UNDERSTANDING THE FACTORS AFFECTING AIRPORT LEVEL DEMAND (ARRIVALS AND DEPARTURES) USING A NOVEL MODELING APPROACH

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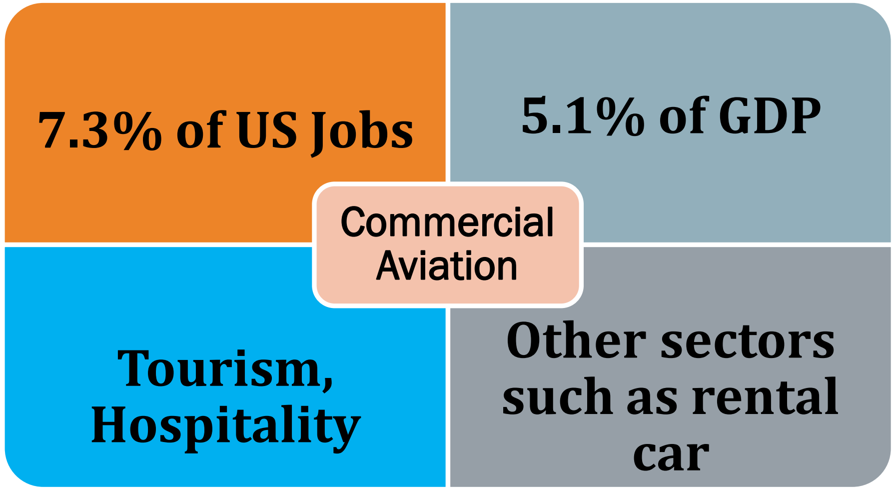
PRESENTATION OUTLINE

BACKGROUND

- Commercial aviation sector is a significant contributor to the US economy



- An important metric to examine the health of this sector is passenger demand at airports

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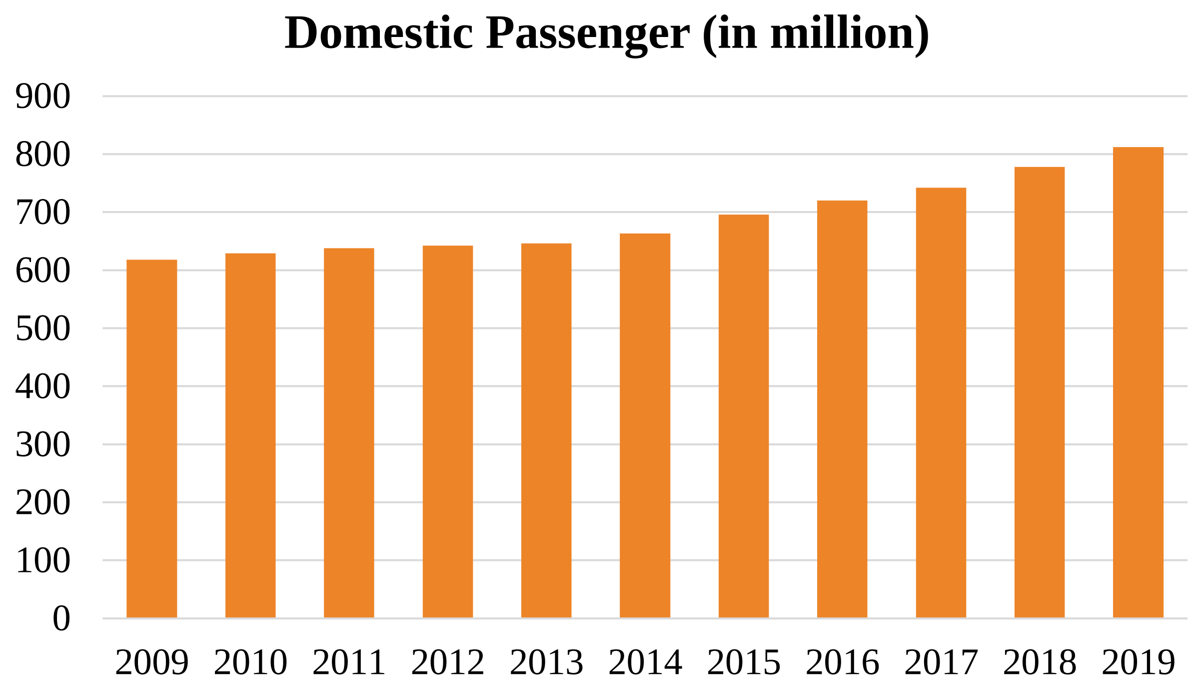
BACKGROUND

