

Forecasting: principles and practice

Rob J Hyndman

2.1 State space models

Tren	d	Seasonal	
	##Nothods V No	dals A	M
N	##Methods V Mo	$y_t = (1_{t-1} + 1_{t+s_{t-m_t}})(1_{t+\varepsilon_t})$	$y_t \equiv \ell_{t-1} s_{t-m}(\mathbb{1} a_t \varepsilon_t)$
	$\ell_t \equiv \ell_{t-1} (1 + \epsilon_{t} \epsilon_t)$	$\ell_t \equiv \ell_{t-1} + \alpha (\ell_{t-1} + s_{t-m}) \varepsilon_t$	$\ell_t \equiv \ell_{t-1} (\# \alpha \epsilon_{\alpha} \epsilon_{1})_{-m}$
	###Exponential s	matathine+methods	$s_t = s_{t=m}(4 \text{ perke})_{-1}$
	$y_t = (\ell_{t+1} + b \ell_{t+1}) \cdot (\ell_t + \varepsilon_t)$	$ \frac{\text{rh} \bar{\text{o}} \text{o'thing}^{+} \text{methods}}{y_{t} = (\ell_{t-1} + t \ell_{t-1} + \epsilon_{t-1} + \epsilon_{t-1} + \epsilon_{t})} $	$y_t = (\ell_{t-1} + b_{t-1})s_{t-m}(\mathbb{1} e_t \varepsilon_t)$
A	$\ell_t \equiv (\ell_{t-1} + b_{t-1}) (\alpha \in \alpha \varepsilon_t)$	$\ell_t \equiv \ell_{t-1} + b_{t-1} + \alpha (\ell_{t-1} + b_{t-1} + s_{t-m}) \varepsilon_t$	$\ell_t \equiv (\ell_{t-1} + b_{t-1}) (\Phi \in k_{t-1})_n$
	b <u>⊫</u> b₁At¢∕onit∮nnos t	$hat refurn point foreca$ $s_t = s_{t-m} + y(\theta_{t-1} + \theta_{t-1} + s_{t-m})\varepsilon_t$	$ b_{t=1} + \beta (\ell/\underline{s}_{1-m}b_{t-1})\varepsilon_{t} $
	_ / 1180111111111111111111111111111111111	$s_t \equiv s_{t-m} + \gamma (\ell_{t-1} + b_{t-1} + s_{t-m}) \varepsilon_t$	$\mathbf{s}_{t} \equiv \mathbf{s}_{t-m}(1 \times \mathbf{s}_{t} \mathcal{E}(\mathbf{s}_{t-1} + b_{t-1})$
	$y_t \equiv (\ell_{t+1} + \ell_t) \ell_{t+1} + (\ell_t + \varepsilon_t)$	$y_t = (\ell_{t-1} + \phi b_{t-1} + s_{t-m_t})(\ell_t + \varepsilon_t)$	$y_t \equiv (\ell_{t-1} + \phi b_{t-1}) s_{t-m} (\mathbb{1} \otimes_t \varepsilon_t)$
A_d	$\ell_t = (\ell_{t-1} + \phi b \ell_{t-1})(\alpha s_t \alpha \varepsilon_t)$	$\ell_t = \ell_{t-1} + \phi b_{t-1} + \alpha \epsilon \ell_{t-1} + \phi b_{t-1} + s_{t-m}) \varepsilon_t$	$\ell_t = (\ell_{t-1}) + (\ell_t \ell_{t-1}) (\alpha_t s_t \ell_{t} s_{t-1})_n$
	$b_t \equiv \phi b_{t-1} + \beta (\ell_{t-1} + \phi b_{t-1}) \varepsilon_t$	$b_t \equiv \phi b_{t-1} + \beta \xi \ell_{t-1} + \phi b_{t-1} + s_{t-m}) \varepsilon_t$	$b_t \equiv \phi b_{t-1} + \beta (\ell/s_{1-m}\phi b_{t-1})\varepsilon_t$
		$s_t \equiv s_{t-m} + \gamma \mathcal{E}(t_{t-1} + \phi b_{t-1} + s_{t-m}) \varepsilon_t$	$s_t \equiv s_{t=m}(4 \times spk(\delta_{t-1} + \phi b_{t-1})$

