

# Reticular Action Model (RAM) Notation

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# Chapter 1

## Description

This is a collection of my personal notes on the Reticular Action Model (RAM) notation that accompanies the **ram** package. You can install the released version of **ram** from GitHub with:

```
remotes::install_github("jeksterslab/ram")
```

See GitHub Pages for the html deployment.



## Chapter 2

# Simple Regression

Let  $v_1$ ,  $v_2$ , and  $u$  be random variables whose associations are given by the regression equation

$$\begin{aligned} v_1 &= m_1 + a_{1,2}v_2 + u \\ &= -3.951208 + 1.269259 \cdot v_2 + u. \end{aligned} \tag{2.1}$$

$v_1$  and  $v_2$  are observed variables and  $u$  is a stochastic error term which is normally distributed around zero with constant variance across values of  $v_2$

$$u \sim \mathcal{N}(m_3 = 0, \omega_{3,3} = 47.659854). \tag{2.2}$$

$v_2$  has a mean of  $m_2 = 13.038328$  and a variance of  $\omega_{2,2} = 7.151261$ .

Below are two ways of specifying this model. The first specification includes the error term  $u$  as a latent variable. The second specification only includes the observed variables.

### 2.1 Specification 1 - Includes Error Term as a Latent Variable

#### 2.1.1 Matrix Notation

$$\text{variables} = \begin{bmatrix} v_1 \\ v_2 \\ u \end{bmatrix} \tag{2.3}$$

$$\mathbf{A} = \begin{bmatrix} 0 & a_{1,2} & 1 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} = \begin{bmatrix} 0 & 1.269259 & 1 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \quad (2.4)$$

$$\Omega = \begin{bmatrix} 0 & 0 & 0 \\ 0 & \omega_{2,2} & 0 \\ 0 & 0 & \omega_{3,3} \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 7.151261 & 0 \\ 0 & 0 & 47.659854 \end{bmatrix} \quad (2.5)$$

$$\mathbf{m} = \begin{bmatrix} m_1 \\ m_2 \\ m_3 \end{bmatrix} = \begin{bmatrix} -3.951208 \\ 13.038328 \\ 0 \end{bmatrix} \quad (2.6)$$

To filter the observed variables, use the following filter matrix

$$\mathbf{F} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix}. \quad (2.7)$$

To include all variables, use the following filter matrix

$$\mathbf{F} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}. \quad (2.8)$$

### 2.1.2 Path Diagram

### 2.1.3 Expectations

$$\mathbb{E}(u) = m_3 = 0 \quad (2.9)$$

$$\mathbb{E}(v_2) = m_2 = 13.038328 \quad (2.10)$$

$$\begin{aligned} \mathbb{E}(v_1) &= \mathbb{E}(m_1 + a_{1,2}v_2 + \varepsilon) \\ &= \mathbb{E}(m_1) + \mathbb{E}(a_{1,2}v_2) + \mathbb{E}(\varepsilon) \\ &= m_1 + a_{1,2}\mathbb{E}(v_2) + \mathbb{E}(\varepsilon) \\ &= m_1 + a_{1,2}m_2 + 0 \\ &= m_1 + a_{1,2}m_2 \\ &= -3.951208 + 1.269259 \times 13.038328 \\ &= 12.5978072 \end{aligned} \quad (2.11)$$



2.1. SPECIFICATION 1 - INCLUDES ERROR TERM AS A LATENT VARIABLE9

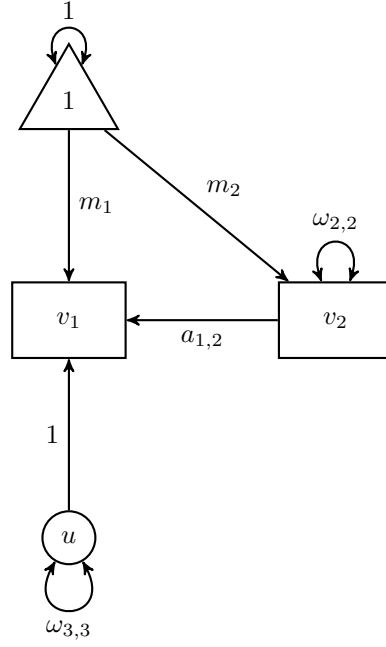


Figure 2.1: The Simple Linear Regression Model (with  $u$ )

$$\begin{aligned} \mathbb{E} \left( \begin{bmatrix} v_1 \\ v_2 \\ u \end{bmatrix} \right) &= \begin{bmatrix} m_1 + a_{1,2}m_2 \\ m_2 \\ m_3 \end{bmatrix} \\ &= \begin{bmatrix} 12.5978072 \\ 13.038328 \\ 0 \end{bmatrix} \end{aligned} \quad (2.12)$$

$$\begin{aligned} \text{Cov}(u, u) &= \text{Var}(u) \\ &= \omega_{3,3} \\ &= 47.659854 \end{aligned} \quad (2.13)$$

$$\begin{aligned}
\text{Cov}(v_1, u) &= \text{Cov}(a_{1,2}v_2 + u, u) \\
&= \text{Cov}(a_{1,2}v_2, u) + \text{Cov}(u, u) \\
&= a_{1,2}^2 \text{Cov}(v_2, u) + \text{Var}(u) \\
&= a_{1,2}^2 \cdot 0 + \omega_{3,3} \\
&= 0 + \omega_{3,3} \\
&= \omega_{3,3} \\
&= 47.659854
\end{aligned} \tag{2.14}$$