- Airline passenger demand and revenue has steadily increased between 2009 and 2019



BACKGROUND

- Understanding the factors influencing airline demand at various airports will be of utmost importance to the industry
- Long-term planning:
  - Airport runway and terminal design
  - Expansion
  - Intermodal transportation facilities
- Operational decisions:
  - Crew management for airport services

OBJECTIVE

- In this study, we identify the key factors of quarterly air passenger arrivals and departures at the airport level
- Dependent Variable:
  - Passenger trips (sourced from BTS) aggregated at the quarter and origin and destination airport
  - Natural logarithm of aggregated arrivals and departures
  - Discretized dependent variables (14 categories: ≤3; >3-4; >4-5, >5-6, >6-7, >7-8, >8-9, >9-10, >10-11, >11-12, >12-13, >13-14, >14-15 and >15)
- The current study develops a joint panel generalized ordered probit model system

CONTRIBUTIONS OF THE CURRENT STUDY

- The first contribution of our study to the literature arises from spatial and temporal data enhancement
- Spatially, the proposed research is conducted at the disaggregate resolution of airport to better incorporate the local factors
- In our study, we conduct our analysis considering 510 airports across the country
- Temporally, the current study examines airline demand at a quarterly level for five annual time points

CONTRIBUTIONS OF THE CURRENT STUDY

- Also, in our study we consider two airport level variables - arrivals and departures
- The second contribution of the research is on empirically examining the appropriate hierarchy of unobserved factors that affect airline demand
- Finally, earlier research has predominantly considered linear regression and its variants
- Linear regression models impose a linear restriction on parameter impacts for independent variables

CONTRIBUTIONS OF THE CURRENT STUDY

- To address this limitation, we recast a recently developed model structure referred to as the grouped response framework
- We translate the scale of the latent propensity to actual observed data
- In the proposed approach, with observed thresholds, we can estimate the variance of the error term
- With finely categorized data, the model will represent a non-linear version of the traditional linear regression
- The proposed framework can be employed to generate a prediction output that is analogous to the linear regression model

ECONOMETRIC METHODOLOGY

- In this study, the dependent variable is airline demand including air passenger arrivals and departures at the airport level
- We employ joint panel GOP model to analyze the airline data

$$D^*_{qrtl} = (\alpha'_r + \gamma'_{qr})x_{qrtl} + (\eta_k)x_{qrtl} + \varepsilon_{qrt}, D_{qrtl} = j \ \ if \ \psi_{j-1} < D^*_{qrtl} \leq \psi_j$$

- In our case, we consider J = 14 and thus the 15 ψ values are as follows: -∞, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15 and +∞
- Variance vectors for arrivals and departures: $\lambda_{Dr} = \exp(\theta'_r x_{qrtl})$
- Threshold specific deviations: $\rho_{jr} = \tau'_{jr} x_{qrtl}$

ECONOMETRIC METHODOLOGY

- Probability expressions for the air travel demand category:

$$P(D_{qrtl})|\gamma,\eta = \Lambda\left[\frac{\psi_j-\left((\alpha_r'+\gamma_{qr}')x_{qrtl}+(\eta_k)x_{qrtl}+\rho_{jr}'\right)}{\lambda_{Dr}}\right] - \Lambda\left[\frac{\psi_{j-1}-\left((\alpha_r'+\gamma_{qr}')x_{qrtl}+(\eta_k)x_{qrtl}+\rho_{j-1,r}'\right)}{\lambda_{Dr}}\right]$$

- Joint likelihood for airport level quarterly arrivals and departures:

$$L_q|\Omega = \prod_{t=1}^{T}\prod_{l=1}^{L}\prod_{r=1}^{2}\prod_{j=1}^{J}\left[P(D_{qrtl})|\gamma,\eta\right]^{d_{qrtlj}}$$

- Unconditional likelihood function: $L_q = \int_{\Omega}(L_q|\Omega)d\Omega$
- Likelihood function: $\text{LL} = \sum_{q=1}^{Q}\ln L_q$

