Pass-through, profits & the political economy of regulation

Felix Grey
Faculty of Economics & EPRG
Cambridge University
&
Robert A. Ritz
Judge Business School & EPRG
Cambridge University

September 2018

Research motivation

- **Research question:** What is the impact of cost-raising regulation on a firm's profits?

Research motivation

- **Research question:** What is the impact of cost-raising regulation on a firm's profits?
  - Market-based environmental regulation
  - Minimum wage legislation
  - Bank capital adequacy regulation

Research motivation

- **Research question:** What is the impact of cost-raising regulation on a firm's profits?
  - Market-based environmental regulation
  - Minimum wage legislation
  - Bank capital adequacy regulation
- **Why is this question important?**
  - Regulated firms
  - Policymakers and political economy of regulation
  - Institutional investors

Overview of this paper

- **Theory**:
  - New 'generalized linear model of competition' (GLM)
  - Cost pass-through as sufficient statistic for profit impact

Overview of this paper

- **Theory**:
  - New 'generalized linear model of competition' (GLM)
  - Cost pass-through as sufficient statistic for profit impact
- **Empirics**:
  - Carbon pricing for aviation: US domestic airline market
  - Substantial pass-through heterogeneity: Winners & losers

Overview of this paper

- **Theory**:
  - New 'generalized linear model of competition' (GLM)
  - Cost pass-through as sufficient statistic for profit impact
- **Empirics**:
  - Carbon pricing for aviation: US domestic airline market
  - Substantial pass-through heterogeneity: Winners & losers
- **Application**:
  - Political economy of regulation: Lobbying & market power
  - Grossman-Helpman 1994 meets Buchanan 1969

Statement of the problem

- Suppose firm i experiences marginal cost shock ΔMC_i

Statement of the problem

- Suppose firm i experiences marginal cost shock ΔMC_i
- Profit impact $\Delta\Pi_i$, in general, depends on:
  - Technology of firm i
  - Demand for i's (differentiated) product
  - Competitors: how many (n), their technologies, their cost shocks (ΔMC_{-i}), their strategies, degree of competitiveness

Statement of the problem

- Suppose firm i experiences marginal cost shock ΔMC_i
- Profit impact $\Delta\Pi_i$, in general, depends on:
  - Technology of firm i
  - Demand for i's (differentiated) product
  - Competitors: how many (n), their technologies, their cost shocks (ΔMC_{-i}), their strategies, degree of competitiveness
- We try to radically simplify the problem, by remaining agnostic about most of the above

Statement of the problem

- Suppose firm i experiences marginal cost shock ΔMC_i
- Profit impact $\Delta\Pi_i$, in general, depends on:
  - Technology of firm i
  - Demand for i's (differentiated) product
  - Competitors: how many (n), their technologies, their cost shocks (ΔMC_{-i}), their strategies, degree of competitiveness
- We try to radically simplify the problem, by remaining agnostic about most of the above
- In the spirit of Sutton 2007: "aim to build the theory in such a way as to focus attention on those predictions which are robust across a range of model specifications which are deemed 'reasonable'."

The basic idea of the GLM

- Consider firm i competing a la Cournot
  - Demand: $p_i = \alpha - \beta x_i - \delta(X - x_i)$

The basic idea of the GLM

- Consider firm i competing a la Cournot
  - Demand: $p_i = \alpha - \beta x_i - \delta(X - x_i)$
  - Marginal cost: $MC_i = c_i + \tau$

The basic idea of the GLM

- Consider firm i competing a la Cournot
  - Demand: $p_i = \alpha - \beta x_i - \delta(X - x_i)$
  - Marginal cost: $MC_i = c_i + \tau$
  - FOC: Linear supply schedule $x_i = (1/\beta)(p_i - c_i - \tau)$

The basic idea of the GLM

- Consider firm i competing a la Cournot
  - Demand: $p_i = \alpha - \beta x_i - \delta(X - x_i)$
  - Marginal cost: $MC_i = c_i + \tau$
  - FOC: Linear supply schedule $x_i = (1/\beta)(p_i - c_i - \tau)$
  - No assumptions on rival's technologies or behaviour...

The basic idea of the GLM

- Consider firm i competing a la Cournot
  - Demand: $p_i = \alpha - \beta x_i - \delta(X - x_i)$
  - Marginal cost: $MC_i = c_i + \tau$
  - FOC: Linear supply schedule $x_i = (1/\beta)(p_i - c_i - \tau)$
  - No assumptions on rival's technologies or behaviour...
- Suppose regulation raises i's marginal cost by $d\tau$
  - Define i's rate of cost pass-through $(dp_i/d\tau)/(dMC_i/d\tau)$

The basic idea of the GLM

- Consider firm i competing a la Cournot
  - Demand: $p_i = \alpha - \beta x_i - \delta(X - x_i)$
  - Marginal cost: $MC_i = c_i + \tau$
  - FOC: Linear supply schedule $x_i = (1/\beta)(p_i - c_i - \tau)$
  - No assumptions on rival's technologies or behaviour...
- Suppose regulation raises i's marginal cost by $d\tau$
  - Define i's rate of cost pass-through $(dp_i/d\tau)/(dMC_i/d\tau)$
  - By construction, pass-through captures margin impact

The basic idea of the GLM

- Consider firm i competing a la Cournot
  - Demand: $p_i = \alpha - \beta x_i - \delta(X - x_i)$
  - Marginal cost: $MC_i = c_i + \tau$
  - FOC: Linear supply schedule $x_i = (1/\beta)(p_i - c_i - \tau)$
  - No assumptions on rival's technologies or behaviour...
- Suppose regulation raises i's marginal cost by $d\tau$
  - Define i's rate of cost pass-through $(dp_i/d\tau)/(dMC_i/d\tau)$
  - By construction, pass-through captures margin impact
  - By linear supply schedule, sales impact is proportional to pass-through

The basic idea of the GLM

- Consider firm i competing a la Cournot
  - Demand: $p_i = \alpha - \beta x_i - \delta(X - x_i)$
  - Marginal cost: $MC_i = c_i + \tau$
  - FOC: Linear supply schedule $x_i = (1/\beta)(p_i - c_i - \tau)$
  - No assumptions on rival's technologies or behaviour...
- Suppose regulation raises i's marginal cost by $d\tau$
  - Define i's rate of cost pass-through $(dp_i/d\tau)/(dMC_i/d\tau)$
  - By construction, pass-through captures margin impact
  - By linear supply schedule, sales impact is proportional to pass-through
- i's pass-through = sufficient statistic for i's profit impact
  - No information needed on (α, β, δ) or c_i

