$$y_{it} = \alpha_i + \beta_{1i}\text{age}_t + \delta_{2t}\text{TVC}_{it} + \varepsilon_{it}$$

$$\alpha_i = \mu_\alpha + \gamma_{01}\text{TIC}_i + \zeta_{\alpha i}$$

$$\beta_{1i} = \mu_{\beta 1} + \gamma_{11}\text{TIC}_i + \zeta_{\beta 1i}$$

$$\mathbf{y}_i = \mathbf{\Lambda}\boldsymbol{\eta}_i + \mathbf{\Delta}\mathbf{z}_{it} + \boldsymbol{\varepsilon}_i$$

$$\boldsymbol{\eta}_i = \boldsymbol{\mu}_\eta + \mathbf{\Gamma}\mathbf{w}_i + \boldsymbol{\zeta}_i$$

$$\begin{pmatrix} y_{i8} \\ y_{i9} \\ y_{i10} \\ y_{i11} \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ 1 & 1 \\ 1 & 2 \\ 1 & 3 \end{pmatrix}\begin{pmatrix} \alpha_i \\ \beta_{1i} \end{pmatrix} + \begin{pmatrix} \delta_{i8} \\ \delta_{i9} \\ \delta_{i10} \\ \delta_{i11} \end{pmatrix}(\text{TVC}_{it}) + \begin{pmatrix} \varepsilon_{i8} \\ \varepsilon_{i9} \\ \varepsilon_{i10} \\ \varepsilon_{i11} \end{pmatrix}$$

$$\begin{pmatrix} \alpha_i \\ \beta_{1i} \end{pmatrix} = \begin{pmatrix} \mu_\alpha \\ \mu_{\beta 1} \end{pmatrix} + \begin{pmatrix} \gamma_{01} \\ \gamma_{11} \end{pmatrix}(\text{TIC}_i) + \begin{pmatrix} \zeta_{\alpha i} \\ \zeta_{\beta 1i} \end{pmatrix}$$

$$\begin{bmatrix} \zeta_{\alpha i} \\ \zeta_{\beta 1i} \end{bmatrix} \sim N\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \psi_{\alpha\alpha} & \\ \psi_{\alpha\beta 1} & \psi_{\beta 1\beta 1} \end{pmatrix}\right)$$

$$\begin{bmatrix} \varepsilon_{i8} \\ \varepsilon_{i9} \\ \varepsilon_{i10} \\ \varepsilon_{i11} \end{bmatrix} \sim N\left(\begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \theta_{\varepsilon 8} & & & \\ & \theta_{\varepsilon 9} & & \\ & & \theta_{\varepsilon 10} & \\ & & & \theta_{\varepsilon 11} \end{pmatrix}\right)$$

$$\mathbf{y}_i = \mathbf{\Lambda}\boldsymbol{\mu}_\eta + \mathbf{\Lambda}\boldsymbol{\zeta}_i + \mathbf{\Lambda}\mathbf{\Gamma}\mathbf{w}_i + \mathbf{\Delta}\mathbf{z}_{it} + \boldsymbol{\varepsilon}_i$$

$$\begin{aligned} y_{it} = {} & \mu_\alpha + \mu_{\beta 1}\text{age}_t + \delta_{2t}\text{TVC}_{it} + \varepsilon_{it} \\ & + \zeta_{\alpha i} + \gamma_{01}\text{TIC}_i \\ & + \zeta_{\beta 1i}\text{age}_t + \gamma_{11}\text{TVC}_{it} \times \text{TIC}_i \end{aligned}$$

```
MODEL:
! Grows BY
Int      by y8@1   y9@1
           y10@1 y11@1;
linear  by y8@0   y9@1
           y10@2 y11@3;
! Regressed ON
Int      on  TIC;
linear on  TIC;
y8       on  TVC;
y9       on  TVC;
y10      on  TVC;
y11      on  TVC;
! Correlated WITH
int with linear;
! Intercepts
[y8-y11@0];
[int];
[linear];
! Residual Variances
y8-y11;
int;
linear;
```

