ASEV 2012 Merit Award

63rd National Conference • Portland, OR
Merit Award Presentation Summary

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Discovery, Innovation, and the Role of Research

The intellectual capital of a company is often viewed as the difference between the value of its assets in accounting terms and its market value. The intellectual capital of an industry can be viewed as the human capital and the pool of knowledge that is generated through education and research at colleges and universities. The purpose of research is the growth of discovery and understanding and, hence, the growth of this intellectual capital. The success of research activity is the product of several components: project funding, researcher effectiveness, staff support, essential research facilities, analytical power, and sample throughput. A general research function is presented to demonstrate how a limitation in any one of these will limit the full potential of the research outcome and how other kinds of incentive support, such as scholarships, seed grants, or gifts and endowments, can enhance the outcome above that expected. The question of what is a reasonable investment in the growth of intellectual capital through research activities can be addressed by looking at the investments that other organizations have chosen to make. Compared to the research investments made by nations, corporations, various crop industries, and a competitor wine industry, the California wine industry has a long history of underinvestment in wine research and an underdevelopment of human and intellectual capital. One of the outcomes of intellectual capital is an informed employee base that can adopt research results and the new ideas, methodologies, and systems that are based on research outcomes. The speed at which people and companies adopt commercial innovations will depend on several factors, but it can generally be characterized by Everett Rogers' adoption curve and extensions of it. The group in which individuals or companies find themselves on the adoption curve will determine their perception of the value and importance of making a research investment.

Research, Innovation, and Intellectual Capital

Innovation depends on the development of new understanding and the development of intellectual capital usually comes from scientific research activity. The adoption of new products and concepts is dependent on this intellectual pool and a commercial need to be competitive.

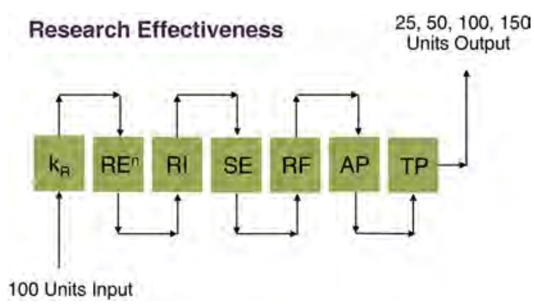
"Intellectual capital is the *knowledge*, applied experience, *enterprise processes and technology*, customer relationships and professional skills which are valuable assets to an organization" (Halim 2010). In one study, the three components of intellectual capital—human (knowledgeable and experienced people), structural (software, process technology, and patents or licenses), and relationship (networks, clients, agreements, etc.)—were highly correlated and interdependent. Human capital seems to be the primary factor in intellectual capital and the other two components depend on it. Research activity is the most effective way to grow intellectual capital, since it grows human and structural capital as well as the understanding and research outcomes from which everyone benefits. The investment in the growth of intellectual capital, like that in education itself, shows a delay in financial return but the return is always positive (Vaisanen et al. 2007).

The growth of intellectual capital is linked directly to research activity, so investment in research becomes the most effective way to achieve this growth. The growth of human capital while the research is in progress is one of the main distinctions between the university research environment and corporate research centers (or research institutes). The greatest yield in intellectual capital comes from university-based research, in particular masters and PhD graduate students, followed by postdoctoral scientists, and low yields from data collection and trials using existing staff.

The link between research activity and the growth of intellectual capital can be undermined by factors that limit or restrict the effectiveness of the research endeavor.

Research Effectiveness

The effectiveness of any research activity depends on several factors, which are multiplied by each other to determine the research outcomes. As shown below, the research effectiveness depends on the number of research equivalents (RE), the quality of the research interactions (RI), the support of the primary activities by the staff equivalence (SE), the capability and throughput of the research facilities (RF), the resolution and capability of the analytical power (AP), and the throughput (TP) of experimental samples. Limitations in any of these blocks will reduce their combined product: the research potential and enhancements or elevation of the research equivalents by scholarship, additional grants, and endowments can actually amplify the research outcome beyond that which would be expected.



Growing Human and Intellectual Capital

While research activity is the way to grow intellectual capital, the fastest way to grow human capital is to support an MS student, while the highest yield in the growth of human capital is to support a PhD student, and the most productive growth of intellectual capital, due to structural capital component alone, is to support a postdoctoral researcher. There is also a moderate growth in structural and relationship capital by supporting a visiting scientist or a researcher on a sabbatical leave. However, this growth will be limited by staff, facilities, and project funding, all of which need to be sufficient and available for optimal delivery of the growth in intellectual capital.