Comparison with structural empirical IO

- **Structural IO**
  - Consumer demand system (often logit structure)
  - Firms' production technologies (often constant MC)
  - Mode of competition (often Bertrand-Nash)

Comparison with structural empirical IO

- **Structural IO**
  - Consumer demand system (often logit structure)
  - Firms' production technologies (often constant MC)
  - Mode of competition (often Bertrand-Nash)
- **GLM approach**
  - No estimation of consumer demand system
  - No assumptions on mode of competition
  - Departures from Nash and/or profit-maximization
  - No estimation of conduct parameters or firms' mark-ups

Comparison with structural empirical IO

- **Structural IO**
  - Consumer demand system (often logit structure)
  - Firms' production technologies (often constant MC)
  - Mode of competition (often Bertrand-Nash)
- **GLM approach**
  - No estimation of consumer demand system
  - No assumptions on mode of competition
  - Departures from Nash and/or profit-maximization
  - No estimation of conduct parameters or firms' mark-ups
- **Trade-off**
  - Weaker assumptions & greater simplicity *vs*
  - Narrower set of questions & no counterfactual analysis

Related literature

- **Cost pass-through**
  - **Empirics**: e.g. De Loecker, Goldberg, Khandelwal & Pavcnik 2016 ($< 100\%$); Fabra & Reguant 2014 ($= 100\%$); Miller, Osborne & Sheu 2017 ($> 100\%$)

Related literature

- **Cost pass-through**
  - **Empirics**: e.g. De Loecker, Goldberg, Khandelwal & Pavcnik 2016 ($< 100\%$); Fabra & Reguant 2014 ($= 100\%$); Miller, Osborne & Sheu 2017 ($> 100\%$)
  - **Pass-through as a tool**: Weyl & Fabinger 2013; Atkin & Donaldson 2015; Bergquist 2017; Miller, Osborne & Sheu 2017; Ganapati, Shapiro & Walker 2017

Related literature

- **Cost pass-through**
  - **Empirics**: e.g. De Loecker, Goldberg, Khandelwal & Pavcnik 2016 ($< 100\%$); Fabra & Reguant 2014 ($= 100\%$); Miller, Osborne & Sheu 2017 ($> 100\%$)
  - **Pass-through as a tool**: Weyl & Fabinger 2013; Atkin & Donaldson 2015; Bergquist 2017; Miller, Osborne & Sheu 2017; Ganapati, Shapiro & Walker 2017
  - **This paper**: Shift from market-wide to firm-specific pass-through, further simplification of incidence analysis

Related literature

- **Marked-based environmental policy**
  - Bovenberg & Goulder 2005; Hepburn, Quah & Ritz 2013; Bushnell, Chyong & Mansur 2014; Fowlie, Reguant & Ryan 2016

Related literature

- **Marked-based environmental policy**
  - Bovenberg & Goulder 2005; Hepburn, Quah & Ritz 2013; Bushnell, Chyong & Mansur 2014; Fowlie, Reguant & Ryan 2016
  - **This paper**: Shift away from electricity & heavy industry, highlight firm-level heterogeneity in profit impacts and larger industry-wide profit loss for airlines

Related literature

- **Marked-based environmental policy**
  - Bovenberg & Goulder 2005; Hepburn, Quah & Ritz 2013; Bushnell, Chyong & Mansur 2014; Fowlie, Reguant & Ryan 2016
  - **This paper**: Shift away from electricity & heavy industry, highlight firm-level heterogeneity in profit impacts and larger industry-wide profit loss for airlines
- **Airline competition**
  - Brander & Zhang 1990; Kim & Sengal 1993; Goolsbee & Syverson 2008; Ciliberto & Tamer 2009; Berry & Jia 2010

Related literature

- **Marked-based environmental policy**
  - Bovenberg & Goulder 2005; Hepburn, Quah & Ritz 2013; Bushnell, Chyong & Mansur 2014; Fowlie, Reguant & Ryan 2016
  - **This paper**: Shift away from electricity & heavy industry, highlight firm-level heterogeneity in profit impacts and larger industry-wide profit loss for airlines
- **Airline competition**
  - Brander & Zhang 1990; Kim & Sengal 1993; Goolsbee & Syverson 2008; Ciliberto & Tamer 2009; Berry & Jia 2010
  - **This paper**: New results on political economy of low-cost vs legacy carriers, special role of Southwest also in terms of pass-through

Theory: Generalized linear model (GLM)

- Firm i sells quantity x_i at price p_i

Theory: Generalized linear model (GLM)

- Firm i sells quantity x_i at price p_i
- Emissions e_i viewed as input to production technology

Theory: Generalized linear model (GLM)

- Firm i sells quantity x_i at price p_i
- Emissions e_i viewed as input to production technology
- Emissions price τ on each unit of i's emissions e_i

Theory: Generalized linear model (GLM)

- Firm i sells quantity x_i at price p_i
- Emissions e_i viewed as input to production technology
- Emissions price τ on each unit of i's emissions e_i
- Profits $\Pi_i = p_i x_i - C_i(x_i, e_i) - \tau e_i$

Theory: Generalized linear model (GLM)

- Firm i sells quantity x_i at price p_i
- Emissions e_i viewed as input to production technology
- Emissions price τ on each unit of i's emissions e_i
- Profits $\Pi_i = p_i x_i - C_i(x_i, e_i) - \tau e_i$
- Regulation may apply to all, some or none of i's rivals

Assumptions of the GLM

Four assumptions hold for firm i for all relevant $\tau \geq 0$:

Assumptions of the GLM

Four assumptions hold for firm i for all relevant $\tau \geq 0$:

A1. *Emissions price-taking*: i takes input prices, including the emissions price τ, as given

Assumptions of the GLM

Four assumptions hold for firm i for all relevant $\tau \geq 0$:

A1. *Emissions price-taking*: i takes input prices, including the emissions price τ, as given

A2. *Cost-minimizing emissions*: i chooses inputs, including emissions e_i, to minimize its costs of producing output x_i

Assumptions of the GLM

Four assumptions hold for firm i for all relevant $\tau \geq 0$:

A1. *Emissions price-taking*: i takes input prices, including the emissions price τ, as given

A2. *Cost-minimizing emissions*: i chooses inputs, including emissions e_i, to minimize its costs of producing output x_i

A3. *Constant returns to scale*: i's unit costs are linear in output $C_i(x_i, e_i) + \tau e_i = k_i(\tau)x_i$, with unit cost $k_i(\tau) = c_i(\tau) + \tau z_i(\tau)$

- $z_i(\tau) \equiv e_i(\tau)/x_i$ is its emissions intensity

Assumptions of the GLM

Four assumptions hold for firm i for all relevant $\tau \geq 0$:

A1. *Emissions price-taking*: i takes input prices, including the emissions price τ, as given

A2. *Cost-minimizing emissions*: i chooses inputs, including emissions e_i, to minimize its costs of producing output x_i

A3. *Constant returns to scale*: i's unit costs are linear in output $C_i(x_i, e_i) + \tau e_i = k_i(\tau)x_i$, with unit cost $k_i(\tau) = c_i(\tau) + \tau z_i(\tau)$

- $z_i(\tau) \equiv e_i(\tau)/x_i$ is its emissions intensity

A4. *Linear product market behaviour*: i's supply satisfies the linear schedule $x_i(\tau) = \psi_i[p_i(\tau) - k_i(\tau)]$

- $[p_i(\tau) - k_i(\tau)] > 0$ is its profit margin, $\psi_i > 0$ is a constant

Key features of the GLM

- Weaker assumptions than many standard oligopoly models

Key features of the GLM

- Weaker assumptions than many standard oligopoly models
- No assumptions on technology or behaviour of i's rivals

Key features of the GLM

- Weaker assumptions than many standard oligopoly models
- No assumptions on technology or behaviour of i's rivals
- No assumptions on demand system or nature of consumer behaviour
  - No assumptions on number of competing products, or extent to which these are substitutes or complements, or whether competition is in strategic substitutes or complements

Key features of the GLM

- Weaker assumptions than many standard oligopoly models
- No assumptions on technology or behaviour of i's rivals
- No assumptions on demand system or nature of consumer behaviour
  - No assumptions on number of competing products, or extent to which these are substitutes or complements, or whether competition is in strategic substitutes or complements
- No equilibrium concept
  - Departures from Nash and/or profit-maximization
  - Rule of thumb behaviour

Special cases with the GLM structure

A4 is satisfied by a *very* wide range of IO models:

- Cournot-Nash with linear demand, including with firm-specific conjectural variations, and linear Stackelberg

Special cases with the GLM structure

A4 is satisfied by a *very* wide range of IO models:

- Cournot-Nash with linear demand, including with firm-specific conjectural variations, and linear Stackelberg
- Bertrand & Cournot with horizontally and/or vertically differentiated products

Special cases with the GLM structure

A4 is satisfied by a *very* wide range of IO models:

- Cournot-Nash with linear demand, including with firm-specific conjectural variations, and linear Stackelberg
- Bertrand & Cournot with horizontally and/or vertically differentiated products
- Two-stage models with linear competition in 2^{nd} stage, e.g.,
    - Strategic forward contracting (Allaz & Vila 1993)
    - Managerial delegation (Fershtman & Judd 1987)

Special cases with the GLM structure

A4 is satisfied by a *very* wide range of IO models:

- Cournot-Nash with linear demand, including with firm-specific conjectural variations, and linear Stackelberg
- Bertrand & Cournot with horizontally and/or vertically differentiated products
- Two-stage models with linear competition in 2^{nd} stage, e.g.,
  - Strategic forward contracting (Allaz & Vila 1993)
  - Managerial delegation (Fershtman & Judd 1987)
- Supply function equilibrium (Klemperer & Meyer 1989)

Special cases with the GLM structure

A4 is satisfied by a *very* wide range of IO models:

- Cournot-Nash with linear demand, including with firm-specific conjectural variations, and linear Stackelberg
- Bertrand & Cournot with horizontally and/or vertically differentiated products
- Two-stage models with linear competition in 2^{nd} stage, e.g.,
    - Strategic forward contracting (Allaz & Vila 1993)
    - Managerial delegation (Fershtman & Judd 1987)
- Supply function equilibrium (Klemperer & Meyer 1989)
- Behavioural biases (Al-Najjar, Baliga & Besanko 2008)

Special cases with the GLM structure

A4 is satisfied by a *very* wide range of IO models:

- Cournot-Nash with linear demand, including with firm-specific conjectural variations, and linear Stackelberg
- Bertrand & Cournot with horizontally and/or vertically differentiated products
- Two-stage models with linear competition in 2$^{\text{nd}}$ stage, e.g.,
  - Strategic forward contracting (Allaz & Vila 1993)
  - Managerial delegation (Fershtman & Judd 1987)
- Supply function equilibrium (Klemperer & Meyer 1989)
- Behavioural biases (Al-Najjar, Baliga & Besanko 2008)
- Common ownership of firms (O'Brien & Salop 2000)

Main result

- Define i's marginal pass-through rate $\rho_i(\tau) \equiv \frac{dp_i(\tau)/d\tau}{dk_i(\tau)/d\tau}$, and let average pass-through $\overline{\rho}_i(\tau) \equiv \frac{1}{\tau}\int_{s=0}^{\tau} \rho_i(s)ds$.

Main result

- Define i's marginal pass-through rate $\rho_i(\tau) \equiv \frac{dp_i(\tau)/d\tau}{dk_i(\tau)/d\tau}$, and let average pass-through $\overline{\rho}_i(\tau) \equiv \frac{1}{\tau}\int_{s=0}^{\tau} \rho_i(s)ds$.

Proposition (1)

In the GLM, the profit impact of emissions pricing τ on firm i satisfies $\Delta\Pi_i(\tau) \equiv -\gamma_i(\tau)\left[\tau e_i(0)\right]$ where:

(a) if τ is small, $\gamma_i(\tau) \simeq 2[1-\overline{\rho}_i(\tau)]$, where $\overline{\rho}_i(\tau) \simeq \rho_i(0)$

(b) in general, $\gamma_i(\tau) \leq \max\{2[1-\overline{\rho}_i(\tau)], 0\}$

Discussion

- So ρ_i is a sufficient statistic for $\Delta\Pi_i$, given τ & $e_i(0)$

Discussion

- So ρ_i is a sufficient statistic for $\Delta\Pi_i$, given τ & $e_i(0)$
  - ρ_i contains *all* relevant information about i's demand & supply conditions (incl. rivals' technologies & behaviour)
  - No extra information on conduct parameters & mark-ups
  - No estimation of ψ_i: $\Delta\Pi_i$ & $e_i(0)$ both proportional to ψ_i

Discussion

- So ρ_i is a sufficient statistic for $\Delta\Pi_i$, given τ & $e_i(0)$
  - ρ_i contains *all* relevant information about i's demand & supply conditions (incl. rivals' technologies & behaviour)
  - No extra information on conduct parameters & mark-ups
  - No estimation of ψ_i: $\Delta\Pi_i$ & $e_i(0)$ both proportional to ψ_i
- Formula for γ_i holds *approximately* even with modest departures from GLM (e.g. from A3 or A4)
  - No *systematic* upward or downward bias in γ_i