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ECONOMETRIC METHODOLOGY

- The current study also outlines the formula for generating the demand prediction
- The continuous latent propensity score (D^*_{qrtl}) generated serves as the estimate of airline demand
- In the presence of alternative specific variables (ρ_{jr}), the latent propensity score needs to be adjusted

$$p_{qrtl} = (\alpha'_r + \gamma'_{qr})x_{qrtl} + (\eta_k)x_{qrtl} + \sum_{j=2}^{J}(\alpha'_r x_{qrtl} > (\psi_j - \rho_{jr})) \times \rho_{jr}$$

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ECONOMETRIC METHODOLOGY

- The adjusted R^2 measure represents the squared error in the model
- The squared error might not penalize the error in observations adequately
- In this study, an equivalent linear regression log-likelihood was generated

$$\left(D_{qrtl}\right) = \Lambda\left[\frac{\psi_j - \left(\omega_r' x_{qrtl}\right)}{\kappa_r}\right] - \Lambda\left[\frac{\psi_{j-1} - \left(\omega_r' x_{qrtl}\right)}{\kappa_r}\right]$$

- Where, ω and κ^2 represent the vector of coefficients and the error variance respectively

DATASET DESCRIPTION

- The airport demand data are sourced from the airline origin and destination survey conducted by BTS
- BTS provides detailed information about 10% of the tickets collected from domestic and international airlines operating in the US
- We considered the domestic air travelers from 2010 to 2018 across the 50 states in US
- Passenger trips in origin and destination survey are aggregated at quarters and airports and scaled appropriately
- We consider 510 airports for which itinerary information are available

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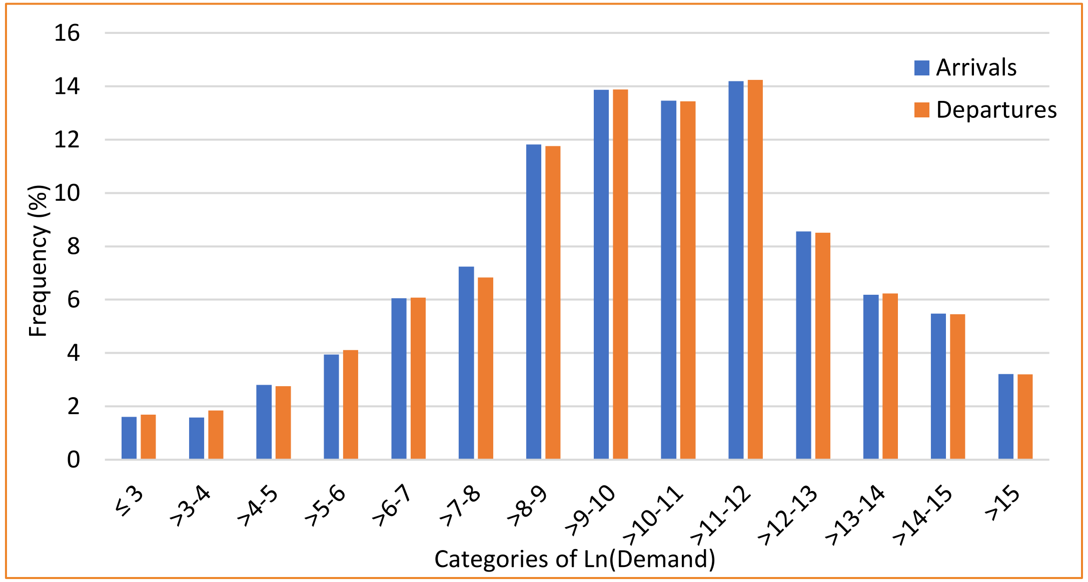
DATASET DESCRIPTION

- After cleaning the data, we obtain a total of 8,477 observations for estimation
- In preparation of dependent variables, we performed log transformation of arrivals and departures



DATASET DESCRIPTION

- The BTS airline data is also augmented with a host of independent variables

Demographic Characteristics	Built Environment	Spatial Factors	Temporal Factors
Population, median income, employment, out of state employment and education at the MSA level	Number of airports in 50mile buffer, crime rate and tourism ranking of the corresponding state	Region including south, north-east, west, mid-west and pacific	Year and quarter of the analysis

MODEL SELECTION

- We perform the model selection by a two-step process
- First, we compare the performance of the independent GOP model with the performance of a linear regression model
- We build equivalent measures for the two models from both approaches: adjusted R^2 and log-likelihood
- The linear regression model for arrivals (departures) with 12 (12) parameters resulted in an adjusted R^2 value of 0.401 (0.397)
- For the GOP arrivals (departures) model with 15 (16) parameters resulted in an adjusted R^2 value of 0.408 (0.405)

