$$U_{ij} = u_{ij} + \underbrace{\epsilon_{ij}}_{\eta_i + 
u_{ij}}$$

$$U_{ij} = u_{ij} + \underbrace{\epsilon_{ij}}_{\eta_i + \nu_{ij}}$$

$$=X_{i}ar{eta}_{j}+Z_{j}ar{\gamma}+\underbrace{\epsilon_{ij}}_{\eta_{i}+
u_{ij}}$$

$$U_{ij} = u_{ij} + \underbrace{\epsilon_{ij}}_{\eta_i + \nu_{ij}}$$

$$\eta_i$$

$$\eta_i$$

$$\eta_i$$

$$\eta_i$$

$$+\underbrace{\overset{\epsilon_{ij}}{\underset{\eta_{i}+}{\longleftarrow}}}_{\eta_{i}+}$$

$$\eta_{i}+$$

$$\eta_i + \nu$$

$$\eta_i + \nu_{ij}$$

$$\eta_i + \nu$$

$$\eta_i + 
u_{ij}$$

 $=X_{i}\left(\bar{\beta}_{i}+\delta_{i}\right)+Z_{i}\left(\bar{\gamma}+\phi_{i}\right)+\nu_{ii}$ 

 $X_i\delta_i + Z_i\phi_i \equiv \eta_i$ 

$$=X_{i}\bar{\beta}_{j}+Z_{j}\bar{\gamma}+\underbrace{\epsilon_{ij}}_{\eta_{i}+\nu_{ij}}$$

$$U_{ij}=u_{ij}+\underbrace{\epsilon_{ij}}_{\eta_i+
u_{ij}}$$

$$\eta_i$$

$$\eta_i$$
 +

$$\eta_i$$

$$\eta_i$$
  $+$ 

$$\eta_i + \nu$$

$$\eta_{i}$$

$$\eta_{i}+\eta_{i}$$

$$\eta_i$$
+ $\iota$ 

$$= X_i \bar{\beta}_j + Z_j \bar{\gamma} + \underbrace{\epsilon_{ij}}$$

$$\eta_i + 
u_{ij}$$

$$\eta_i + 
u_{ij}$$

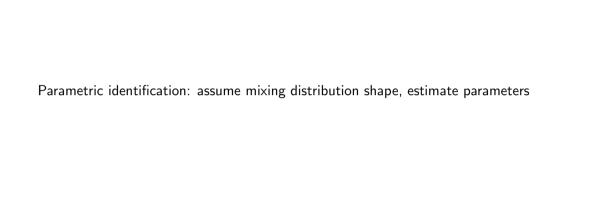
$$\eta_i + 
u_{ij}$$

 $= X_i \beta_{ii} + Z_i \gamma_i + \nu_{ii}$ 

 $=X_{i}(\bar{\beta}_{i}+\delta_{i})+Z_{i}(\bar{\gamma}+\phi_{i})+\nu_{ii}$ 

 $X_i \delta_i + Z_i \phi_i \equiv \eta_i$ 

 $\beta_{ii} \sim N(\bar{\beta}_i, \sigma_{\beta}^2), \ \gamma_i \sim N(\bar{\gamma}, \sigma_{\gamma}^2)$ 



Parametric identification: assume mixing distribution shape, estimate parameters	
But this just pushes problem back one level	

Parametric identification: assume mixing distribution shape, estimate paramete	ers

How can we know if choice variation comes from  $\eta_i$  or  $\nu_{ij}$  part of preferences?

But this just pushes problem back one level...

Cross-sectional data: impossible to separate
Person A chooses different alternative than Person B

Cross-sectional data: impossible to separate

Person A chooses different alternative than Person B

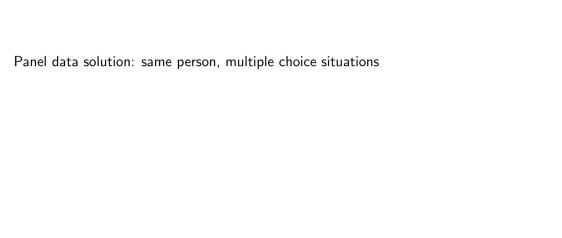
⇒ Different tastes? Or different random shocks?

Cross-sectional data: impossible to separate

Person A chooses different alternative than Person B

⇒ Different tastes? Or different random shocks?

Single observation per person provides no way to distinguish



Panel data solution: same person, multiple choice situations

Persistent patterns across periods  $\Rightarrow$  permanent tastes  $(\delta_i, \phi_i)$ 

Panel data solution: same person, multiple choice situations

Persistent patterns across periods  $\Rightarrow$  permanent tastes  $(\delta_i, \phi_i)$ Random variation across periods  $\Rightarrow$  idiosyncratic tastes  $(\epsilon_{ijt})$  Panel data solution: same person, multiple choice situations

Persistent patterns across periods  $\Rightarrow$  permanent tastes  $(\delta_i, \phi_i)$ 

Random variation across periods  $\Rightarrow$  idiosyncratic tastes  $(\epsilon_{ijt})$ 

Key assumption: tastes  $\delta_i, \phi_i$  stable across choice instances for each person