Measures of Research Investment Intensity

One way to establish what seems like an acceptable level of research investment is to look at what others are doing. Most groups measure the level of investment in research as a percentage of sales or value. This measurement together with the number of people engaged in research are the most widely used metrics.

National research investment levels. If you look at the investment by countries in research and education, one measure is a comparison between the investment in "equipment" versus that in "knowledge." In a comparison of 22 countries, Finland, Sweden, and the United States made the highest investments in the knowledge piece, at about 6% of their gross domestic product (GDP), and a similar investment in the equipment piece (OECD 2006).

Countries can be ranked in terms of their investment in research and the number of scientists and engineers who work in research; the 2011 data of 34 countries has been presented in *R&D Magazine* (R&D 2011). As an example, the United States invests at a rate of 3% of GDP and has about 5000 scientists per million people. In comparison, China is at 1.5% of GDP and has about 1000 scientists per million. Most industrial countries (29 of the 34) are investing at least 1% of GDP, and a majority (24 of 34) had at least 1500 scientists per million in the R&D sector.

If there are 330,000 jobs in the California wine industry (i.e., 0.33 million), as some figures suggest, then that would lead to an expectation that approximately 500 scientists and engineers would be engaged in grape and wine research in California. It seems that all of the full-time researchers at California universities, USDA, and company researchers combined would be less than 100, probably closer to 50, indicating a serious shortage of the research activity in this sector.

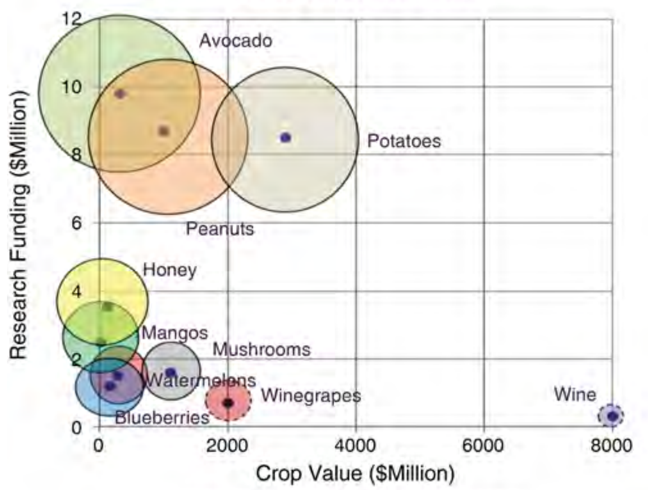
Corporate research investment levels. If instead, the corporate investment rates in research are considered, they can be sorted into two groups, one with investments greater than 10% of sales (such as Google, Microsoft, Roche, Merck, Intel, and Nokia) and the others with between 2 and 10% of sales (such as Bayer, Honda, Toyota, Ford, GM, Siemens, IBM, Samsung, and HP). In related data, companies are also ranked in terms of the research investment per employee, as thousands of $US. All of the companies in the high investment group are investing above $50K per employee, while those in the second group are above $10K per employee. All of the major global companies are investing more than 2% of sales and more than $10K per employee. Even at 1% of sales, for California wine with a $10B value FOB (freight on board), the California industry's annual research investment might be expected to be $100 million or at $5K per employee, $150 million per year. The current investment rate in wine research is about 100 times below what might be expected from these corporate investment rates.

Research Investment by U.S. Agriculture Groups

A study using data from 1989, reported by the Economic Research Service of the USDA, indicates that in general, public research in "fruit crops" was at $140 million and ~1.5% of crop value. In terms of grape value, that would be ~$30 million for grape research and perhaps four times that, or $120 million for a corresponding value of wine. An alternative view that is more specific among the agriculture sector comes from a number of federal "research and marketing orders" that have been established by petition and an election, under the supervision of the USDA. These include national orders representing the honey, mango, peanut, avocado, potato, blueberry, mushroom, and watermelon industries.

USDA ARS	2005 National Marketing Orders			
	Assessment $/ton	Res. fund $M	Crop value $M	% Value
Blueberries	12	1.2	165	0.582
Avocado	50	9.8	326	2.405
Honey	20	3.54	127	1.394
Mangos	10	2.5	15.7	1.592
Mushrooms	4.2	1.6	1107.6	0.130
Watermelon	4	1.5	280	0.482
Potato	4	8.5	2900	0.276
Grapes	1	0.7	2000	0.028
Peanuts	4	8.7	1000	0.696
Wine	1	0.3	6000	0.004