- Add unique TVC for each time
- Add same TVC for all times
- Add TIC of slope
- Add TIC of intercept
- Make residual variances ≠
- Have intercept & slope covary
- Make slope random
- Make intercept random
- Add fixed slope
- Add fixed intercept
- Null

$$y_{it} = \alpha_i + \beta_{1i}\text{age}_t + \delta_2\,\text{TVC}_{it} + \varepsilon_{it}$$
$$\alpha_i = \mu_\alpha + \gamma_{01}\text{TIC}_i + \zeta_{\alpha i}$$
$$\beta_{1i} = \mu_{\beta 1} + \gamma_{11}\text{TIC}_i + \zeta_{\beta 1i}$$
$$\mathbf{y}_i = \boldsymbol{\Lambda}\boldsymbol{\eta}_i + \boldsymbol{\Delta}\mathbf{z}_{it} + \boldsymbol{\varepsilon}_i$$
$$\boldsymbol{\eta}_i = \boldsymbol{\mu}_\eta + \boldsymbol{\Gamma}\mathbf{w}_i + \boldsymbol{\zeta}_i$$

$$\begin{pmatrix} y_{i8} \\ y_{i9} \\ y_{i10} \\ y_{i11} \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ 1 & 1 \\ 1 & 2 \\ 1 & 3 \end{pmatrix} \begin{pmatrix} \alpha_i \\ \beta_{1i} \end{pmatrix} + \begin{pmatrix} \delta_i \\ \delta_i \\ \delta_i \\ \delta_i \end{pmatrix} \left(\text{TVC}_{it}\right) + \begin{pmatrix} \varepsilon_{i8} \\ \varepsilon_{i9} \\ \varepsilon_{i10} \\ \varepsilon_{i11} \end{pmatrix}$$

$$\begin{pmatrix} \alpha_i \\ \beta_{1i} \end{pmatrix} = \begin{pmatrix} \mu_\alpha \\ \mu_{\beta 1} \end{pmatrix} + \begin{pmatrix} \gamma_{01} \\ \gamma_{11} \end{pmatrix} \left(\text{TIC}_i\right) + \begin{pmatrix} \zeta_{\alpha i} \\ \zeta_{\beta 1i} \end{pmatrix}$$

$$\begin{bmatrix} \zeta_{\alpha i} \\ \zeta_{\beta 1i} \end{bmatrix} \sim N\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \psi_{\alpha\alpha} & \\ \psi_{\alpha\beta 1} & \psi_{\beta 1\beta 1} \end{pmatrix} \right)$$

$$\begin{bmatrix} \varepsilon_{i8} \\ \varepsilon_{i9} \\ \varepsilon_{i10} \\ \varepsilon_{i11} \end{bmatrix} \sim N\left(\begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \theta_{\varepsilon 8} & & & \\ & \theta_{\varepsilon 9} & & \\ & & \theta_{\varepsilon 10} & \\ & & & \theta_{\varepsilon 11} \end{pmatrix} \right)$$

$$\mathbf{y}_i = \boldsymbol{\Lambda}\boldsymbol{\mu}_\eta + \boldsymbol{\Lambda}\boldsymbol{\zeta}_i + \boldsymbol{\Lambda}\boldsymbol{\Gamma}\mathbf{w}_i + \boldsymbol{\Delta}\mathbf{z}_{it} + \boldsymbol{\varepsilon}_i$$
$$y_{it} = \mu_\alpha + \mu_{\beta 1}\text{age}_t + \delta_2\,\text{TVC}_{it} + \varepsilon_{it} + \zeta_{\alpha i} + \gamma_{01}\text{TIC}_i + \zeta_{\beta 1i}\text{age}_t + \gamma_{11}\text{TVC}_{it} \times \text{TIC}_i$$

```
MODEL:
! Grows BY
Int     by y8@1  y9@1
           y10@1 y11@1;
linear  by y8@0  y9@1
           y10@2 y11@3;
! Regressed ON
Int     on  TIC;
linear  on  TIC;
y8      on  TVC (delta);
y9      on  TVC (delta);
y10     on  TVC (delta);
y11     on  TVC (delta);
! Correlated WITH
int with linear;
! Intercepts
[y8-y11@0];
[int];
[linear];
! Residual Variances
y8-y11;
int;
linear;
```