MODEL SELECTION

- LL and BIC value for the equivalent linear regression framework -37,363.3 (with 24 parameters) and 74,876.2, respectively
- LL and BIC value for the proposed GOP system is -37,128.0 (with 31 parameters) and 74,449.3, respectively
- In the second step, three variants of GOP models are compared
- The BIC values for the three models are as follows: a) Independent GOP model: 74,449.3, b) Restricted GOP model: 74,374.9 and c) Joint Panel GOP model: 60,475.1

ESTIMATION RESULTS

Variables	Arrivals	Departures
Propensity Components		
Demographic Factors		
Population	▲	▲
Median income	▲	▲
Out of state employment	▼	▼
Education Level (Base: High(% adults without high school degree <=12%))		
Low	▼	▼
Built Environment Factors		
No. of airports	▲	▲
Tourist's Attraction (Base: Others)		
Top10	▲	▲
Bottom10	▼	▼

ESTIMATION RESULTS

Variables	Arrivals	Departures
Propensity Components		
Spatial Factors		
Region (Base: West and Mid-West)		
South	▲	▲
North-East	▼	▼
Pacific	▼	▼
Temporal Factors		
Quarter (Base: Quarter 1)		
Quarter 2&4	▲	▲
Quarter 3	▲	▲

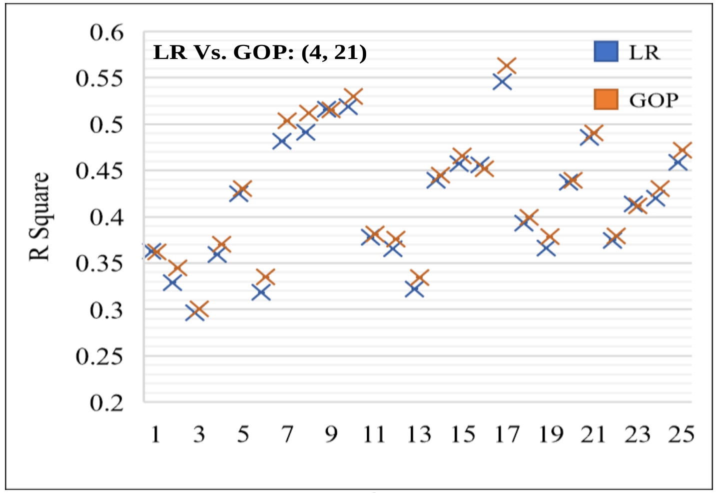
ESTIMATION RESULTS

- The proposed model also allows for category specific deviations on various predefined thresholds
- We estimated unobserved effects at multiple levels: airports, year, quarter, airport – year and airport – quarter
- Airport – year and airport – quarter level effects have significant influence on air travel demand
- These variables indicate that the air passenger arrivals and departures may vary for different airports based on the unobserved effects

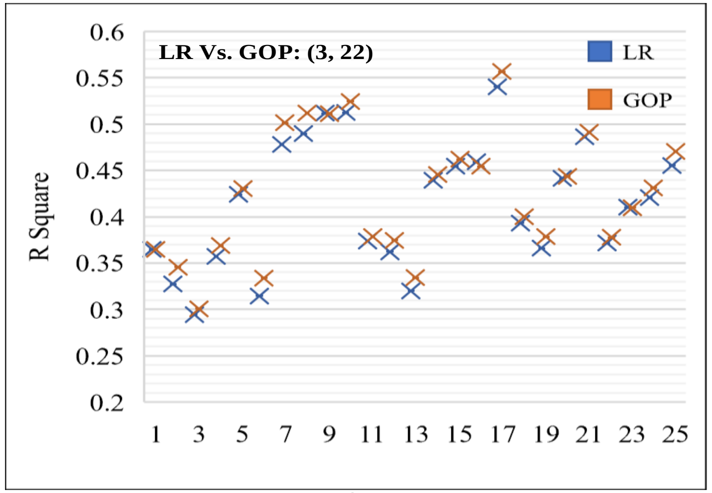
MODEL VALIDATION

- A validation test is performed based on quarterly passenger arrivals and departures for year 2017
- The validation set consists of 1,609 observations for 415 airports
- 25 data samples, of 100 airports each, are randomly generated from the hold out validation sample
- For the arrival model, the GOP model performs better than LR model in 43 out of 50 cases (R^2: 21 and LL: 22) while for the departure model, the GOP model performs better in 45 cases (R^2: 22 and LL: 23)

