

## NAG Library Function Document

### nag\_tsa\_multi\_inp\_model\_forecast (g13bjc)

#### 1 Purpose

`nag_tsa_multi_inp_model_forecast` (g13bjc) produces forecasts of a time series (the output series) which may depend on one or more other (input) series via a previously estimated multi-input model. The future values of any input series must be supplied. Standard errors of the forecasts are produced. If future values of some of the input series have been obtained as forecasts using ARIMA models for those series, this may be allowed for in the calculation of the standard errors.

#### 2 Specification

```
#include <nag.h>
#include <nagg13.h>

void nag_tsa_multi_inp_model_forecast (Nag_ArimaOrder *arimav,
    Integer nseries, Nag_TransfOrder *transfv, double para[], Integer npara,
    Integer nev, Integer nfv, const double xxy[], Integer tdxxy,
    double rmsxy[], const Integer mrx[], Integer tdmrx, const double parx[],
    Integer ldparx, Integer tdpax, double fva[], double fsd[],
    Nag_G13_Opt *options, NagError *fail)
```

#### 3 Description

`nag_tsa_multi_inp_model_forecast` (g13bjc) has two stages. The first stage is essentially the same as a call to the model estimation function `nag_tsa_multi_inp_model_estim` (g13bec), with zero iterations. In particular, all the arguments remain unchanged in the supplied input series transfer function models and output noise series ARIMA model except that a further iteration takes place for any  $\omega$  corresponding to a simple input. The internal nuisance arguments associated with the pre-observation period effects of the input series are estimated where requested, and so are any backforecasts of the output noise series. The output components  $z_t$  and  $n_t$ , and residuals  $a_t$  are calculated exactly as described in the Section 3 of `nag_tsa_multi_inp_model_estim` (g13bec).

In the second stage, the forecasts of the output series  $y_t$  are calculated for  $t = n + 1, n + 2, \dots, n + L$  where  $n$  is the latest time point of the observations and  $L$  is the maximum lead time of the forecasts.

First the new values,  $x_t$  for any input series are used to form the input components  $z_t$  for  $t = n + 1, n + 2, \dots, n + L$  using the transfer function models:

$$(a) \quad z_t = \delta_1 z_{t-1} + \delta_2 z_{t-2} + \dots + \delta_p z_{t-p} + \omega_0 x_{t-b} - \omega_1 x_{t-b-1} - \dots - \omega_q x_{t-b-q}.$$

The output noise component  $n_t$  for  $t = n + 1, n + 2, \dots, n + L$  is then forecast by setting  $a_t = 0$  for  $t = n + 1, n + 2, \dots, n + L$  and using the ARIMA model equations:

$$(b) \quad e_t = \phi_1 e_{t-1} + \phi_2 e_{t-2} + \dots + \phi_p e_{t-p} + a_t - \theta_1 a_{t-1} - \theta_2 a_{t-2} - \dots - \theta_q a_{t-q}.$$

$$(c) \quad w_t = \Phi_1 w_{t-s} + \Phi_2 w_{t-2s} + \dots + \Phi_P w_{t-Ps} + e_t - \Theta_1 e_{t-s} - \Theta_2 e_{t-2s} - \dots - \Theta_Q e_{t-Qs}.$$

$$(d) \quad n_t = (\nabla^d \nabla_s^D)^{-1} (w_t + c).$$

This last step of ‘integration’ reverses the process of differencing. Finally the output forecasts are calculated as

$$y_t = z_{1,t} + z_{2,t} + \dots + z_{m,t} + n_t.$$

The forecast error variance of  $y_{t+l}$  (i.e., at lead time  $l$ ) is  $S_l^2$ , which is the sum of parts which arise from the various input series, and the output noise component. That part due to the output noise is

$$sn_l^2 = V_n \times (\psi_0^2 + \psi_1^2 + \dots + \psi_{l-1}^2)$$

$V_n$  is the estimated residual variance of the output noise ARIMA model, and  $\psi_0, \psi_1, \dots$ , are the ‘psi-weights’ of this model as defined in Box and Jenkins (1976). They are calculated by applying the equations (b), (c) and (d) above for  $t = 0, 1, \dots, L$ , but with artificial values for the various series and with the constant  $c$  set to 0. Thus all values of  $a_t, e_t, w_t$  and  $n_t$  are taken as zero for  $t < 0$ ;  $a_t$  is taken to be 1 for  $t = 0$  and 0 for  $t > 0$ . The resulting values of  $n_t$  for  $t = 0, 1, \dots, L$  are precisely  $\psi_0, \psi_1, \dots, \psi_L$  as required.

Further contributions to  $S_l^2$  come only from those input series, for which future values are forecasts which have been obtained by applying input series ARIMA models. For such a series the contribution is

$$sz_l^2 = V_x \times (\nu_0^2 + \nu_1^2 + \dots + \nu_{l-1}^2)$$

$V_x$  is the estimated residual variance of the input series ARIMA model. The coefficients  $\nu_0, \nu_1, \dots$  are calculated by applying the transfer function model equation (a) above for  $t = 0, 1, \dots, L$ , but again with artificial values of the series. Thus all values of  $z_t$  and  $x_t$  for  $t < 0$  are taken to be zero, and  $x_0, x_1, \dots$  are taken to be the psi-weight sequence  $\psi_0, \psi_1, \dots$  for the input series ARIMA model. The resulting values of  $z_t$  for  $t = 0, 1, \dots, L$  are precisely  $\nu_0, \nu_1, \dots, \nu_L$  as required.

