Factor Substitution with Biased Technical Change: the Dairy Product Industry in the United States

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Motivation-I

- Dissertation: Effects of California's Carbon Pricing on the Dairy Processing and Manufacturing Industry: Policy Distortions, Technological Change, and Emissions Leakage
  - The effects of a carbon pricing program in the presence of other distorting policies
  - The long-run effects of carbon pricing: induced technological changes
  - The spillover effects through trading

Carbon Cap-and-Trade

- The California Air Resources Board (ARB) adopted the greenhouse gases (GHGs) cap-and-trade in October 2011
- Large food processing facilities, including dairy products manufacturers, are covered by the program
  - ARB will grandfather the majority of allowances to all industrial sources during the initial period
- By 2020, up to 17% increase in electricity price, and 46% increase in natural gas price (California Air Resources Board, 2010)

Motivation-II

- An increase in energy price affects energy use and the consequent carbon emissions through:
  - Input substitution
  - Induced changes in the mix of products
  - Induced changes in the scale of production
  - Induced energy-saving technological changes (Hicks, 1932)

Research Question

Technological change in the dairy processing and manufacturing industry in the United States

- Distinctive features of the industry
  - multiple products: different energy intensities, joint in production
  - distorted input market: minimum prices of milk based on utilization
- Goals of this research
  - elasticities of substitution between energy and other inputs: milk, capital, labor, and other
  - the rate and biases of technological change

Factor demand relationships: food processing industry

- Energy use in the dairy processing and manufacturing industry (Xu and Flapper, 2009, 2011)
- Empirical studies on the substitution between energy and other inputs in the food-processing industry
  - Huang (1991): Factors: labor, capital, and energy; Tech change: NO
  - Goodwin and Brester (1995): Factors: labor, capital, energy, food materials, and other; Tech change: NO
  - Morrison Paul and MacDonald (2003): Tech change: including a time trend, and using effective prices
  - Celikkol and Stefanou (1999): Factors: farm input, marketing input, and capital; Tech change: including a time trend, and long-run prices

Studies on technological change

- Three alternative approaches to specify technological change in an econometric model
  - technological change variables: such as, a time trend (Binswanger, 1974) or previous prices (Celikkol and Stefanou, 1999)
  - factor-augmenting efficiency indices to distinguish between observed and effective prices and quantities (Feng and Serletis, 2008; Leon-Ledesma, McAdam, and Willman, 2010)
  - parameters as functions of technology-changing variables (Fulginiti and Perrin, 1993)
- Potential concerns
  - the rate and biases of technological change are not directly observable
  - alternative rationales may exist

Technological change: latent variables

- Following Jin and Jorgenson (2010), describe the rate and biases of technical change by latent variables, and recover these variables by applying the Kalman filter (Kalman, 1960, 1963)
  - An advantage of the Kalman filter: the latent variables can be projected into the future
- Extending Jin and Jorgenson (2010) to a multi-output production technology
- Incorporating the distinctive features of the dairy industry into the model

Econometric Model

- Cost function: $C(\mathbf{y}, \mathbf{w}, f)$, where $\mathbf{y}$ is a vector of outputs, $\mathbf{w}$ is a vector of input prices, f represents the state of technology.
- A flexible functional form: translog

$$\begin{aligned} \ln C_{it} = {} & \alpha_0 + \sum_i \alpha_i \ln y_{it} + \sum_j \alpha_j \ln w_{jt} \\ & + \frac{1}{2} \sum_i \sum_{i'} \alpha_{ii'} \ln y_{it} \ln y_{i't} + \frac{1}{2} \sum_j \sum_{j'} \alpha_{jj'} \ln w_{jt} \ln w_{j't} \\ & + \sum_i \sum_j \alpha_{ij} \ln y_{it} \ln w_{jt} + \sum_j f_{jt} \ln w_{jt} + f_{it} \end{aligned} \quad (1)$$

  - i,i': different dairy products; j,j': inputs: capital, labor, energy, milk, and other;
  - f_{jt}: biases of technological change for input j;
  - f_{it}: the state of technology in the production of dairy product i.

