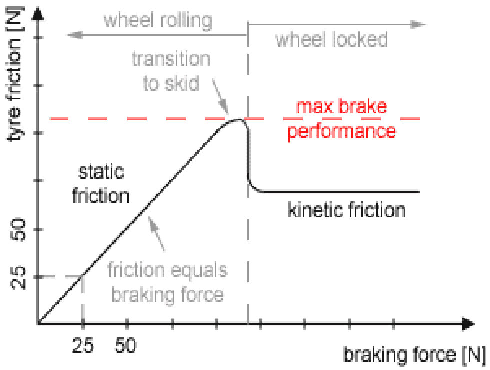
Analysis of drivers' risk compensation response to vehicle safety features



Fred Mannering
University of South Florida

Background

- **Individual drivers face a trade-off between speed and safety**

- **They reach an optimal speed/safety trade-off by:**
  - Type of vehicle owned (performance and safety equipment)
  - Driving behavior (adherence to speed limits, tailgating, acceptance gap selection, etc.)

What can change drivers' optimal speed/safety tradeoff?

- Technological changes to vehicle
- Changes in drivers' skill set
- Improvements in roadway design
- Changes in traffic conditions
- Changes in drivers' risk-taking

Study Motivation –
Advances in Vehicle Technologies

- Air bags
  (driver, passenger, and side airbags)
- Anti-lock brakes
- Traction control
- Electronic stability control
- Lane departure warning/corrections
- Autonomous braking

What do we expect ABS and Airbags?

- **Anti-lock brakes (with shorter braking distances) should:**
  - Reduce the frequency of accidents
  - Reduce the severity of accidents once they occur (lower collision speeds)
- **Air bags should:**
  - Reduce the severity of accidents once they occur (better occupant protection)

Some trends...

- There has been a general decline in fatalities per mile driven over several decades
- However, in 3 of the last 5 years, the number of fatalities per mile driven have surprisingly increased.

Why are fatality rates rising?

- Changes in traffic conditions and/or laws (congestion, higher speed limits)
- Changes in vehicle fleet composition (SUVs, light trucks, mini-vans)
- Changes in driver behavior

Offset hypothesis

- Consumers respond to safety innovations by becoming less vigilant about safety
- Past aggregate economic work has found evidence of offsetting behavior with seatbelts and other safety devices

Good Morning America

https://www.youtube.com/watch?v=0W5Z1PKlZ5I

Example:
Side Airbag Effectiveness?

- Insurance Institute for Highway Safety reports:
  - 2004: 45% effective in reducing fatalities
  - 2006: 37% effective in reducing fatalities
  - 2008: 29% effective in reducing fatalities
  - Today?
- **Problem:**

  Drivers that own cars with side airbags are not a random sample of the driving population

Need for disaggregate data…

- **Must account for self-selectivity**
(what types of consumers are most likely to switch to new safety devices?)

- And, will such consumers be more, less or equally as likely to be accident-involved after the switch to vehicles with safety devices?