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N	##Methods V Mo	$y_{t} \equiv (\ell_{t+1} + \epsilon_{t+nn_{t}})(\ell_{t+\epsilon_{t}})$	$y_t \equiv \ell_{t-1} s_{t-m} (\exists \exists_t \varepsilon_t)$
	$\ell_t \equiv \ell_{t-1} (\mathbb{1} \alpha \epsilon_{\alpha} \epsilon_t)$	$\ell_t \equiv \ell_{t-1} + \alpha (\ell_{t-1} + s_{t-m}) \varepsilon_t$	$\ell_t \equiv \ell_{t-1} (\# \alpha \epsilon_{\alpha} \epsilon_{\gamma})_{-m}$
	###Evnonential s	mābthi no -methods	$s_t = s_{t=m}(4 $
	$y_t = (\ell_{t+1}) + b\ell_{t+1} + (\ell_t + \varepsilon_t)$	$y_t = (\ell_{t-1} + \ell_{t-1} + \epsilon_{t-1} + \epsilon_{t-1} + \epsilon_{t-1} + \epsilon_{t-1})$	$y_t = (\ell_{t-1} + b_{t-1})s_{t-m}(\mathbb{1} e_t \varepsilon_t)$
A	$\ell_t \equiv (\ell_{t-1} + b_{t-1})(\alpha \in \alpha \varepsilon_t)$	$\ell_t \equiv \ell_{t-1} + b_{t-1} + \alpha \xi \ell_{t-1} + b_{t-1} + s_{t-m}) \varepsilon_t$	$\ell_t \equiv (\ell_{t-1} + b \ell_{t-1}) (\alpha \in \ell \varepsilon_t)_n$
	^b <u></u> b₁Algorithms t	$hat return point forecase s_t = s_{t-m} + y(t_{t-1} + b_{t-1} + s_{t-m})\varepsilon_t$	$S^{t}S_{t=1}^{b_{t=1}} + \beta \mathcal{E}(s_{1}-mb_{t-1})\varepsilon_{t}$
	_ ,gerreriire e	$s_t \equiv s_{t-m} + \gamma (\ell_{t-1} + b_{t-1} + s_{t-m}) \varepsilon_t$	$\mathbf{s}_{t} \equiv \mathbf{s}_{t-m}(1 + \mathbf{s}_{t}) \mathcal{E}(\mathbf{s}_{t-1} + \mathbf{b}_{t-1})$
	$y_t \equiv (\ell_{t+1} + \phi b_{t+1})(\ell_{t+1})$	$y_t \equiv (\ell_{t-1} + \phi b \ell_{t-1} + s_{t-m_t})(\ell_{t+\epsilon_t})$	$y_t \equiv (\ell_{t-1} + \phi b_{t-1}) s_{t-m} (\mathbb{1} \in \epsilon_t)$
A_d	###kanovations s	tate-space amode is s_{t-m}) ε_t $b_t \equiv \phi b_{t-1} + \beta \xi \ell_{t-1} + \phi b_{t-1} + s_{t-m}) \varepsilon_t$	$\ell_t = (\ell_{t-1} + \ell_t) b(t_{t-1}) (\alpha s_t t s_{\ell_t})_n$
	$b_t \equiv \phi b_{t-1} + \beta (\ell_{t-1} + \phi b_{t-1}) \varepsilon_t$	$b_t \equiv \phi b_{t-1} + \beta (\ell_{t-1} + \phi b_{t-1} + s_{t-m}) \varepsilon_t$	$b_t \equiv \phi b_{t-1} + \beta (\ell/s_{1-t} + \phi b_{t-1}) \varepsilon_t$
		$s_t \equiv s_{t-m} + \gamma (\ell_{t-1} + \phi b_{t-1} + s_{t-m}) \varepsilon_t$	$s_t \equiv s_{t=m}(4 $