In adding such contributions  $sz_l^2$  to  $sn_l^2$  to make up the total forecast error variance  $S_l^2$ , it is assumed that the various input series with which these contributions are associated, are statistically independent of each other.

When using the function in practice an ARIMA model is required for all the input series. In the case of those inputs for which no such ARIMA model is available (or its effects are to be excluded), the corresponding orders and arguments and the estimated residual variance should be set to zero.

## 4 References

Box G E P and Jenkins G M (1976) *Time Series Analysis: Forecasting and Control* (Revised Edition) Holden-Day

## 5 Arguments

1: **arimav** – Nag\_ArimaOrder \*

Pointer to structure of type Nag\_ArimaOrder with the following members:

<b>p</b> – Integer	
<b>d</b> – Integer	<i>Input</i>
<b>q</b> – Integer	<i>Input</i>
<b>bigp</b> – Integer	<i>Input</i>
<b>bigd</b> – Integer	<i>Input</i>
<b>bigq</b> – Integer	<i>Input</i>
<b>s</b> – Integer	<i>Input</i>

*On entry:* these seven members of **arimav** must specify the orders vector  $(p, d, q, P, D, Q, s)$ , respectively, of the ARIMA model for the output noise component.

$p, q, P$  and  $Q$  refer, respectively, to the number of autoregressive ( $\phi$ ), moving average ( $\theta$ ), seasonal autoregressive ( $\Phi$ ) and seasonal moving average ( $\Theta$ ) arguments.

$d, D$  and  $s$  refer, respectively, to the order of non-seasonal differencing, the order of seasonal differencing and the seasonal period.

*Constraints:*

$$\begin{aligned} p, d, q, P, D, Q, s &\geq 0; \\ p + q + P + Q &> 0; \\ s &\neq 1; \\ \text{if } s = 0, P + D + Q &= 0; \\ \text{if } s > 1, P + D + Q &> 0; \\ d + s \times (P + D) &\leq n; \\ p + d - q + s \times (P + D - Q) &\leq n. \end{aligned}$$

2: **nseries** – Integer *Input*

*On entry:* the number of input and output series. There may be any number of input series (including none), but only one output series.

*Constraint:* **nseries** > 1 if there are no arguments in the model (that is  $p = q = P = Q = 0$  and **options.cfired** = Nag.TRUE), **nseries** ≥ 1 otherwise.

3: **transfv** – Nag\_TransfOrder \*

Pointer to structure of type Nag\_TransfOrder with the following members:

<b>b</b> – Integer *		<i>Input</i>
<b>q</b> – Integer *		<i>Input</i>
<b>p</b> – Integer *		
<b>r</b> – Integer *		<i>Input</i>

*On entry:* before use these member pointers **must** be allocated memory by calling `nag_tsa_transf_orders` (g13byc) which allocates **nseries** – 1 elements to each pointer. The memory allocated to these pointers must be given the transfer function model orders  $b$ ,  $q$  and  $p$  of each of the input series. The order arguments for input series  $i$  are held in the  $i$ th element of the allocated memory for each pointer. **transfv**→**b**[ $i$  – 1] holds the value  $b_i$ , **transfv**→**q**[ $i$  – 1] holds the value  $q_i$  and **transfv**→**p**[ $i$  – 1] holds the value  $p_i$ .

For a simple input,  $b_i = q_i = p_i = 0$ .

**transfv**→**r**[ $i$  – 1] holds the value  $r_i$ , where  $r_i = 1$  for a simple input, and  $r_i = 2$  or 3 for a transfer function input.

The choice  $r_i = 3$  leads to estimation of the pre-period input effects as nuisance arguments, and  $r_i = 2$  suppresses this estimation. This choice may affect the returned forecasts.

When  $r_i = 1$ , any nonzero contents of the  $i$ th element of the memory of **transfv**→**b**, **transfv**→**q** and **transfv**→**p** are ignored.

*Constraint:* **transfv**→**r**[ $i$  – 1] = 1, 2 or 3, for  $i = 1, 2, \dots, \mathbf{nseries} - 1$

The memory allocated to the members of **transfv** must be freed by a call to `nag_tsa_trans_free` (g13bzc)

4: **para**[**npara**] – double *Input/Output*

*On entry:* estimates of the multi-input model arguments. These are in order firstly the ARIMA model arguments:  $p$  values of  $\phi$  arguments,  $q$  values of  $\theta$  arguments,  $P$  values of  $\Phi$  arguments,  $Q$  values of  $\Theta$  arguments. These are followed by the transfer function model argument values  $\omega_0, \omega_1, \dots, \omega_{q_1}$ , and  $\delta_1, \delta_2, \dots, \delta_{p_1}$  for the first of any input series and similarly for each subsequent input series. The final component of **para** is the value of the constant  $c$ .

