Implications of Simultaneity in Pest Damage Functions

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Project: "Encouraging Cooperation Between Commercial Producers and Residential Users of an Invasive Species Host: Designing Collective Pest Management Institutions for the Olive Fruit Fly in California"

Introduction

- To evaluate economic impact of a pest, need to link biological and economic systems via a damage function
- Dominant approach ("population-based model")
  - % yield loss at harvest = f(pest population)
- Pitfalls
  - Underlying factors, e.g. temperature, affect crop susceptibility <u>and</u> pest populations/activity (endogeneity)
  - Assumes linearity
  - Trapping numbers proxy for pest populations

Motivation

- Theoretical analysis by Christiaans, Eichner, and Pethig (2007)
  - Population-based approach does not describe mechanics of damage process
  - Structural damage specification: constrained optimization behavior by pest and host
  - Pest management results: target inputs that reduce crop susceptibility, pest populations, or both
- Heat makes fat fruit, fat fruit makes plentiful flies, more flies damage more fruit
- Objective: Formulate and estimate a structural damage function that addresses simultaneity

Application

- California olive fruit fly
  - Invasive detected in 1998, spread through all CA olive-growing regions by 2004
- Extensive infestation dataset (Burrack and Zalom)
  - 81,267 olives dissected; over space, time, cultivar
- Different infestation rates by cultivar
  - Min. volume threshold for damage
  - Heat drives changes in fruit size and in fly activity, both influence infestation rates

Research Questions

- How do we define damage?
- What environmental and management factors influence olive fruit fly damage rates?
  - Which affect fruit susceptibility? Fly populations? Both?
- How do structural and population-based approaches perform in terms of predictions over space, growing season, and cultivar?

Structural Damage Function

$$DG_{it} = f_D(\boldsymbol{HC}_{it},\boldsymbol{WT}_{it},\boldsymbol{MG}_{it},\boldsymbol{X}_{it}) + \varepsilon_{it}$$

$$HC_{Kit} = f_V(\boldsymbol{WT}_{it}^V, \boldsymbol{MG}_{it}^V, \boldsymbol{X}_{it}^V, \boldsymbol{Z}_{it}) + v_{it}$$

$$i = 1,\ldots,N,\ t = 1,\ldots,T$$

- Host characteristics (***HC***) affect fly preference
  - Volume, shape, color, oil/water content, etc.

- Factors that affect fly reproductive activity and development
  - Temperature (***WT***)
  - Management practices (***MG***): irrigation, own-orchard management practices, practices used on nearby trees outside test plot

- Factors that affect olive volume (HC_K)
  - Temperature ($\boldsymbol{WT}^V$), ***MG***, humidity and precipitation (***Z***)

- H_0: Cov(ε,v) = 0 ; H_A: Cov(ε,v) ≠ 0

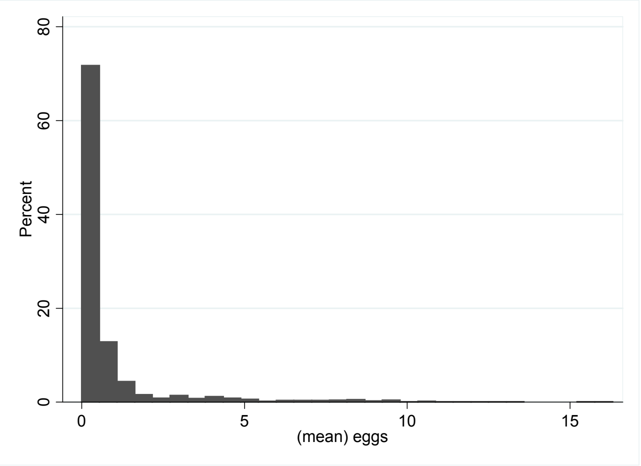
Data

- Primary: field infestation dataset for 2005
  - Infestation (oviposition stings, eggs, larvae, pupae)
    - We use multiple measures of infestation
  - Fruit measurements
  - Orchard management practices
  - Trapping numbers

- Secondary: weather
  - Daily min/max temps, humidity, precipitation
  - Olive growing degree days, fly larva degree days, days outside adult activity thresholds

Empirical Issues & Methods

- Damage definition: continuous vs. binary
- Triangular system
  - Heckman's sample selection bias correction (1979)
  - Identification (***Z***)
- Panel dataset
  - Fixed effects
- Probability mass at zero
  - Tobit estimation method