- Generate same point forecasts but can also generate forecast intervals.
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	$\ell_t \equiv \ell_{t-1} (\mathbb{1} \alpha \epsilon_{\alpha} \epsilon_t)$	$\ell_t \equiv \ell_{t-1} + \alpha (\ell_{t-1} + s_{t-m}) \varepsilon_t$	$\ell_t \equiv \ell_{t-1} (\# \alpha \epsilon_{\alpha} \epsilon_{\gamma})_{-m}$
	###Evnonential s	mābthi no -methods	$s_t = s_{t=m}(4 $
	$y_t = (\ell_{t+1}) + b\ell_{t+1} + (\ell_t + \varepsilon_t)$	$y_t = (\ell_{t-1} + \ell_{t-1} + \epsilon_{t-1} + \epsilon_{t-1} + \epsilon_{t-1} + \epsilon_{t-1})$	$y_t = (\ell_{t-1} + b_{t-1})s_{t-m}(\mathbb{1} e_t \varepsilon_t)$
A	$\ell_t \equiv (\ell_{t-1} + b_{t-1})(\alpha \in \alpha \varepsilon_t)$	$\ell_t \equiv \ell_{t-1} + b_{t-1} + \alpha \xi \ell_{t-1} + b_{t-1} + s_{t-m}) \varepsilon_t$	$\ell_t \equiv (\ell_{t-1} + b \ell_{t-1}) (\alpha \in \ell \varepsilon_t)_n$
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	_ ,gerreriire e	$s_t \equiv s_{t-m} + \gamma (\ell_{t-1} + b_{t-1} + s_{t-m}) \varepsilon_t$	$\mathbf{s}_{t} \equiv \mathbf{s}_{t-m}(1 + \mathbf{s}_{t}) \mathcal{E}(\mathbf{s}_{t-1} + \mathbf{b}_{t-1})$
	$y_t \equiv (\ell_{t+1} + \phi b_{t+1})(\ell_{t+1})$	$y_t \equiv (\ell_{t-1} + \phi b \ell_{t-1} + s_{t-m_t})(\ell_{t+\epsilon_t})$	$y_t \equiv (\ell_{t-1} + \phi b_{t-1}) s_{t-m} (\mathbb{1} \in \epsilon_t)$
A_d	###kanovations s	tate-space amode is s_{t-m}) ε_t $b_t \equiv \phi b_{t-1} + \beta \xi \ell_{t-1} + \phi b_{t-1} + s_{t-m}) \varepsilon_t$	$\ell_t = (\ell_{t-1} + \ell_t) b(t_{t-1}) (\alpha s_t t s_{\ell_t})_n$
	$b_t \equiv \phi b_{t-1} + \beta (\ell_{t-1} + \phi b_{t-1}) \varepsilon_t$	$b_t \equiv \phi b_{t-1} + \beta (\ell_{t-1} + \phi b_{t-1} + s_{t-m}) \varepsilon_t$	$b_t \equiv \phi b_{t-1} + \beta (\ell/s_{1-t} + \phi b_{t-1}) \varepsilon_t$
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	###Evnonential s	mābthi no -methods	$s_t = s_{t=m}(4 $
	$y_t = (\ell_{t+1}) + b\ell_{t+1} + (\ell_t + \varepsilon_t)$	$y_t = (\ell_{t-1} + \ell_{t-1} + \epsilon_{t-1} + \epsilon_{t-1} + \epsilon_{t-1} + \epsilon_{t-1})$	$y_t = (\ell_{t-1} + b_{t-1})s_{t-m}(\mathbb{1} e_t \varepsilon_t)$
A	$\ell_t \equiv (\ell_{t-1} + b_{t-1})(\alpha \in \alpha \varepsilon_t)$	$\ell_t \equiv \ell_{t-1} + b_{t-1} + \alpha \xi \ell_{t-1} + b_{t-1} + s_{t-m}) \varepsilon_t$	$\ell_t \equiv (\ell_{t-1} + b \ell_{t-1}) (\alpha \in \ell \varepsilon_t)_n$
	^b <u></u> b₁Algorithms t	$hat return point forecase s_t = s_{t-m} + y(t_{t-1} + b_{t-1} + s_{t-m})\varepsilon_t$	$S^{t}S_{t=1}^{b_{t=1}} + \beta \mathcal{E}(s_{1}-mb_{t-1})\varepsilon_{t}$
	_ ,gerreriire e	$s_t \equiv s_{t-m} + \gamma (\ell_{t-1} + b_{t-1} + s_{t-m}) \varepsilon_t$	$\mathbf{s}_{t} \equiv \mathbf{s}_{t-m}(1 + \mathbf{s}_{t}) \mathcal{E}(\mathbf{s}_{t-1} + \mathbf{b}_{t-1})$
	$y_t \equiv (\ell_{t+1} + \phi b_{t+1})(\ell_{t+1})$	$y_t \equiv (\ell_{t-1} + \phi b \ell_{t-1} + s_{t-m_t})(\ell_{t+\epsilon_t})$	$y_t \equiv (\ell_{t-1} + \phi b_{t-1}) s_{t-m} (\mathbb{1} \in \epsilon_t)$
A_d	###kanovations s	tate-space amode is s_{t-m}) ε_t $b_t \equiv \phi b_{t-1} + \beta \xi \ell_{t-1} + \phi b_{t-1} + s_{t-m}) \varepsilon_t$	$\ell_t = (\ell_{t-1} + \ell_t) b(t_{t-1}) (\alpha s_t t s_{\ell_t})_n$
	$b_t \equiv \phi b_{t-1} + \beta (\ell_{t-1} + \phi b_{t-1}) \varepsilon_t$	$b_t \equiv \phi b_{t-1} + \beta (\ell_{t-1} + \phi b_{t-1} + s_{t-m}) \varepsilon_t$	$b_t \equiv \phi b_{t-1} + \beta (\ell/s_{1-t} + \phi b_{t-1}) \varepsilon_t$
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A	$\ell_t \equiv (\ell_{t-1} + b_{t-1})(\alpha \in \alpha \varepsilon_t)$	$\ell_t \equiv \ell_{t-1} + b_{t-1} + \alpha \xi \ell_{t-1} + b_{t-1} + s_{t-m}) \varepsilon_t$	$\ell_t \equiv (\ell_{t-1} + b \ell_{t-1}) (\alpha \in \ell \varepsilon_t)_n$
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	_ ,gerreriire e	$s_t \equiv s_{t-m} + \gamma (\ell_{t-1} + b_{t-1} + s_{t-m}) \varepsilon_t$	$\mathbf{s}_{t} \equiv \mathbf{s}_{t-m}(1 + \mathbf{s}_{t}) \mathcal{E}(\mathbf{s}_{t-1} + \mathbf{b}_{t-1})$
	$y_t \equiv (\ell_{t+1} + \phi b_{t+1})(\ell_{t+1})$	$y_t \equiv (\ell_{t-1} + \phi b \ell_{t-1} + s_{t-m_t})(\ell_{t+\epsilon_t})$	$y_t \equiv (\ell_{t-1} + \phi b_{t-1}) s_{t-m} (\mathbb{1} \in \varepsilon_t)$
A_d	###kanovations s	tate-space amode is s_{t-m}) ε_t $b_t \equiv \phi b_{t-1} + \beta \xi \ell_{t-1} + \phi b_{t-1} + s_{t-m}) \varepsilon_t$	$\ell_t = (\ell_{t-1} + \ell_t) b(t_{t-1}) (\alpha s_t t s_{\ell_t})_n$
	$b_t \equiv \phi b_{t-1} + \beta (\ell_{t-1} + \phi b_{t-1}) \varepsilon_t$	$b_t \equiv \phi b_{t-1} + \beta (\ell_{t-1} + \phi b_{t-1} + s_{t-m}) \varepsilon_t$	$b_t \equiv \phi b_{t-1} + \beta (\ell/s_{1-t} + \phi b_{t-1}) \varepsilon_t$
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	$y_t = (\ell_{t+1}) + b\ell_{t+1} + (\ell_t + \varepsilon_t)$	$y_t = (\ell_{t-1} + \ell_{t-1} + \epsilon_{t-1} + \epsilon_{t-1} + \epsilon_{t-1} + \epsilon_{t-1})$	$y_t = (\ell_{t-1} + b_{t-1})s_{t-m}(\mathbb{1} e_t \varepsilon_t)$
A	$\ell_t \equiv (\ell_{t-1} + b_{t-1})(\alpha \in \alpha \varepsilon_t)$	$\ell_t \equiv \ell_{t-1} + b_{t-1} + \alpha \xi \ell_{t-1} + b_{t-1} + s_{t-m}) \varepsilon_t$	$\ell_t \equiv (\ell_{t-1} + b \ell_{t-1}) (\alpha \in \ell \varepsilon_t)_n$
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	$y_t \equiv (\ell_{t+1} + \phi b_{t+1})(\ell_{t+1})$	$y_t \equiv (\ell_{t-1} + \phi b \ell_{t-1} + s_{t-m_t})(\ell_{t+\epsilon_t})$	$y_t \equiv (\ell_{t-1} + \phi b_{t-1}) s_{t-m} (\mathbb{1} \in \varepsilon_t)$
A_d	###kanovations s	tate-space amode is s_{t-m}) ε_t $b_t \equiv \phi b_{t-1} + \beta \xi \ell_{t-1} + \phi b_{t-1} + s_{t-m}) \varepsilon_t$	$\ell_t = (\ell_{t-1} + \ell_t) b(t_{t-1}) (\alpha s_t t s_{\ell_t})_n$
	$b_t \equiv \phi b_{t-1} + \beta (\ell_{t-1} + \phi b_{t-1}) \varepsilon_t$	$b_t \equiv \phi b_{t-1} + \beta (\ell_{t-1} + \phi b_{t-1} + s_{t-m}) \varepsilon_t$	$b_t \equiv \phi b_{t-1} + \beta (\ell/s_{1-t} + \phi b_{t-1}) \varepsilon_t$
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A	$\ell_t \equiv (\ell_{t-1} + b_{t-1})(\alpha \in \alpha \varepsilon_t)$	$\ell_t \equiv \ell_{t-1} + b_{t-1} + \alpha \xi \ell_{t-1} + b_{t-1} + s_{t-m}) \varepsilon_t$	$\ell_t \equiv (\ell_{t-1} + b \ell_{t-1}) (\alpha \in \ell \varepsilon_t)_n$
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	$y_t \equiv (\ell_{t+1} + \phi b_{t+1})(\ell_{t+1})$	$y_t \equiv (\ell_{t-1} + \phi b \ell_{t-1} + s_{t-m_t})(\ell_{t+\epsilon_t})$	$y_t \equiv (\ell_{t-1} + \phi b_{t-1}) s_{t-m} (\mathbb{1} \in \epsilon_t)$
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	$b_t \equiv \phi b_{t-1} + \beta (\ell_{t-1} + \phi b_{t-1}) \varepsilon_t$	$b_t \equiv \phi b_{t-1} + \beta (\ell_{t-1} + \phi b_{t-1} + s_{t-m}) \varepsilon_t$	$b_t \equiv \phi b_{t-1} + \beta (\ell/s_{1-t} + \phi b_{t-1}) \varepsilon_t$
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Tren	d	Seasonal	
	##N40+bands \/ N46	adole A	M
N	##Methods V Mo	$ \frac{dels}{y_t = (\ell_{t-1} + s_{t-n_{t}})(\mathfrak{d}_{t} + \varepsilon_t)} $	$y_t \equiv \ell_{t-1} s_{t-m} (\mathbb{1} a_t \varepsilon_t)$
	$\ell_t \equiv \ell_{t-1} (\# \alpha \epsilon_{\alpha} \epsilon_t)$	$\ell_t \equiv \ell_{t-1} + \alpha \xi \ell_{t-1} + s_{t-m} \varepsilon_t$	$\ell_t \equiv \ell_{t-1} \left(\pm \alpha \epsilon_{\alpha} \ell_{\gamma} \right)_{-m}$
	###Evnonential	mōʻoʻthijing methods—	$s_t = s_{t=m}(4 $
	$y_t = (\ell_{t-1} + b \ell_{t-1})(\ell_t + \varepsilon_t)$	$y_t = (\ell_{t+1} + b\ell_{t+1} + s_{t+not})(\ell_t + \varepsilon_t)$	$y_t = (\ell_{t-1} + b_{t-1})s_{t-m}(\mathbb{1} \alpha_t \varepsilon_t)$
A	$\ell_t \equiv (\ell_{t-1} + b \ell_{t-1}) (\alpha \in \alpha \varepsilon_t)$	$\ell_t \equiv \ell_{t-1} + b_{t-1} + \alpha(\ell_{t-1} + b_{t-1} + s_{t-m})\varepsilon_t$	$\ell_t \equiv (\ell_{t+1} + b_{t+1}) (\alpha \in \ell_{\varepsilon_t})_n$
	b⊫ b₁Al¢toritthmos 1	that return point forecase $s_t \equiv s_{t-m} + \gamma \xi \ell_{t-1} + \ell_{t-1} + s_{t-m}) \varepsilon_t$	$ast \in b_{t-1} + \beta (\ell/\underline{s_1} - mb_{t-1}) \varepsilon_t$
	_ /gorrer	$s_t \equiv s_{t-m} + \gamma (\ell_{t-1} + b_{t-1} + s_{t-m}) \varepsilon_t$	$s_t \equiv s_{t-m}(\# \mathcal{L}_{t}(b)_{t-1} + b_{t-1})$
	$y_t \equiv (\ell_{t-1} + \ell_t b \ell_{t-1}) (\ell_t + \varepsilon_t)$	$y_t \equiv (\ell_{t+1} + \ell_t) b_{t+1} + s_{t+m_t} (t_t + \varepsilon_t)$	$y_t \equiv (\ell_{t-1} + \phi b_{t-1}) s_{t-m} (\mathbb{1} \oplus_t \varepsilon_t)$
A_d	###Imnovations s	tate-space amodels st-m)	$\varepsilon_t = \ell_{t-1} + \phi b t_{t-1} + (\alpha s_t \ell s_{t+1})_n$
	$b_t \equiv \phi b_{t-1} + \beta (\ell_{t-1} + \phi b_{t-1}) \varepsilon_t$	$b_t \equiv \phi b_{t-1} + \beta (\ell_{t-1} + \phi b_{t-1} + s_{t-m}) \varepsilon_t$	$b_t \equiv \phi b_{t-1} + \beta (\ell / \underline{s}_{l-m} \phi b_{t-1}) \varepsilon_t$
		$s_t \equiv s_{t-m} + \gamma (\ell_{t-1} + \phi b_{t-1} + s_{t-m}) \varepsilon_t$	$s_t \equiv s_{t-m}(\pm \varkappa \varepsilon_t \xi \delta_{t-1} + \phi b_{t-1})$

