Case Study: ARS Research on Bovine Quantitative Genetics and Genomics

Assessing the Benefits of ARS R&D Within an Economic Framework

March 10-11, 2008

The research team selected three case studies from 12 potential candidate studies

- ERS and ARS in collaboration applied criteria relating to:
  - Characteristics of the research
  - Potential obstacles to the case studies
  - Logistical factors
- Most candidate case studies exemplified more than one criterion
- Bovine quantitative genetics and genomics was chosen for a number of reasons, including:
  - Some more fundamental research
  - ARS plays a significant coordinating role
  - Market structure and interest group behavior are relevant to the research
  - Research has fairly well defined limits
  - Key informant readily identified

One way to define the research program is by using the 2007-2012 Action Plan for ARS NP 101

- NP 101, Food Animal Production, has three components:
  - Understanding, Improving and Effectively Using Animal Genetic Resources (18 projects)
  - Enhancing Animal Adaptation, Well-Being and Efficiency in Diverse Production Systems (20 projects)
  - Measuring and Enhancing Product Quality (5 projects)
- Appropriated Budget of approximately $46.5 million annually

We counted scientists listed under component 1 whose research treats beef cattle, dairy cattle, or both

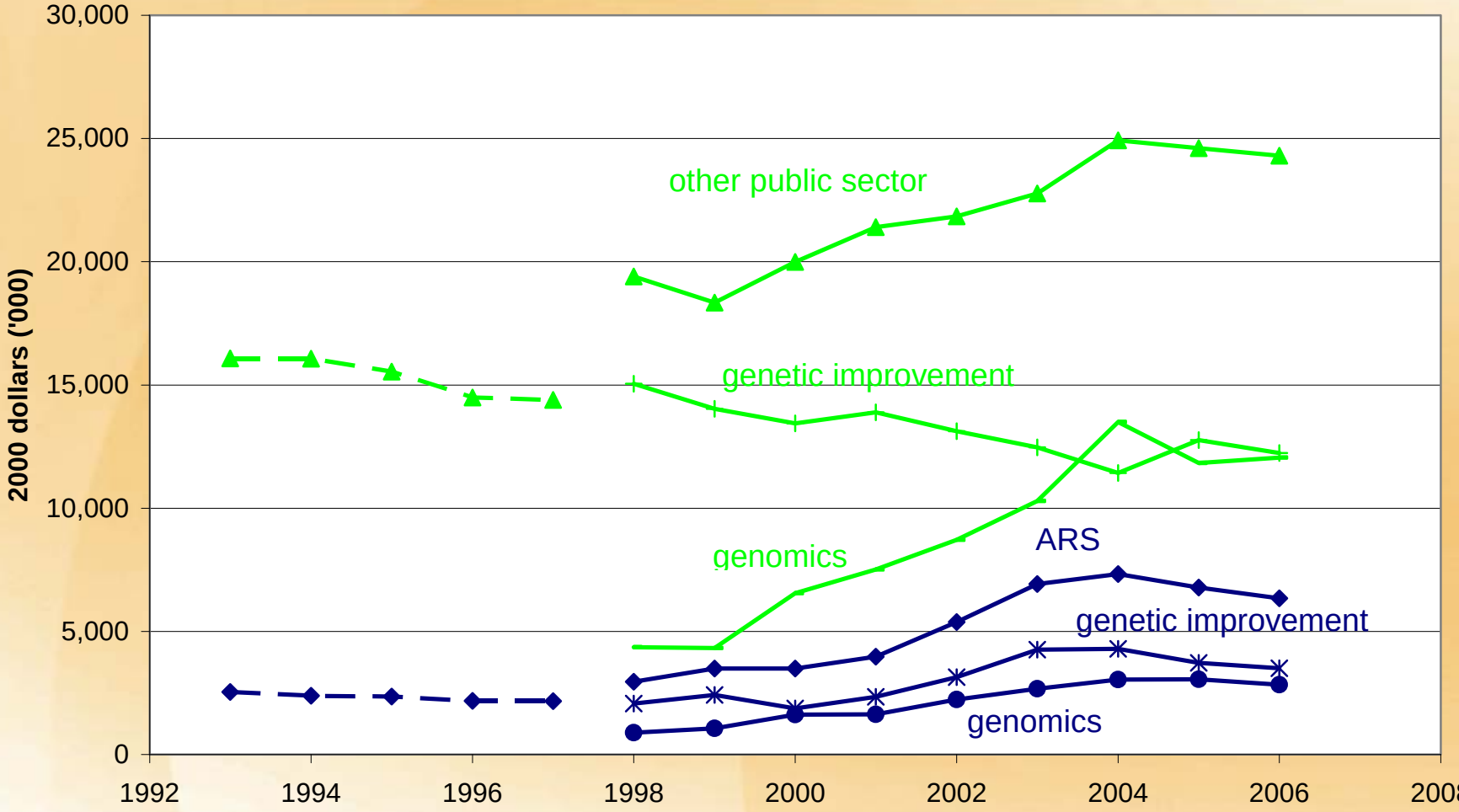
- 42 out of 102 scientists total for NP 101
- Can make further ad hoc assumptions about scientists whose research crosses NP 101 components, crosses species, or both
- Perhaps between 20 and 25 FTE SYs currently devoted to bovine quantitative genetics and genomics at ARS