Next steps

- To progress further, two possible approaches:

Next steps

- To progress further, two possible approaches:

1. Choose specific theory of competition to determine ρ_i

Next steps

- To progress further, two possible approaches:

1. Choose specific theory of competition to determine ρ_i
   - e.g. Cournot-Nash gives $\rho_i = \frac{\sum_i \Delta k_i}{(n+1)\Delta k_i}$, so $\frac{\rho_i}{\rho_j} = \frac{\Delta k_j}{\Delta k_i}$

Next steps

- To progress further, two possible approaches:

1. Choose specific theory of competition to determine ρ_i
    - e.g. Cournot-Nash gives $\rho_i = \frac{\sum_i \Delta k_i}{(n+1)\Delta k_i}$, so $\frac{\rho_i}{\rho_j} = \frac{\Delta k_j}{\Delta k_i}$
2. Estimate ρ_i empirically

Next steps

- To progress further, two possible approaches:

1. Choose specific theory of competition to determine ρ_i
    - e.g. Cournot-Nash gives $\rho_i = \frac{\sum_i \Delta k_i}{(n+1)\Delta k_i}$, so $\frac{\rho_i}{\rho_j} = \frac{\Delta k_j}{\Delta k_i}$
2. Estimate ρ_i empirically
    - e.g. next part of this talk on US airlines

Background on aviation and climate policy

- **Global aviation:**
  - CO_2 emissions are 2.5% of total – but 5% by impact
  - Set to rise to 25% in 2050 without new policies

Background on aviation and climate policy

- **Global aviation:**
  - CO_2 emissions are 2.5% of total – but 5% by impact
  - Set to rise to 25% in 2050 without new policies
- **Policy problem:**
  - Aviation is growing fast but hard to decarbonise

Background on aviation and climate policy

- **Global aviation:**
  - CO_2 emissions are 2.5% of total – but 5% by impact
  - Set to rise to 25% in 2050 without new policies
- **Policy problem:**
  - Aviation is growing fast but hard to decarbonise
- **Policy so far:**
  - 2012 inclusion of aviation in EU ETS – politically fraught...
  - Chinese regional ETSs
  - 2016 ICAO agreement – emissions offset system
  - 2018 Swedish carbon tax on aviation

Background on aviation and climate policy

- **Global aviation:**
  - CO_2 emissions are 2.5% of total – but 5% by impact
  - Set to rise to 25% in 2050 without new policies
- **Policy problem:**
  - Aviation is growing fast but hard to decarbonise
- **Policy so far:**
  - 2012 inclusion of aviation in EU ETS – politically fraught...
  - Chinese regional ETSs
  - 2016 ICAO agreement – emissions offset system
  - 2018 Swedish carbon tax on aviation
- **US aviation:**
  - World's largest market, with 30% of global aviation emissions
  - 2014: 172 million tCO_2, value \$8.6 billion at \$50/tCO_2

Empirical question & strategy

- **Research question:** What is the impact of a \$50/tCO_2 carbon price on US airlines' profits?

Empirical question & strategy

- **Research question:** What is the impact of a \$50/tCO_2 carbon price on US airlines' profits?

- Product: a flight on carrier i on route j

Empirical question & strategy

- **Research question:** What is the impact of a \$50/tCO_2 carbon price on US airlines' profits?
- Product: a flight on carrier i on route j
- GLM: Aggregate profit impact on carrier i across its j routes:

$$\Delta\Pi_i \simeq -2(1-\rho_i)\tau e_i(0)$$

where $\rho_i = \sum_j \frac{e_{ij}(0)}{e_i(0)}\rho_{ij}$ is weighted-average pass-through

Empirical question & strategy

- **Research question:** What is the impact of a \$50/tCO_2 carbon price on US airlines' profits?
- Product: a flight on carrier i on route j
- GLM: Aggregate profit impact on carrier i across its j routes:

$$\Delta\Pi_i \simeq -2(1-\rho_i)\tau e_i(0)$$

where $\rho_i = \sum_j \frac{e_{ij}(0)}{e_i(0)}\rho_{ij}$ is weighted-average pass-through

- Predict carbon cost pass-through by estimating fuel cost pass-through
  - Wide variation in fuel costs over time (factor of 5)
  - Airlines cannot influence fuel price

Empirical strategy

- Example route: Phoenix Sky Harbor International Airport, (PHX) to San Antonio International Airport (SAT)

Empirical strategy

- Example route: Phoenix Sky Harbor International Airport, (PHX) to San Antonio International Airport (SAT)
- Example product: i = Southwest, j =PHX-SAT

Empirical strategy

- Example route: Phoenix Sky Harbor International Airport, (PHX) to San Antonio International Airport (SAT)
- Example product: i = Southwest, j =PHX-SAT
- Important heterogeneities across carrier-routes:
  - Product differentiation: leg room, service, refreshments, loyalty rewards, airports, etc
  - Cost structure
  - Routes flown (product mix)
  - Competitors on a given route: their identity, products, prices, costs, strategies

The data

- We use data from the Bureau of Transportation Statistics

The data

- We use data from the Bureau of Transportation Statistics
- Time period: 2002Q1 to 2014Q4

The data

- We use data from the Bureau of Transportation Statistics
- Time period: 2002Q1 to 2014Q4
- Average quarterly price p_{ijt}, from a 10% sample of all tickets (DB1A)
  - One way (split returns), ignore direction
  - Exclude: international, frequent fliers, non-economy, prices >5 times 'standard', some others

The data

- We use data from the Bureau of Transportation Statistics
- Time period: 2002Q1 to 2014Q4
- Average quarterly price p_{ijt}, from a 10% sample of all tickets (DB1A)
  - One way (split returns), ignore direction
  - Exclude: international, frequent fliers, non-economy, prices >5 times ‘standard’, some others
- Per-passenger fuel cost k_{ijt} constructed from fuel expenditure by aircraft (Form 41), and aircraft share by route (T-100)

The data

- Keep all carrier-routes which are:
  - direct flights (standard in airlines literature)
  - continuously operated (to enable regression)

The data

- Keep all carrier-routes which are:
  - direct flights (standard in airlines literature)
  - continuously operated (to enable regression)
- Focus on 7 largest carriers:
  - Legacy carriers: Alaska, American, Delta, Hawaiian, United, US Airways
  - Low cost carrier: Southwest

The data

- Keep all carrier-routes which are:
  - direct flights (standard in airlines literature)
  - continuously operated (to enable regression)
- Focus on 7 largest carriers:
  - Legacy carriers: Alaska, American, Delta, Hawaiian, United, US Airways
  - Low cost carrier: Southwest
- Resulting sample is a balanced panel:
  - $N = 615$ carrier-routes over $T = 52$ quarters
  - 26% by revenue of all US aviation activity over the period