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Tren	d	Seasonal	
	##Nathada V Na	dolo A	M
N	##Methods V Mo	$y_{t} \equiv (\ell_{t+1} + \epsilon_{t+nn_{t}})(\ell_{t+\epsilon_{t}})$	$y_t \equiv \ell_{t-1} s_{t-m} (\exists \exists_t \varepsilon_t)$
	$\ell_t \equiv \ell_{t-1} (\mathbb{1} \alpha \epsilon_{\alpha} \epsilon_t)$	$\ell_t \equiv \ell_{t-1} + \alpha (\ell_{t-1} + s_{t-m}) \varepsilon_t$	$\ell_t \equiv \ell_{t-1} (\# \alpha \epsilon_{\alpha} \epsilon_{\gamma})_{-m}$
	###Evnonential s	mābthi no -methods	$s_t = s_{t=m}(4 $
	$y_t = (\ell_{t+1}) + b\ell_{t+1} + (\ell_t + \varepsilon_t)$	$y_t = (\ell_{t-1} + \ell_{t-1} + \epsilon_{t-1} + \epsilon_{t-1} + \epsilon_{t-1} + \epsilon_{t-1})$	$y_t = (\ell_{t-1} + b_{t-1})s_{t-m}(\mathbb{1} e_t \varepsilon_t)$
A	$\ell_t \equiv (\ell_{t-1} + b_{t-1})(\alpha \in \alpha \varepsilon_t)$	$\ell_t \equiv \ell_{t-1} + b_{t-1} + \alpha \xi \ell_{t-1} + b_{t-1} + s_{t-m}) \varepsilon_t$	$\ell_t \equiv (\ell_{t-1} + b \ell_{t-1}) (\alpha \in \ell \varepsilon_t)_n$
	^b <u></u> b₁Algorithms t	$hat return point forecase s_t = s_{t-m} + y(t_{t-1} + b_{t-1} + s_{t-m})\varepsilon_t$	$S^{t}S_{t=1}^{b_{t=1}} + \beta \mathcal{E}(s_{1}-mb_{t-1})\varepsilon_{t}$
	_ ,gerreriire e	$s_t \equiv s_{t-m} + \gamma (\ell_{t-1} + b_{t-1} + s_{t-m}) \varepsilon_t$	$\mathbf{s}_{t} \equiv \mathbf{s}_{t-m}(1 + \mathbf{s}_{t}) \mathcal{E}(\mathbf{s}_{t-1} + \mathbf{b}_{t-1})$
	$y_t \equiv (\ell_{t+1} + \phi b_{t+1})(\ell_{t+1})$	$y_t \equiv (\ell_{t-1} + \phi b \ell_{t-1} + s_{t-m_t})(\ell_{t+\epsilon_t})$	$y_t \equiv (\ell_{t-1} + \phi b_{t-1}) s_{t-m} (\mathbb{1} \in \epsilon_t)$
A_d	###kanovations s	tate-space amode is s_{t-m}) ε_t $b_t \equiv \phi b_{t-1} + \beta \xi \ell_{t-1} + \phi b_{t-1} + s_{t-m}) \varepsilon_t$	$\ell_t = (\ell_{t-1} + \ell_t) b(t_{t-1}) (\alpha s_t t s_{\ell_t})_n$
	$b_t \equiv \phi b_{t-1} + \beta (\ell_{t-1} + \phi b_{t-1}) \varepsilon_t$	$b_t \equiv \phi b_{t-1} + \beta (\ell_{t-1} + \phi b_{t-1} + s_{t-m}) \varepsilon_t$	$b_t \equiv \phi b_{t-1} + \beta (\ell/s_{1-t} + \phi b_{t-1}) \varepsilon_t$
		$s_t \equiv s_{t-m} + \gamma (\ell_{t-1} + \phi b_{t-1} + s_{t-m}) \varepsilon_t$	$s_t \equiv s_{t=m}(4 $