The CRIS system can also be used to define bovine quantitative genetics and genomics research at ARS

- Most precise—special searches for ARS research, perhaps listed under
  - "Live beef cattle" or "live dairy cattle" as "Subject of Investigation"
  - "Genetic improvement of animals" or "animal genome" under "Knowledge Area"
- CRIS categories shift over time
- Using simplifying assumptions on more aggregate data
  - Knowledge Area "genetics" or "genome" only applies to live farm animals
  - Allocation to a KA within a species is in the same proportion as allocation to that KA for all species

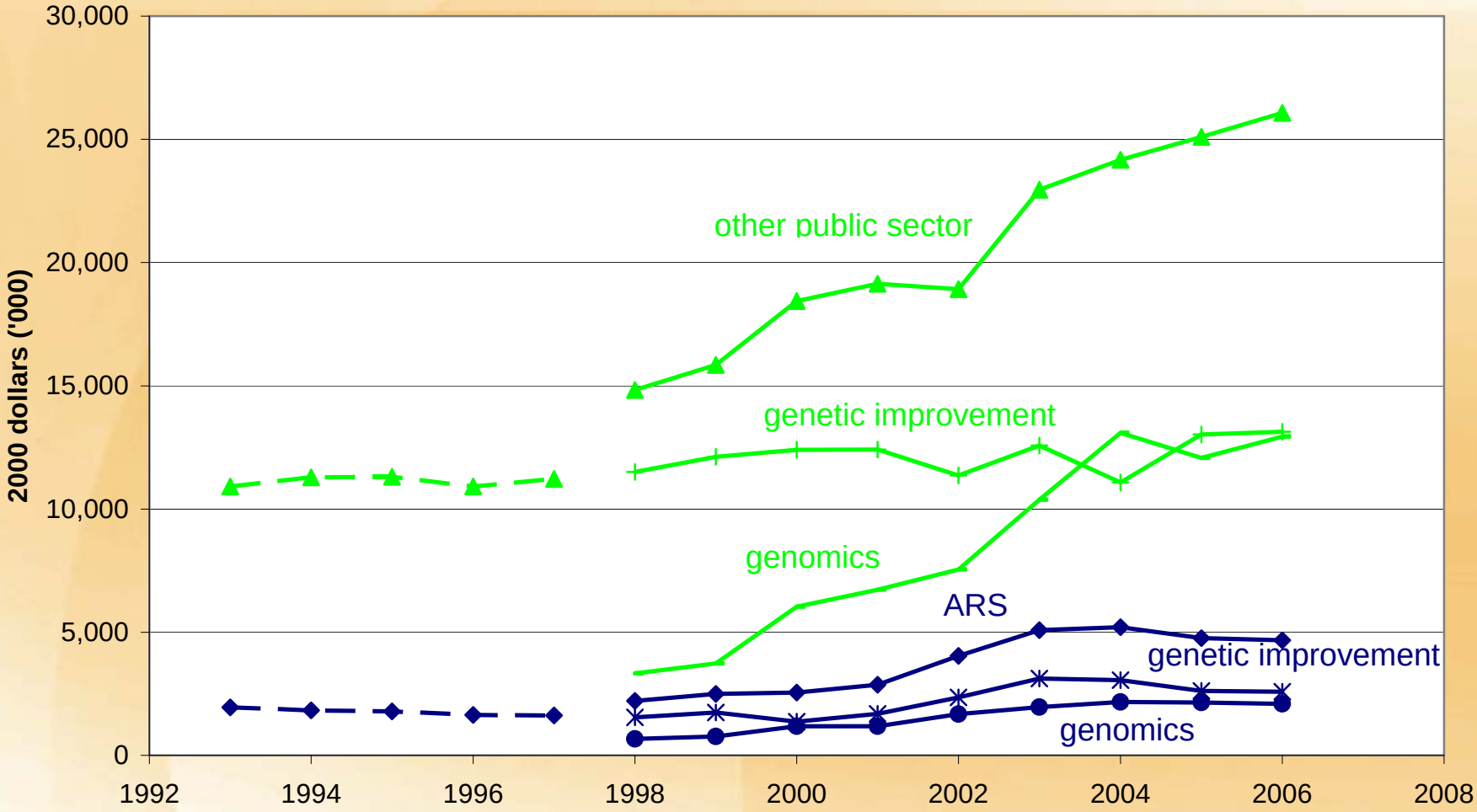
(Although crops research expenditures are greater than livestock research expenditures for all public sector commodity research, beef research and dairy research are the biggest single commodities)