Add unique TVC for each time

- Add same TVC for all times
- Add TIC of slope
- Add TIC of intercept
- Make residual variances ≠
- Have intercept & slope covary
- Make slope random
- Make intercept random
- Add fixed slope
- Add fixed intercept
- Null

$$y_{it} = \alpha_i + \beta_{1i}\text{age}_t + \varepsilon_{it}$$
$$\alpha_i = \mu_\alpha + \gamma_{01}\text{TIC}_i + \zeta_{\alpha i}$$
$$\beta_{1i} = \mu_{\beta 1} + \gamma_{11}\text{TIC}_i + \zeta_{\beta 1 i}$$
$$\mathbf{y}_i = \mathbf{\Lambda}\boldsymbol{\eta}_i + \boldsymbol{\varepsilon}_i$$
$$\boldsymbol{\eta}_i = \boldsymbol{\mu}_\eta + \mathbf{\Gamma}\mathbf{w}_i + \boldsymbol{\zeta}_i$$

$$\begin{pmatrix} y_{i8} \\ y_{i9} \\ y_{i10} \\ y_{i11} \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ 1 & 1 \\ 1 & 2 \\ 1 & 3 \end{pmatrix} \begin{pmatrix} \alpha_i \\ \beta_{1i} \end{pmatrix} + \begin{pmatrix} \varepsilon_{i8} \\ \varepsilon_{i9} \\ \varepsilon_{i10} \\ \varepsilon_{i11} \end{pmatrix}$$

$$\begin{pmatrix} \alpha_i \\ \beta_{1i} \end{pmatrix} = \begin{pmatrix} \mu_\alpha \\ \mu_{\beta 1} \end{pmatrix} + \begin{pmatrix} \gamma_{01} \\ \gamma_{11} \end{pmatrix} (\text{TIC}_i) + \begin{pmatrix} \zeta_{\alpha i} \\ \zeta_{\beta 1 i} \end{pmatrix}$$

$$\begin{bmatrix} \zeta_{\alpha i} \\ \zeta_{\beta 1 i} \end{bmatrix} \sim N\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \psi_{\alpha\alpha} & \\ \psi_{\alpha\beta 1} & \psi_{\beta 1\beta 1} \end{pmatrix} \right)$$

$$\begin{bmatrix} \varepsilon_{i8} \\ \varepsilon_{i9} \\ \varepsilon_{i10} \\ \varepsilon_{i11} \end{bmatrix} \sim N\left(\begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \theta_{\varepsilon 8} & & & \\ & \theta_{\varepsilon 9} & & \\ & & \theta_{\varepsilon 10} & \\ & & & \theta_{\varepsilon 11} \end{pmatrix} \right)$$

$$\mathbf{y}_i = \mathbf{\Lambda}\boldsymbol{\mu}_\eta + \mathbf{\Lambda}\boldsymbol{\zeta}_i + \mathbf{\Lambda}\mathbf{\Gamma}\mathbf{w}_i + \boldsymbol{\varepsilon}_i$$
$$y_{it} = \mu_\alpha + \mu_{\beta 1}\text{age}_t + \varepsilon_{it} + \zeta_{\alpha i} + \gamma_{01}\text{TIC}_i + \zeta_{\beta 1 i}\text{age}_t + \gamma_{11}\text{TVC}_{it} \times \text{TIC}_i$$

```
MODEL:
! Grows BY
Int      by y8@1  y9@1
            y10@1 y11@1;
linear  by y8@0  y9@1
            y10@2 y11@3;
! Regressed ON
Int     on  TIC;
linear on  TIC;

! Correlated WITH
int with linear;
! Intercepts
[y8-y11@0];
[int];
[linear];
! Residual Variances
y8-y11;
int;
linear;
```

Add unique TVC for each time

Add same TVC for all times

- Add TIC of slope
- Add TIC of intercept
- Make residual variances ≠
- Have intercept & slope covary
- Make slope random
- Make intercept random
- Add fixed slope
- Add fixed intercept
- Null

$$y_{it} = \alpha_i + \beta_{1i}\text{age}_t + \varepsilon_{it}$$
$$\alpha_i = \mu_\alpha + \gamma_{01}\text{TIC}_i + \zeta_{\alpha i}$$
$$\beta_{1i} = \mu_{\beta 1} + \zeta_{\beta 1 i}$$
$$\mathbf{y}_i = \mathbf{\Lambda}\boldsymbol{\eta}_i + \boldsymbol{\varepsilon}_i$$
$$\boldsymbol{\eta}_i = \boldsymbol{\mu}_\eta + \mathbf{\Gamma}\mathbf{w}_i + \boldsymbol{\zeta}_i$$

