University Research Productivity and its Impact on the Regional Agricultural Economy: The Case of Colorado State University and the Colorado Economy

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Introduction
The economic impacts of university research and technology transfer on industrial R&D and commercial innovation are important to university and state leaders, and have been the subject of economic analysis. University research is a major engine of innovation to knowledge creation and high tech industries, interaction between university and industry generates positive social returns as well as economic growth and development.

History of University and U.S. Policy Changes
- Research Mission: By late 20th century, transformed to research university, kept original educational mission: Hatch Act of 1887.

Literature Review
- Knowledge Production Function: Griliches (1979), and Pakes & Griliches (1984) analyzed patent data as a useful indicator of research productivity. University knowledge capital created by U.S. universities has been developed as an empirical model of the relationship between knowledge flows and patents.
- Academic Knowledge Production: Jaffe (1989) modeled the knowledge spillovers from university-R&D. Mansfield (1991, 1995) analyzed the extent to which industry's new products and processes were based on recent academic research. Adams & Griliches (1998) analyzed the research productivity of U.S. research universities by academic field. Czarni & Genova (2009) applied a polynomial distributed lag model to the research inputs and outputs of research universities.
- Academic Intellectual Property: Manwaring et al (2001) show how university knowledge and research activities by universities increased in recent years due to public policy. According to Shane (2002), to the extent that universities foster faculty entrepreneurship, they help to overcome a range of market failures.

Research Questions
- What are the historical trends of CSU’s knowledge production and technology transfer, across all of the different colleges, departments, and research units of the university?
- How do changes in research inputs affect research outputs, across the different units of the university?
- How can we model the dynamics of university knowledge production inputs and outputs?
- What is the importance of a state university’s research on innovation and economic development within the state economy?

Data Description
- A comprehensive database of Colorado State University’s research inputs and outputs from 1989 to 2012.
- Table 1: Summary Statistics: Various research inputs and outputs.

Model Framework
- The quantitative relationship between research inputs and outputs is called the “Knowledge Production Function (KPF)” by Pakes & Griliches (1994) and can be modeled by a number of production function forms. To determine the systematic relationship between inputs and outputs.
- Equation 1: Given the panel data model, using a negative binomial NPE with polynomial distributed lags, for determining the systematic relationship between inputs and outputs.
- Equation 2: Hence, the model becomes a partially linear model with the count dependent variable is negative binomial. If beta is transformed as polynomial distributed lag:

\[ y_{it} = \beta_0 + \beta_1 x_{it} + \beta_2 z_{it} + \epsilon_{it} \]

where: \( y_{it} \) is a college, department, or research, and \( z_{it} \) is a panel.

Equation 3: Unrestricted PDL model after recovering beta.
- Equation 4: Imposing end-point restriction: Restricted PDL model.
- Equation 5: Create a Collaboration Index (millions $) as a proxy variable measuring intercollegial university collaboration activities. It consists of grant awards from industry-sponsors ("private"), published academic articles with industry co-authors ("industry"), transformed by the average dollar per article, and departmental level expenditures on inter-sectoral "partnerships".

Equation 6: Tech transfer metrics consists of invention disclosures, patent applications ("patent"), and startup companies ("startups").

Selected Empirical Results
- Table 3: Select regression results, at department level, 1999-2012.
- Table 4: Geographic distance of industry co-authors with CSU’s publications by research categories (1999-2012).
- Table 5: Geographic location of CSU affiliated startups by research categories (1989-2012).

Conclusions
This study investigated CSU's knowledge production and technology transfer, and how they impact commercial innovation, especially in the agriculture-related sectors. Although it is only one institution, we attempt to ascertain the systematic relationship between research inputs and outputs. Preliminary empirical results suggest that CSU's research outputs are heterogeneous, with public domain research outputs (publications) having more systematic relationship with research inputs, compared to other channels. In economic impact, CSU's publication output is significant both locally and globally, and CSU's research expenditures as input and patents as output. The collaboration, from co-authorship on articles, shows out-of-state and foreign collaboration of 75%, from patent applications, 41% from Colorado affiliated startup companies in "sticky" knowledge transfer, with only 10% local out of state and none in a foreign location.

Selected References
- "University Research Productivity and its Impact on the Regional Agricultural Economy: The Case of Colorado State University and the Colorado Economy," by Yoo Hwan Lee, Gregory D. Griff
- "Knowledge is not only an important issue of economic growth from innovation in both traditional and high-tech industries, interaction between university and industry generates positive social returns as well as economic growth and development."
- "Knowledge Production Function: Griliches (1979), and Pakes & Griliches (1984) analyzed patent data as a useful indicator of research productivity. University knowledge capital created by U.S. universities has been developed as an empirical model of the relationship between knowledge flows and patents."