Bibilometric analysis for discovery of future trends in agricultural technology: the case of Taiwan

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Introduction

Fundamental research is an important source of new knowledge, and the basis for new innovation over the long term. Aligning fundamental research with the long term focus of scientific development is an issue that all countries are grappling with. In this paper, the experience of Taiwan in predicting science and technology advances in agriculture is presented to illustrate how the bibliometric information can be applied to science forecasting, and how that can help with developing strategies for fundamental research.

Bibliometrics was founded 50 years ago by Eugene Garfield. It is used to describe, assess and monitor scientific activity both globally and in individual countries. Analysis of the scientific literature reveals the real value of fundamental research, and reflects important topics for the future. Today the OECD, APEC and the EU all use the publishing of papers as an important metric of scientific ability.

Research policy is a difficult area in many countries. There is rarely a clear link between research investment and fundamental research. This creates a need for new methods of prioritizing research topics when allocating funding. Science foresight is one way to resolve this problem.

The concept of "foresight" was made popular in the 1930s by H.G. Wells. In 1985, Coates applied it to US public policy, and defined foresight as a process of analysis for long term future policy, including policy formulation, planning and decision-making. The process involves observing all possible trends and clues, and developing a set of optimal strategies, with constant reference to the implementation of policy. Foresight, then, is oriented to the long term, focused on being a complement to decision-making (particularly policy making in the areas of research and innovation). It assumes that the future is unclear, and its purpose is to identify opportunities and threats, and to respond to them. In strategy management today, there are many methodologies and techniques

for analyzing and predicting long term trends: Delphi, scenario analysis, trend analysis, modeling, SWOT, literature analysis, etc.

Previous literature has stressed the impact of policy making on academic research, but there has been little work as yet on science and technology policy from the perspective of the scientific literature. In 2004-2005, Japan completed its eighth foresight survey, involving a Delphi survey, but also supplementary scenario analysis, literature analysis and surveys of research fronts and public demand. The objectives of the survey were to present conclusions that were both normative and descriptive, technical and social. This allowed the drafters to present more objective policy advice in their final report.

Buffeted by market liberalization, globalization and the knowledge economy, Agriculture is facing transformation in its operating model, technological development and decision-making mechanisms. Agriculture must find ways to make use of limited technological resources, and invest in technologies where Taiwan has particular strength, in order to enhance the nation's competitiveness in international agricultural markets. To allocate resources more efficiently the Taiwanese Council of Agriculture worked with the Scientific Research Committee in 2008 to commission a plan named “Building-Up Technology Foresight System for Agriculture”from the Taiwan Institute of Economic Research (TIER). It involved surveys of public demand, international trends, drafting of vision, and analysis of technology demands and trends. Following this preparatory research, future scientific areas for development were produced, and questionnaires designed for two rounds of Delphi surveys. Through this process, consensus is reached about the directions of future science and technology development, and key areas for growth. To achieve the goals laid out, technology resources must appropriately allocated, and research strategies adjusted, and here scientometrics and text mining can be of use.

Objectives

Historical experience suggests that scientific development often follows an "S curve": with a new invention, progress is slow at first, then through a process of trial and error, the field begins to be systematized. In the growth period, development is sustained and fast. Finally, when the technology is mature, an upper limit is approached, and development slows again. When the limit of the technology has been reached, and the mature technology begins a decline, and is ripe for replacement by a newer invention. In this paper, we use

bibliometrical methods to explore Taiwan's unique strengths in agricultural technology. There are two main objectives: (1) to understand important future areas for research in agriculture in Taiwan and globally; (2) to develop a corresponding plan for fundamental research in Taiwan.

Method

First, 74 important research topics for agriculture in Taiwan were identified, which were divided into 10 research areas. These research areas were assigned relative competitive advantage indices (RCA) and compared against world trends.

