Asymmetric Price Adjustments in Airlines

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Motivation

- Large price dispersion in airlines. Borenstein and Rose (JPE 1994), Gerardi and Shapiro (JPE 2009).
- Positive demand shifts drive prices up:
  - Basic prediction of economic theory.
  - Common view among travelers and the media:

    "The inevitable outcome of limited seats and stronger demand will be higher fares."

    New York Times, May 31, 2010
- Do prices fall as a response to negative demand shifts?

Motivation

- Potential explanations for the asymmetric response:
  - Simple convex supply curve.
  - Models with costly capacity and demand uncertainty: Prescott (JPE 1976), Eden (JPE 1990), Dana (Rand 1999)
  - Menu costs. Mankiw (QJE 1985), Ball and Mankiw (1994)
  - 'Asymmetric pricing.' (changes in costs) Peltzman (JPE 2000)
  - Collusion / Market power.
  - Uninformed consumers. Tappata (Rand 2009)
  - Inventories. Borenstein and Shepard (Rand 2002)

Motivation: Dynamic pricing in airlines

- Key characteristics:
  - Fixed capacity.
  - Perishable good.
  - Aggregate demand uncertainty.
  - Advance sales.
- Carriers exploit 'fences' such as:
  - Saturday-night-stayover.
  - Advance purchase discounts.
  - Minimum- and maximum-stay.
  - Refundable tickets.
  - Frequent flier miles.
  - Blackouts.
  - Volume discounts.
  - Fare classes (e.g. coach, first class)
- Airlines have the most sophisticated pricing systems in the world.

Contribution of the current paper

- First to explain price variation over different departure dates.
- Finds strong evidence of an asymmetric response.
- Combines different sources of asymmetries.
- Positive cost shifts have a positive effect, but negative demand shifts have no effect on prices.
- Cost shifts have larger effect on prices during summer travel.
- Less evidence that the shifts are related to the size of the demand shift or weekend and holiday travel.
- Importance of capacity constraints as a source of asymmetric pricing.
- Importance of asymmetric pricing to stabilize demand fluctuations.

Construction of the Data

- Minimum available non-refundable fare from *expedia.com*.
    - Controls for more expensive refundable fares.
- 126 days (18 weeks) for 48 flights departing between Tuesday June 9 and Monday October 12, 2009. Keeping the same flight-number.
    - Controls for time-invariant specific characteristics.
- One-way, non-stop, economy-class.
    - Connecting passengers / sophisticated itineraries / legs.
    - Uncertainty in the return portion of the ticket.
    - Saturday-night-stayover / min- and max-stay.
    - Fare classes (e.g. coach, first class).
- American, Alaska, Continental, Delta, United and US Airways.

Data

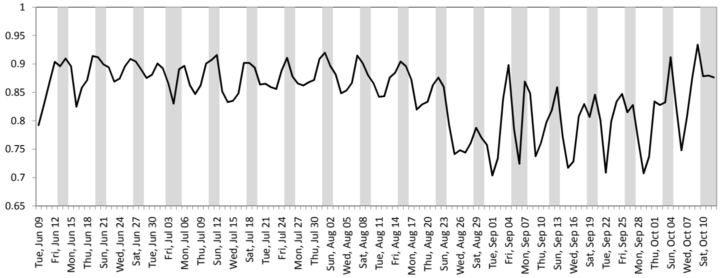

Figure: Realized demand. Shaded areas: Weekends and holidays

Decomposition of $\textsc{Price}_t$

Decompose $\textsc{Price}_t$ into:

$$\textsc{Price}_t = \textsc{Price}_t^P + \textsc{Price}_t^T.$$

Permanent component as a random walk with time-varying drift:

$$\textsc{Price}_t^P = \mu + \textsc{Price}_{t-1}^P + \nu_t,$$

ν_t is a normally distributed i.i.d. r.v.

Transitory component $\textsc{Price}_t^T$

Transitory component as an autoregressive process:

$$\phi(L) \cdot \textsc{Price}_t^T = \gamma_0(L) \cdot \textsc{Cost}_t + \gamma_1(L) \cdot \textsc{Cost}_t \cdot S_t + \varepsilon_t,$$

$$\phi(L) = \sum_{k=0}^{K} \phi_k \cdot L^k; \qquad \phi_0 = 1; \qquad \gamma_i(L) = \sum_{j=0}^{J} \gamma_{j,i} \cdot L^j.$$

S_t indicator variable equal to 0 or 1 to capture the regime switches in the response.

