young, A.J., 428
Yule, G.U., 7, 47, 57, 197
Yule-Walker equations
introduction, 57
obtaining parameter estimates of AR process, 237–38
and partial autocorrelation function, 64–66
in AR(2) process, 61–62
in VAR(p) process, 510–11

Z
Zadeh, L.A., 92
Zakoian, J.-M., 362, 363, 370, 375