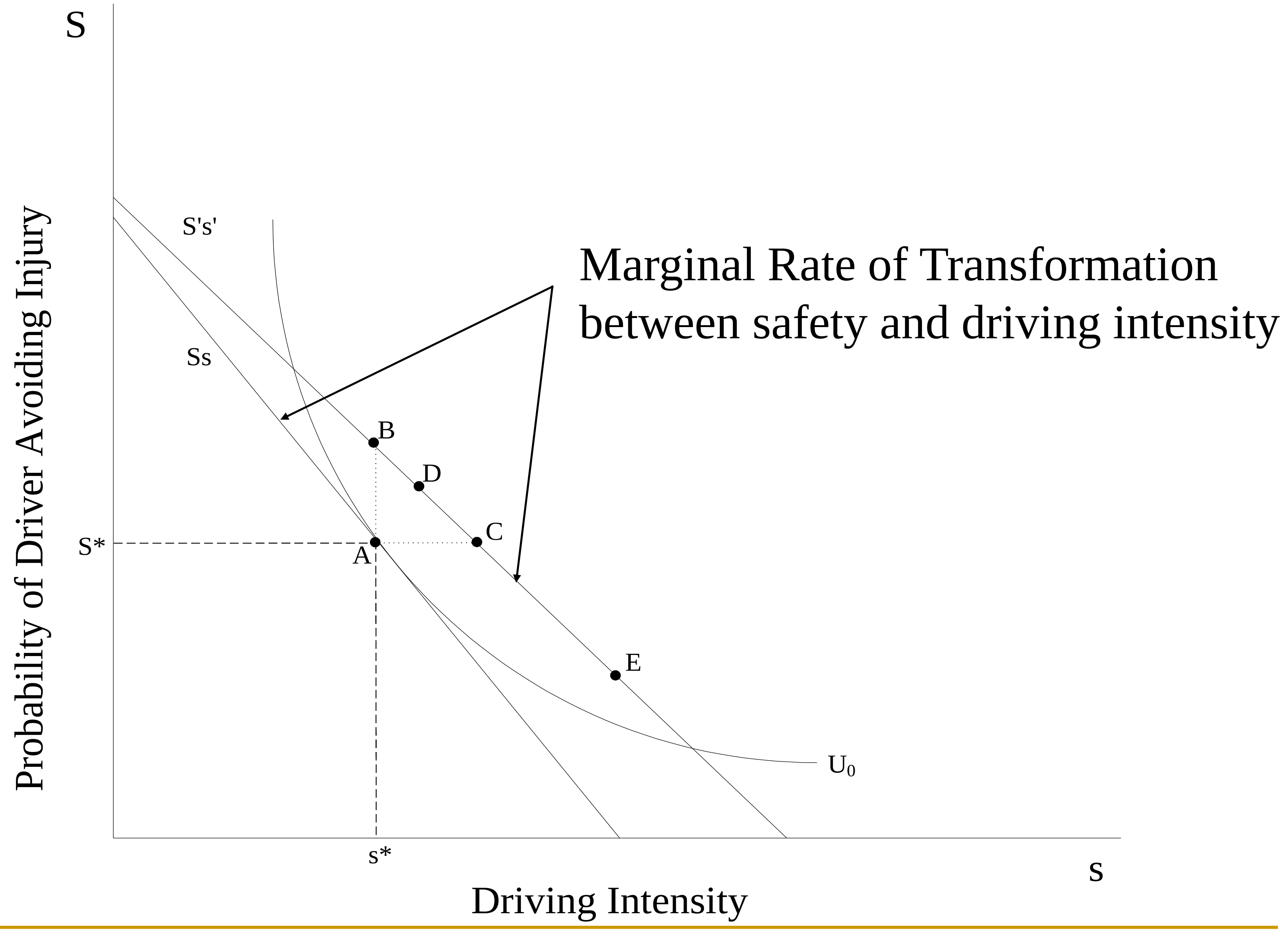
Importance of self selectivity…

- Consider high-performance sports cars with their history of high accident involvement
    - Corvette
    - Mercedes SL65AMG
    - Etc.

Importance of self selectivity…

- Such vehicles offer superior braking, acceleration, traction control, cornering performance, electronic stability control, etc.
- However:
  - Such vehicles attract risk-seeking drivers
  - Some drivers may not have the skill set to take manage the performance
  - Such vehicles shift the relationship between speed and safety (can drive faster at the same level of safety)