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Tren	d	Seasonal	
	##Nathada V Na	dolo A	M
N	##Methods V Mo	$y_{t} \equiv (\ell_{t+1} + \epsilon_{t+nn_{t}})(\ell_{t+\epsilon_{t}})$	$y_t \equiv \ell_{t-1} s_{t-m} (\exists \exists_t \varepsilon_t)$
	$\ell_t \equiv \ell_{t-1} (\mathbb{1} \alpha \epsilon_{\alpha} \epsilon_t)$	$\ell_t \equiv \ell_{t-1} + \alpha (\ell_{t-1} + s_{t-m}) \varepsilon_t$	$\ell_t \equiv \ell_{t-1} (\# \alpha \epsilon_{\alpha} \epsilon_{\gamma})_{-m}$
	###Evnonential s	mābthi no -methods	$s_t = s_{t=m}(4 $
	$y_t = (\ell_{t+1}) + b\ell_{t+1} + (\ell_t + \varepsilon_t)$	$y_t = (\ell_{t-1} + \ell_{t-1} + \epsilon_{t-1} + \epsilon_{t-1} + \epsilon_{t-1} + \epsilon_{t-1})$	$y_t = (\ell_{t-1} + b_{t-1})s_{t-m}(\mathbb{1} e_t \varepsilon_t)$
A	$\ell_t \equiv (\ell_{t-1} + b_{t-1})(\alpha \in \alpha \varepsilon_t)$	$\ell_t \equiv \ell_{t-1} + b_{t-1} + \alpha \xi \ell_{t-1} + b_{t-1} + s_{t-m}) \varepsilon_t$	$\ell_t \equiv (\ell_{t-1} + b \ell_{t-1}) (\alpha \in \ell \varepsilon_t)_n$
	^b <u></u> b₁Algorithms t	$hat return point forecase s_t = s_{t-m} + y(t_{t-1} + b_{t-1} + s_{t-m})\varepsilon_t$	$S^{t}S_{t=1}^{b_{t=1}} + \beta \mathcal{E}(s_{1}-mb_{t-1})\varepsilon_{t}$
	_ ,gerreriire e	$s_t \equiv s_{t-m} + \gamma (\ell_{t-1} + b_{t-1} + s_{t-m}) \varepsilon_t$	$\mathbf{s}_{t} \equiv \mathbf{s}_{t-m}(1 + \mathbf{s}_{t}) \mathcal{E}(\mathbf{s}_{t-1} + \mathbf{b}_{t-1})$
	$y_t \equiv (\ell_{t+1} + \phi b_{t+1})(\ell_{t+1})$	$y_t \equiv (\ell_{t-1} + \phi b \ell_{t-1} + s_{t-m_t})(\ell_{t+\epsilon_t})$	$y_t \equiv (\ell_{t-1} + \phi b_{t-1}) s_{t-m} (\mathbb{1} \in \varepsilon_t)$
A_d	###kanovations s	tate-space amode is s_{t-m}) ε_t $b_t \equiv \phi b_{t-1} + \beta \xi \ell_{t-1} + \phi b_{t-1} + s_{t-m}) \varepsilon_t$	$\ell_t = (\ell_{t-1} + \ell_t) b(t_{t-1}) (\alpha s_t t s_{\ell_t})_n$
	$b_t \equiv \phi b_{t-1} + \beta (\ell_{t-1} + \phi b_{t-1}) \varepsilon_t$	$b_t \equiv \phi b_{t-1} + \beta (\ell_{t-1} + \phi b_{t-1} + s_{t-m}) \varepsilon_t$	$b_t \equiv \phi b_{t-1} + \beta (\ell/s_{1-t} + \phi b_{t-1}) \varepsilon_t$
		$s_t \equiv s_{t-m} + \gamma (\ell_{t-1} + \phi b_{t-1} + s_{t-m}) \varepsilon_t$	$s_t \equiv s_{t=m}(4 $