Identification logic:
Person consistently chooses similar alternatives across $\mathcal T$ situations

Identification logic:

Person consistently chooses similar alternatives across T situations

 $\Rightarrow$  Reveals their  $\delta_i$ ,  $\phi_i$  (permanent taste parameters)

Identification logic:

Person consistently chooses similar alternatives across T situations

 $\Rightarrow$  Reveals their  $\delta_i$ ,  $\phi_i$  (permanent taste parameters)

Larger  $T \rightarrow$  better separation of  $\delta_i, \phi_i$  from noise

Identification logic:

Person consistently chooses similar alternatives across T situations

$$\Rightarrow$$
 Reveals their  $\delta_i, \phi_i$  (permanent taste parameters)

Larger  $T \rightarrow$  better separation of  $\delta_i, \phi_i$  from noise

$$T o \infty \Rightarrow$$
 can perfectly identify each person's  $\delta_i, \phi_i$ 

Different types of variation can identify taste heterogeneity:
Panel data: Same person, multiple choice situations

Panel data: Same person, multiple choice situations

Persistent choices across time  $\Rightarrow$  reveals individual  $\delta_i, \phi_i$ 

## AUTOMOBILE PRICES IN MARKET EQUILIBRIUM

By STEVEN BERRY, JAMES LEVINSOHN, AND ARIEL PAKES1

This paper develops techniques for empirically analyzing demand and supply in differentiated products markets and then against these techniques to analyze qualifration in the U.S. automobile industry. Our primary goal is to present a framework which enables one to bottam cultimates of demand and cost parameters for a class of elapsyshistic differentiated products markets. These estimates can be obtained using only widely variable product-ford and aggregate consumer-level data, and they are consistent with a structural model of equilibration in an elapsyshistic industry. When we apply the technomiates the control of the control of the control of the control of the parameters for (essentially) all models marketed over a neutro service and

Keywords: Demand and supply, differentiated products, discrete choice, aggregation, simultaneity, automobiles.

## 1. INTRODUCTION

THIS PAPER DEVELOPS TECHNIQUES for empirically analyzing demand and supply in differentiated products markets and then applies these techniques to analyze equilibrium in the U.S. automobile industry. Our primary goal is to present a framework that enables one to obtain estimates of demand and cost parameters for a class of oligopolistic differentiated products markets. Estimates from our framework can be obtained using only widely available product-level and aggregate consumer-level data, and they are consistent with a structural model of equilibrium in an oligopolistic industry. When we apply the techniques developed here to the U.S. automobile market, we obtain cost and demand parameters for (essentially) all models marketed over a twenty year period. On the cost side, we estimate cost as a function of product characteristics. On the demand side, we estimate own- and cross-price elasticities as well as elasticities of demand with respect to vehicle attributes (such as weight or fuel efficiency). These elasticities, together with the cost-side parameters, play central roles in the analysis of many policy and descriptive issues (see, e.g., Pakes, Berry, and Levinsohn (1993) and Berry and Pakes (1993)).

Our general approach posits a distribution of consumer preferences over products. These preferences are then explicitly aggregated into a market-level demand system that, in turn, is combined with an assumption on cost functions and on pricing behavior to generate equilibrium prices and quantities. The

We would like to thank Don Andrews, Tim Breamban, Gay Chambertain, Se Gridisches, pred Hamman, G. Mustik Mohatteren, Whitter Newey, Frank Works, and the Economic Acadepia Hamman, G. Mustik Mohatteren, Whitter Newey, Frank Works, and the Economic Acadepia Hamman, and the Commenta of the Commenta of

Persistent choices across time  $\Rightarrow$  reveals individual  $\delta_i$ ,  $\phi_i$ 

Berry, Levinsohn, Pakes (1995) approach: Multiple markets, aggregate shares

Panel data: Same person, multiple choice situations

Panel data: Same person, multiple choice situations

Persistent choices across time  $\Rightarrow$  reveals individual  $\delta_i, \phi_i$ 

Berry, Levinsohn, Pakes (1995) approach: Multiple markets, aggregate shares

Substitution patterns across products within markets  $\Rightarrow$  reveals distribution of  $\delta_i, \phi_i$ 

Panel data: Same person, multiple choice situations

Persistent choices across time  $\Rightarrow$  reveals individual  $\delta_i, \phi_i$ 

Berry, Levinsohn, Pakes (1995) approach: Multiple markets, aggregate shares

7 7 7 7 7 7 65 6

Alternative: Use exclusion restrictions/valid instruments when panel data unavailable

Substitution patterns across products within markets  $\Rightarrow$  reveals distribution of  $\delta_i$ ,  $\phi_i$ 

Panel data: Same person, multiple choice situations

Persistent choices across time  $\Rightarrow$  reveals individual  $\delta_i, \phi_i$ 

Berry, Levinsohn, Pakes (1995) approach: Multiple markets, aggregate shares

Alternative: Use exclusion restrictions/valid instruments when panel data unavailable

Substitution patterns across products within markets  $\Rightarrow$  reveals distribution of  $\delta_i$ ,  $\phi_i$ 

Key insight: Many ways of leveraging variation to separate  $\delta_i,\phi_i$  from  $u_{ij}$