$$\begin{pmatrix} y_{i8} \\ y_{i9} \\ y_{i10} \\ y_{i11} \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ 1 & 1 \\ 1 & 2 \\ 1 & 3 \end{pmatrix} \begin{pmatrix} \alpha_i \\ \beta_{1i} \end{pmatrix} + \begin{pmatrix} \varepsilon_{i8} \\ \varepsilon_{i9} \\ \varepsilon_{i10} \\ \varepsilon_{i11} \end{pmatrix}$$

$$\begin{pmatrix} \alpha_i \\ \beta_{1i} \end{pmatrix} = \begin{pmatrix} \mu_\alpha \\ \mu_{\beta 1} \end{pmatrix} + \begin{pmatrix} \gamma_{01} \\ \end{pmatrix} (\text{TIC}_i) + \begin{pmatrix} \zeta_{\alpha i} \\ \zeta_{\beta 1 i} \end{pmatrix}$$

$$\begin{bmatrix} \zeta_{\alpha i} \\ \zeta_{\beta 1 i} \end{bmatrix} \sim N\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \psi_{\alpha\alpha} & \\ \psi_{\alpha\beta 1} & \psi_{\beta 1 \beta 1} \end{pmatrix} \right)$$

$$\begin{bmatrix} \varepsilon_{i8} \\ \varepsilon_{i9} \\ \varepsilon_{i10} \\ \varepsilon_{i11} \end{bmatrix} \sim N\left(\begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \theta_{\varepsilon 8} & & & \\ & \theta_{\varepsilon 9} & & \\ & & \theta_{\varepsilon 10} & \\ & & & \theta_{\varepsilon 11} \end{pmatrix} \right)$$

$$\mathbf{y}_i = \mathbf{\Lambda}\boldsymbol{\mu}_\eta + \mathbf{\Lambda}\boldsymbol{\zeta}_i + \mathbf{\Lambda}\mathbf{\Gamma}\mathbf{w}_i + \boldsymbol{\varepsilon}_i$$
$$y_{it} = \mu_\alpha + \mu_{\beta 1}\text{age}_t + \varepsilon_{it} + \zeta_{\alpha i} + \gamma_{01}\text{TIC}_i + \zeta_{\beta 1 i}\text{age}_t$$

```
MODEL:
! Grows BY
Int      by y8@1   y9@1
            y10@1 y11@1;
linear  by y8@0   y9@1
            y10@2 y11@3;
! Regressed ON
Int      on  TIC;

! Correlated WITH
int with linear;
! Intercepts
[y8-y11@0];
[int];
[linear];
! Residual Variances
y8-y11;
int;
linear;
```

Add unique TVC for each time

Add same TVC for all times

Add TIC of slope

Add TIC of intercept

Make residual variances ≠

Have intercept & slope covary

Make slope random

Make intercept random

Add fixed slope

Add fixed intercept

Null

$$y_{it} = \alpha_i + \beta_{1i}\text{age}_t + \varepsilon_{it}$$
$$\alpha_i = \mu_\alpha + \zeta_{ai}$$
$$\beta_{1i} = \mu_{\beta 1} + \zeta_{\beta 1i}$$
$$\mathbf{y}_i = \mathbf{\Lambda}\boldsymbol{\eta}_i + \boldsymbol{\varepsilon}_i$$
$$\boldsymbol{\eta}_i = \boldsymbol{\mu}_\eta + \boldsymbol{\zeta}_i$$

$$\begin{pmatrix} y_{i8} \\ y_{i9} \\ y_{i10} \\ y_{i11} \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ 1 & 1 \\ 1 & 2 \\ 1 & 3 \end{pmatrix} \begin{pmatrix} \alpha_i \\ \beta_{1i} \end{pmatrix} + \begin{pmatrix} \varepsilon_{i8} \\ \varepsilon_{i9} \\ \varepsilon_{i10} \\ \varepsilon_{i11} \end{pmatrix}$$

$$\begin{pmatrix} \alpha_i \\ \beta_{1i} \end{pmatrix} = \begin{pmatrix} \mu_\alpha \\ \mu_{\beta 1} \end{pmatrix} + \begin{pmatrix} \zeta_{\alpha i} \\ \zeta_{\beta 1i} \end{pmatrix}$$

$$\begin{bmatrix} \zeta_{\alpha i} \\ \zeta_{\beta 1i} \end{bmatrix} \sim N\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \psi_{\alpha\alpha} & \\ \psi_{\alpha\beta 1} & \psi_{\beta 1\beta 1} \end{pmatrix} \right)$$