*On exit:* the input estimates are unaltered except that any  $\omega$  estimates corresponding to a simple input will be undated by a single iteration.

5: **npara** – Integer *Input*

*On entry:* the exact number of  $\phi$ ,  $\theta$ ,  $\Phi$ ,  $\Theta$ ,  $\omega$ ,  $\delta$ ,  $c$  arguments, so that **npara** =  $p + q + P + Q + \mathbf{nseries} + \sum (p_i + q_i)$ , the summation being over all the input series. ( $c$  must be included whether its value was previously estimated or was set fixed.)

6: **nev** – Integer *Input*

*On entry:* the number of original (undifferenced) values in each of the input and output time-series.

- 7: **nfv** – Integer *Input*  
*On entry:* the number of forecast values of the output series required.  
*Constraint:* **nfv** > 0.
- 8: **xy**[(**nev** + **nfv**) × **tdxy**] – const double *Input*  
**Note:** the (*i*, *j*)th element of the matrix is stored in **xy**[(*i* − 1) × **tdxy** + *j* − 1].  
*On entry:* the columns of **xy** must contain in the first **nev** places, the past values of each of the input and output series, in that order. In the next **nfv** places, the columns relating to the input series (i.e., columns 0 to **nseries** − 2) contain the future values of the input series which are necessary for construction of the forecasts of the output series *y*.
- 9: **tdxy** – Integer *Input*  
*On entry:* the stride separating matrix column elements in the array **xy**.  
*Constraint:* **tdxy** ≥ **nseries**.
- 10: **rmsxy**[**nseries**] – double *Input/Output*  
*On entry:* elements of **rmsxy**[0] to **rmsxy**[**nseries** − 2] must contain the estimated residual variance of the input series ARIMA models. In the case of those inputs for which no ARIMA model is available or its effects are to be excluded in the calculation of forecast standard errors, the corresponding entry of **rmsxy** should be set to 0.  
*On exit:* **rmsxy**[**nseries** − 1] contains the estimated residual variance of the output noise ARIMA model which is calculated from the supplied series. Otherwise **rmsxy** is unchanged.
- 11: **mr**[7 × **tdmr**] – const Integer *Input*  
*On entry:* the orders array for each of the input series ARIMA models. Thus, column *i* − 1 contains values of *p*, *d*, *q*, *P*, *D*, *Q*, *s* for input series *i*. In the case of those inputs for which no ARIMA model is available, the corresponding orders should be set to 0.  
If there are no input series then **NULL** may be supplied in place of **mr**.
- 12: **tdmr** – Integer *Input*  
*On entry:* the stride separating matrix column elements in the array **mr**.  
*Constraint:* **tdmr** ≥ **nseries** − 1.
- 13: **par**[**ldpar** × **tdpar**] – const double *Input*  
**Note:** the (*i*, *j*)th element of the matrix is stored in **par**[(*i* − 1) × **tdpar** + *j* − 1].  
*On entry:* values of the arguments (*φ*, *θ*, *Φ*, and *Θ*) for each of the input series ARIMA models. Thus column *i* contains **mr**[*i*] values of *φ*, **mr**[(2) × **tdmr** + *i*] values of *θ*, **mr**[(3) × **tdmr** + *i*] values of *Φ* and **mr**[(5) × **tdmr** + *i*] values of *Θ* – in that order.  
Values in the columns relating to those input series for which no ARIMA model is available are ignored.  
If there are no input series then **NULL** may be supplied in place of **par**.
- 14: **ldpar** – Integer *Input*  
*On entry:* the maximum number of arguments in any of the input series ARIMA models. If there are no input series then **ldpar** is not referenced.  
*Constraint:* **ldpar** ≥ *nce* = max(1, (**mr**[*i*] + **mr**[(2) × **tdmr** + *i*] + **mr**[(3) × **tdmr** + *i*] + **mr**[(5) × **tdmr** + *i*])), for *i* = 0, 1, ..., **nseries** − 1.

- 15: **tdparx** – Integer *Input*  
*On entry:* the stride separating matrix column elements in the array **parx**.  
*Constraint:* **tdparx**  $\geq$  **nseries** – 1.
- 16: **fva[nfv]** – double *Output*  
*On exit:* the required forecast values for the output series.
- 17: **fsd[nfv]** – double *Output*  
*On exit:* the standard errors for each of the forecast values.
- 18: **options** – Nag\_G13\_Opt \* *Input/Output*  
*On entry/exit:* a pointer to a structure of type Nag\_G13\_Opt whose members are optional parameters for nag\_tsa\_multi\_inp\_model\_forecast (g13bjc). If the optional parameters are not required, then the null pointer, G13\_DEFAULT, can be used in the function call tonag\_tsa\_multi\_inp\_model\_forecast (g13bjc). Details of the optional parameters and their types are given below in Section 11.
- 19: **fail** – NagError \* *Input/Output*  
The NAG error argument (see Section 2.7 in How to Use the NAG Library and its Documentation).