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Tren	d	Seasonal	
	##Nathada V Na	dolo A	M
N	##Methods V Mo	$y_{t} \equiv (\ell_{t+1} + \epsilon_{t+nn_{t}})(\ell_{t+\epsilon_{t}})$	$y_t \equiv \ell_{t-1} s_{t-m} (\exists \exists_t \varepsilon_t)$
	$\ell_t \equiv \ell_{t-1} (\mathbb{1} \alpha \epsilon_{\alpha} \epsilon_t)$	$\ell_t \equiv \ell_{t-1} + \alpha (\ell_{t-1} + s_{t-m}) \varepsilon_t$	$\ell_t \equiv \ell_{t-1} (\# \alpha \epsilon_{\alpha} \epsilon_{\gamma})_{-m}$
	###Evnonential s	mābthi no -methods	$s_t = s_{t=m}(4 $
	$y_t = (\ell_{t+1}) + b\ell_{t+1} + (\ell_t + \varepsilon_t)$	$y_t = (\ell_{t-1} + \ell_{t-1} + \epsilon_{t-1} + \epsilon_{t-1} + \epsilon_{t-1} + \epsilon_{t-1})$	$y_t = (\ell_{t-1} + b_{t-1})s_{t-m}(\mathbb{1} e_t \varepsilon_t)$
A	$\ell_t \equiv (\ell_{t-1} + b_{t-1})(\alpha \in \alpha \varepsilon_t)$	$\ell_t \equiv \ell_{t-1} + b_{t-1} + \alpha \xi \ell_{t-1} + b_{t-1} + s_{t-m}) \varepsilon_t$	$\ell_t \equiv (\ell_{t-1} + b \ell_{t-1}) (\alpha \in \ell \varepsilon_t)_n$
	^b <u></u> b₁Algorithms t	$hat return point forecase s_t = s_{t-m} + y(t_{t-1} + b_{t-1} + s_{t-m})\varepsilon_t$	$S^{t}S_{t=1}^{b_{t=1}} + \beta \mathcal{E}(s_{1}-mb_{t-1})\varepsilon_{t}$
	_ ,gerreriire e	$s_t \equiv s_{t-m} + \gamma (\ell_{t-1} + b_{t-1} + s_{t-m}) \varepsilon_t$	$\mathbf{s}_{t} \equiv \mathbf{s}_{t-m}(1 + \mathbf{s}_{t}) \mathcal{E}(\mathbf{s}_{t-1} + \mathbf{b}_{t-1})$
	$y_t \equiv (\ell_{t+1} + \phi b_{t+1})(\ell_{t+1})$	$y_t \equiv (\ell_{t-1} + \phi b \ell_{t-1} + s_{t-m_t})(\ell_{t+} \varepsilon_t)$	$y_t \equiv (\ell_{t-1} + \phi b_{t-1}) s_{t-m} (\mathbb{1} \in \varepsilon_t)$
A_d	###kanovations s	tate-space amode is s_{t-m}) ε_t $b_t \equiv \phi b_{t-1} + \beta \xi \ell_{t-1} + \phi b_{t-1} + s_{t-m}) \varepsilon_t$	$\ell_t = (\ell_{t-1} + \ell_t) b(t_{t-1}) (\alpha s_t t s_{\ell_t})_n$
	$b_t \equiv \phi b_{t-1} + \beta (\ell_{t-1} + \phi b_{t-1}) \varepsilon_t$	$b_t \equiv \phi b_{t-1} + \beta (\ell_{t-1} + \phi b_{t-1} + s_{t-m}) \varepsilon_t$	$b_t \equiv \phi b_{t-1} + \beta (\ell/s_{1-t} + \phi b_{t-1}) \varepsilon_t$
		$s_t \equiv s_{t-m} + \gamma (\ell_{t-1} + \phi b_{t-1} + s_{t-m}) \varepsilon_t$	$s_t \equiv s_{t=m}(4 $