1. Source of data

   To determine the important research topics, the Agricultural Technology Foresight Commission was formed, with 3-4 members for each area of research. Conferences were held, and topics were selected based on global developments and the Taiwan Mid-Term Agricultural Technology Development Plan.

   The ISI Web of Knowledge was sampled using keywords and Boolean links. Searches were conducted on 74 keywords in the literature, (Table 1 shows the examples in the research area "grain"). The number of papers written on a keyword for each country was counted, and averages calculated. Where a paper had multiple authors, the paper was included in the count for all the countries represented by its authors.

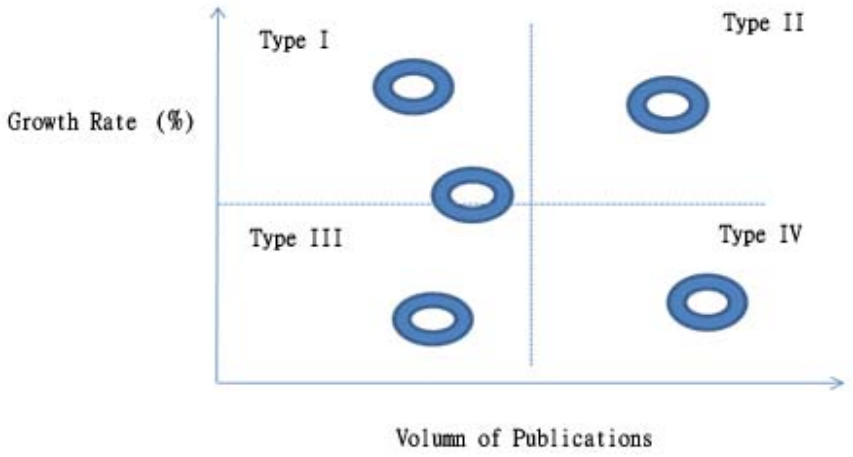
Table 1. Keyword clusters (grain)

Development of rice varieties to prevent or lower risk of metabolic syndromes	{ [ts=(variet* or breeding or cultivar$) and ts=(rice)] or [ts=(strain$ or race$) same ts=(rice)] } and ts=("metabolic syndrome$" or "blood pressure" or "hypertension" or cholesterol or "blood lipid$" or "blood lipo protein$" or hypercholesterolemia or hypertriglyceridemia or "blood sugar" or "blood glucose" or hyperglycemia or obes*)
Improvement of high-quality seed and seedling production technology for the tropics and sub-tropics	ts=(tropical or subtropical) and [ts=(seed$ or seedling$) same ts=(production)]

2. Analysis

2.1 Global research

The period from 1990-1999 was taken as a baseline for each keyword, and the period 2000-2009 the observation period. The rate of increase in publications over the two periods was compared, to understand how fast the research community for this topic was growing. With the mode of growth rates as axes, the topics are plotted into the four quadrants, corresponding to phases on the technology development curve. The phases are labeled: embryonic, emergent, growing and mature. (See Figure 1.)



I. Emerging topics: knowledge is still growing
II. Embryonic topics: not yet considered seriously by researchers
III. Growing topics: knowledge base well established
IV. Mature topics: accumulation of knowledge almost complete

Figure 1. Structure of literature (global)

2.2 Research in Taiwan

The analysis in Taiwan was conducted in the same way, with 1990-1999 as the baseline, and 2000-2009 as the observation period.

2.3 Comparison of fast growth topics globally and in Taiwan

To determine Taiwan's relative research strengths, the measure

relative comparative advantage (RCA), first proposed by Balassa in 1965, was used. RCA is frequently used to assess an industry's competitiveness in trade, but it has also been adopted in other areas as a general measure of a relative strength. In this study, RCA was calculated as in (1). Research in Taiwan was then compared to global research to find where Taiwan has a relative advantage. To show graphically the topics in which Taiwan has particular strengths, the Taiwan RCA and global growth rate in research literature are plotted on axes calibrated to the medians of the two variables. Based on their position in the plot, the stage in the development S curve of each research topic can be calculated, and a suitable strategy applied.