Models Estimated

Type	DG Description	Independent Variables
Structural	Mean # eggs/olive	***HC*** = (volume, volume*late, shape) ***WT*** = (temp, temp sq., min. temp var.) ***MG*** = (irrigation, grd. cover, maint.) ***Z*** = (humidity, precip.) Site, cultivar indicators
	Mean # larvae/olive	
Population-Based	Mean # eggs/olive	Contemporaneous trapping
		Lagged trapping (≤ 4 weeks)
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		Lagged trapping (≤ 4 weeks)

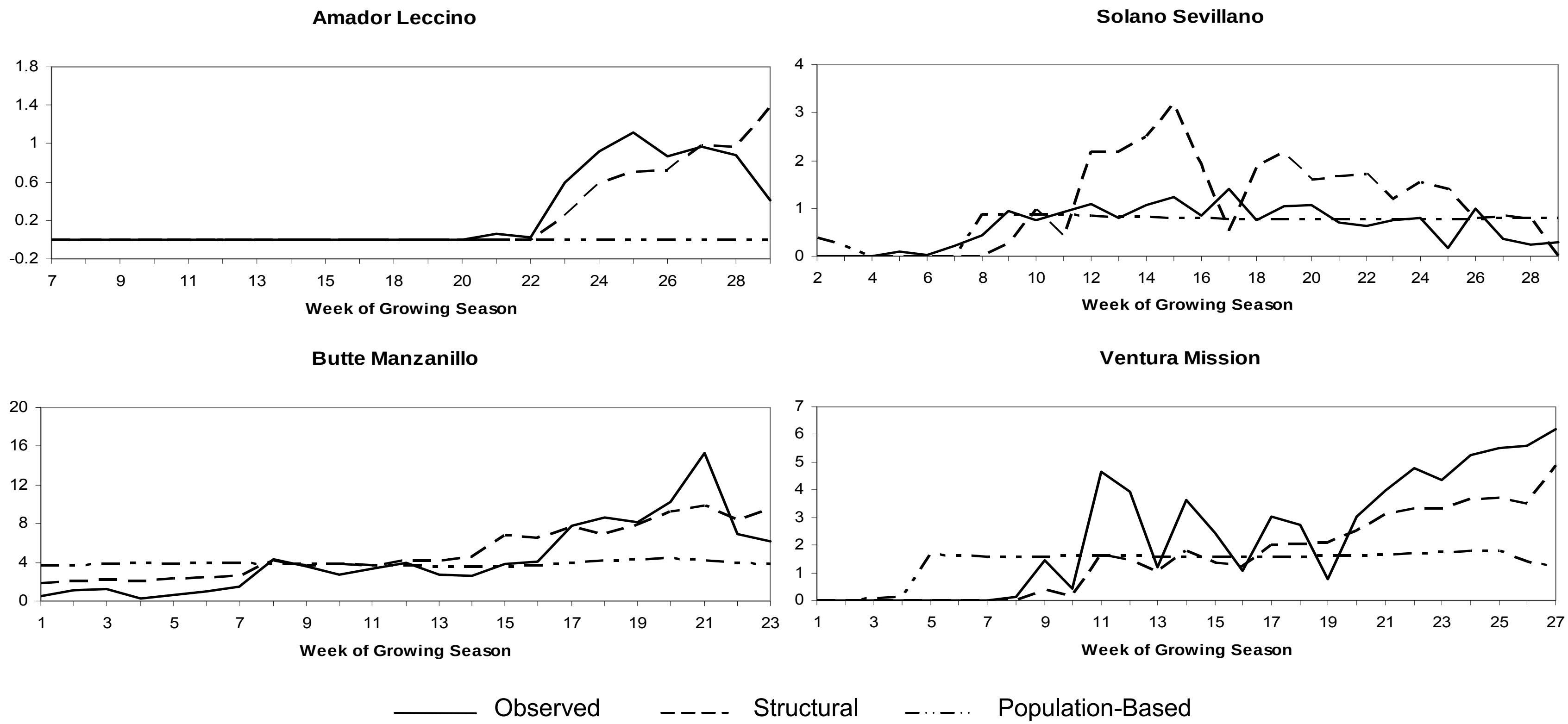
Empirical Results

- Structural Models
  - Eggs
    - Olive volume late in the season (-)
    - Days outside adult activity thresholds (-)
    - Irrigation*heat (+)
  - Larvae
    - Olive volume late in the season (-)
    - Accumulated larval degree-days (-)
  - Endogeneity
    - Reject H_0 for eggs, not larvae
    - Results differ by olive type: reject H_0 for table olives, not for oil