$$\begin{bmatrix} \varepsilon_{i8} \\ \varepsilon_{i9} \\ \varepsilon_{i10} \\ \varepsilon_{i11} \end{bmatrix} \sim N\left(\begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \theta_{\varepsilon 8} & & & \\ & \theta_{\varepsilon 9} & & \\ & & \theta_{\varepsilon 10} & \\ & & & \theta_{\varepsilon 11} \end{pmatrix} \right)$$

$$\mathbf{y}_i = \mathbf{\Lambda}\boldsymbol{\mu}_\eta + \mathbf{\Lambda}\boldsymbol{\zeta}_i + \boldsymbol{\varepsilon}_i$$
$$y_{it} = \mu_\alpha + \mu_{\beta 1}\text{age}_t + \varepsilon_{it} + \zeta_{ai} + \zeta_{\beta 1i}\text{age}_t$$

```
MODEL:
! Grows BY
Int     by y8@1   y9@1
           y10@1 y11@1;
linear  by y8@0   y9@1
           y10@2 y11@3;
! Regressed ON

! Correlated WITH
int with linear;
! Intercepts
[y8-y11@0];
[int];
[linear];
! Residual Variances
y8-y11;
int;
linear;
```

Add unique TVC for each time

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Make intercept random

Add fixed slope

Add fixed intercept

Null

$$y_{it} = \alpha_i + \beta_{1i}\text{age}_t + \varepsilon_{it}$$
$$\alpha_i = \mu_\alpha + \zeta_{\alpha i}$$
$$\beta_{1i} = \mu_{\beta 1} + \zeta_{\beta 1 i}$$
$$\mathbf{y}_i = \boldsymbol{\Lambda}\boldsymbol{\eta}_i + \boldsymbol{\varepsilon}_i$$
$$\boldsymbol{\eta}_i = \boldsymbol{\mu}_\eta + \boldsymbol{\zeta}_i$$

$$\begin{pmatrix} y_{i8} \\ y_{i9} \\ y_{i10} \\ y_{i11} \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ 1 & 1 \\ 1 & 2 \\ 1 & 3 \end{pmatrix} \begin{pmatrix} \alpha_i \\ \beta_{1i} \end{pmatrix} + \begin{pmatrix} \varepsilon_{i8} \\ \varepsilon_{i9} \\ \varepsilon_{i10} \\ \varepsilon_{i11} \end{pmatrix}$$

$$\begin{pmatrix} \alpha_i \\ \beta_{1i} \end{pmatrix} = \begin{pmatrix} \mu_\alpha \\ \mu_{\beta 1} \end{pmatrix} + \begin{pmatrix} \zeta_{\alpha i} \\ \zeta_{\beta 1 i} \end{pmatrix}$$

$$\begin{bmatrix} \zeta_{\alpha i} \\ \zeta_{\beta 1 i} \end{bmatrix} \sim N\begin{pmatrix} \begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \psi_{\alpha\alpha} & \\ \psi_{\alpha\beta 1} & \psi_{\beta 1 \beta 1} \end{pmatrix} \end{pmatrix}$$

$$\begin{bmatrix} \varepsilon_{i8} \\ \varepsilon_{i9} \\ \varepsilon_{i10} \\ \varepsilon_{i11} \end{bmatrix} \sim N\begin{pmatrix} \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \theta_\varepsilon & & & \\ & \theta_\varepsilon & & \\ & & \theta_\varepsilon & \\ & & & \theta_\varepsilon \end{pmatrix} \end{pmatrix}$$

$$\mathbf{y}_i = \boldsymbol{\Lambda}\boldsymbol{\mu}_\eta + \boldsymbol{\Lambda}\boldsymbol{\zeta}_i + \boldsymbol{\varepsilon}_i$$
$$y_{it} = \mu_\alpha + \mu_{\beta 1}\text{age}_t + \varepsilon_{it} + \zeta_{\alpha i} + \zeta_{\beta 1 i}\text{age}_t$$

```
MODEL:
! Grows BY
Int      by y8@1   y9@1
            y10@1 y11@1;
linear  by y8@0   y9@1
            y10@2 y11@3;
! Regressed ON

! Correlated WITH
int with linear;
! Intercepts
[y8-y11@0];
[int];
[linear];
! Residual Variances
y8-y11(epsilon);
int;
linear;
```

Add unique TVC for each time

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Have intercept & slope covary