ε_t normally distributed i.i.d. r.v.

Lo and Piger (2005)

Fixed transition probabilities (FTP)

First-order Markov-switching fixed transitions probabilities:

$$\begin{aligned}
P(S_t = 0|S_{t-1} = 0) &= \frac{\exp(c_0)}{(1 + \exp(c_0))} \\
P(S_t = 1|S_{t-1} = 0) &= 1 - P(S_t = 0|S_{t-1} = 0) \\
P(S_t = 1|S_{t-1} = 1) &= \frac{\exp(c_1)}{(1 + \exp(c_1))} \\
P(S_t = 0|S_{t-1} = 1) &= 1 - P(S_t = 1|S_{t-1} = 1)
\end{aligned}$$

Time-varying transition probabilities (TVTP)

First-order Markov-switching time-varying transitions probabilities:

$$P(S_t = 0|S_{t-1} = 0) = \frac{\exp(c_0 + z_t' \cdot a_0)}{(1 + \exp(c_0 + z_t' \cdot a_0))}$$

$$P(S_t = 1|S_{t-1} = 1) = \frac{\exp(c_1 + z_t' \cdot a_1)}{(1 + \exp(c_1 + z_t' \cdot a_1))}$$

Four specifications for the vector z_t:

- $z_t = (z_{1t}, z_{2t}, ..., z_{qt})'$: Vector of state variables.
- $a_0 = (a_{01}, a_{02}, ..., a_{0q})'$: Vector of coefficients. ('low' response)
- $a_1 = (a_{11}, a_{12}, ..., a_{1q})'$: Vector of coefficients. ('high' response)

Asymmetries specifications

Four specifications for the vector z_t:

- $\text{SIGN}_t = 1$, if the demand shift is positive.
- $\text{SIZE}_t = 1$, if the demand shift is more than one standard deviation away from its mean.
- $\text{WKND}_t = 1$, if the departure date is during a weekend or holiday.
- $\text{SUMM}_t = 1$, if the departure date is during the summer.

Significance of the regime-switch

- Markov-switching state-space representation:
  - Kim (1994) filter.
- Significance of the regime-switch.
  - Hansen (1992): H_0: $\gamma_{j,0} = \gamma_{j,1}$ for all j
  - p-value of 0.01.

Table: Model Selection

Elements of z_t	SIC	AIC	Log likelihood	LR test[a]
FTP				
None	-2.5543	-2.8374	155.7086	
TVTP				
SIGN	-2.5205	-2.8551	158.6084	0.0550
SIZE	-2.4816	-2.8161	156.6226	0.4009
WKND	-2.4947	-2.8293	157.2945	0.2048
SUMM	-2.5256	-2.8601	158.8659	0.0425

Note: [a] p-value for a test of the null of the FTP.

Table: MLE Parameter Estimates

Parameter	FTP	SIGN	SIZE	WKND	SUMM
σ_ν	0.0039	0.0061	0.0046	0.0008	0.0051
	(0.0005)	(0.0037)	(0.0064)	(0.0038)	(0.0049)
σ_ϵ	0.0472	0.0462	0.0460	0.0478	0.0455
	(0.0041)	(0.0038)	(0.0039)	(0.0039)	(0.0037)
ϕ_1	0.1995	0.1235	0.1911	0.2190	0.1856
	(0.1173)	(0.0935)	(0.1228)	(0.0137)	(0.0858)
ϕ_2	-0.0100	-0.0038	-0.0091	-0.0120	-0.0086
	(0.0117)	(0.0058)	(0.0117)	(0.0598)	(0.0080)
$\gamma_{0,0}$	0.0995	0.1518	0.0908	0.0861	0.0862
	(0.1150)	(0.0966)	(0.1073)	(0.0882)	(0.0971)
$\gamma_{1,0}$	-0.1122	-0.1390	-0.1288	-0.1098	-0.1404
	(0.0954)	(0.0879)	(0.0948)	(0.0929)	(0.0913)
$\gamma_{0,1}$	2.4106	2.0317	2.3063	2.5431	2.2110
	(0.5238)	(0.5869)	(0.6688)	(0.4653)	(0.5563)
$\gamma_{1,1}$	0.8779	1.5148	0.9326	0.7594	0.8841
	(0.4517)	(0.6347)	(0.4614)	(0.4390)	(0.3893)
c_0	2.2963	21.3711	1.3803	1.7558	3.4565
	(0.5620)	(—[b])	(0.8459)	(0.5647)	(1.0222)
c_1	0.0434	-0.3268	-0.0754	0.1339	0.8511
	(0.4481)	(0.9417)	(1.9404)	(0.9612)	(0.7516)
a_{01}		-9.6909	1.0691	4.6457	-8.0797
		(0.5538)	(1.2950)	(1.6140)	(1.2852)
a_{02}		-10.7071	1.0616	19.8223	5.2679
		(—[b])	(1.2449)	(—[b])	(—[b])
Log likelihood	155.7086	158.6084	156.6226	157.2945	158.8659