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Tren	d Seasonal	
	##Mathods \/ Madals A	M
N	##Methods V Models $\psi_t = \ell_{t-1}(t, \ell_t, \epsilon_t)$	$y_t \equiv \ell_{t-1} s_{t-m} (1 \in \epsilon_t)$
	$\ell_t \equiv \ell_{t-1} (\pm \alpha \epsilon_t \epsilon_t) \qquad \qquad \ell_t \equiv \ell_{t-1} \pm \alpha \epsilon_{t-1} + \epsilon_{t-m}) \epsilon_t$	$\ell_t \equiv \ell_{t-1} (\# \alpha \epsilon_{\alpha} \epsilon_{\S})_{-m}$
	###Evnonential small time thods	$s_t = s_{t=m}(4 $
	###Exponential smoothing here thods $y_t = (\ell_{t+1} + i \ell_{t+1} +$	$y_t = (\ell_{t-1} + b_{t-1})s_{t-m}(\mathbb{1} e_t \varepsilon_t)$
A	$\ell_t \equiv \ell_{t-1} + b_{t-1} + b_{t-1} + \alpha \varepsilon_t \qquad \qquad \ell_t \equiv \ell_{t-1} + b_{t-1} + \alpha \varepsilon_{t-1} + b_{t-1} + s_{t-m} \varepsilon_t$	$\ell_t \equiv (\ell_{t-1} + b_{t+1}) (\alpha \in k_t k_{\varepsilon_t})_n$
	$b = b_i Algorithms that verture boint forecast s_i = s_{i-m} + \gamma (s_{i-1} + b_{i-1} + s_{i-m}) \varepsilon_i$	$asts_{t=1}^{b} + \beta (\ell/s_{1} - mb_{t-1}) \varepsilon_{t}$
	$\mathbf{s}_{t} \equiv \mathbf{s}_{t-m} + \gamma \boldsymbol{\xi} \ell_{t-1} + b_{t-1} + s_{t-m} \boldsymbol{\varepsilon}_{t}$	$s_t \equiv s_{t-m}(t + y_t \in (0)_{t-1} + b_{t-1})$
	$y_t \equiv (\ell_{t-1} + \ell_t + \ell_t) \qquad \qquad y_t \equiv (\ell_{t-1} + \ell_t + \ell_t) \qquad \qquad y_t \equiv (\ell_{t-1} + \ell_t + \ell_t)$	$y_t \equiv (\ell_{t-1} + \phi b_{t-1}) s_{t-m} (\mathbb{1} \otimes_t \varepsilon_t)$
A_d	###mnovations state-space models s_{t-m} ε_t $b_t \equiv \phi b_{t-1} + \beta (\ell_{t-1} + \phi b_{t-1}) \varepsilon_t$ $b_t \equiv \phi b_{t-1} + \beta (\ell_{t-1} + \phi b_{t-1} + s_{t-m}) \varepsilon_t$	$\ell_t = (\ell_{t-1}) + (p) \ell_{t-1}) (\alpha + \ell_t \ell_{\theta} \epsilon_t)_n$
	$b_t \equiv \phi b_{t-1} + \beta (\ell_{t-1} + \phi b_{t-1}) \varepsilon_t \qquad b_t \equiv \phi b_{t-1} + \beta (\ell_{t-1} + \phi b_{t-1} + s_{t-m}) \varepsilon_t$	$b_t \equiv \phi b_{t-1} + \beta (\ell/s_1 - h \phi b_{t-1}) \varepsilon_t$
	$s_t \equiv s_{t-m} + \gamma (\ell_{t-1} + \phi b_{t-1} + s_{t-m}) \varepsilon_t$	$s_t \equiv s_{t=m}(+ $