(1) $$RCA_{i,j} = \frac{P_{i,j} / \sum_{i=1}^{24} P_{i,j}}{P_{i,w} / \sum_{i=1}^{24} P_{i,w}}$$

Preliminary Results

1. Grain production in Taiwan

There are 16 topics of research for grain (k1-k16). Analysis of fundamental research in each of these areas reveals five embryonic topics, three emergent topics, five growing topics, and the rest mature topics. The five growing topics are: 1. Safety testing for agricultural products and product tracking management systems; 2. Maintaining stable productivity and intensive horticulture; 3. Collecting and preserving genetic material, adaptation of agricultural species to climate change, development of low-energy, low-emissions, low-water use systems. 5. Development of efficient, labor-saving, safe technologies for use with agricultural products. (See Figure 2.)

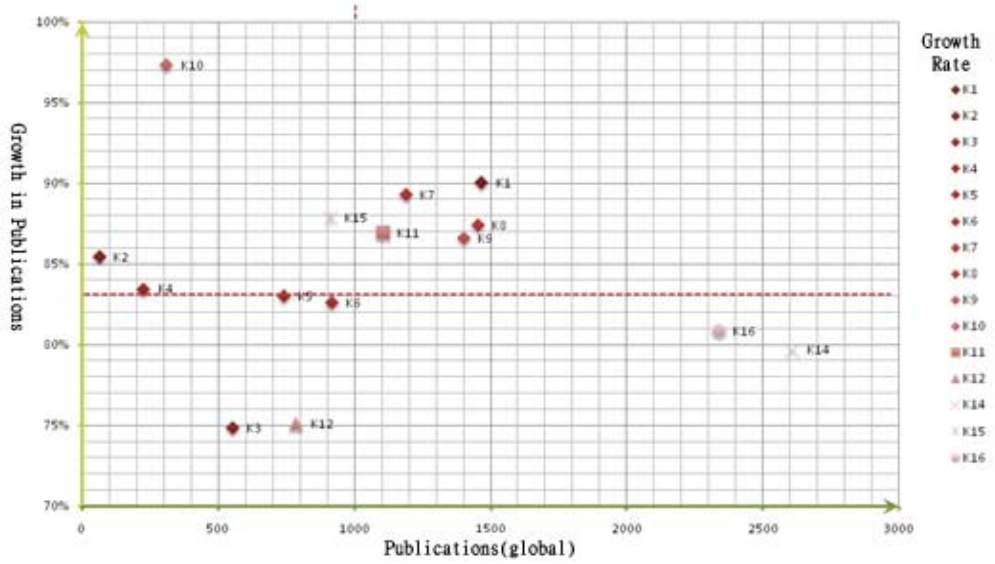


Figure 2. Global research into topics in the research area "grain"

Using the RCA formula, Taiwan's relative advantage in each topic can be calculated. As Figure 3 shows, Taiwan has a fairly high relative advantage in five topics.

