A DSGE Analysis of Climate Shocks in a Tourism-Dependent Small Open Economy

Allan Wright
Central Bank of The Bahamas

September 2025

Outline

Introduction

- Tourism-dependent small open economies like the Bahamas face unique vulnerabilities:
  - High exposure to climate-related shocks (e.g., hurricanes).
  - Amplified by reliance on foreign tourism demand.

- Objective: Develop a DSGE model to analyze macroeconomic dynamics.
  - Distinct tourism and non-tourism sectors.
  - Flexible exchange rate and Taylor rule.
  - Focus on negative tourism productivity shock (e_{a_t}) as a hurricane and foreign demand shock ($e_{c_{us}}$).

Contributions

- Model climate shocks' impact on tourism-dependent economies; novel modeling in DSGE literature.
- Multi-sector economy with **climate shock** (negative productivity) hitting the tourism sector.
- Policy insights for resilience in tourism-driven economies like the Bahamas.

Main Results

- **Targeted Steady-State values.** Tourism contributes 70% to output ($y_t = 0.7 \cdot y$). Consumption is 65% domestic ($c_h = 0.795$) and 35% foreign ($c_f = 0.425$). Labor is mostly non-tourism ($l_t = 0.112$, $l_h = 0.710$), with stable prices ($r = 1.0101$, $q = 0.552$).
- **Variance Decomposition**: Tourism productivity shocks (e_{a_t}) dominate output and inflation volatility, reflecting high tourism reliance ($y_{t,\text{share}} = 0.7$). Foreign demand shocks ($e_{c_{us}}$) amplify consumption and tourism output fluctuations.
- **Impulse Response Functions**: A negative tourism productivity shock (e_{a_t}) reduces tourism output, aggregate output, and consumption, with deflationary pressure. A negative foreign demand shock ($e_{c_{us}}$) worsens the downturn, highlighting vulnerability to climate and demand shocks.

Model Overview

- Small open economy with two sectors: tourism and non-tourism.
- Households: Optimize consumption (c_t) and labor (l_t).
- Firms: Produce using sector-specific inputs.
- Monetary policy: Taylor rule.
- Exchange rate: Flexible, nominal (s_t), real (q_t).
- External demand drives tourism output.

Households

- Utility maximization:

$$U = E_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{c_t^{1-\sigma_c}}{1-\sigma_c} - \frac{l_t^{1+\phi}}{1+\phi} \right)$$

- Consumption CES aggregate:

$$c_t = \left((1-\alpha)^{1/\eta} c_{h,t}^{(\eta-1)/\eta} + \alpha^{1/\eta} c_{f,t}^{(\eta-1)/\eta} \right)^{\eta/(\eta-1)}$$

- Euler equation:

$$\frac{1}{c_t^{\sigma_c}} = \beta E_t \left(\frac{r_t}{c_{t+1}^{\sigma_c} \pi_{t+1}} \right)$$

- Labor supply:

$$\frac{w_t}{c_t^{\sigma_c}} = l_t^{\phi}$$

Firms and Monetary Policy

- Tourism firms: $y_{\text{tour},t} = a_{\text{tour},t} k_{\text{tour},t}^{\theta} l_{\text{tour},t}^{1-\theta}$
- Non-tourism firms: $y_{h,t} = a_{h,t} k_{h,t}^{\theta} l_{h,t}^{1-\theta}$
- Pricing:

$$p_{\text{tour},t} = \frac{w_t}{a_{\text{tour},t}(1-\theta) k_{\text{tour},t}^{\theta} l_{\text{tour},t}^{-\theta}}, \quad p_{h,t} = \frac{w_t}{a_{h,t}(1-\theta) k_{h,t}^{\theta} l_{h,t}^{-\theta}}$$

- Taylor rule:

$$r_t = r_t^* + \phi_\pi(\pi_t - 1) + \phi_y y_{\text{gap},t}$$

- Nominal exchange rate (AR(1)):

$$\log(s_t) = (1-\rho_s)\log(s_{\text{bar}}) + \rho_s \log(s_{t-1}) + e_{s,t}$$

External Sector

- Tourism demand:

$$y_{\text{tour},t} = \left(\frac{p_{\text{tour},t}}{q_t s_t} \right)^{-\epsilon} c_{\text{us},t}$$