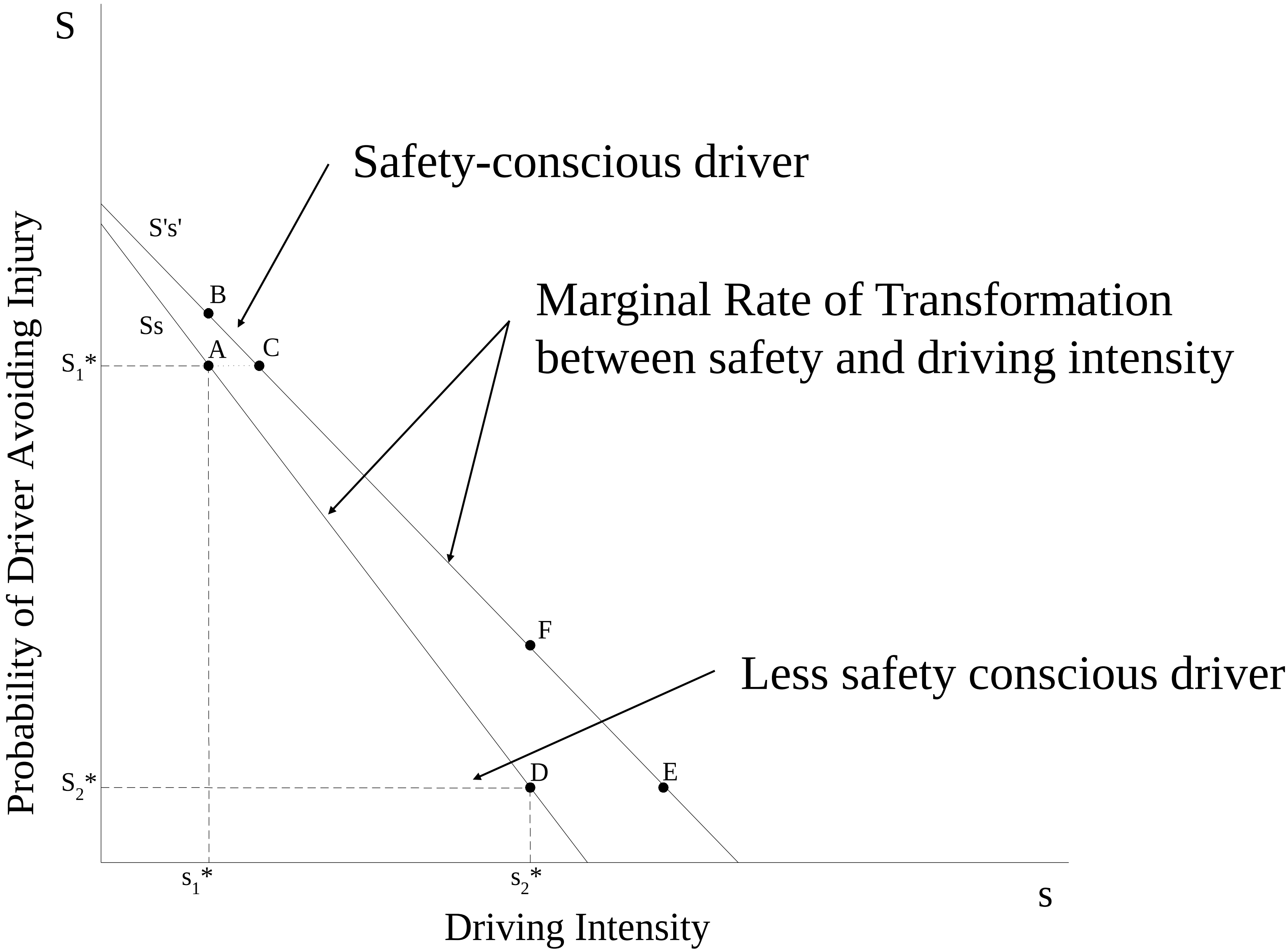

TOOLS



S
Probability of Driver Avoiding Injury
S's'
Ss
Marginal Rate of Transformation
between safety and driving intensity
B
D
C
S*
A
E
U0
s*
s
Driving Intensity

Summarizing…

- If intensity is a normal good, consumption should be to the right of B
- Range could be from B (consume all safety) or to C (consume all intensity)
- Or even over consume intensity (for example, point E)



S
Safety-conscious driver
S's'
B
Ss
A
C
S1*
Marginal Rate of Transformation
between safety and driving intensity
Probability of Driver Avoiding Injury
F
Less safety conscious driver
D
E
S2*
s1*
s2*
s
Driving Intensity

Econometric model

$$P_1(Accident_i) = \alpha_1 Airbag + \alpha_2 ABS + \beta_1 X_1 + \varepsilon_1$$

$$P_2(ABS) = \beta_2 X_2 + \varepsilon_2$$

$$P_3(Airbag) = \beta_3 X_3 + \varepsilon_3$$

- Accident severity levels *i,* with abs/airbag probabilities
- X are vectors determining accident outcomes and safety choices,
- ε error terms,
- α, β are estimable parameters

Model estimation

- Need to account for contemporaneous correlation of error terms and endogeneity of discrete airbag and antilock brake choices