Make slope random

Make intercept random

Add fixed slope

Add fixed intercept

Null

$$y_{it} = \alpha_i + \beta_{1i}\text{age}_t + \varepsilon_{it}$$
$$\alpha_i = \mu_\alpha + \zeta_{\alpha i}$$
$$\beta_{1i} = \mu_{\beta 1} + \zeta_{\beta 1 i}$$
$$\mathbf{y}_i = \mathbf{\Lambda}\boldsymbol{\eta}_i + \boldsymbol{\varepsilon}_i$$
$$\boldsymbol{\eta}_i = \boldsymbol{\mu}_\eta + \boldsymbol{\zeta}_i$$

$$\begin{pmatrix} y_{i8} \\ y_{i9} \\ y_{i10} \\ y_{i11} \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ 1 & 1 \\ 1 & 2 \\ 1 & 3 \end{pmatrix} \begin{pmatrix} \alpha_i \\ \beta_{1i} \end{pmatrix} + \begin{pmatrix} \varepsilon_{i8} \\ \varepsilon_{i9} \\ \varepsilon_{i10} \\ \varepsilon_{i11} \end{pmatrix}$$

$$\begin{pmatrix} \alpha_i \\ \beta_{1i} \end{pmatrix} = \begin{pmatrix} \mu_\alpha \\ \mu_{\beta 1} \end{pmatrix} + \begin{pmatrix} \zeta_{\alpha i} \\ \zeta_{\beta 1 i} \end{pmatrix}$$

$$\begin{bmatrix} \zeta_{\alpha i} \\ \zeta_{\beta 1 i} \end{bmatrix} \sim N\begin{pmatrix} \begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \psi_{\alpha\alpha} & \\ & \psi_{\beta 1 \beta 1} \end{pmatrix} \end{pmatrix}$$

$$\begin{bmatrix} \varepsilon_{i8} \\ \varepsilon_{i9} \\ \varepsilon_{i10} \\ \varepsilon_{i11} \end{bmatrix} \sim N\begin{pmatrix} \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \theta_\varepsilon & & & \\ & \theta_\varepsilon & & \\ & & \theta_\varepsilon & \\ & & & \theta_\varepsilon \end{pmatrix} \end{pmatrix}$$

$$\mathbf{y}_i = \mathbf{\Lambda}\boldsymbol{\mu}_\eta + \mathbf{\Lambda}\boldsymbol{\zeta}_i + \boldsymbol{\varepsilon}_i$$
$$y_{it} = \mu_\alpha + \mu_{\beta 1}\text{age}_t + \varepsilon_{it} + \zeta_{\alpha i} + \zeta_{\beta 1 i}\text{age}_t$$

```
MODEL:
! Grows BY
Int       by y8@1   y9@1
             y10@1 y11@1;
linear  by y8@0   y9@1
             y10@2 y11@3;
! Regressed ON

! Correlated WITH
int with linear@0;
! Intercepts
[y8-y11@0];
[int];
[linear];
! Residual Variances
y8-y11(epsilon);
int;
linear;
```

Add unique TVC for each time

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Have intercept & slope covary

Make slope random

Make intercept random

Add fixed slope

Add fixed intercept

Null

$$y_{it} = \alpha_i + \beta_{1i}\text{age}_t + \varepsilon_{it}$$
$$\alpha_i = \mu_\alpha + \zeta_{ai}$$
$$\beta_{1i} = \mu_{\beta 1} +$$
$$\mathbf{y}_i = \boldsymbol{\Lambda}\boldsymbol{\eta}_i + \boldsymbol{\varepsilon}_i$$
$$\boldsymbol{\eta}_i = \boldsymbol{\mu}_\eta + \boldsymbol{\zeta}_i$$

$$\begin{pmatrix} y_{i8} \\ y_{i9} \\ y_{i10} \\ y_{i11} \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ 1 & 1 \\ 1 & 2 \\ 1 & 3 \end{pmatrix} \begin{pmatrix} \alpha_i \\ \beta_{1i} \end{pmatrix} + \begin{pmatrix} \varepsilon_{i8} \\ \varepsilon_{i9} \\ \varepsilon_{i10} \\ \varepsilon_{i11} \end{pmatrix}$$

$$\begin{pmatrix} \alpha_i \\ \beta_{1i} \end{pmatrix} = \begin{pmatrix} \mu_\alpha \\ \mu_{\beta 1} \end{pmatrix} + \begin{pmatrix} \zeta_{\alpha i} \\ \; \end{pmatrix}$$