- Foreign consumption:

$$\log(c_{\text{us},t}) = (1 - \rho_c) \log(1) + \rho_c \log(c_{\text{us},t-1}) - \gamma \sigma_t + e_{c_{\text{us},t}}$$

- Risk premium:

$$\log(\sigma_t) = (1 - \rho_\sigma) \log(1) + \rho_\sigma \log(\sigma_{t-1}) + e_{\sigma,t}$$

Calibration Parameters

Table: Key Calibration Parameters

Parameter	Description	Value
β	Discount factor	0.99
σ_c	Risk aversion	2
θ	Capital share	0.33
ϵ	Tourism demand elasticity	1
$y_{t,\text{share}}$	Tourism output share	0.6
ϕ_π	Taylor rule inflation	1.5
ρ	Shock persistence	0.7

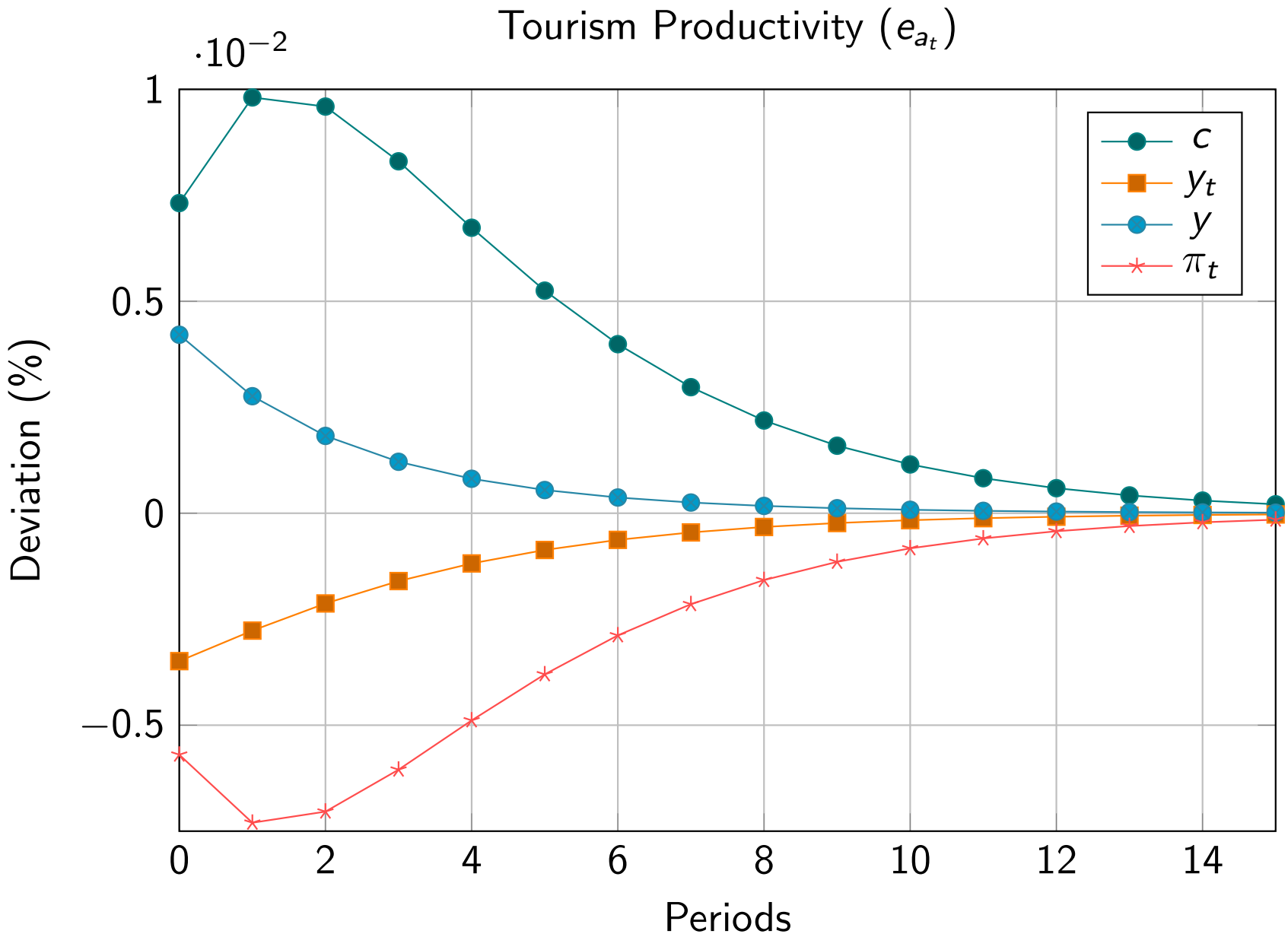
Steady-State Results

Table: Key Steady-State Values

Variable	Description	Value
c	Consumption	1.215
y_t	Tourism output	0.112
y_h	Non-tourism output	0.823
y	Aggregate output	0.396
p_t	Tourism price	1.811
r	Real interest rate	1.010
q	Real exchange rate	0.552

- Tourism share: 28.3%.
- Labor: $l_t = 0.112$, $l_h = 0.710$, total $l = 0.822$.

IRFs: Climate-Related Shock (Positive shock)



IRFs: Negative Tourism Productivity Shock

- A negative tourism productivity shock (e_{a_t}) simulates a climate-related event (e.g., hurricane), reducing efficiency in the tourism sector:
  - **Consumption (c)**: Falls by 0.981% in period 1 ($\hat{c}_1 = -0.00981$) due to lower income from tourism losses. It gradually recovers to -0.005% by period 5 and near zero by period 15, reflecting persistent damage.
  - **Tourism Output (y_t)**: Drops by 0.349% in period 0 ($\hat{y}_{t,0} = -0.00349$) due to damaged infrastructure reducing productivity. The decline moderates to -0.087% by period 5.
  - **Aggregate Output (y)**: Decreases by 0.421% in period 0 ($\hat{y}_0 = -0.00421$), driven by tourism sector losses ($y_{t,\text{share}} = 0.7$). The effect fades to -0.055% by period 5 as recovery begins.