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Tren	d	Seasonal	
	##NActhoda V NA	adala A	M
N	$\# \# \underset{y_t \equiv \ell_{t-1}(\mathbb{H} \exists_{t} \epsilon_t)}{Nds} V Mo$	$ \frac{dels}{y_t = (\ell_{t-1} + s_{s_{t-m_t}})(\ell_{t} + \varepsilon_t)} $	$y_t \equiv \ell_{t-1} s_{t-m} (\mathbb{1} s_t \varepsilon_t)$
	$\ell_t \equiv \ell_{t-1} (\mathbb{1} \alpha \epsilon_t \varepsilon_t)$	$\ell_t \equiv \ell_{t-1} + \alpha(\ell_{t-1} + s_{t-m})\varepsilon_t$	$\ell_t \equiv \ell_{t-1} (\# \alpha \epsilon_{\alpha} \epsilon_{\gamma})_{-m}$
	###Evnonential	smathille a mathods	$s_t = s_{t=m}(4 $
	$y_t = (\ell_{t+1} + b\ell_{t+1})(\ell_t + \varepsilon_t)$	$y_t = (\ell_{t-1} + \ell_{t} + \ell_{t-1} + \ell_{t} + \ell_{t})$	$y_t = (\ell_{t-1} + b_{t-1})s_{t-m}(\mathbb{1} \triangleleft_t \varepsilon_t)$
A	$\ell_t \equiv (\ell_{t+1} + b\ell_{t+1})(\alpha \in \alpha \varepsilon_t)$	$\ell_t \equiv \ell_{t-1} + b_{t-1} + \alpha (\ell_{t-1} + b_{t-1} + s_{t-m}) \varepsilon_t$	$\ell_t \equiv (\ell_{t-1} + b_{t-1}) (\alpha \in \ell_{\varepsilon_t})_n$
	^b <u> </u> b₁Alg∕orit/hms t	that return point forecast $s_t \equiv s_{t-m} + \gamma \in (\ell_{t-1} + \ell_{t-1} + s_{t-m}) \varepsilon_t$	$asts_{t=1}^{b_{t=1}+\beta \in \ell/s_1-hb_{t-1})\varepsilon_t}$
	_ ,8	$s_t \equiv s_{t-m} + \gamma \xi \ell_{t-1} + b_{t-1} + s_{t-m}) \varepsilon_t$	$s_t \equiv s_{t-m}(\# \mathcal{L}_{t}(b_{t-1} + b_{t-1}))$
	$y_t \equiv (\ell_{t+1} + \ell_t) b_{t+1} + (\ell_t + \varepsilon_t)$	$y_t \equiv (\ell_{t+1} + \phi b \ell_{t+1} + s_{t+m_t})(\ell_t + \varepsilon_t)$	$y_t \equiv (\ell_{t-1} + \phi b_{t-1}) s_{t-m} (\mathbb{1} \oplus_t \varepsilon_t)$
A_d	###mnovations s	$\begin{array}{l} \mathbf{State} = \mathbf{Spage} \text{ anode } \mathbf{s} \\ b_t \equiv \phi b_{t-1} + \beta (\theta_{t-1} + \phi b_{t-1} + s_{t-m}) \varepsilon_t \end{array}$	$\ell_t = (\ell_{t-1}) + (\epsilon_t b) \ell_{t-1} + (\alpha + \ell_t \epsilon_t)_n$
	$b_t \equiv \phi b_{t-1} + \beta (\ell_{t-1} + \phi b_{t-1}) \varepsilon_t$	$b_t \equiv \phi b_{t-1} + \beta (\ell_{t-1} + \phi b_{t-1} + s_{t-m}) \varepsilon_t$	$b_t \equiv \phi b_{t-1} + \beta (\ell \ell / \underline{s}_{1-m} \phi b_{t-1}) \varepsilon_t$
		$s_t \equiv s_{t-m} + \gamma \epsilon \ell_{t-1} + \phi b_{t-1} + s_{t-m} \epsilon_t$	$s_t \equiv s_{t=m}(\# \mathcal{H}_{t}) + \phi b_{t-1}$

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ETS in R

ets(h02)

##Example: drug sales

```
## ETS(M,Ad,M)
##
## Call:
   ets(y = h02)
##
##
     Smoothing parameters:
##
       alpha = 0.1953
##
       beta = 1e-04
##
       gamma = 1e-04
##
       phi = 0.9798
##
     Initial states:
##
##
       l = 0.3945
##
       b = 0.0085
##
       s = 0.874 \ 0.8197 \ 0.7644 \ 0.7693 \ 0.6941 \ 1.2838
##
               1.326 1.1765 1.1621 1.0955 1.0422 0.9924
##
##
     sigma:
              0.0676
```

3