$$\begin{bmatrix} \zeta_{\alpha i} \\ \zeta_{\beta 1 i} \end{bmatrix} \sim N\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \psi_{\alpha\alpha} & \\ & \end{pmatrix} \right)$$

$$\begin{bmatrix} \varepsilon_{i8} \\ \varepsilon_{i9} \\ \varepsilon_{i10} \\ \varepsilon_{i11} \end{bmatrix} \sim N\left(\begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \theta_\varepsilon & & & \\ & \theta_\varepsilon & & \\ & & \theta_\varepsilon & \\ & & & \theta_\varepsilon \end{pmatrix} \right)$$

$$\mathbf{y}_i = \boldsymbol{\Lambda}\boldsymbol{\mu}_\eta + \boldsymbol{\Lambda}\boldsymbol{\zeta}_i + \boldsymbol{\varepsilon}_i$$
$$y_{it} = \mu_\alpha + \mu_{\beta 1}\text{age}_t + \varepsilon_{it} + \zeta_{ai}$$

```
MODEL:
! Grows BY
Int     by y8@1   y9@1
           y10@1 y11@1;
linear  by y8@0   y9@1
           y10@2 y11@3;
! Regressed ON

! Correlated WITH
int with linear@0;
! Intercepts
[y8-y11@0];
[int];
[linear];
! Residual Variances
y8-y11(epsilon);
int;
linear@0;
```

Add unique TVC for each time

Add same TVC for all times

Add TIC of slope

Add TIC of intercept

Make residual variances ≠

Have intercept & slope covary

Make slope random

Make intercept random

Add fixed slope

Add fixed intercept

Null

$$y_{it} = \alpha_i + \beta_{1i}\text{age}_t + \varepsilon_{it}$$
$$\alpha_i = \mu_\alpha$$
$$\beta_{1i} = \mu_{\beta 1}$$
$$\mathbf{y}_i = \mathbf{\Lambda}\boldsymbol{\eta}_i + \boldsymbol{\varepsilon}_i$$
$$\boldsymbol{\eta}_i = \boldsymbol{\mu}_\eta$$

$$\begin{pmatrix} y_{i8} \\ y_{i9} \\ y_{i10} \\ y_{i11} \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ 1 & 1 \\ 1 & 2 \\ 1 & 3 \end{pmatrix} \begin{pmatrix} \alpha_i \\ \beta_{1i} \end{pmatrix} + \begin{pmatrix} \varepsilon_{i8} \\ \varepsilon_{i9} \\ \varepsilon_{i10} \\ \varepsilon_{i11} \end{pmatrix}$$

$$\begin{pmatrix} \alpha_i \\ \beta_{1i} \end{pmatrix} = \begin{pmatrix} \mu_\alpha \\ \mu_{\beta 1} \end{pmatrix}$$

$$\begin{bmatrix} \zeta_{\alpha i} \\ \zeta_{\beta 1 i} \end{bmatrix} \sim N\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} & \\ & \end{pmatrix} \right)$$

$$\begin{bmatrix} \varepsilon_{i8} \\ \varepsilon_{i9} \\ \varepsilon_{i10} \\ \varepsilon_{i11} \end{bmatrix} \sim N\left(\begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \theta_\varepsilon & & & \\ & \theta_\varepsilon & & \\ & & \theta_\varepsilon & \\ & & & \theta_\varepsilon \end{pmatrix} \right)$$

$$\mathbf{y}_i = \mathbf{\Lambda}\boldsymbol{\mu}_\eta + \boldsymbol{\varepsilon}_i$$
$$y_{it} = \mu_\alpha + \mu_{\beta 1}\text{age}_t + \varepsilon_{it}$$

```
MODEL:
! Grows BY
Int     by y8@1  y9@1
           y10@1 y11@1;
linear  by y8@0  y9@1
           y10@2 y11@3;
! Regressed ON

! Correlated WITH
int with linear@0;
! Intercepts
[y8-y11@0];
[int];
[linear];
! Residual Variances
y8-y11(epsilon);
int@0;
linear@0;
```