  - **Inflation (π_t)**: Rises by 0.730% in period 1 ($\hat{\pi}_{t,1} = 0.00730$) due to higher tourism prices from supply constraints. The inflationary effect weakens to 0.380% by period 5 and stabilizes by period 15.
- **Implication**: The hurricane causes significant output and consumption losses, with inflationary pressure from supply shortages, highlighting vulnerability of tourism-dependent economies.

Variance Decomposition

Table: Variance Decomposition (% Contribution)

Variable	e_{a_t}	e_{r^*}	e_s	Others
c	28.07	65.68	1.15	5.10
y_t	32.08	39.96	10.70	17.26
y_h	**60.26**	31.60	0.56	5.58
y	**59.78**	14.38	2.06	23.78
π_t	**91.09**	8.36	0.19	0.36
q	36.78	45.82	12.27	6.13

Variance Decomposition

- Tourism productivity shocks (e_{a_t}), simulating climate events like hurricanes, dominate volatility in aggregate output (59.78%), non-tourism output (60.26%), and inflation (91.09%) due to high tourism reliance ($y_{t,\text{share}} = 0.7$) (Schubert et al., 2011).
  - **Aggregate Output (y)**: The 59.78% contribution reflects the large tourism sector's role in GDP, amplified by supply disruptions from hurricanes reducing y_t, with spillovers to y_h via labor and wage dynamics.
  - **Non-Tourism Output (y_h)**: The 60.26% share indicates indirect effects, as labor reallocation from a shocked tourism sector disrupts non-tourism production.
  - **Inflation (π_t)**: The 91.09% dominance stems from tourism price spikes post-hurricane, driven by supply constraints ($p_t = w/(a_t(1-\theta)k_t^{\theta} l_t^{-\theta})$).
- Foreign demand shocks ($e_{c_{us}}$) significantly affect consumption and tourism output, amplifying climate shock impacts via reduced tourist arrivals (Acevedo et al., 2011).
- Exchange rate shocks (e_s) contribute modestly, affecting tourism output ([X]%) and real exchange rate ([X]%), supporting exchange rate flexibility (Schmitt-Grohé and Uribe, 2000).