real public sector beef quantitative genetics and genomics research expenditures



Source: ERS calculations from CRIS data

real public sector dairy quantitative genetics and genomics research expenditures



Source: ERS calculations from CRIS data

Many actors produce and use bovine quantitative genetics and genomics research

Genetic Theory

Statistical Theory

Molecular Biology

ARS

Universities (specific beef or dairy improvement research)

Breed associations

AI companies

Seedstock companies

DNA technology companies

consultants

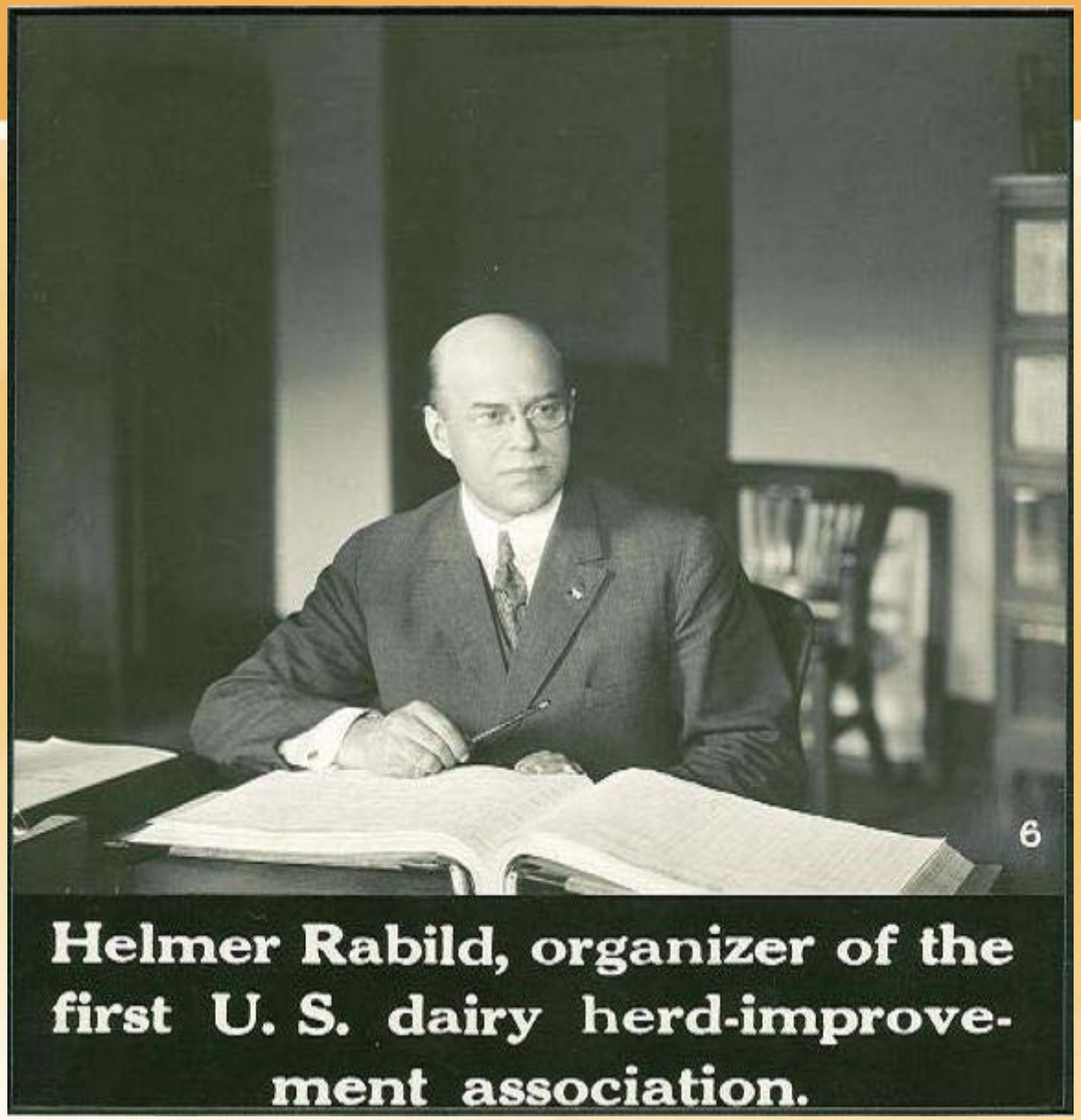
Individual breeders (farmers)

Caution!