## 6 Error Indicators and Warnings

### NE\_2\_INT\_ARG\_LT

On entry, **ldparx** =  $\langle value \rangle$  while *nce* =  $\langle value \rangle$ . These arguments must satisfy **ldparx**  $\geq$  *nce*. (See the expression for *nce* in Section 5 where **ldparx** is described).

On entry, **tdmrx** =  $\langle value \rangle$  while **nseries** – 1 =  $\langle value \rangle$ . These arguments must satisfy **tdmrx**  $\geq$  **nseries** – 1.

On entry, **tdparx** =  $\langle value \rangle$  while **nseries** – 1 =  $\langle value \rangle$ . These arguments must satisfy **tdparx**  $\geq$  **nseries** – 1.

On entry, **tdxxy** =  $\langle value \rangle$  while **nseries** =  $\langle value \rangle$ . These arguments must satisfy **tdxxy**  $\geq$  **nseries**.

### NE\_ALLOC\_FAIL

Dynamic memory allocation failed.

### NE\_ARIMA\_TEST\_FAILED

On entry, or during execution, one or more sets of the ARIMA ( $\phi$ ,  $\theta$ ,  $\Phi$  or  $\Theta$ ) arguments do not satisfy the stationarity or invertibility test conditions.

### NE\_BAD\_PARAM

On entry, argument **options.cfired** had an illegal value.

### NE\_CONSTRAINT

General constraint:  $\langle value \rangle$ .

### NE\_DELTA\_TEST\_FAILED

On entry, or during execution, one or more sets of  $\delta$  arguments do not satisfy the stationarity or invertibility test conditions.

**NE\_G13\_OPTIONS\_NOT\_INIT**

On entry, the option structure, **options**, has not been initialized using `nag_tsa_options_init` (g13bxc).

**NE\_G13\_ORDERS\_NOT\_INIT**

On entry, the orders array structure **transfv** in function `nag_tsa_transf_orders` (g13byc) has not been initialized.

**NE\_INT\_ARG\_LE**

On entry, **nfv** =  $\langle value \rangle$ .  
Constraint: **nfv** > 0.

**NE\_INT\_ARG\_LT**

On entry, **nseries** =  $\langle value \rangle$ .  
Constraint: **nseries**  $\geq 1$ .

**NE\_INT\_ARRAY\_2**

Value  $\langle value \rangle$  given to **transfv**→**r**[ $\langle value \rangle$ ] not valid. Correct range for elements if **transfv**→**r** is  $1 \leq \text{transfv} \rightarrow \mathbf{r}[i] \leq 3$ .

**NE\_INTERNAL\_ERROR**

An internal error has occurred in this function. Check the function call and any array sizes. If the call is correct then please contact NAG for assistance.

**NE\_INVALID\_NSER**

On entry, **nseries** = 1 and there are no arguments in the model, i.e., ( $p = q = P = Q = 0$  and **options.cfired** = Nag.TRUE).

**NE\_MAT\_NOT\_POS\_DEF**

Attempt to invert the second derivative matrix needed in the calculation of the covariance matrix of the parameter estimates has failed. The matrix is not positive definite, possibly due to rounding errors.

**NE\_NPARA\_MR\_MT\_INCONSIST**

On entry, there is inconsistency between **npara** on the one hand and the elements in the orders structures, **arimav** and **transfv** on the other.

**NE\_NSER\_INCONSIST**

Value of **nseries** passed to `nag_tsa_transf_orders` (g13byc) was  $\langle value \rangle$  which is not equal to the value  $\langle value \rangle$  passed in this function.

**NE\_SOLUTION\_FAIL\_CONV**

Iterative refinement has failed to improve the solution of the equations giving the latest estimates of the arguments. This occurred because the matrix of the set of equations is too ill-conditioned.

**7 Accuracy**

The computation used is believed to be stable.

**8 Parallelism and Performance**

`nag_tsa_multi_inp_model_forecast` (g13bjc) is not threaded in any implementation.

## 9 Further Comments

The time taken by `nag_tsa_multi_inp_model_forecast` (g13bjc) is approximately proportional to the product of the length of each series and the square of the number of arguments in the multi-input model.

## 10 Example

The data in this example relate to 40 observations of an output time series and 5 input time series. This example differs from Section 10 in `nag_tsa_multi_inp_model_estim` (g13bec) in `nag_tsa_multi_inp_model_estim` (g13bec) in that there are now 4 simple input series. The output series has one autoregressive ( $\phi$ ) argument and one seasonal moving average ( $\Theta$ ) argument. The seasonal period is 4. The transfer function input (the fifth in the set) is defined by orders  $b_5 = 1$ ,  $q_5 = 0$ ,  $p_5 = 1$ ,  $r_5 = 3$ , so that it allows for pre-observation period effects. The initial values of the specified model are:

$$\begin{aligned} \phi &= 0.495, \Theta = 0.238, \omega_1 = -0.367 \quad \omega_2 = -3.876 \quad \omega_3 = 4.516 \\ \omega_4 &= 2.474 \quad \omega_5 = 8.629 \quad \delta_1 = 0.688, c = -82.858. \end{aligned}$$

A further eight values of the input series are supplied, and it is assumed that the values for the fifth series have themselves been forecast from an ARIMA model with orders 2 0 2 0 1 1 4, in which  $\phi_1 = 1.6743$ ,  $\phi_2 = -0.9505$ ,  $\theta_1 = 1.4605$ ,  $\theta_2 = -0.4862$  and  $\Theta_1 = 0.8993$ , and for which the residual mean square is 0.1720.