Note: The ML estimate of c_0 appears on the boundary, violating regularity conditions. Hence, to calculate the standard errors, $c_0 = 0$ was imposed to calculate the second derivatives of the log likelihood.

PRICE_t^T

- Positively skewed PRICE_t^T

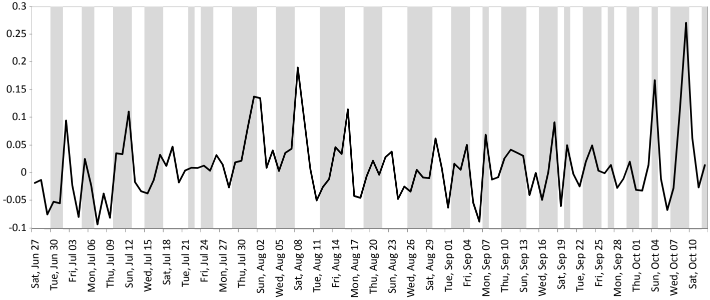

Figure: PRICE_t^T. Shaded areas: $\text{SIGN}_t = 1$

State dependent Impulse Response Functions

- Simulate the path of $\textsc{Price}_{t+j}^T$ as captured by: $\hat{\gamma}_{0,0}$, $\hat{\gamma}_{1,0}$, $\hat{\gamma}_{0,1}$, and $\hat{\gamma}_{1,1}$.
- $\textsc{Price}_{t-1}^T = \textsc{Price}_{t-2}^T = 0$, $\varepsilon_{t+j} = 0$, $\forall j$ and $\textsc{Cost}_{t-j} = 0$, $j \neq 0$.
- $\textsc{Cost}_t = 5.5\%$

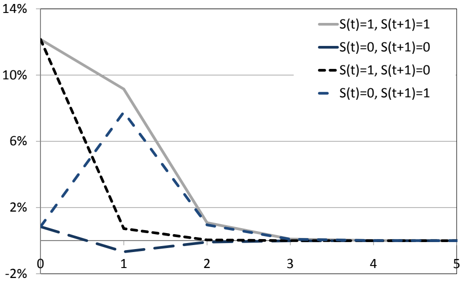

Figure: State dependent IRF of $\textsc{Price}_t^T$. TVTP: $\textsc{Sign}$

Transition Probabilities

- Determine the transition probabilities as captured by:

  $\hat{c}_0$, $\hat{c}_1$, $\hat{a}_{01}$ and $\hat{a}_{02}$

- When $\text{SIGN}_{t-1} = \text{SIGN}_t = 0$:

  $$P(S_t = 0 | S_{t-1} = 0) = \exp(\hat{c}_0)/(1 + \exp(\hat{c}_0)) = 1$$
  $$P(S_t = 1 | S_{t-1} = 0) = 0$$

- When $\text{SIGN}_{t-1} = \text{SIGN}_t = 1$:

  $$P(S_t = 0 | S_{t-1} = 0) = \exp(\hat{c}_0 + \hat{a}_{01} + \hat{a}_{02})/(1 + \exp(\hat{c}_0 + \hat{a}_{01} + \hat{a}_{02})) = 0.726$$
  $$P(S_t = 1 | S_{t-1} = 0) = 0.274$$

- Positive demand shifts are more likely to have a large effect on prices than negative demand shifts.