Descriptive statistics

	Southwest				Legacy			
	mean	s.d.	min	max	mean	s.d.	min	max
Price ($)	157.31	40.52	74.78	298.91	230.82	78.21	52.14	683.50
Fuel cost ($)	29.22	15.69	5.29	101.52	50.08	31.05	2.33	366.63
Distance (miles)	688	407	148	2,106	1,097	706	84	3,784
Emissions (tCO_2)	0.13	0.06	0.03	0.44	0.21	0.11	0.02	1.18
Emissions cost ($)	6.70	2.92	1.71	21.92	10.47	5.54	1.12	59.12
Passengers (000s)	195	172	5	1,172	153	135	4	1,263
No. firms	3.28	2.41	1.00	17.00	3.67	2.24	1.00	17.00
Fraction seats filled	0.72	0.10	0.33	0.97	0.79	0.10	0.23	0.97
Revenue ($ million)	24.76	18.78	0.83	135.07	28.99	24.92	0.33	238.11
Revenue in sample	0.42	–	–	–	0.34	–	–	–
No. routes	212	–	–	–	403	–	–	–
No. observations	11,024	–	–	–	20,956	–	–	–

Fuel prices and fuel costs

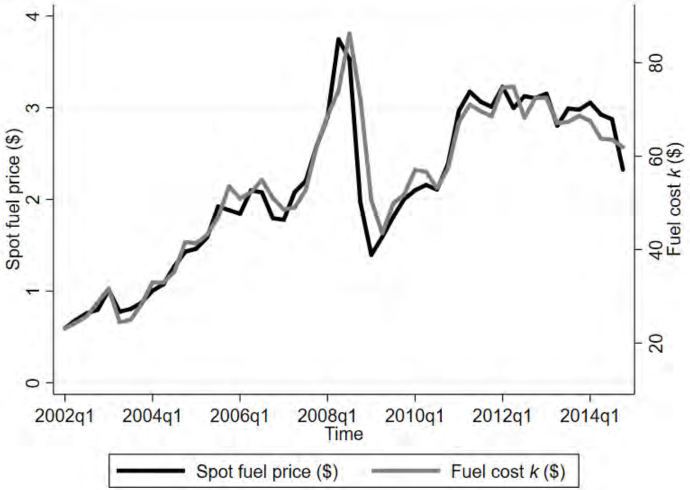


Figure: Average per-passenger fuel cost k_t and the spot price of jet fuel.

Fuel costs and ticket prices

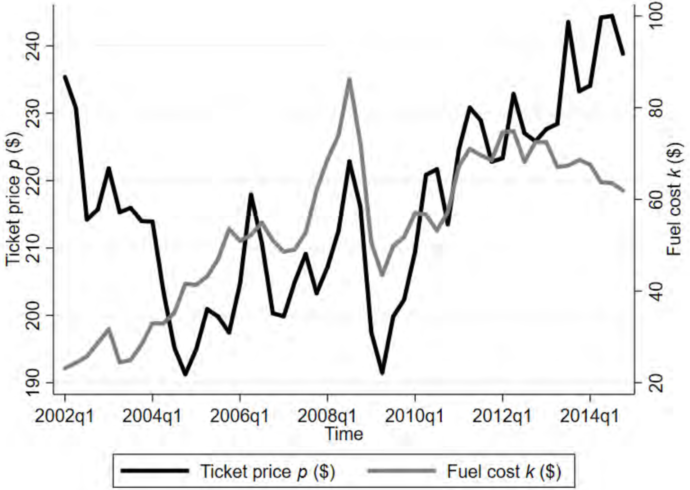


Figure: Ticket prices (left axis), and per-passenger fuel and non-fuel costs (right axis).

Baseline regression specification

- Estimate cost pass-through at the carrier-route level:

$$p_{ijt} = \rho_{ij}^{m} \sum_{m=0}^{3} k_{ij,t-m} + X'_{ijt}\beta_{ij} + \epsilon_{ijt} \tag{1}$$

where:

- "Equilibrium" pass-through $\rho_{ij} = \sum_{m=o}^{3} \rho_{ij}^{m}$
- X_{ijt} is a vector of covariates:
  - GDP growth g_{jt}, proxy for demand
  - Index of labour and maintenance costs c_{it}
  - Number of competitor firms n_{jt}
  - Number of potential entrants n_{jt}^{p}
  - Quarterly dummies q_t

Estimation approach

- We find Mean Group (Pesaran & Smith 1995) estimates for carrier pass-through rates:
  - run a separate regression for each ij
  - calculate emissions-weighted average for airline i

Estimation approach

- We find Mean Group (Pesaran & Smith 1995) estimates for carrier pass-through rates:
  - run a separate regression for each ij
  - calculate emissions-weighted average for airline i

- Endogeneity: k_{ijt} constructed by dividing whole plane's fuel consumption by number of filled seats, which depends on p_{ijt}

Estimation approach

- We find Mean Group (Pesaran & Smith 1995) estimates for carrier pass-through rates:
  - run a separate regression for each ij
  - calculate emissions-weighted average for airline i
- Endogeneity: k_{ijt} constructed by dividing whole plane's fuel consumption by number of filled seats, which depends on p_{ijt}
- Hence, k_{ijt} endogenous - use spot fuel price as an instrument. First stage regression:

$$k_{ij,t-m} = \sum_{q=0}^{7} \gamma_{ij}^{m,q} f_{t-q} + X'_{ijt}\beta_{ij}^{m} + \epsilon_{ijt}^{m} \quad \text{for each } m \in \{0,1,2,3\}$$

Estimation approach

- We find Mean Group (Pesaran & Smith 1995) estimates for carrier pass-through rates:
  - run a separate regression for each ij
  - calculate emissions-weighted average for airline i
- Endogeneity: k_{ijt} constructed by dividing whole plane's fuel consumption by number of filled seats, which depends on p_{ijt}
- Hence, k_{ijt} endogenous - use spot fuel price as an instrument. First stage regression:

$$k_{ij,t-m} = \sum_{q=0}^{7} \gamma_{ij}^{m,q} f_{t-q} + X'_{ijt}\beta_{ij}^{m} + \epsilon_{ijt}^{m} \quad \text{for each } m \in \{0,1,2,3\}$$

- 2SLS estimate using $\hat{k}_{ijt}$ in Equation (1)