The following are computed and printed out: the estimated residual variance for the output noise series, the eight forecast values and their standard errors, and the values of the components  $z_t$  and the output noise component  $n_t$ .

### 10.1 Program Text

```
/* nag_tsa_multi_inp_model_forecast (g13bjc) Example Program.
 *
 * NAGPRODCODE Version.
 *
 * Copyright 2016 Numerical Algorithms Group.
 *
 * Mark 26, 2016.
 */

#include <nag.h>
#include <stdio.h>
#include <string.h>
#include <nag_string.h>
#include <nag_stdlib.h>
#include <nagg13.h>

#define PARX(I, J) parx[(I) *tdparx + J]
#define XXY(I, J) xxy[(I) *tdxxy + J]
#define MRX(I, J) mrx[(I) *tdmrx + J]

int main(void)
{
    Integer exit_status = 0;
    Integer i, inser, j, ldparx, *mrx = 0, n, nev, nfv, npara;
    Integer nseries, tdmrx, tdparx, tdxxy;
    Nag_ArimaOrder arimav;
    Nag_G13_Opt options;
    Nag_TransfOrder transfv;
    double *fsd = 0, *fva = 0, *para = 0, *parx = 0, *rmsxy = 0;
    double *xxy = 0;
    NagError fail;

    INIT_FAIL(fail);

    printf("nag_tsa_multi_inp_model_forecast (g13bjc) Example Program "
           "Results\n");
#ifdef _WIN32
```

```

    scanf_s(" %*[^\\n]"); /* Skip heading in data file */
#else
    scanf(" %*[^\\n]"); /* Skip heading in data file */
#endif

#define ZT(I, J) options.zt[(J)+(I) *options.tdzt]

/*
 * Initialize the option-setting function.
 */
/* nag_tsa_options_init (g13bxc).
 * Initialization function for option setting
 */
nag_tsa_options_init(&options);

#ifdef _WIN32
    scanf_s("%" NAG_IFMT "%" NAG_IFMT "%" NAG_IFMT "", &nev, &nfv, &nseries);
#else
    scanf("%" NAG_IFMT "%" NAG_IFMT "%" NAG_IFMT "", &nev, &nfv, &nseries);
#endif
if (nseries > 0 && nev > 0 && nvf > 0) {
    /*
     * Set option variable to the desired value.
     */
    options.cfixed = Nag_TRUE;
    /*
     * Allocate memory to the arrays in structure transfv containing
     * the transfer function model orders of the input series.
     */
    /* nag_tsa_transf_orders (g13byc), see above. */
    nag_tsa_transf_orders(nseries, &transfv, &fail);
    if (fail.code != NE_NOERROR) {
        printf("Error from nag_tsa_transf_orders (g13byc).\\n%s\\n",
            fail.message);
        exit_status = 1;
        goto END;
    }
    /*
     * Read the orders vector of the ARIMA model for the output noise
     * component into structure arimav.
     */
#ifdef _WIN32
    scanf_s("%" NAG_IFMT "%" NAG_IFMT "%" NAG_IFMT "%" NAG_IFMT "%" NAG_IFMT "%" NAG_IFMT
        "" "%" NAG_IFMT "%" NAG_IFMT "", &arimav.p, &arimav.d, &arimav.q,
        &arimav.bigp, &arimav.bigd, &arimav.bigq, &arimav.s);
#else
    scanf("%" NAG_IFMT "%" NAG_IFMT "%" NAG_IFMT "%" NAG_IFMT "%" NAG_IFMT "%" NAG_IFMT ""
        "" "%" NAG_IFMT "%" NAG_IFMT "", &arimav.p, &arimav.d, &arimav.q,
        &arimav.bigp, &arimav.bigd, &arimav.bigq, &arimav.s);
#endif
    /*
     * Read the transfer function model orders of the input series into
     * structure transfv.
     */
    inser = nseries - 1;

    for (j = 0; j < inser; ++j)
#ifdef _WIN32
        scanf_s("%" NAG_IFMT "", &transfv.b[j]);
#else
        scanf("%" NAG_IFMT "", &transfv.b[j]);
#endif
    for (j = 0; j < inser; ++j)
#ifdef _WIN32
        scanf_s("%" NAG_IFMT "", &transfv.q[j]);
#else
        scanf("%" NAG_IFMT "", &transfv.q[j]);
#endif
    for (j = 0; j < inser; ++j)
#ifdef _WIN32
        scanf_s("%" NAG_IFMT "", &transfv.p[j]);