Filtered probability, $P(S_t = 1|t)$. TVTP: SIGN

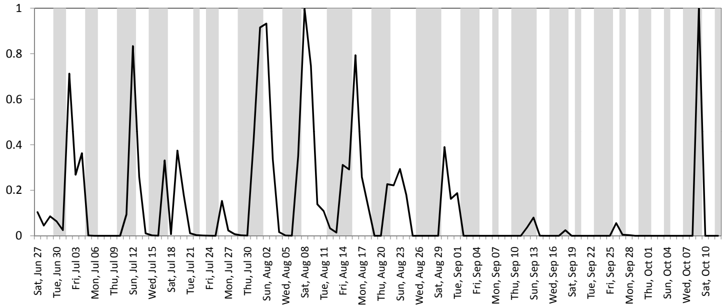

Figure: Filtered probability, $P(S_t = 1|t)$. TVTP: SIGN. Shaded areas: $\text{SIGN}_t = 1$

Filtered probability, $P(S_t = 1|t)$. TVTP: SUMM

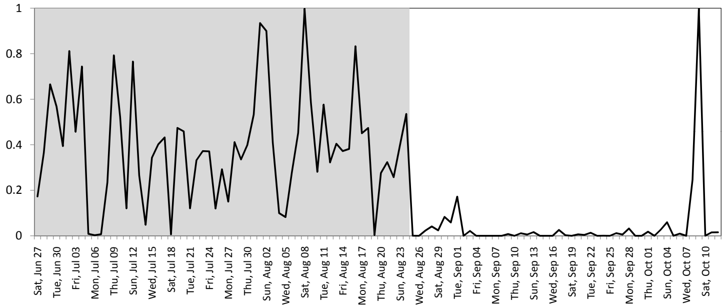

Figure: Filtered probability, $P(S_t = 1|t)$. TVTP: SUMM. Shaded areas: $\text{SUMM}_t = 1$

Combined Asymmetries

- Combined asymmetries.
  - Robustness of the SUMM specification.
  - Variation *within* the summer departure dates.

Table: Model Selection

Elements of z_t	SIC	AIC	Log likelihood	LR test[a]	LR test[b]
TVTP					
SUMM, SIGN	-2.4805	-2.8665	161.1919	0.0269	0.0977
SUMM, SIZE	-2.4356	-2.8216	158.9030	0.1719	0.9636
SUMM, WKND	-2.4678	-2.8538	160.5428	0.0464	0.1870
SUMM, SUMM×SIGN	-2.4953	-2.8814	161.9495	0.0141	0.0458
SUMM, SUMM×SIZE	-2.4629	-2.8489	160.2956	0.0569	0.2394
SUMM, SUMM×WKND	-2.4648	-2.8509	160.3938	0.0525	0.2170

Note: [a] p-value for a test of the null of the FTP model. [b] p-value for a test of the null of the SUMM model.

State Dependent Impulse Response Functions

- State dependent IRF.

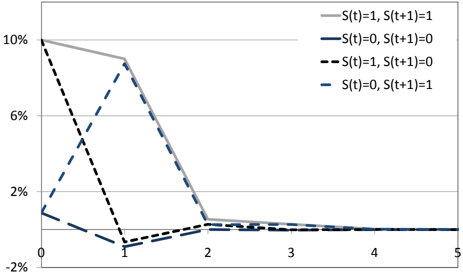

Figure: State dependent IRF of PRICE_t^T. TVTP: SUMM, SIGN×SUMM

Filtered probability, $P(S_t = 1|t)$

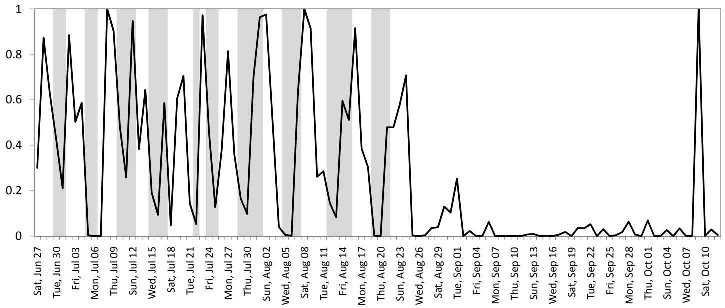

Figure: Filtered probability, $P(S_t = 1|t)$. TVTP: SUMM, $\text{SIGN}\times\text{SUMM}$. Shaded areas: $\text{SIGN}_t \times \text{SUMM}_t = 1$

Conclusions

- Strong evidence of response asymmetries.
- Prices are more sensitive to demand fluctuations during summer.
- Positive demand shifts are more likely to have a positive effect.
- Importance of capacity constraints as a source of 'asymmetric pricing.'
- Importance of pricing to stabilize demand fluctuations.
- Results are consistent with:
  - Simple convex supply curve.
  - Models with costly capacity and demand uncertainty: Prescott (1976), Eden (1990), Dana (1999)
  - Menu cost models. Ball and Mankiw (1994)
  - 'Asymmetric pricing.' Peltzman (2000)