Biases of Technological Change

- Share equations:

(2) $$s_{Kt} = \frac{w_{Kt} K_{it}}{C_{it}} = \alpha_K + \sum_j \alpha_{Kj} \ln w_{jt} + \sum_i \alpha_{iK} \ln y_{it} + f_{Kt}$$

- Biases of technological change

(3) $$\Delta K_t = f_{Kt} - f_{Kt-1}$$

  - the changes in the shares of inputs, holding input prices and output quantities (mix) constant
  - $\Delta_{Kt} > 0$: technological change is "capital-using"

Rate of Technological Change

- Rate of technological change

$$(4) \qquad \Delta T_t = -\sum_j \ln w_{jt}(f_{jt} - f_{jt-1}) - (f_{it} - f_{it-1})$$

  - the negative of the change in production cost, holding input prices and output quantities constant
  - the first term: the rate of induced technical change (Jin and Jorgenson, 2010)
  - the second term: autonomous technical change

Econometric Estimation

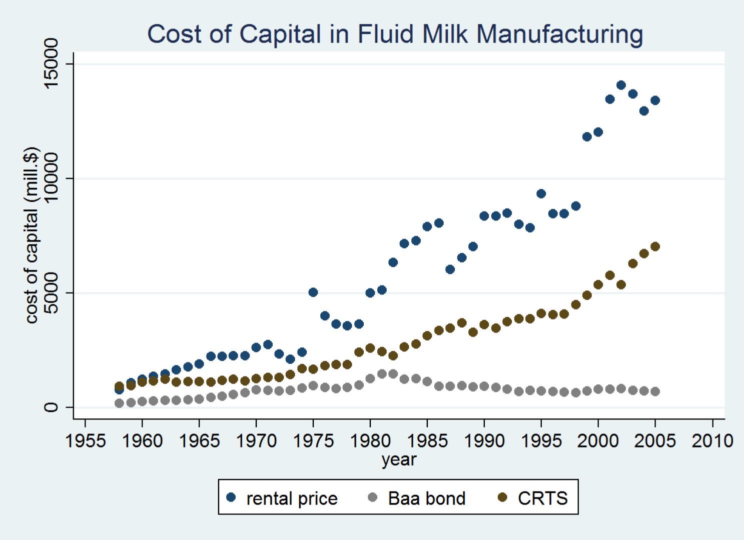
- The Kalman filter (Kalman, 1960, 1963; Hamilton, 1994)
  - State equation: $\xi_t = F\xi_{t-1} + \nu_t$
    ξ_t : the vector of latent variables
  - Observation equation: $y_t = A'x_t + H'\xi_t + \omega_t$
    y_t: the vector of dependent variables;
    x_t: the vector of explanatory variables
- Computation of the Kalman filter
  - filtering: estimate the unknown parameters using maximum likelihood estimation (MLE)
  - smoothing: estimate the latent variables, given the MLE estimates, using the backward recursion (Hamilton, 1994)

Data Sources

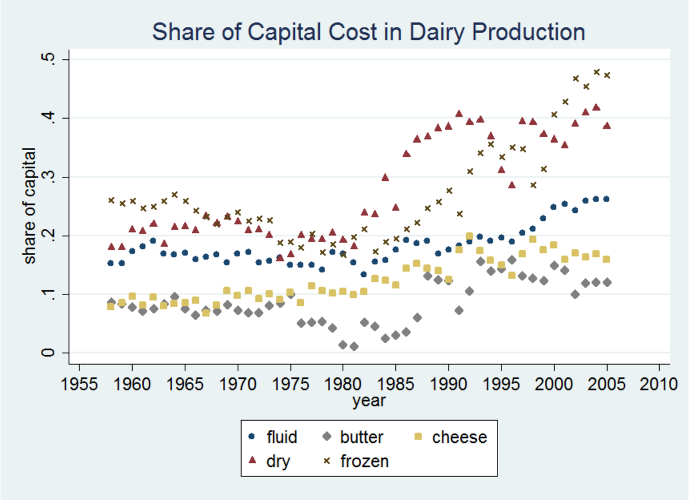
- NBER Manufacturing Productivity Database: 1958-2005
  - dairy processing and manufacturing industries: NAICS 311511-311520
  - variables: total value of shipments, cost of labor, energy, and materials, stock of capital, price deflators for value of shipments, energy and materials
- Census of Manufactures (CM) and the Annual Survey of Manufactures (ASM)
  - resales of products, changes in inventories, and resales of materials
- United States Department of Agriculture
  - prices of Class I milk and the blend prices of milk