- Add unique TVC for each time
- Add same TVC for all times
- Add TIC of slope
- Add TIC of intercept
- Make residual variances ≠
- Have intercept & slope covary
- Make slope random
- Make intercept random
- **Add fixed slope**
- **Add fixed intercept**
- **Null**

$$y_{it} = \alpha_i + \varepsilon_{it}$$

$$\alpha_i = \mu_\alpha$$

$$\mathbf{y}_i = \boldsymbol{\Lambda}\boldsymbol{\eta}_i + \boldsymbol{\varepsilon}_i$$

$$\boldsymbol{\eta}_i = \boldsymbol{\mu}_\eta$$

$$\begin{pmatrix} y_{i8} \\ y_{i9} \\ y_{i10} \\ y_{i11} \end{pmatrix} = \begin{pmatrix} 1 \\ 1 \\ 1 \\ 1 \end{pmatrix} (\alpha_i) + \begin{pmatrix} \varepsilon_{i8} \\ \varepsilon_{i9} \\ \varepsilon_{i10} \\ \varepsilon_{i11} \end{pmatrix}$$

$$\begin{pmatrix} \alpha_i \\ \beta_{1i} \end{pmatrix} = \begin{pmatrix} \mu_\alpha \\ 0 \end{pmatrix}$$

$$\begin{bmatrix} \zeta_{\alpha i} \\ \zeta_{\beta 1i} \end{bmatrix} \sim N\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} & \\ & \end{pmatrix} \right)$$

$$\begin{bmatrix} \varepsilon_{i8} \\ \varepsilon_{i9} \\ \varepsilon_{i10} \\ \varepsilon_{i11} \end{bmatrix} \sim N\left(\begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \theta_\varepsilon & & & \\ & \theta_\varepsilon & & \\ & & \theta_\varepsilon & \\ & & & \theta_\varepsilon \end{pmatrix} \right)$$

$$\mathbf{y}_i = \boldsymbol{\Lambda}\boldsymbol{\mu}_\eta + \boldsymbol{\varepsilon}_i$$

$$y_{it} = \mu_\alpha + \varepsilon_{it}$$

```
MODEL:
! Grows BY
Int      by y8@1   y9@1
            y10@1 y11@1;
linear  by y8@0   y9@1
            y10@2 y11@3;
! Regressed ON

! Correlated WITH
int with linear@0;
! Intercepts
[y8-y11@0];
[int];
[linear@0];
! Residual Variances
y8-y11(epsilon);
int@0;
linear@0;
```

- Add unique TVC for each time
- Add same TVC for all times
- Add TIC of slope
- Add TIC of intercept
- Make residual variances ≠
- Have intercept & slope covary
- Make slope random
- Make intercept random
- Add fixed slope
- **Add fixed intercept**
- **Null**

$$y_{it} = 0 + \varepsilon_{it}$$

$$\mathbf{y}_i = \mathbf{0} + \boldsymbol{\varepsilon}_i$$

$$\begin{pmatrix} y_{i8} \\ y_{i9} \\ y_{i10} \\ y_{i11} \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \end{pmatrix} + \begin{pmatrix} \varepsilon_{i8} \\ \varepsilon_{i9} \\ \varepsilon_{i10} \\ \varepsilon_{i11} \end{pmatrix}$$

$$\begin{pmatrix} \alpha_i \\ \beta_{1i} \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \end{pmatrix}$$

$$\begin{bmatrix} \zeta_{\alpha i} \\ \zeta_{\beta 1i} \end{bmatrix} \sim N\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} & \\ & \end{pmatrix}$$

$$\begin{bmatrix} \varepsilon_{i8} \\ \varepsilon_{i9} \\ \varepsilon_{i10} \\ \varepsilon_{i11} \end{bmatrix} \sim N\begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \theta_\varepsilon & & & \\ & \theta_\varepsilon & & \\ & & \theta_\varepsilon & \\ & & & \theta_\varepsilon \end{pmatrix}$$

$$\mathbf{y}_i = \mathbf{0} + \boldsymbol{\varepsilon}_i$$

$$y_{it} = 0 + \varepsilon_{it}$$

```
MODEL:
! Grows BY
Int     by y8@1  y9@1
           y10@1 y11@1;
linear  by y8@0  y9@1
           y10@2 y11@3;
! Regressed ON

! Correlated WITH
int with linear@0;
! Intercepts
[y8-y11@0];
[int@0];
[linear@0];
! Residual Variances
y8-y11(epsilon);
int@0;
linear@0;
```

- Add unique TVC for each time
- Add same TVC for all times
- Add TIC of slope
- Add TIC of intercept
- Make residual variances ≠
- Have intercept & slope covary
- Make slope random
- Make intercept random
- Add fixed slope
- Add fixed intercept
- **Null**