```



```

#else
    scanf("%" NAG_IFMT " ", &transfv.p[j]);
#endif
    for (j = 0; j < inser; ++j)
#ifdef _WIN32
        scanf_s("%" NAG_IFMT " ", &transfv.r[j]);
#else
        scanf("%" NAG_IFMT " ", &transfv.r[j]);
#endif

    npara = 0;
    for (i = 0; i < inser; ++i)
        npara = npara + transfv.q[i] + transfv.p[i];
    npara = npara + arimav.p + arimav.q + arimav.bigp + arimav.bigq + nseries;
    ldparx = 8;
    if (npara >= 1) {
        if (!(fsd = NAG_ALLOC(nfv, double)) ||
            !(fva = NAG_ALLOC(nfv, double)) ||
            !(para = NAG_ALLOC(npara, double)) ||
            !(parx = NAG_ALLOC(ldparx * (nseries - 1), double)) ||
            !(rmsxy = NAG_ALLOC(nseries, double)) ||
            !(xxy = NAG_ALLOC((nev + nfv) * (nseries), double)) ||
            !(mrx = NAG_ALLOC(7 * (nseries - 1), Integer)))
        {
            printf("Allocation failure\n");
            exit_status = -1;
            goto END;
        }
        tdmrx = nseries - 1;
        tdpax = nseries - 1;
        tdxdy = nseries;

        for (i = 0; i < npara; ++i)
#ifdef _WIN32
            scanf_s("%lf", &para[i]);
#else
            scanf("%lf", &para[i]);
#endif
        n = nev + nfv;
        for (i = 0; i < n; ++i)
            for (j = 0; j < nseries; ++j)
#ifdef _WIN32
                scanf_s("%lf", &XXY(i, j));
#else
                scanf("%lf", &XXY(i, j));
#endif
        for (i = 0; i < nseries; ++i)
#ifdef _WIN32
            scanf_s("%lf", &rmsxy[i]);
#else
            scanf("%lf", &rmsxy[i]);
#endif
        for (i = 0; i < 7; ++i)
            for (j = 0; j < inser; ++j)
#ifdef _WIN32
                scanf_s("%" NAG_IFMT " ", &MRX(i, j));
#else
                scanf("%" NAG_IFMT " ", &MRX(i, j));
#endif
        for (i = 0; i < 5; ++i)
            for (j = 0; j < inser; ++j)
#ifdef _WIN32
                scanf_s("%lf", &PARX(i, j));
#else
                scanf("%lf", &PARX(i, j));
#endif

        /* nag_tsa_multi_inp_model_forecast (g13bjc), see above. */
        fflush(stdout);
        nag_tsa_multi_inp_model_forecast(&arimav, nseries, &transfv, para,
                                         npara, nev, nfv, xxy, tdxdy, rmsxy,

```

```

        mrx, tdmrx, parx, ldparx,
        tdparr, fva, fsd, &options, &fail);

if (fail.code == NE_NOERROR || fail.code == NE_SOLUTION_FAIL_CONV ||
    fail.code == NE_MAT_NOT_POS_DEF) {
    printf("%1" NAG_IFMT " sets of observations were processed.\n", nev);
    printf("\nThe residual mean square for the output ");
    printf("series is %10.4f\n\n", rmsxy[nseries - 1]);
    printf("The forecast values and their standard errors are\n\n");
    printf("\n   i       fva       fsd\n\n");
    for (i = 0; i < nfv; ++i)
        printf("%4" NAG_IFMT "%10.3f%10.4f\n", i + 1, fva[i], fsd[i]);
    printf("\nThe values of z(t) and noise(t) are\n\n");
    printf("   i       z1       z2       z3       z4\n\n");
    for (i = 0; i < n; ++i) {
        printf("%4" NAG_IFMT " ", i + 1);
        for (j = 0; j < nseries - 1; ++j)
            printf("%10.3f ", ZT(i, j));
        printf("%10.3f\n", options.noise[i]);
    }
}
else {
    printf("Error from nag_tsa_multi_inp_model_forecast (g13bjc). "
        "\n%s\n", fail.message);
    exit_status = 1;
    goto END;
}
}
else {
    printf("npara is out of range: npara = %-3" NAG_IFMT "\n", npara);
    /* nag_tsa_free (g13xzc).
    * Freeing function for use with g13 option setting
    */
    nag_tsa_free(&options);
    /* nag_tsa_trans_free (g13bzc), see above. */
    nag_tsa_trans_free(&transfv);
    exit_status = 1;
    goto END;
}
}
else {
    printf("One or more of nseries, nev and nfv are out of range:"
        " nseries = %-3" NAG_IFMT ", nv = %-3" NAG_IFMT " while "
        "nfv = %-3" NAG_IFMT "q\n", nseries, nev, nfv);
    exit_status = 1;
    goto END;
}
/* nag_tsa_free (g13xzc), see above. */
nag_tsa_free(&options);
/* nag_tsa_trans_free (g13bzc), see above. */
nag_tsa_trans_free(&transfv);

END:
NAG_FREE(fsd);
NAG_FREE(fva);
NAG_FREE(para);
NAG_FREE(parx);
NAG_FREE(rmsxy);
NAG_FREE(xxy);
NAG_FREE(mrx);

return exit_status;
}