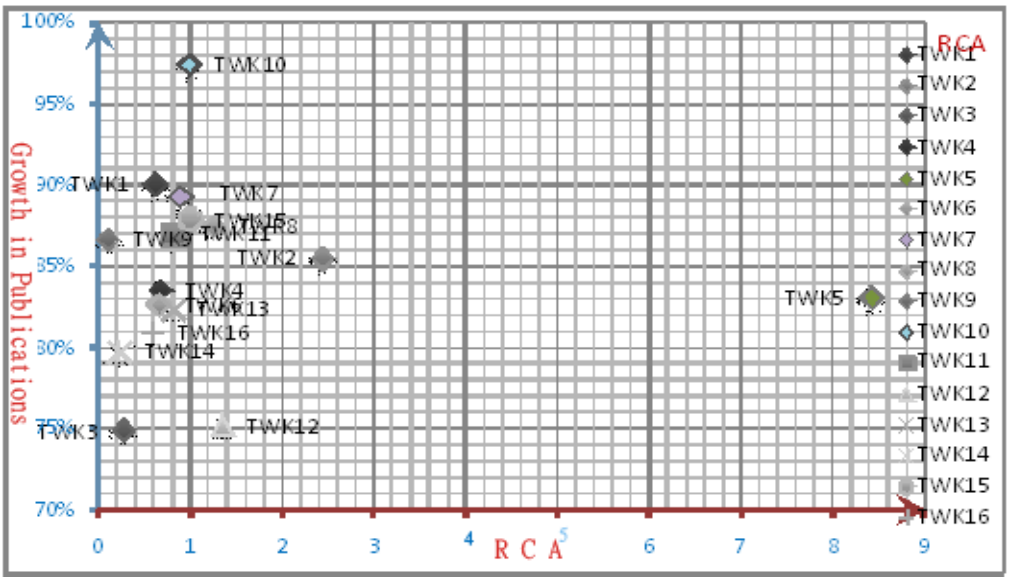


Figure 3. Taiwanese RCA analysis for "grain" topics

2. Research development strategies

Research strategies vary along the technology development curve, as in Table 2, and based on Taiwan's level of advantage.

For embryonic topics, if a topic is one where Taiwan has an advantage, it

can assess local or regional demand and determine the level of potential earnings, and make the topic a key part of Taiwan's development plan. If Taiwan does not have a significant advantage in an embryonic topic, the focus should be on exploring market niches and fundamental research.

For emergent topics, when Taiwan has strengths in the topic, it should focus on strategic fundamental research, creating key knowledge and innovative research methods to maintain its advantage, with mid- to long-term application as the objective. If Taiwan has only a low RCA, it should work with other countries, import the latest tools and knowledge and then move toward long-term goals.

Topics which are growing worldwide and in which Taiwan has particular strengths represent an opportunity for the country. Plans should focus on technology integration, transfer and application for specified results in the short to medium term. Where there are business opportunities but Taiwan does not have strengths, then the strategy should involve tightly focused investment on a specific research topic. Topic analysis is therefore highly important in this scenario.

Mature topics in which Taiwan has research strength are the most promising areas. With a focus on application and technology development, Taiwan can quickly transfer technical knowledge into commercial products. If Taiwan does not have a comparative advantage in the topic, then topic assessment may assist in discussions of the best niches and opportunities to import expert knowledge and transform it into an applicable technology. In this process, international cooperation will be an important method.

Table 2. Development strategies for foresight topics

Taiwan/ World	**Mature**	**Growing**	**Emergent**	**Embryonic**
Relative competitive advantage high	Most promising. Develop applications and technology, quickly convert science knowledge into commercial products.	Opportunity. Focus on technology integration, transfer and application for concrete results in the short to medium term.	Strategic fundamental research, key knowledge and innovative research methods to maintain advantage. **(TWK2, TWK5)**	Assess local or regional demand, determine topics with potential for profit. Key part of Taiwan's development plan. **(TWK6,TWK12)**

		(TWK7, TWK8)		
Low competitive advantage	Topic analysis for best niches and opportunities, import expert knowledge and transform it into an applicable technologies. International cooperation important. **(TWK14,TWK16)**	Tightly focused investment on a specific research topic. Topic analysis vital. **(TWK1, TWK9, TWK11)**	Work with other countries, import tools and knowledge, move toward long-term goals. **(TWK13, TWK4, TWK10, TWK15)**	Exploring market niches and fundamental research. **(TWK3,TWK4,TWK 13)**

Preliminary Conclusion

The methods adopted in this study provide support for evidence-based, data-driven, bottom-up decision-making. The objective is not to reject the opinions of experts; rather it is to let the data speak for itself, and to assist in carrying out fast, effective exploration and analysis of that data. Applying the concept of the S-curve and bibliometric guidance to the direction of fundamental research, this study helps us to develop strategies for international cooperation, and its methodology could be applied in any country.

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