- Flows of knowledge and material are not all one way, and not all vertical
- Some research areas overlap
- Research partnerships are fairly common

ARS/USDA made important historical contributions to genetic improvement of beef and dairy cattle

- USDA Bureau of Animal Industry defined relationships among animals, inbreeding coefficients, heritability measures
- National milk recording program
- Selection in Hereford herd, development of breeding lines, progeny testing of steers from promising sires
- First national dairy sire evaluations



Helmer Rabild, organizer of the first U. S. dairy herd-improvement association.

Since the 1960s, ARS has continued to make important inputs to genetic improvement of beef and dairy cattle

- The Germplasm Evaluation and Utilization Project at the Meat Animal Research Center (MARC) took the lead in defining levels of genetic variation for beef cattle traits that contribute to life cycle efficiency
- MARC research on sire breed evaluation for top-cross performance, across-breed expected progeny differences (EPDs), and heterosis contributed to much wider use of cross-breeding
- New dairy trait evaluations were added to evaluations for milk yield and milkfat composition
- The Animal Improvement Products Laboratory (AIPL) played a significant role in the application of statistical animal models to dairy production

ARS has taken a leadership role in the development of bovine genomics and transgenics

- Production of large half-sib beef families to develop first gene map in cattle and to identify quantitative trait loci (QTL)
- Use of dairy cattle records and relationship information to map QTL in dairy cattle
- First panels of DNA markers for paternity testing
- Commercial application of DNA markers for traits
- Important role in bovine genome sequencing effort
- First transgenic cattle for mastitis resistance
- Launching of whole genome selection/whole genome association studies using high-density SNP chip genotyping platforms

Many users of ARS technology in bovine quantitative genetics or genomics would find it difficult to obtain this technology from alternative sources

- Complexity and completeness of ARS data
- ARS' ability to apply systems approaches
- ARS' ability to integrate new research with older findings
- DNA data from ARS--quality very high
- Availability due to intellectual property issues

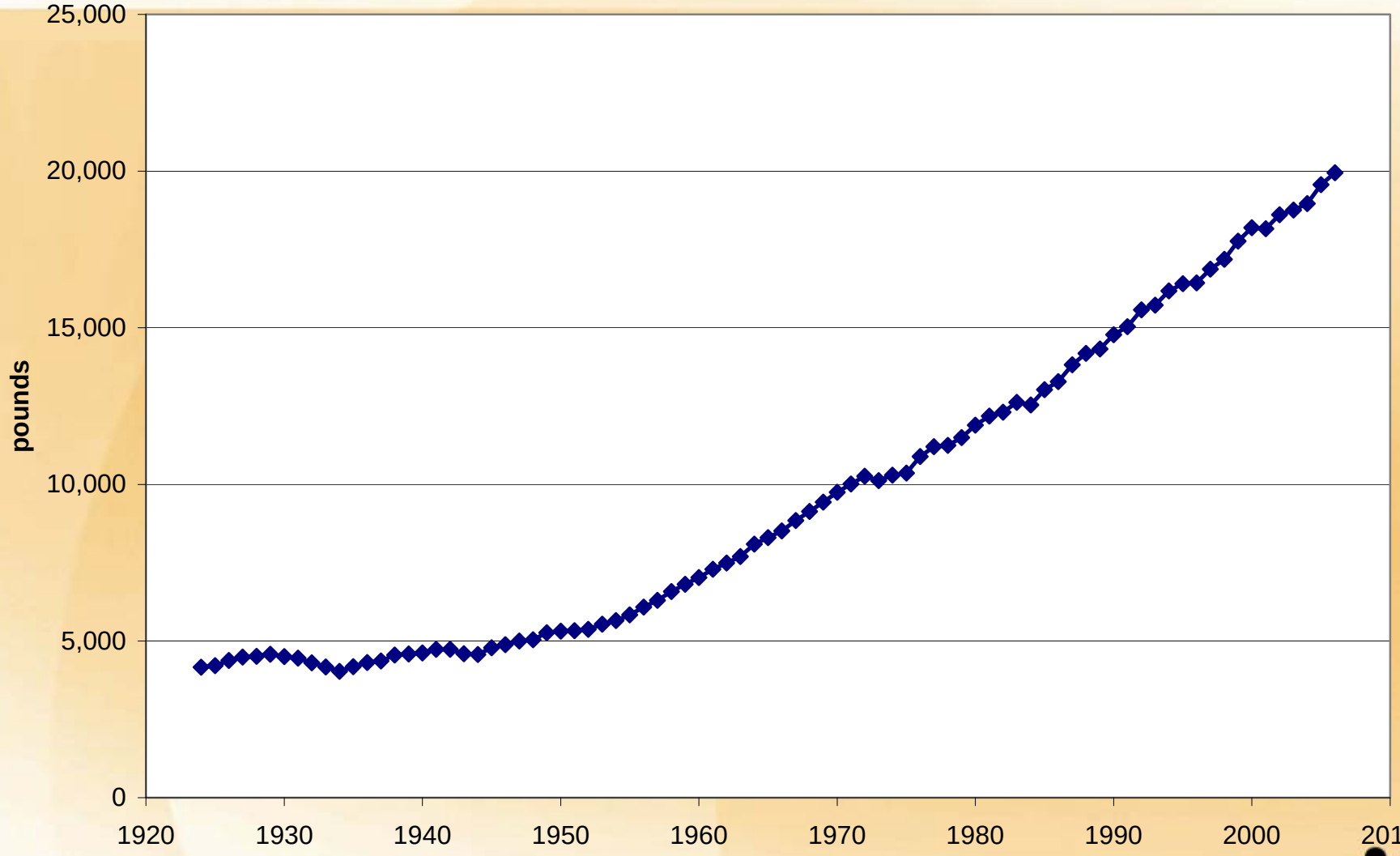
- However, this does not answer questions such as:
  - Does ARS cover all areas where it may have a research advantage (e.g. GxE interactions, particularly for beef cattle)?
  - Does ARS do research in areas where other institutions may have a research advantage?