$$\text{Cov}(v_2, u) = 0 \tag{2.15}$$

$$\begin{aligned}
\text{Cov}(v_1, v_1) &= \text{Cov}(a_{1,2}v_2 + u, a_{1,2}v_2 + u) \\
&= \text{Cov}(a_{1,2}v_2, a_{1,2}v_2) + \text{Cov}(a_{1,2}v_2, u) + \text{Cov}(a_{1,2}v_2, u) + \text{Cov}(u, u) \\
&= a_{1,2}^2 \text{Cov}(v_2) + a_{1,2} \text{Cov}(v_2, u) + a_{1,2} \text{Cov}(v_2, u) + \text{Var}(u, u) \\
&= a_{1,2}^2 \text{Var}(v_2) + a_{1,2}0 + a_{1,2}0 + \omega_{3,3} \\
&= a_{1,2}^2 \omega_{2,2} + \omega_{3,3} \\
&= 1.269259^2 \times 7.151261 + 47.659854 \\
&= 59.1806671
\end{aligned} \tag{2.16}$$

$$\begin{aligned}
\text{Cov}(v_2, v_1) &= \text{Cov}(v_2, a_{1,2}v_2 + u) \\
&= \text{Cov}(v_2, a_{1,2}v_2) + \text{Cov}(v_2, u) \\
&= a_{1,2} \text{Cov}(v_2, v_2) + 0 \\
&= a_{1,2} \text{Var}(v_2) \\
&= a_{1,2} \omega_{2,2} \\
&= 1.269259 \times 7.151261 \\
&= 9.0768024
\end{aligned} \tag{2.17}$$

$$\begin{aligned}
\text{Cov}(v_2, v_2) &= \text{Var}(v_2) \\
&= \omega_{2,2} \\
&= 7.151261
\end{aligned} \tag{2.18}$$

$$\begin{aligned} \text{Cov} \left( \begin{bmatrix} v_1 \\ v_2 \\ u \end{bmatrix} \right) &= \begin{bmatrix} a_{1,2}^2 \omega_{2,2} + \omega_{3,3} & a_{1,2} \omega_{2,2} & \omega_{3,3} \\ a_{1,2} \omega_{2,2} & \omega_{2,2} & 0 \\ \omega_{3,3} & 0 & \omega_{3,3} \end{bmatrix} \\ &= \begin{bmatrix} 59.1806671 & 9.0768024 & 47.659854 \\ 9.0768024 & 7.151261 & 0 \\ 47.659854 & 0 & 47.659854 \end{bmatrix} \end{aligned} \tag{2.19}$$

2.1.3.1 Using the ram() Package

```
knitr::kable(
  ram::mutheta(
    m,
    A = A,
    filter = filter
  ),
  col.names = "$\\boldsymbol{\\mu}$",
  escape = FALSE
)
```

	$\mu$
$v_1$	12.59781
$v_2$	13.03833
$u$	0.00000

```
knitr::kable(
  ram::Sigmatheta(
    A = A,
    Omega = Omega,
    filter = filter
  ),
  escape = FALSE
)
```

	$v_1$	$v_2$	$u$
$v_1$	59.180667	9.076802	47.65985
$v_2$	9.076802	7.151261	0.00000
$u$	47.659854	0.000000	47.65985

## 2.2 Specification 2 - Observed Variables

### 2.2.1 Matrix Notation

$$\text{variables} = \begin{bmatrix} v_1 \\ v_2 \end{bmatrix} \quad (2.20)$$

$$\mathbf{A} = \begin{bmatrix} 0 & a_{1,2} \\ 0 & 0 \end{bmatrix} = \begin{bmatrix} 0 & 1.269259 \\ 0 & 0 \end{bmatrix} \quad (2.21)$$

$$\Omega = \begin{bmatrix} \omega_{1,1} & 0 \\ 0 & \omega_{2,2} \end{bmatrix} = \begin{bmatrix} 47.659854 & 0 \\ 0 & 7.151261 \end{bmatrix} \quad (2.22)$$

$$\mathbf{m} = \begin{bmatrix} m_1 \\ m_2 \end{bmatrix} = \begin{bmatrix} -3.951208 \\ 13.038328 \end{bmatrix} \quad (2.23)$$

$$\mathbf{F} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \quad (2.24)$$

### 2.2.2 Path Diagram

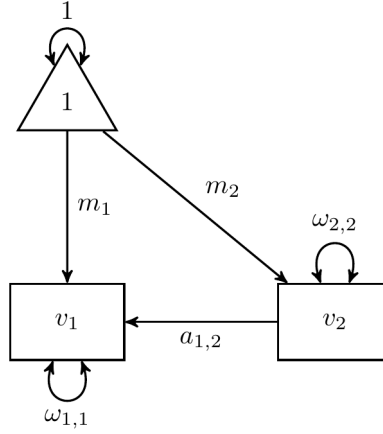


Figure 2.2: The Simple Linear Regression Model (without  $u$ )

#### 2.2.2.1 Using the `ram()` Package

```
knitr::kable(
  ram::mutheta(
    m,
    A = A,
    filter = filter
  ),
  col.names = "$\\boldsymbol{\\mu}$",
  escape = FALSE
)
```

	$\mu$
$v_1$	12.59781
$v_2$	13.03833

```
knitr::kable(
  ram::Sigmatheta(
    A = A,
    Omega = Omega,
    filter = filter
  ),
  escape = FALSE
)
```

	$v_1$	$v_2$
$v_1$	59.180667	9.076802
$v_2$	9.076802	7.151261