Cost of Capital

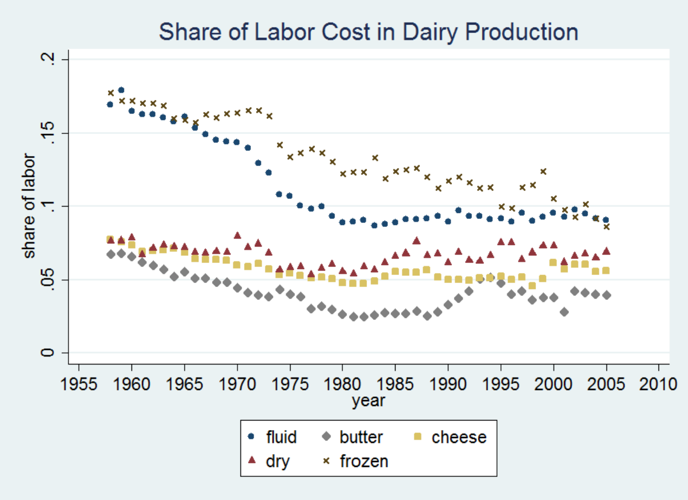
- Constant returns to scale (Jin and Jorgenson, 2010)
  - cost of capital = value of shipments - expenditures on variable inputs
- Bureau of Labor Statistics: capital rental prices
  - rental prices: NAICS 3-digit (311, 312): Food and Beverage and Tobacco Products
- Moody's Baa Corporate Bond Index


Cost of Capital in Fluid Milk Manufacturing
cost of capital (mill.$)
0
5000
10000
15000
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
year
rental price
Baa bond
CRTS

Shares of Input Cost



Shares of Input Cost



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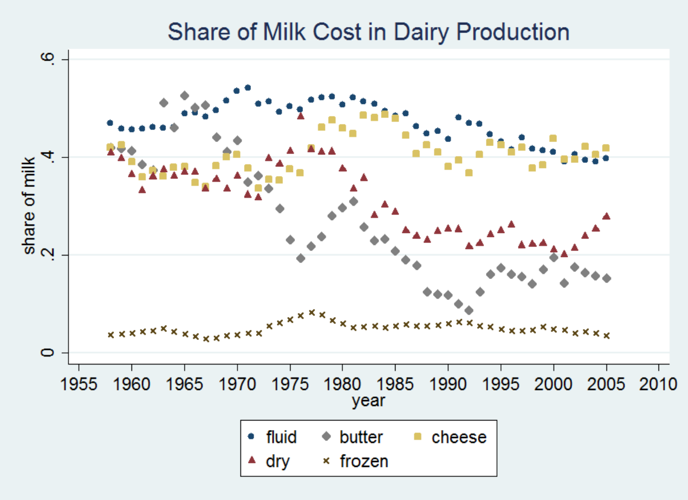
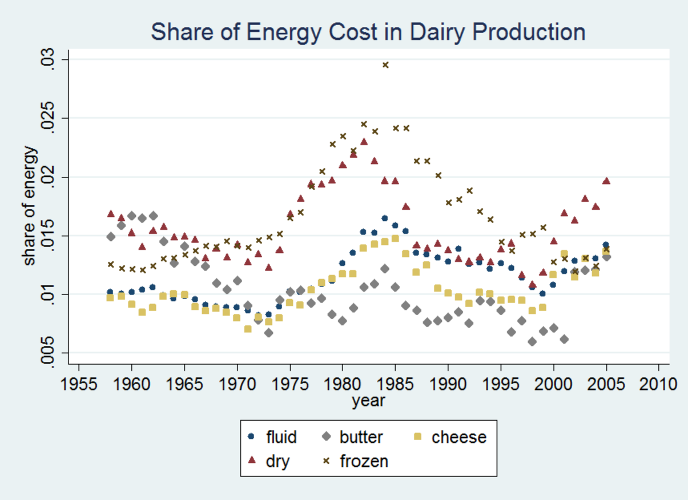


Shares of Input Cost



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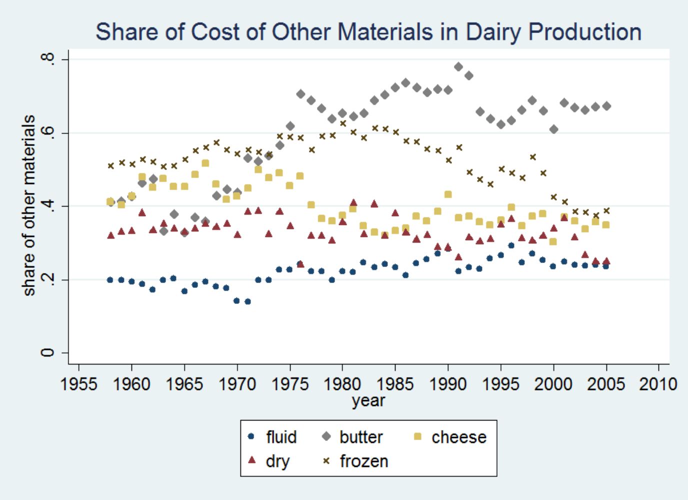

Caveats

- Aggregation bias
  - The Longitudinal Business Database of the U.S. Census Bureau

Extensions

- Comparison across regions
- A case study of California: California Manufacturing Cost Annual

Thank you!

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