A national level focus and a long time horizon are important factors determining ARS comparative advantages in research

- Data from large animal populations over long periods of time
- Ability to provide practical validation of theoretical findings

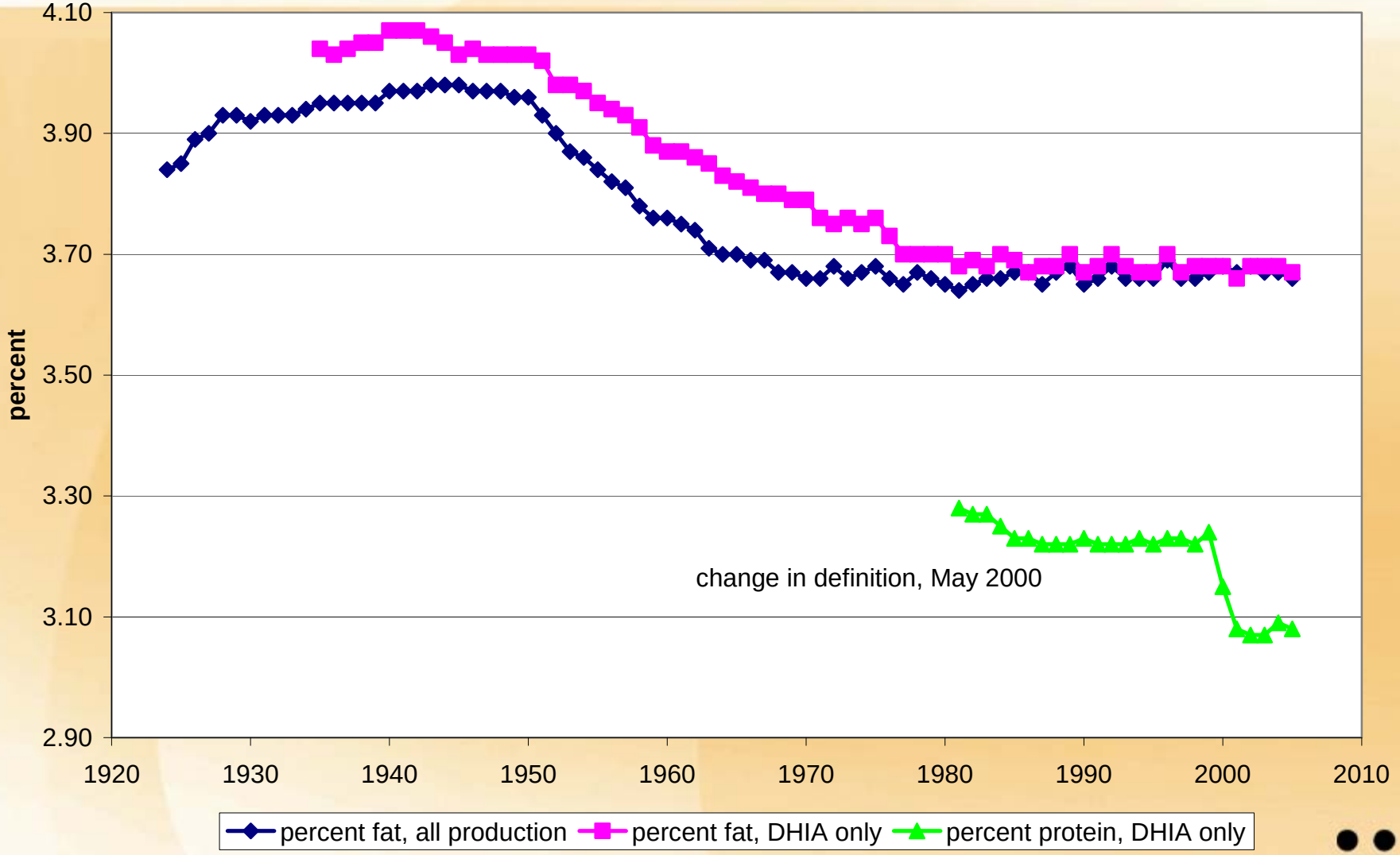
Thinking about outcomes . . .