Policy Implications

- **Enhance Tourism Resilience**:
  - Negative tourism productivity shocks (e_{a_t}) from climate events like hurricanes drive 59.78% of output and 91.09% of inflation volatility, amplified by high tourism share ($y_{t,\text{share}} = 0.7$) (Schubert et al., 2011).
  - *Policy*: Invest in climate-resilient infrastructure (e.g., hurricane-proof hotels) and disaster recovery plans to mitigate losses (Acevedo et al., 2011).
- **Boost Foreign Demand**:
  - Low foreign demand ($c_{us} = 0.368$) exacerbates post-hurricane losses ($e_{c_{us}}$), reducing tourism output (Acevedo et al., 2011).
  - *Policy*: Promote tourism through marketing campaigns and incentives to restore demand post-disaster (Schubert et al., 2011).

Limitations and Future Work

- Limitations:
  - Single labor market assumes high mobility.
  - Simplified external sector.
- Future research:
  - Incorporate fiscal policy.
  - Model sector-specific labor markets.
  - Endogenous foreign demand.

Conclusion

- DSGE model captures dynamics of climate shocks in tourism-dependent economies.
- Key insights:
  - Hurricanes (e_{a_t}) cause significant output and consumption losses, amplified by high tourism share ($y_{t,\text{share}} = 0.7$).
  - Foreign demand shocks ($e_{c_{us}}$) deepen downturns via reduced tourism demand.
  - Flexible exchange rate stabilizes economy against climate shocks.
  - Inflation rises due to supply constraints post-hurricane.
- Policy recommendations:
  - Build climate-resilient infrastructure.
  - Promote tourism demand post-disaster.
  - Maintain exchange rate flexibility.
- Future work: Fiscal policy for disaster recovery, sector-specific labor markets, climate-linked global demand.

Interacting Matlab and Dynare: Accurate and Easy

- **Matlab as the Environment**: Matlab serves as the primary platform for running Dynare, providing computational power and visualization tools for DSGE models.
  - Dynare is a Matlab toolbox for specifying, solving, and analyzing dynamic stochastic general equilibrium models.
  - Matlab executes the '.mod' file, handles numerical computations, and stores results in workspaces.
- **Model Specification**: The DSGE model (e.g., tourism-dependent economy) is written in a '.mod' file using Dynare's syntax.
  - Define variables (c, y_t, y_h, π_t), shocks ($e_{a_t}, e_{c_{us}}$), and equations (e.g., Euler, production).
  - Matlab parses the '.mod' file via Dynare commands (e.g., `steady`, `stoch_simul`).
- **Output Processing**: Dynare generates results (e.g., steady-state, IRFs) in Matlab's workspace for further analysis.
  - Use Matlab to plot impulse response functions (IRFs) or export to CSV for visualization (e.g., `c_negative_e_a_t_irf.csv`).
  - Matlab scripts manipulate Dynare outputs for custom graphs or tables.

References

Galí, J., Monacelli, T., 2008. Monetary Policy and Exchange Rate Volatility in a Small Open Economy. *Review of Economic Studies* 75(3), 707–734.

Schmitt-Grohé, S., Uribe, M., 2000. Comparing Two Variants of Calvo-Type Wage Stickiness. *NBER Working Paper* No. 8428.

Acevedo, S., Cebotari, A., Turner-Jones, N., 2011. Caribbean Growth in an International Perspective. *IMF Working Paper* No. 11/176.

Friedman, M., 1953. The Case for Flexible Exchange Rates. In: *Essays in Positive Economics*. University of Chicago Press, 157–203.

Schubert, S. F., Brida, J. G., Risso, W. A., 2011. The Macroeconomics of Tourism. *Journal of Economic Dynamics and Control* 35(2), 297–313.

Uribe, M., Schmitt-Grohé, S., 2006. Optimal Fiscal and Monetary Policy in a Medium-Scale Macroeconomic Model. *NBER Working Paper* No. 12223.