Modelling and Forecasting Australian Domestic Tourism

George Athanasopoulos & Rob Hyndman

MONASH University
Outline

1. Background
2. Data
3. Regression models
4. Exponential smoothing via innovations state space models
5. Innovations state space models with exogenous variables
6. Forecasts
7. Conclusions and future research
Australian Tourism Industry:

1. International Arrivals
2. Outbound
3. Domestic Tourism

$55$ billion - more than $3$ times international arrivals (TFC 2005)
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My research - Research Fellow
Australian Tourism Industry:

1. International Arrivals
2. Outbound
3. Domestic Tourism
   - $55 billion - more than 3 times international arrivals (TFC 2005)
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My research - Research Fellow

- Tourism Australia
- STCRC
- Monash University
Outline of presentation:

1. Data
2. Regression framework
3. Exponential smoothing
4. Exp smoothing + Exogenous variables
5. Forecasts
6. Conclusions and Further research
Outline

1. Background
2. Data
3. Regression models
4. Exponential smoothing via innovations state space models
5. Innovations state space models with exogenous variables
6. Forecasts
7. Conclusions and future research
National Visitor Survey - Visitor Nights
(1998Q1-2005:Q2)
Aggregate Data & TFC Forecasts:
Outline

1. Background
2. Data
3. Regression models
4. Exponential smoothing via innovations state space models
5. Innovations state space models with exogenous variables
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Tourism demand function:

\[ VN^i_t = f(t, DEBT_t, DPI_t, GDP_t, BALI_t, OLYMP_t, MAR_t, JUN_t, SEP_t, \varepsilon_t) \]
Tourism demand function:

\[ VN_t^i = f(t, DEBT_t, DPI_t, GDP_t, BALI_t, OLYMP_t, MAR_t, JUN_t, SEP_t, \varepsilon_t) \]

- \( VN_t^i \) - \( \ln(\text{Visitor nights per capita travelling for purpose } i) \)
Tourism demand function:

\[ V\text{N}_t^i = f(t, DEBT_t, DPI_t, GDP_t, BALI_t, OLYMP_t, MAR_t, JUN_t, SEP_t, \varepsilon_t) \]

- \( V\text{N}_t^i \) - \( \ln(\text{Visitor nights per capita travelling for purpose } i) \)
- \( t \) - exponential trend
Tourism demand function:

\[ VN_t^i = f(t, DEBT_t, DPI_t, GDP_t, BALI_t, OLYMP_t, MAR_t, JUN_t, SEP_t, \varepsilon_t) \]

- \( VN_t^i \) - \( \ln(\text{Visitor nights per capita travelling for purpose } i) \)
- \( t \) - exponential trend
- \( DEBT_t \) - Growth rate of real personal debt per capita
Tourism demand function:

\[ VN_i^t = f(t, DEBT_t, DPI_t, GDP_t, BALI_t, OLYMP_t, MAR_t, JUN_t, SEP_t, \varepsilon_t) \]

- \( VN_i^t \) - \( \ln(\text{Visitor nights per capita travelling for purpose } i) \)
- \( t \) - exponential trend
- \( DEBT_t \) - Growth rate of real personal debt per capita
- \( DPI_t \) - Growth rate of domestic price index
Tourism demand function:

\[ VN_t^i = f(t, DEBT_t, DPI_t, GDP_t, BALI_t, OLYMP_t, MAR_t, JUN_t, SEP_t, \varepsilon_t) \]

- \( VN_t^i \) - Ln(Visitor nights per capita travelling for purpose \( i \))
- \( t \) - exponential trend
- \( DEBT_t \) - Growth rate of real personal debt per capita
- \( DPI_t \) - Growth rate of domestic price index
- \( GDP_t \) - Growth rate of real GDP per capita
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- \( MAR_t, JUN_t, SEP_t \) - Seasonal dummies

Step 1: Run OLS and test for up to 1 lag of each variable.
Step 2: Sequentially drop insignificant parameters and estimate efficiently using SUR.
Tourism demand function:

\[ VN_i^t = f(t, DEBT_t, DPI_t, GDP_t, BALI_t, OLYMP_t, MAR_t, JUN_t, SEP_t, \varepsilon_t) \]

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Tourism demand function:

\[ V_{t}^{i} = f(t, DEBT_{t}, DPI_{t}, GDP_{t}, BALI_{t}, OLYMP_{t}, MAR_{t}, JUN_{t}, SEP_{t}, \varepsilon_{t}) \]

- \( V_{t}^{i} \) - \( \ln(\text{Visitor nights per capita travelling for purpose } i) \)
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**Step 1:** Run OLS and test for upto 1 lag of each variable.
Tourism demand function:

\[ VN_i^t = f(t, DEBT_t, DPI_t, GDP_t, BALI_t, OLYMP_t, MAR_t, JUN_t, SEP_t, \varepsilon_t) \]

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**Step 1:** Run OLS and test for upto 1 lag of each variable.
**Step 2:** Sequentially drop insignificant parameters and estimate efficiently using SUR.
Estimated demand system:

<table>
<thead>
<tr>
<th>Regressor</th>
<th>Holiday</th>
<th>VFR</th>
<th>Business</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>7505.57*</td>
<td>7020.25*</td>
<td>6441.09*</td>
<td>5771.92*</td>
</tr>
<tr>
<td></td>
<td>(13.33)</td>
<td>(21.03)</td>
<td>(22.84)</td>
<td>(47.28)</td>
</tr>
<tr>
<td>$t$</td>
<td>$-5.91^*$</td>
<td></td>
<td>$-6.17^*$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.50)</td>
<td></td>
<td>(0.88)</td>
<td></td>
</tr>
<tr>
<td>$D_{t-1}$</td>
<td>4.41*</td>
<td></td>
<td>5.91*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.23)</td>
<td></td>
<td>(2.00)</td>
<td></td>
</tr>
<tr>
<td>$P_{t-1}$</td>
<td>$-4.11^*$</td>
<td></td>
<td>7.58*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.64)</td>
<td></td>
<td>(2.89)</td>
<td></td>
</tr>
<tr>
<td>$Y_t$</td>
<td>$-43.71^*$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(8.14)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$BALLY_t$</td>
<td></td>
<td>56.61*</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(17.75)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$OLYMP_t$</td>
<td></td>
<td></td>
<td>148.00*</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(51.26)</td>
<td></td>
</tr>
<tr>
<td>$MAR_t$</td>
<td>338.09*</td>
<td>170.33*</td>
<td>$-170.83^*$</td>
<td>$-540.23^*$</td>
</tr>
<tr>
<td></td>
<td>(13.06)</td>
<td>(26.87)</td>
<td>(24.28)</td>
<td>(64.74)</td>
</tr>
<tr>
<td>$JUN_t$</td>
<td>$-43.19^*$</td>
<td>$-71.36^*$</td>
<td>$-42.57$</td>
<td>$-460.75^*$</td>
</tr>
<tr>
<td></td>
<td>(12.40)</td>
<td>(26.87)</td>
<td>(24.51)</td>
<td>(64.74)</td>
</tr>
<tr>
<td>$SEP_t$</td>
<td>27.78</td>
<td>$-33.73$</td>
<td>55.03*</td>
<td>$-109.13$</td>
</tr>
<tr>
<td></td>
<td>(14.01)</td>
<td>(27.84)</td>
<td>(25.57)</td>
<td>(66.86)</td>
</tr>
</tbody>
</table>

$R^2$ 0.98 0.79 0.86 0.77
$\bar{R}^2$ 0.98 0.75 0.82 0.74

* Significant at the 5% level.
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Innovation state space models - $ETS(A, -, A)$:
Innovation state space models - $ETS(A,-,A)$:

<table>
<thead>
<tr>
<th>No trend</th>
<th>Additive trend</th>
<th>Damped trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>$y_t = l_{t-1} + s_{t-m} + \varepsilon_t$</td>
<td>$y_t = l_{t-1} + b_{t-1} + s_{t-m} + \varepsilon_t$</td>
<td>$y_t = l_{t-1} + b_{t-1} + s_{t-m} + \varepsilon_t$</td>
</tr>
<tr>
<td>$l_t = l_{t-1} + \alpha \varepsilon_t$</td>
<td>$l_t = l_{t-1} + b_{t-1} + \alpha \varepsilon_t$</td>
<td>$l_t = l_{t-1} + b_{t-1} + \alpha \varepsilon_t$</td>
</tr>
<tr>
<td>$s_t = s_{t-m} + \gamma \varepsilon_t$</td>
<td>$b_t = b_{t-1} + \beta \varepsilon_t$</td>
<td>$b_t = \phi b_{t-1} + \beta \varepsilon_t$</td>
</tr>
<tr>
<td></td>
<td>$s_t = s_{t-m} + \gamma \varepsilon_t$</td>
<td>$s_t = s_{t-m} + \gamma \varepsilon_t$</td>
</tr>
</tbody>
</table>

where: $0 < \alpha < 1$, $0 < \beta < \alpha$, $0 < \gamma < 1$, $0 < \phi < 0.98$. 
Innovation state space models - \textit{ETS}(A,-,A):

\begin{align*}
\text{No trend} & \quad y_t = l_{t-1} + s_{t-m} + \varepsilon_t \\
& \quad l_t = l_{t-1} + \alpha \varepsilon_t \\
& \quad s_t = s_{t-m} + \gamma \varepsilon_t \\
\hat{y}_{n+h} &= l_n + s_{n+h-m} \\
\text{Additive trend} & \quad y_t = l_{t-1} + b_{t-1} + s_{t-m} + \varepsilon_t \\
& \quad l_t = l_{t-1} + b_{t-1} + \alpha \varepsilon_t \\
& \quad b_t = b_{t-1} + \beta \varepsilon_t \\
& \quad s_t = s_{t-m} + \gamma \varepsilon_t \\
\hat{y}_{n+h} &= l_n + b_n + s_{n+h-m} \\
\text{Damped trend} & \quad y_t = l_{t-1} + b_{t-1} + s_{t-m} + \varepsilon_t \\
& \quad l_t = l_{t-1} + b_{t-1} + \alpha \varepsilon_t \\
& \quad b_t = \phi b_{t-1} + \beta \varepsilon_t \\
& \quad s_t = s_{t-m} + \gamma \varepsilon_t \\
\hat{y}_{n+h} &= l_n + (1 + \phi + \cdots + \phi^{h-1}) b_n \\
& \quad + s_{n+h-m} \\
\end{align*}

where: \(0 < \alpha < 1, \quad 0 < \beta < \alpha, \quad 0 < \gamma < 1, \quad 0 < \phi < 0.98.\)
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Innovation state space model including exogenous variables - $ETSX(A,A_D,N,X)$:
Innovation state space model including exogenous variables - $ETSX(A, A_D, N, X)$:

**Damped trend**

$y_t = l_{t-1} + b_{t-1} + x_t' \delta + \epsilon_t$
Innovation state space model including exogenous variables - \( ETSX(A,A_D,N,X) \):

**Damped trend**

\[
\begin{align*}
    y_t &= l_{t-1} + b_{t-1} + x'_t \delta + \varepsilon_t \\
    l_t &= l_{t-1} + b_{t-1} + \alpha \varepsilon_t \\
    b_t &= \phi b_{t-1} + \beta \varepsilon_t \\
    \hat{y}_{n+h} &= l_n + (1 + \phi + \cdots + \phi^{h-1}) b_n + \hat{x}'_{n+h} \hat{\delta}
\end{align*}
\]

where: \( 0 < \alpha < 1, \ 0 < \beta < \alpha, \ 0 < \gamma < 1, \ 0 < \phi < 0.98 \).

\[
X = (DEBT, DPI, GDP, BALI, OLYMP, MAR, JUN, SEP)
\]
Estimates of the *ETSX* models:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Holiday</th>
<th>VFR</th>
<th>Business</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \alpha )</td>
<td>0.13</td>
<td>0.00</td>
<td>0.47</td>
<td>0.01</td>
</tr>
<tr>
<td>( \beta )</td>
<td>0.01</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>( \phi )</td>
<td>0.98</td>
<td>0.97</td>
<td>0.98</td>
<td>0.76</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variable</th>
<th>( D_{t-1} )</th>
<th>( P_{t-1} )</th>
<th>( Y_t )</th>
<th>( BALI_t )</th>
<th>( OLYMP_t )</th>
<th>( MAR_t )</th>
<th>( JUN_t )</th>
<th>( SEP_t )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6.79</td>
<td>-7.25</td>
<td>-67.67</td>
<td>132.09</td>
<td>104.05</td>
<td>661.69</td>
<td>-65.52</td>
<td>48.64</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>213.54</td>
<td>-72.54</td>
<td>-31.95</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-95.78</td>
<td>-21.25</td>
<td>32.91</td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
<td>-129.18</td>
<td>-116.15</td>
<td>-27.51</td>
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</tbody>
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### Forecast comparisons:

<table>
<thead>
<tr>
<th>Category</th>
<th>MAPE</th>
<th>Regr</th>
<th>ETS</th>
<th>ETSX</th>
<th>TFC</th>
</tr>
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<tbody>
<tr>
<td>Holiday</td>
<td>5.8</td>
<td>4.8</td>
<td>5.0</td>
<td>7.0</td>
<td></td>
</tr>
<tr>
<td>VFR</td>
<td>4.8</td>
<td>5.2</td>
<td>5.5</td>
<td>8.5</td>
<td></td>
</tr>
<tr>
<td>Business</td>
<td>5.2</td>
<td>9.5</td>
<td>6.4</td>
<td>7.4</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>7.7</td>
<td>6.5</td>
<td>7.6</td>
<td>17.6</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>4.5</td>
<td>4.3</td>
<td>4.2</td>
<td>4.9</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>5.9</td>
<td>6.5</td>
<td>6.1</td>
<td>10.1</td>
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### Forecast comparisons:

**Holdout sample:** (2004:Q3-2005:Q2)

<table>
<thead>
<tr>
<th></th>
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<tr>
<td><strong>Total</strong></td>
<td><strong>4.5</strong></td>
<td><strong>4.3</strong></td>
<td><strong>4.2</strong></td>
<td><strong>4.9</strong></td>
<td></td>
</tr>
</tbody>
</table>

**Average:**

- MAPE: 5.9
- Regr: 6.5
- ETS: 6.1
- ETSX: 10.1
Forecast comparisons:
Holdout sample: (2004:Q3-2005:Q2)

<table>
<thead>
<tr>
<th>MAPE</th>
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Long term annual forecasts for each component:

PANEL A: Holiday

PANEL B: VFR

PANEL C: Business

PANEL D: Other

--- Regr  --- ETS  --- ETSX  --- TFC
Outline

1. Background
2. Data
3. Regression models
4. Exponential smoothing via innovations state space models
5. Innovations state space models with exogenous variables
6. Forecasts
7. Conclusions and future research
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- Statistical models outperform TFC forecasts

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- Construction of prediction intervals via theory or simulation
- Application to other data e.g. international arrivals
- Hierarchical forecasting - Australia, States, Regional
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Thank you!!!