```

## 10.2 Program Data

```
nag_tsa_multi_inp_model_forecast (g13bjc) Example Program Data
  40      8      6
  1      0      0      0      0      1      4
  0      0      0      0      1
  0      0      0      0      0
  0      0      0      0      1
  1      1      1      1      3
  0.4950  0.2380 -0.3670 -3.8760  4.5160  2.4740  8.6290  0.6880
-82.8580
  1.0      1.0      0.0      0.0      8.075 105.0
  1.0      0.0      1.0      0.0      7.819 119.0
  1.0      0.0      0.0      1.0      7.366 119.0
  1.0     -1.0     -1.0     -1.0      8.113 109.0
  2.0      1.0      0.0      0.0      7.380 117.0
  2.0      0.0      1.0      0.0      7.134 135.0
  2.0      0.0      0.0      1.0      7.222 126.0
  2.0     -1.0     -1.0     -1.0      7.768 112.0
  3.0      1.0      0.0      0.0      7.386 116.0
  3.0      0.0      1.0      0.0      6.965 122.0
  3.0      0.0      0.0      1.0      6.478 115.0
  3.0     -1.0     -1.0     -1.0      8.105 115.0
  4.0      1.0      0.0      0.0      8.060 122.0
  4.0      0.0      1.0      0.0      7.684 138.0
  4.0      0.0      0.0      1.0      7.580 135.0
  4.0     -1.0     -1.0     -1.0      7.093 125.0
  5.0      1.0      0.0      0.0      6.129 115.0
  5.0      0.0      1.0      0.0      6.026 108.0
  5.0      0.0      0.0      1.0      6.679 100.0
  5.0     -1.0     -1.0     -1.0      7.414  96.0
  6.0      1.0      0.0      0.0      7.112 107.0
  6.0      0.0      1.0      0.0      7.762 115.0
  6.0      0.0      0.0      1.0      7.645 123.0
  6.0     -1.0     -1.0     -1.0      8.639 122.0
  7.0      1.0      0.0      0.0      7.667 128.0
  7.0      0.0      1.0      0.0      8.080 136.0
  7.0      0.0      0.0      1.0      6.678 140.0
  7.0     -1.0     -1.0     -1.0      6.739 122.0
  8.0      1.0      0.0      0.0      5.569 102.0
  8.0      0.0      1.0      0.0      5.049 103.0
  8.0      0.0      0.0      1.0      5.642  89.0
  8.0     -1.0     -1.0     -1.0      6.808  77.0
  9.0      1.0      0.0      0.0      6.636  89.0
  9.0      0.0      1.0      0.0      8.241  94.0
  9.0      0.0      0.0      1.0      7.968 104.0
  9.0     -1.0     -1.0     -1.0      8.044 108.0
 10.0      1.0      0.0      0.0      7.791 119.0
 10.0      0.0      1.0      0.0      7.024 126.0
 10.0      0.0      0.0      1.0      6.102 119.0
 10.0     -1.0     -1.0     -1.0      6.053 103.0
 11.0      1.0      0.0      0.0      5.941  0.0
 11.0      0.0      1.0      0.0      5.386  0.0
 11.0      0.0      0.0      1.0      5.811  0.0
 11.0     -1.0     -1.0     -1.0      6.716  0.0
 12.0      1.0      0.0      0.0      6.923  0.0
 12.0      0.0      1.0      0.0      6.939  0.0
 12.0      0.0      0.0      1.0      6.705  0.0
 12.0     -1.0     -1.0     -1.0      6.914  0.0
  0.0      0.0      0.0      0.0      0.1720  0.0
  0      0      0      0      2
  0      0      0      0      0
  0      0      0      0      2
  0      0      0      0      0
  0      0      0      0      1
  0      0      0      0      1
  0      0      0      0      4
```

0.0	0.0	0.0	0.0	1.6743
0.0	0.0	0.0	0.0	-0.9505
0.0	0.0	0.0	0.0	1.4605
0.0	0.0	0.0	0.0	-0.4862
0.0	0.0	0.0	0.0	0.8993

### 10.3 Program Results

nag\_tsa\_multi\_inp\_model\_forecast (g13bjc) Example Program Results

Parameters to g13bjc

nseries..... 6

cfixed..... Nag\_TRUE

outfile..... stdout

40 sets of observations were processed.

The residual mean square for the output series is 20.0902

The forecast values and their standard errors are

i	fva	fsd
1	93.398	4.4822
2	96.958	6.1498
3	86.046	7.0315
4	77.589	7.2885
5	82.139	7.3327
6	96.276	7.5220
7	98.345	8.0883
8	93.577	8.8020