milk per cow, U.S. dairy production



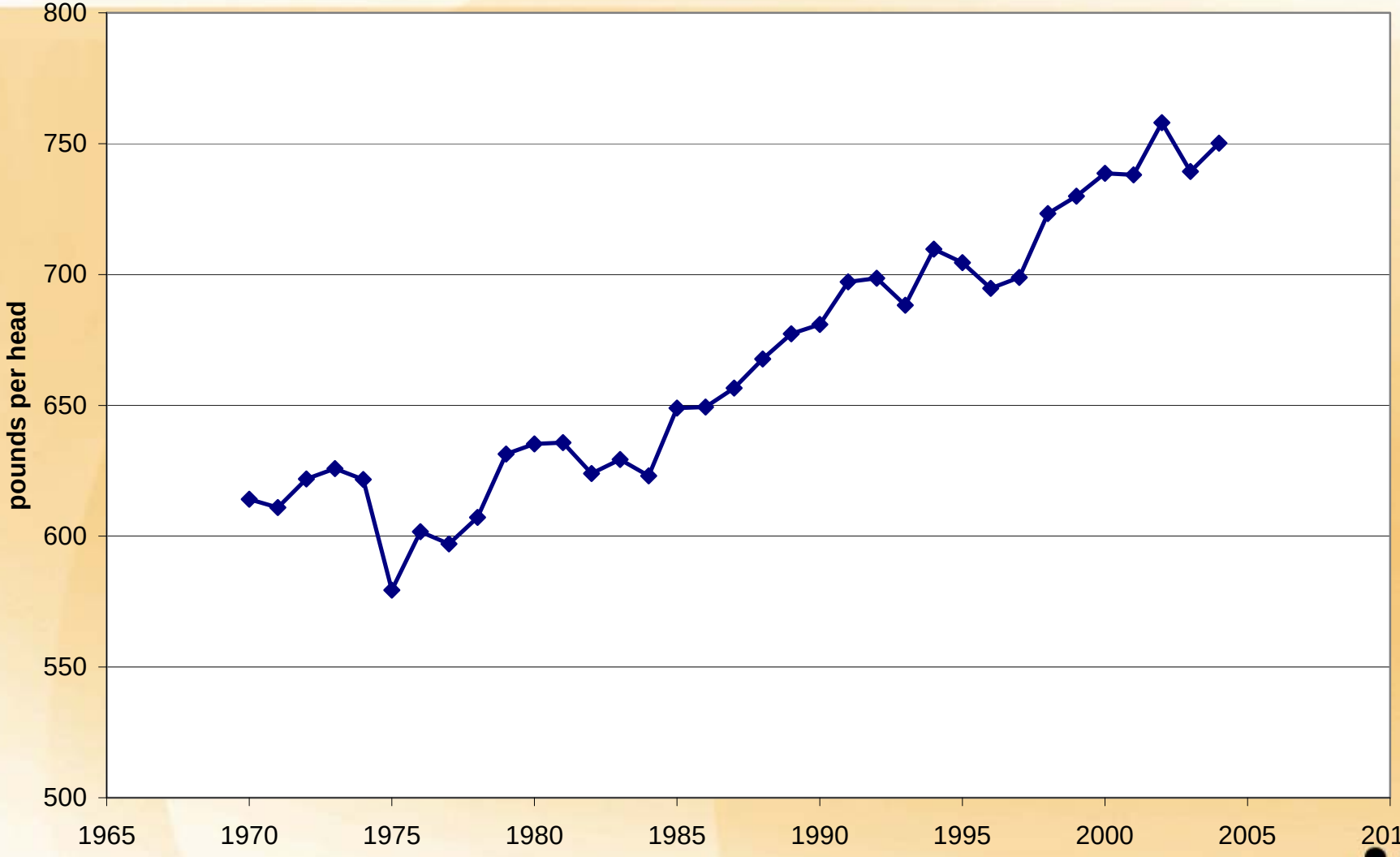
Source: NASS

fat and protein percentages 1924-2005



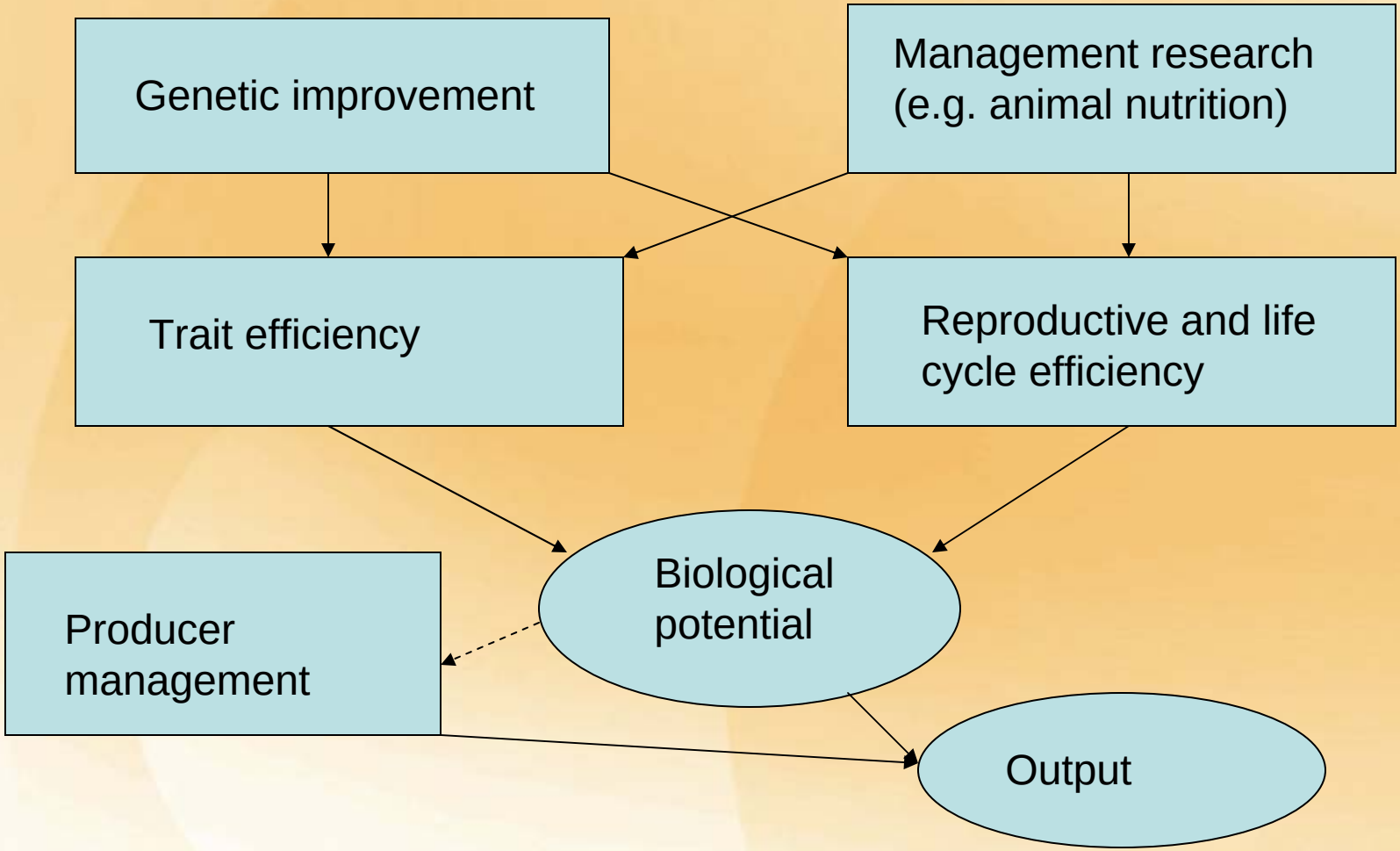
Source: NASS

Average U.S. commercial dressed cattle weight



Source: ERS Meat Yearbook

There are relationships between gains in production traits resulting from research, the gains in those traits recorded in producers herds, and the shift in supply used to measure benefits, but they can be complex.