- Population-Based Models
  - Contemporaneous trapping (+), 2-4 week lags (+)

Out-of-Sample Prediction

- SF predicts variable infestation rates over the growing season; PB relatively constant



Conclusions:
Olive Fruit Fly Analysis

- Weather and management practices drive host susceptibility and pest activity

- Differences in results across cultivars suggest a deeper structural model

- Structural model reflects intra-seasonal heterogeneity in infestation rates
  - Source of heterogeneity in management incentives
  - Coupled with pest mobility creates treatment externalities

Simultaneity

- History in agricultural economics (Working 1927; Haavelmo 1943)
- Complicates estimation of causal relationships w/ non-experimental data
- Implications of endogeneity in biological systems for bioeconomic modeling

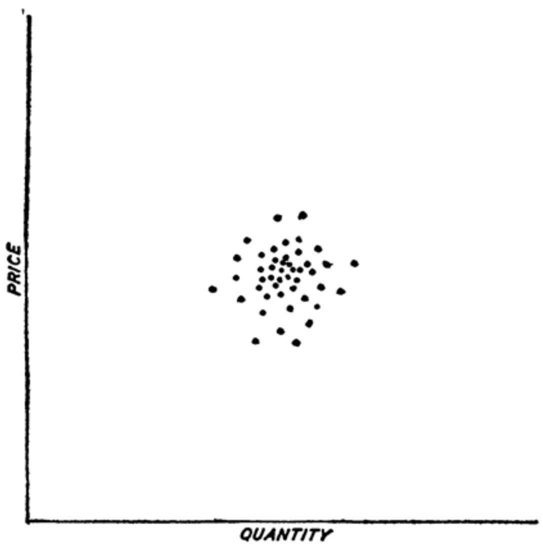


FIGURE III

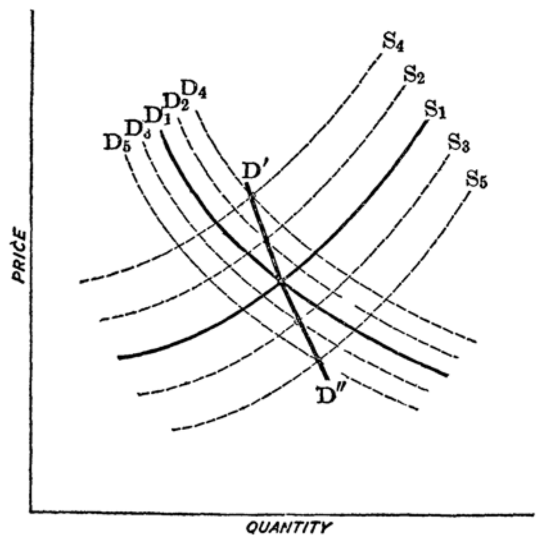


FIGURE VIII

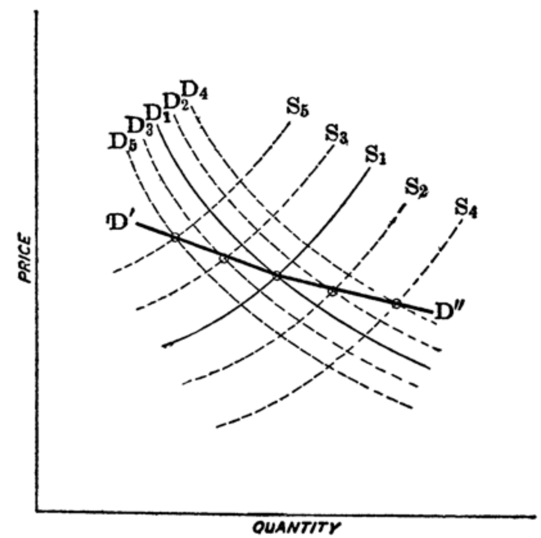


FIGURE IX

Source: E.J. Working. 1927. QJE 41(2): 212-235

Identification

- Key to correcting for simultaneity is a plausible identifying restriction

- Our identifying assumption:
  - Moisture (humidity, precip) inhibits olive growth, but does not affect fly activity
  - Based on scientific studies of olive and olive fly phenology

- Exceptional dataset permits estimation of structural damage function


Thank you
Comments and Questions?