The values of  $z(t)$  and noise(t) are

i	z1	z2	z3	z4	z5	noise
1	-0.339	-3.889	0.000	0.000	188.603	-79.375
2	-0.339	-0.000	4.514	0.000	199.438	-84.613
3	-0.339	-0.000	0.000	2.479	204.683	-87.823
4	-0.339	3.889	-4.514	-2.479	204.383	-91.940
5	-0.678	-3.889	0.000	0.000	210.623	-89.056
6	-0.678	-0.000	4.514	0.000	208.591	-77.426
7	-0.678	-0.000	0.000	2.479	205.070	-80.870
8	-0.678	3.889	-4.514	-2.479	203.407	-87.624
9	-1.017	-3.889	0.000	0.000	206.974	-86.068
10	-1.017	-0.000	4.514	0.000	206.132	-87.628
11	-1.017	-0.000	0.000	2.479	201.920	-88.381
12	-1.017	3.889	-4.514	-2.479	194.819	-75.698
13	-1.356	-3.889	0.000	0.000	203.974	-76.729
14	-1.356	-0.000	4.514	0.000	209.884	-75.041
15	-1.356	-0.000	0.000	2.479	210.705	-76.828
16	-1.356	3.889	-4.514	-2.479	210.373	-80.912
17	-1.695	-3.889	0.000	0.000	205.942	-85.358
18	-1.695	-0.000	4.514	0.000	194.575	-89.394
19	-1.695	-0.000	0.000	2.479	185.866	-86.650
20	-1.695	3.889	-4.514	-2.479	185.509	-84.709
21	-2.035	-3.889	0.000	0.000	191.606	-78.682
22	-2.035	-0.000	4.514	0.000	193.194	-80.673
23	-2.035	-0.000	0.000	2.479	199.896	-77.340
24	-2.035	3.889	-4.514	-2.479	203.497	-76.358
25	-2.374	-3.889	0.000	0.000	214.552	-80.290
26	-2.374	-0.000	4.514	0.000	213.770	-79.910
27	-2.374	-0.000	0.000	2.479	216.796	-76.901
28	-2.374	3.889	-4.514	-2.479	206.780	-79.302
29	-2.713	-3.889	0.000	0.000	200.416	-91.814
30	-2.713	-0.000	4.514	0.000	185.941	-84.742

31	-2.713	-0.000	0.000	2.479	171.495	-82.261
32	-2.713	3.889	-4.514	-2.479	166.673	-83.857
33	-3.052	-3.889	0.000	0.000	173.418	-77.477
34	-3.052	-0.000	4.514	0.000	176.573	-84.035
35	-3.052	-0.000	0.000	2.479	192.594	-88.021
36	-3.052	3.889	-4.514	-2.479	201.261	-87.105
37	-3.391	-3.889	0.000	0.000	207.879	-81.599
38	-3.391	-0.000	4.514	0.000	210.249	-85.372
39	-3.391	-0.000	0.000	2.479	205.262	-85.350
40	-3.391	3.889	-4.514	-2.479	193.874	-84.379
41	-3.730	-3.889	0.000	0.000	185.617	-84.600
42	-3.730	0.000	4.514	0.000	178.969	-82.795
43	-3.730	0.000	0.000	2.479	169.607	-82.309
44	-3.730	3.889	-4.514	-2.479	166.832	-82.409
45	-4.069	-3.889	0.000	0.000	172.733	-82.636
46	-4.069	0.000	4.514	0.000	178.579	-82.748
47	-4.069	0.000	0.000	2.479	182.739	-82.804
48	-4.069	3.889	-4.514	-2.479	183.582	-82.831

## 11 Optional Parameters

A number of optional input and output arguments to `nag_tsa_multi_inp_model_forecast` (g13bjc) are available through the structure argument **options** of type `Nag_G13_Opt`. An argument may be selected by assigning an appropriate value to the relevant structure member and those arguments not selected will be assigned default values. If no use is to be made of any of the optional parameters you should use the null pointer, `G13_DEFAULT`, in place of **options** when calling `nag_tsa_multi_inp_model_forecast` (g13bjc); the default settings will then be used for all arguments.

Before assigning values to **options** the structure must be initialized by a call to the function `nag_tsa_options_init` (g13bxc). Values may then be assigned directly to the structure members in the normal C manner.

Options selected by direct assignment are checked within `nag_tsa_multi_inp_model_forecast` (g13bjc) for being within the required range, if outside the range, an error message is generated.

When all calls to `nag_tsa_multi_inp_model_forecast` (g13bjc) have been completed and the results contained in the options structure are no longer required; then `nag_tsa_free` (g13xzc) should be called to free the NAG allocated memory from **options**.

### 11.1 Optional Parameters Checklist and Default Values

For easy reference, the following list shows the input and output members of **options** which are valid for `nag_tsa_multi_inp_model_forecast` (g13bjc) together with their default values where relevant.

```
Boolean list           Nag_TRUE
Boolean cfixed         Nag_FALSE
double *zt
double *noise
```

### 11.2 Description of the Optional Parameters

**List** – Nag\_Boolean Default = Nag\_TRUE

*On entry:* if **options.List** = Nag\_TRUE then the argument settings which are used in the call to `nag_tsa_multi_inp_model_forecast` (g13bjc) will be printed.

**cfixed** – Nag\_Boolean Default = Nag\_FALSE

*On entry:* **options.cfixed** must be set to Nag\_FALSE if the constant was estimated when the model was fitted, and Nag\_TRUE if it was held at a fixed value. This only affects the degrees of freedom used in calculating the estimated residual variance.

$$\text{Default memory} = (\mathbf{nev} + \mathbf{nfv}) \times (\mathbf{nseries} - 1)$$

```
noise = double *
```

Default memory = **nev** + **nfv**

*On exit:* this pointer is allocated memory internally with  $\mathbf{nev} + \mathbf{nfv}$  elements. It holds the output noise component  $n_t$ .