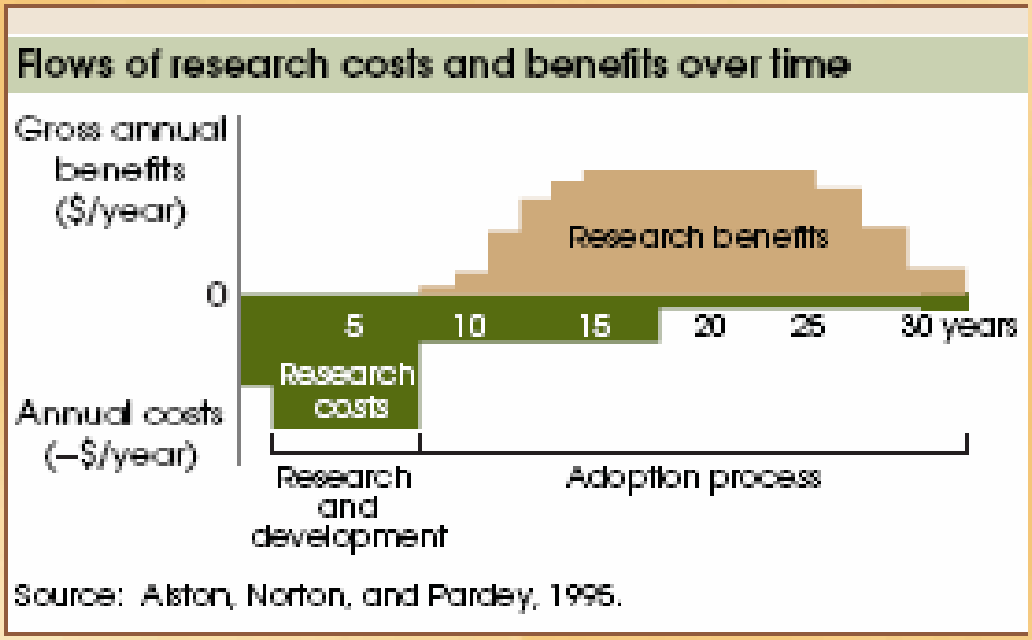
There are external economic factors that could influence measurement of benefits

- Do dairy pricing policies affect measurement of benefits to dairy research (Fox *et al*., 1992)?
- Do substitution effects (e.g. pork for beef) mean beef and pork research should be evaluated in a common framework (White and Araji, 1991)?

Should non-market benefits and costs be included in economic evaluation?

- Is there a net environmental benefit in the reduction in dairy cattle numbers (25 million in 1945, 9 million today)?
- Is there a net environmental cost to beef produced in commercial feedlots?
- Could consumer preference for animal welfare be measured using contingent valuation methods or market studies, then included in selection indices (Oleson *et al*., 2006)?

A few examples of potential economic studies of beef and dairy genetic and genomic research follow



Ex post studies of returns to beef and dairy genetic improvement research would be relatively broad in coverage

- Beef and dairy studies would probably be conducted separately
- All research providers would be considered
- Past examples are limited in number, and primarily address all dairy or all beef research, not simply genetic improvement, e.g.
  - Bredahl and Peterson 1976, U.S. dairy, U.S. other livestock
  - Norton 1981, U.S. dairy, U.S. other livestock
  - Smith *et al*. 1983, U.S. dairy
  - Widmer *et al*. 1988, Canada beef
  - Norton *et al*. 1992, U.S. dairy, U.S. other livestock
  - Fox *et al.* 1992, Canada dairy
  - Klein *et al*. 1994, Canada beef
- One study (Farquharson *et al*., 2003) looks at genetic improvement for beef in Australia
- Estimating returns to genetic research might be more difficult for livestock than for crops (see Frisvold *et al*., 2003 for a crops example)

A study of the application of bovine genomics could be more narrowly focused

- Time and cost savings of sire evaluations using DNA data instead of conventional progeny tests

A study of economic weights to be given to reproductive/lifetime efficiency criteria relative to production traits might assist management decisions

- More data might be available for such a study in dairy production
- Such a study would have some of the complexity of *ex post* studies of returns to genetic improvement research
- In addition, the *ex ante* nature of the study would require care in forecasting biological and economic variables

Thank you!