Illustration for Southwest on PHX-SAT

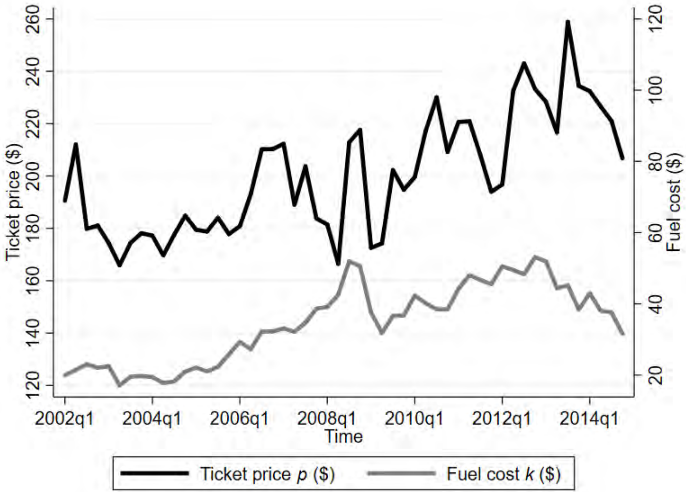


Illustration for Southwest on PHX-SAT

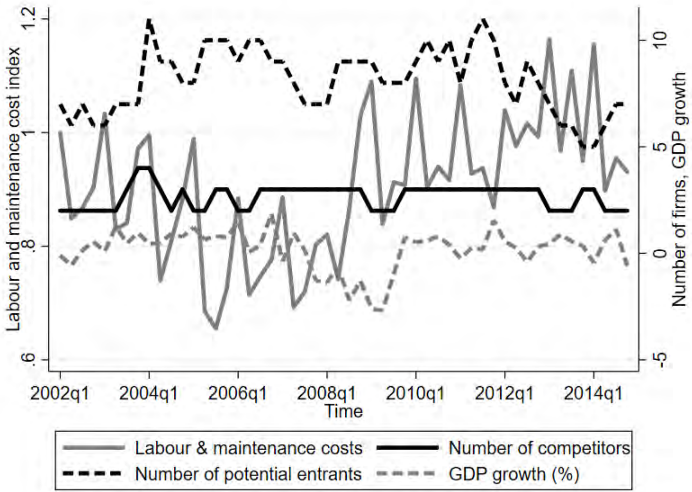


Illustration for Southwest on PHX-SAT

Results	
Pass through	1.38
	(0.32)
Profit impact (% of revenue)	2.22
	(1.83)
Descriptive statistics	
Price ($)	200.32
Fuel cost ($)	32.59
Number of firms	2.57
Number of potential entrants	8.10
Distance (miles)	843
Emissions (tCO_2)	0.13
Emissions cost ($)	6.40
Passengers, annual	76,014
Proportion of seats filled	0.73
Revenue in 2014 ($ million)	17.36
No. of observations	52

Main empirical results

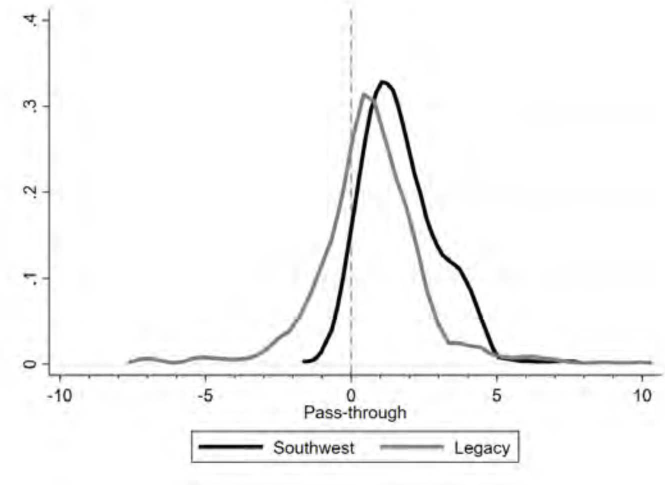
- Repeat 2SLS estimation for $N = 615$ carrier-routes, calculate weighted average pass-through and profit impact

Main empirical results

- Repeat 2SLS estimation for $N = 615$ carrier-routes, calculate weighted average pass-through and profit impact

	Southwest	Legacy	All
Pass through	1.48	0.55	0.78
	(0.04)	(0.06)	(0.05)
Profit impact (% revenue)	2.95	-3.56	-1.59
	(0.22)	(0.51)	(0.36)
Profit neutral permit allocation	-0.96	0.90	0.43
	(0.07)	(0.13)	(0.10)
No. routes	*212*	*403*	*615*
No. obs.	*11,024*	*20,956*	*31,980*

Pass-through heterogeneity



Estimated profit impacts of carbon pricing

- Substantial heterogeneity of profit impact:
  - Southwest +2.95% (± 0.44) of revenue
  - Legacy –3.56% (± 1.02) of revenue

Estimated profit impacts of carbon pricing

- Substantial heterogeneity of profit impact:
  - Southwest +2.95% (± 0.44) of revenue
  - Legacy –3.56% (± 1.02) of revenue

- Assuming our routes are representative of all routes flown by the airlines, total profit impacts:
  - Southwest +\$0.51 (± 0.07) billion
  - Legacy –\$1.46 (± 0.41) billion

Estimated profit impacts of carbon pricing

- Substantial heterogeneity of profit impact:
  - Southwest +2.95% (± 0.44) of revenue
  - Legacy –3.56% (± 1.02) of revenue
- Assuming our routes are representative of all routes flown by the airlines, total profit impacts:
  - Southwest +\$0.51 (± 0.07) billion
  - Legacy –\$1.46 (± 0.41) billion
- For comparison, reported 5-year average profits:
  - Southwest \$1.17 billion
  - Legacy \$4.26 billion

What explains differences in pass-through?

	Southwest			Legacy		
	Short *distance* $\in [0, 570)$	Medium *distance* $\in [570, 1034)$	Long *distance* $\in [1034, 3784]$	Short *distance* $\in [0, 570)$	Medium *distance* $\in [570, 1034)$	Long *distance* $\in [1034, 3784]$
Small $n \in [1, 2.3)$	2.00 (0.10) *34*	1.03 (0.07) *30*	0.80 (0.07) *24*	1.03 (0.22) *39*	0.26 (0.29) *29*	0.73 (0.09) *49*
Medium $n \in [2.3, 4.3)$	2.48 (0.10) *35*	0.90 (0.09) *19*	0.60 (0.08) *11*	0.58 (0.31) *34*	0.78 (0.21) *56*	0.00 (0.12) *53*
Large $n \in [4.3, 12.5]$	2.55 (0.10) *33*	0.87 (0.09) *20*	0.64 (0.16) *7*	-0.18 (1.28) *27*	0.87 (0.12) *60*	0.68 (0.08) *59*
All n	2.40 (0.56) *102*	0.91 (0.38) *68*	0.70 (0.33) *42*	0.46 (2.35) *99*	0.75 (1.14) *143*	0.46 (0.59) *161*

Standard errors in parentheses, number of routes in italics.