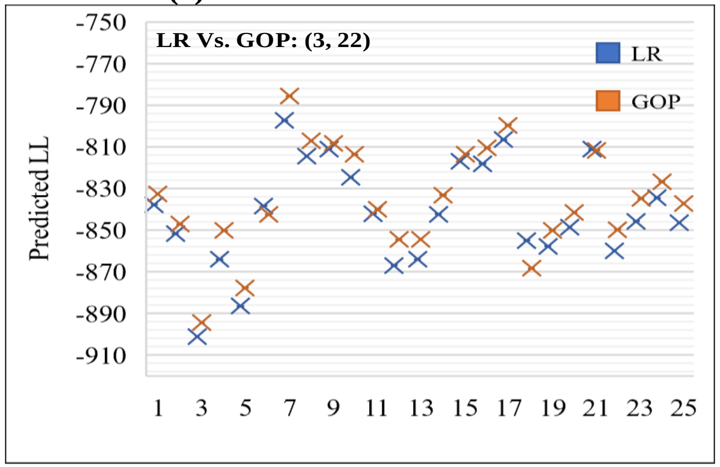
MODEL VALIDATION



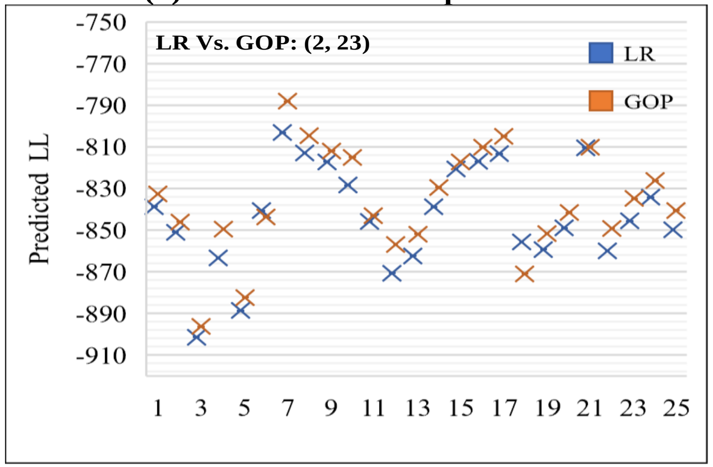
(a) Predicted R^2 for arrivals



(b) Predicted R^2 for departures



(c) Predicted LL for arrivals



(d) Predicted LL for departures

MODEL VALIDATION

- Subsequently, we compared the performance of the three GOP model systems
- The LL and BIC values computed using the validation dataset also clearly highlights the superiority of the joint panel GOP model

Model System	Log-likelihood	BIC
Independent GOP	-6972.12	14,131.12
Restricted GOP	-6972.13	14,058.80
Joint Panel GOP	-5868.40	11,857.37

POLICY ANALYSIS

Variables	Arrivals	Departures
Population	23.66	23.86
Median income	19.38	19.49
Out of state employment	-0.27	-0.27
Education Status (Low)	-45.00	-45.26
No. of airports	32.43	32.62
Top10	60.03	60.22
Bottom10	-29.87	-29.96
Quarter 2&4	8.51	8.54
Quarter 3	15.33	15.40

* percentage change of aggregate probability of the highest demand category due to changes of independent variables

SUMMARY

- Understanding the factors affecting airline demand at US airports is important for long-term planning and operational decisions.
- The current study contributes to the existing literature along multiple directions
- The proposed research develops a joint panel generalized ordered probit model system with observed thresholds for modeling air passenger arrivals and departures
- The proposed model is estimated using airline data compiled by BTS for 510 airports across the US

SUMMARY

- The joint panel model that accommodates for the presence of unobserved heterogeneity performs the best in terms of empirical context
- We perform an elasticity analysis to quantify the impact of the factors on airline demand
- The results identify important predictors for airline demand
- In particular, they highlight the role of tourism in the state, regional population and median income
- Augmenting the data in our research with local economic indicators and airport specific attributes might be an avenue for future research

QUESTIONS