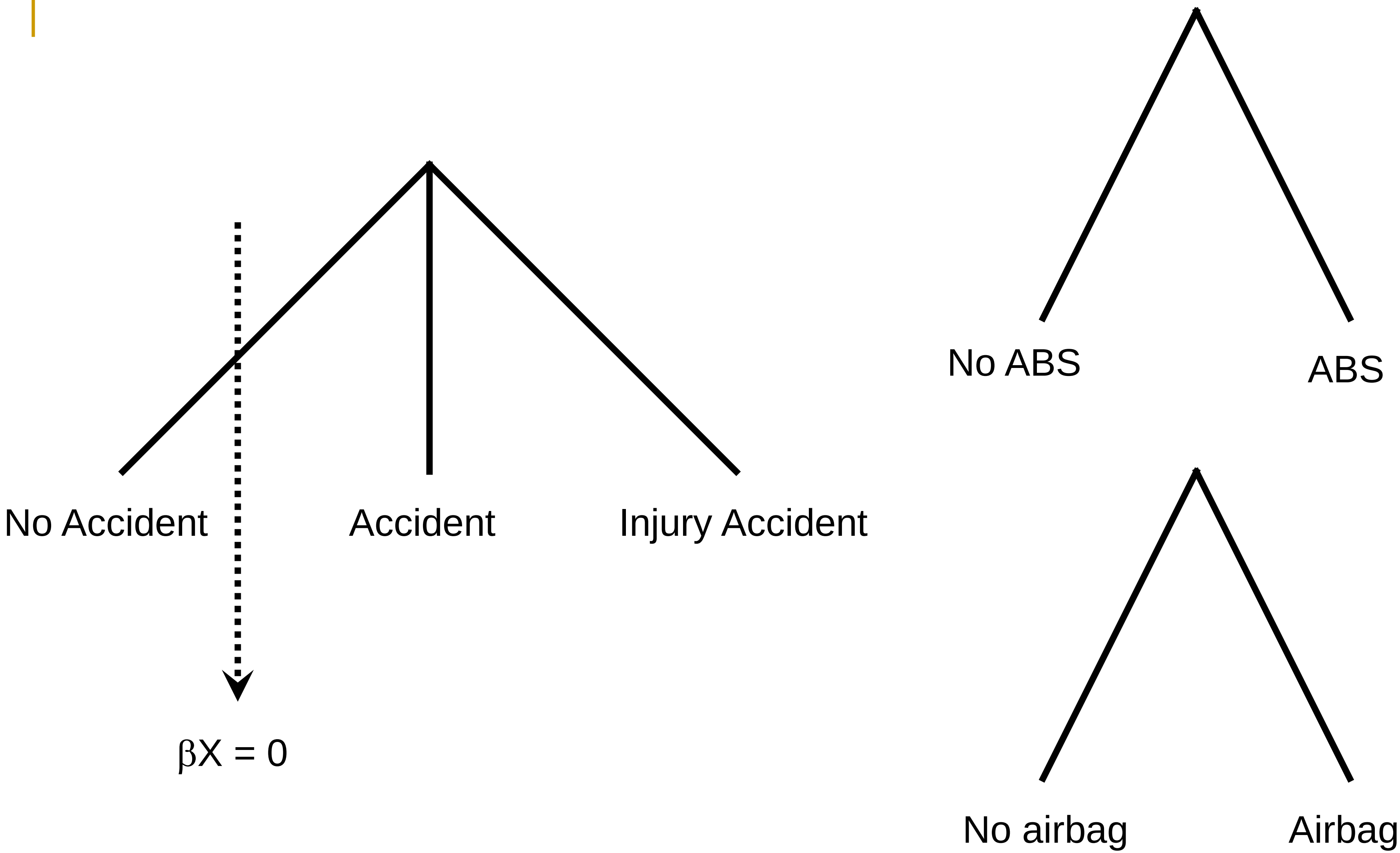
- Accident outcomes will be:
  - no accident
  - non-injury accident
  - Injury accident

Data…

- 1307 Washington State drivers monitored from 1992-1996 with socio-economics and vehicle data (6,234 observations on annual data)
- 271 switched from non-airbag to airbag
- 270 switched from non-ABS to ABS
- 614 accidents observed
- Linked to Washington State data on all reported accidents

Econometrics

- Modeling system has one trinomial model (no accident, accident, injury accident) and two binary models (ABS/no; airbag/no)
- The trinomial accident outcome model is coded as 3 binary variables with Y_i =1 if outcome i occurs and 0 otherwise.
- The no-accident outcome is used as the base, so without loss of generality we have 4 binary variables (2 for accident outcomes an one each for airbag and ABS choices)