What explains differences in pass-through?

	Southwest			Legacy		
	All weighted	All un-weighted	Common un-weighted	All weighted	All un-weighted	Common un-weighted
Pass through	1.48	1.72	1.61	0.55	0.69	0.98
	(0.04)	(0.04)	(0.09)	(0.06)	(0.06)	(0.18)
No. routes	*212*	*212*	*49*	*403*	*403*	*49*

Standard errors in parentheses, number of routes in italics.

Decomposition of pass-through difference

(1) Southwest flies different routes:

- Pass-through on all routes *vs* on common routes
- Explains 62% of the original difference

Decomposition of pass-through difference

(1) Southwest flies different routes:

- Pass-through on all routes *vs* on common routes
- Explains 62% of the original difference

(2) Southwest is more fuel efficient on like-for-like routes:

- Fuel cost: $k_{Southwest} = \$26$ and $k_{Legacy} = \$31$
- If products are homogenous, then $\frac{\rho_i}{\rho_j} = \frac{\Delta k_j}{\Delta k_i}$
- Explains 26% of original difference

Decomposition of pass-through difference

(1) Southwest flies different routes:

- Pass-through on all routes *vs* on common routes
- Explains 62% of the original difference

(2) Southwest is more fuel efficient on like-for-like routes:

- Fuel cost: $k_{Southwest} = \$26$ and $k_{Legacy} = \$31$
- If products are homogenous, then $\frac{\rho_i}{\rho_j} = \frac{\Delta k_j}{\Delta k_i}$
- Explains 26% of original difference

(3) Residual: Southwest has a different demand profile on like-for-like routes:

- Differentiated-product demand-side asymmetries
- Pass-through heterogeneity even for a uniform cost shock

Further results and robustness checks

Further results and robustness checks

- Entry and exit
  - Allow $\rho_{ij}(n_{ijt})$ by including an interaction term in regression
  - Look at subset of routes where n_{ijt} is stable over time

Further results and robustness checks

- Entry and exit
  - Allow $\rho_{ij}(n_{ijt})$ by including an interaction term in regression
  - Look at subset of routes where n_{ijt} is stable over time
- Competition from Southwest
  - Dummy for Southwest presence and *potential* entry

Further results and robustness checks

- Entry and exit
  - Allow $\rho_{ij}(n_{ijt})$ by including an interaction term in regression
  - Look at subset of routes where n_{ijt} is stable over time
- Competition from Southwest
  - Dummy for Southwest presence and *potential* entry
- Input price volatility
  - Implications for emissions trading vs carbon tax

Further results and robustness checks

- Entry and exit
  - Allow $\rho_{ij}(n_{ijt})$ by including an interaction term in regression
  - Look at subset of routes where n_{ijt} is stable over time
- Competition from Southwest
  - Dummy for Southwest presence and *potential* entry
- Input price volatility
  - Implications for emissions trading vs carbon tax
- Asymmetric cost pass-through: Rockets and feathers

Further results and robustness checks

- Entry and exit
  - Allow $\rho_{ij}(n_{ijt})$ by including an interaction term in regression
  - Look at subset of routes where n_{ijt} is stable over time
- Competition from Southwest
  - Dummy for Southwest presence and *potential* entry
- Input price volatility
  - Implications for emissions trading vs carbon tax
- Asymmetric cost pass-through: Rockets and feathers
- Bankruptcy of legacy carriers

Further results and robustness checks

- Entry and exit
  - Allow $\rho_{ij}(n_{ijt})$ by including an interaction term in regression
  - Look at subset of routes where n_{ijt} is stable over time
- Competition from Southwest
  - Dummy for Southwest presence and *potential* entry
- Input price volatility
  - Implications for emissions trading vs carbon tax
- Asymmetric cost pass-through: Rockets and feathers
- Bankruptcy of legacy carriers
- Fixed effects estimation

Further results and robustness checks

- Entry and exit
  - Allow $\rho_{ij}(n_{ijt})$ by including an interaction term in regression
  - Look at subset of routes where n_{ijt} is stable over time
- Competition from Southwest
  - Dummy for Southwest presence and *potential* entry
- Input price volatility
  - Implications for emissions trading vs carbon tax
- Asymmetric cost pass-through: Rockets and feathers
- Bankruptcy of legacy carriers
- Fixed effects estimation
- Log specification: Pass-through elasticity

Application: Political economy of regulation

- GLM brings together two strands of literature:
  - Second-best emissions tax with market power (Buchanan 1969; Requate 2006; Fowlie, Reguant & Ryan 2016)
  - Political contributions to lobby government "for sale" (Grossman & Helpman 1994; Goldberg & Maggi 1999; Bombardini 2008)

Application: Political economy of regulation

- GLM brings together two strands of literature:
  - Second-best emissions tax with market power (Buchanan 1969; Requate 2006; Fowlie, Reguant & Ryan 2016)
  - Political contributions to lobby government "for sale" (Grossman & Helpman 1994; Goldberg & Maggi 1999; Bombardini 2008)

- Government payoff: $U_{\text{gov}}(\tau) = W(\tau) + \lambda \sum_{i=1}^{n} K_i(\tau)$
  - K_i is i's political contribution (in eqm, linear in profit)

Application: Political economy of regulation

- GLM brings together two strands of literature:
  - Second-best emissions tax with market power (Buchanan 1969; Requate 2006; Fowlie, Reguant & Ryan 2016)
  - Political contributions to lobby government "for sale" (Grossman & Helpman 1994; Goldberg & Maggi 1999; Bombardini 2008)

- Government payoff: $U_{\text{gov}}(\tau) = W(\tau) + \lambda \sum_{i=1}^{n} K_i(\tau)$
  - K_i is i's political contribution (in eqm, linear in profit)

- Now assume GLM (A1–A4) holds for each i
- Constant emissions intensity for each i
- Utility-maximizing consumers (differentiated products)
- Emissions damages function $D(E)$

The political equilibrium carbon price

Proposition (2)

At an interior solution:

$$\tau^{\star}(\lambda) = \left[\frac{D'(E(\tau))}{1 - \frac{(1+2\lambda)}{\eta(\tau)} \sum_{i=1}^{n} \frac{e_i(\tau)}{E(\tau)} [1 - \rho_i(\tau)]} \right]_{\tau = \tau^{\star}(\lambda)}$$

where $\eta \equiv [dE(\tau)/E(\tau)] / [d\tau/\tau] < 0$ *is the carbon price elasticity of industry-level emissions.*