No Accident
Accident
Injury Accident
βX = 0
No ABS
ABS
No airbag
Airbag

Econometrics

- So, $Y_i = \beta_i X_i + \varepsilon_i; \quad i = 1\ldots4$

  with $\varepsilon_i \sim N(0,1)$

- With Φ_4 the cumulative 4-variate normal density function, outcome variable w and $\widetilde{\Sigma}$ covariance matrix, the likelihood function is (with observations k to N):

$$L(\beta_1,\ldots,\beta_4,\Sigma) = \prod_{k=1}^{N} \Phi_4(w_{1k},\ldots,w_{4k};\widetilde{\Sigma})$$

Econometrics

- Closed form solution does not exist so multivariate normal probabilities computed by GHK simulator
- Estimated with STATA using 800 random draws (little difference in parameter estimates between 400 and 800 draws).
- We include weighting so our sample replicates aggregate data. With weights *WT* the log-likelihood becomes:

$$\log\left(L\left(\beta_1,\ldots,\beta_4,\Sigma\right)\right)=\sum_{k=1}^{N} WT_k\cdot\log\left(\Phi_4(w_{1k},\ldots,w_{4k};\tilde{\Sigma})\right)$$

Estimation details

- Considered possible misclassification of accident outcomes (Hausman/Abrevaya/Scott-Morton, 1998 *Journal of Econometrics*)
- Considered random effects (for repeat observations from individuals)
- Considered random parameters (various distributions…not significant)
- Likelihood ratio test shows error term correlation significant among equations

Airbag choice model

Factors increasing likelihood of owning airbag:

Airbag history indicator (1 if driver owned another vehicle with airbags)

Airbag discount indicator
(1 if driver received an insurance discount for airbags)

Male driver indicator

Married driver indicator

College indicator (1 if driver has some college education)

Factors decreasing likelihood of owning airbag:

Age of Vehicle (years)

Children indicator (1 if driver has children under 14)
Early airbags were a child-safety concern

ABS choice model

Factors increasing likelihood of owning ABS:

- ABS history indicator (1 if driver owned another vehicle with ABS)
- ABS discount indicator (1 if driver received an insurance discount for ABS)
- Male driver indicator
- Married driver indicator
- Children indicator (1 if driver has children under 14)
- College indicator (1 if driver has some college education)

Factors decreasing likelihood of owning ABS:

- Age of Vehicle (years)

Accident Model Expectations

- With no change in behavior, airbags should reduce injury accidents
- With no change in behavior, ABS should decrease accident frequency (accidents and injury accidents)

Probability of accident (standard error)

Airbag indicator (1 if vehicle with airbags)	**-0.340 (0.477)**
ABS indicator (1 if vehicle with ABS)	**0.088 (0.271)**
Elderly indicator (1 if driver is over 70 yr. old)	-0.002 (0.0003)
Male indicator (1 if driver has children under 14)	-0.005 (0.0008)
Age of driver in households with 4 or more members	-0.001 (0.0003)
Commuter indicator (1 if driver commute > 15 miles)	0.265 (0.076)
Urban extensive indicator (1 if driver resides in urban area, 20K+ miles/yr)	0.190 (0.098)
College indicator (1 if driver has some college education)	0.027 (0.0074)

Probability of accident with injury

Airbag indicator (1 if vehicle with airbags)	**-0.471 (0.530)**
ABS indicator (1 if vehicle with ABS)	**-0.180 (0.489)**
Elderly indicator (1 if driver is over 70 years old)	-0.003 (0.001)
Male indicator (1 if driver has children under 14)	-0.091 (0.032)
Age of driver in households with 4+ members	-0.083 (0.026)
Long distance commuter indicator (1 if driver commute > 15 miles)	0.148 (0.0245)
Urban extensive indicator (1 if driver resides in urban area, 20K+ miles/yr)	0.667 (0.251)
College indicator (1 if driver has some college education)	-0.355 (0.198)

Airbags and accident probabilities…

- Effect of airbag is statistically insignificant in injury accident model suggesting that they are ineffective or drivers with airbags may drive more aggressively

- Peterson, Hoffer and Millner (1995) found injury claims increased on vehicles following airbag adoption as a standard feature

ABS and accident probabilities…

- ABS should decrease accident frequency (accidents and injury accidents)
- ABS had a statistically insignificant impact on injury accidents and accidents
- Smiley (2000) found claims on ABS vehicles were higher and taxi drivers reduced headways when driving with ABS

Implications of findings…

- Our disaggregate findings corroborate some previously presented aggregate findings
- Drivers seem to have accrued benefits with greater mobility (driving faster, etc.)
- Non-airbag/ABS owners may be at greater risk because of offsetting behavior

END