Political equilibrium carbon price for US airlines

Social cost of carbon \$50/tCO_2

Lobbying influence (λ)	Carbon price elasticity of emissions (η) –0.06	–0.16	–0.26
0	\$10.71 *(100%)*	\$21.05 *(100%)*	\$27.08 *(100%)*
0.1	\$9.26 *(96%)*	\$18.87 *(93%)*	\$24.81 *(91%)*
0.2	\$8.15 *(94%)*	\$17.09 *(88%)*	\$22.89 *(85%)*
0.5	\$6.00 *(89%)*	\$13.33 *(79%)*	\$18.57 *(73%)*

Conclusion

- Understanding the profit impact of regulation is important for regulated firms, policymakers and investors

Conclusion

- Understanding the profit impact of regulation is important for regulated firms, policymakers and investors
- We introduce a new, simple, flexible theoretical framework allowing large-scale estimation based on pass-through as a sufficient statistic

Conclusion

- Understanding the profit impact of regulation is important for regulated firms, policymakers and investors
- We introduce a new, simple, flexible theoretical framework allowing large-scale estimation based on pass-through as a sufficient statistic
- For US airlines, we find large heterogeneities in carbon cost pass-through between Southwest and legacy carriers

Conclusion

- Understanding the profit impact of regulation is important for regulated firms, policymakers and investors
- We introduce a new, simple, flexible theoretical framework allowing large-scale estimation based on pass-through as a sufficient statistic
- For US airlines, we find large heterogeneities in carbon cost pass-through between Southwest and legacy carriers
- We hope the GLM will also be useful in other contexts in IO, public economics, international trade and networks

Thank you

Appendix: Southwest, PHX-SAT

Pass through	1.38***
	(0.32)
No. firms	2.05
	(3.26)
No. potential entrants	-2.11
	(2.03)
Labour & maintenance cost index	166.81
	(99.12)
GDP growth	537.72*
	(281.76)
Quarter 1	-3.87
	(7.87)
Quarter 2	5.55
	(4.54)
Quarter 3	15.81***
	(5.58)
Constant	113.99***
	(17.20)
No. of observations	52

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Appendix: Full Mean Group Estimates

	Southwest	Legacy
Pass-through	1.48***	0.55***
	(0.03)	(0.06)
GDP growth	173.85***	93.21*
	(18.44)	(53.27)
No. firms	-1.91***	-7.08***
	(0.37)	(0.84)
No. potential entrants	-1.13***	-1.13**
	(0.15)	(0.42)
Labour and maintenance cost index	122.66***	97.88***
	(8.69)	(6.53)
Quarter 1	-5.75***	-7.97***
	(0.53)	(1.69)
Quarter 2	4.32***	10.94***
	(0.48)	(1.23)
Quarter 3	-1.71***	12.77***
	(0.50)	(1.47)
No. routes	212	403
No. obs.	11,024	20,956

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Appendix: Descriptive statistics by carrier

	WN	AA	AS	DL	HA	UA	US
Price ($)	157.31	226.29	205.46	230.86	166.68	245.56	240.44
Fuel cost ($)	29.22	54.52	43.36	47.20	41.54	55.32	42.15
Distance (miles)	688	1,163	726	1,041	1,110	1,277	957
Emissions (tCO_2)	0.13	0.24	0.18	0.19	0.17	0.22	0.18
Emissions cost ($)	6.70	12.04	9.13	9.39	8.33	11.15	9.06
Passengers (000s)	195	159	158	155	331	141	127
No. firms	3.28	3.79	2.57	3.35	2.78	4.65	3.05
Fraction seats filled	0.72	0.79	0.70	0.81	0.81	0.81	0.79
Revenue ($ million)	24.76	31.46	24.82	29.36	35.12	29.46	24.19
Revenue in sample	0.42	0.39	0.41	0.26	0.40	0.45	0.27
No. routes	212	111	35	90	10	101	56
No. observations	11,024	5,772	1,820	4,680	520	5,252	2,912

Appendix: Pass-through estimates by carrier

	WN	AA	AS	DL	HA	UA	US
Pass through	1.48	0.90	0.21	0.79	0.92	-0.09	0.69
	(0.04)	(0.08)	(0.09)	(0.14)	(0.18)	(0.09)	(0.40)
Profit impact (%)	2.95	-0.80	-6.41	-1.39	-0.54	-9.58	-2.31
	(0.22)	(0.69)	(0.70)	(0.94)	(1.31)	(0.76)	(2.93)
No. routes	*212*	*111*	*35*	*90*	*10*	*101*	*56*
No. observations	*11,024*	*5,772*	*1,820*	*4,680*	*520*	*5,252*	*2,912*

Appendix: Further pass-through results

	Southwest	Legacy
(a) Baseline (2SLS)	1.48 (0.03) *212*	0.55 (0.06) *403*
(b) OLS	1.34 (0.03) *212*	0.43 (0.04) *403*
(c) Late period: 2005-2014 only	1.50 (0.06) *229*	0.62 (0.06) *413*
(d) n-interaction	1.45 (0.04) *212*	0.64 (0.07) *403*
(e) Baseline with $\Delta n = 0$	1.54 (0.12) *24*	0.66 (0.19) *17*
(f) Baseline with $\Delta n \leq 1$	1.63 (0.08) *50*	0.82 (0.12) *57*
(g) Fixed effects specification	1.31 (0.05) *212*	0.57 (0.06) *403*
(h) Log specification	0.21 (0.01) *212*	0.15 (0.01) *403*

Appendix: Interaction coefficients

	Southwest	Legacy
(a) No. firms n	0.00	-0.01
	(1.45)	(0.21)
	183	*379*
(b) Volatility	-0.018	-0.010
	(0.001)	(0.001)
	212	*403*
(c) Bankruptcy dummy	–	0.15
	–	(0.03)
	–	*358*
(d) Southwest present dummy	–	-0.24
	–	(0.08)
	–	*209*
(e) Southwest present dummy	–	0.05
	–	(0.20)
	–	*108*
Southwest potential	–	-0.91
	–	(0.36)
	–	*108*

Standard errors in parentheses, number of routes in italics.

Appendix: Emissions elasticity estimation

Fuel price elasticity	-0.16***
	(0.04)
No. firms	-0.05
	(0.04)
No. potential entrants	0.02
	(0.02)
Labour & maintenance cost index	-0.67**
	(0.25)
GDP growth	-0.79
	(0.84)
Quarter 1	-0.02
	(0.02)
Quarter 2	-0.02
	(0.02)
Quarter 3	-0.05***
	(0.01)
Constant	15.73***
	(0.34)
No. observations	52

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$