Fruit and Vegetable Research Investments – USDA ARS Data 2005



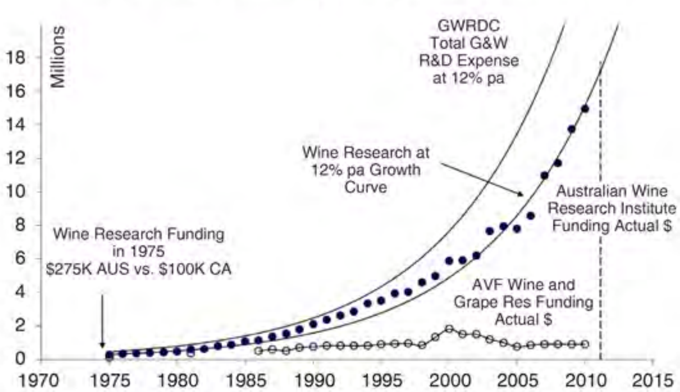
Note: "Winegrape" based in Grape value, "Wine" based on Wine FOB value.

The table and figure show that the avocado, honey, and mango groups all invest above 1% of value, while the blueberry, watermelon and peanut groups invest at above 0.5% of value. The investment for wine research in California is approximately 0.01% of value at the producer level.

A Grape and Wine Industry Research Example

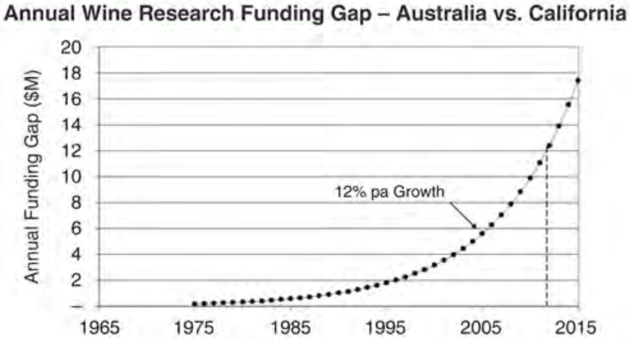
Perhaps the most comparable example of industry investment in research is the Australian Grape and Wine Research model. This program is funded by a mandated industry levy that is matched with federal government funds and awarded to various research organizations by the Grape and Wine Research Development Corporation (GWRDC), with the majority historically awarded to the Australian Wine Research Institute (AWRI). Shown below is the level of funding for wine research (dots) over the past 35 years. Also shown are the combined (grape and wine) awards from the American Vineyard Foundation (AVF) as open dots, and the total funding by the GWRDC program of grape and wine research (solid line). Both the GWRDC and AWRI curves have been growing at approximately 12% per annum.

Wine and Grape Research Funding CA vs. Australia

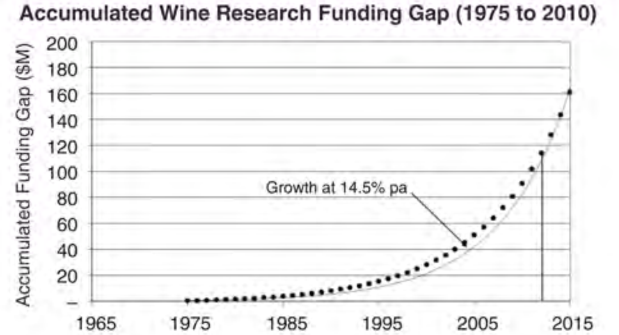


The annual difference in investment between Australia and California, in wine research alone, is now close to $12 million. Throughout the past 35 years, the accumulated funding gap has approached $120 million.

Annual Wine Research Funding Gap – Australia vs. California



Accumulated Wine Research Funding Gap (1975 to 2010)



Over the past 30 years, the California industry investment for wine and grape research, in real terms, has doubled, while the unit value of grapes has increased almost four-fold, and the corresponding wine value has increased by almost 16-fold. In aggregate terms, the size of the industry has increased by 2.3 times as well, leading to a crop value increase of 10 times and a wine value increase of perhaps 40 times. During this period, the consumer price index has quadrupled, meaning that the purchasing power of the research investment has been essentially halved.

Adoption Patterns, Innovation, and the Funding of Research

In order to understand the time delay between a project being funded, the project being completed, and a discovery being commercialized and then adopted by a majority of companies in the industry, it is helpful to look at the nature of adoption of other examples. The rate at which newly developed, disease-resistant corn cultivars were adopted by farmers in Iowa was reported in the early 1960s by Everett Rogers. This led to the concept of an adoption curve, in which different groups of farmers were grouped according to their willingness to adopt the new cultivars and to phase out the old ones (Rogers 1962). Using a normal distribution as the population model, Rogers classified them as “innovators and technology enthusiasts,” “early adopters and visionaries,” “early majority pragmatists,” “late majority conservatives,” and “laggards and skeptics” in the order of their adoption of the new corn.

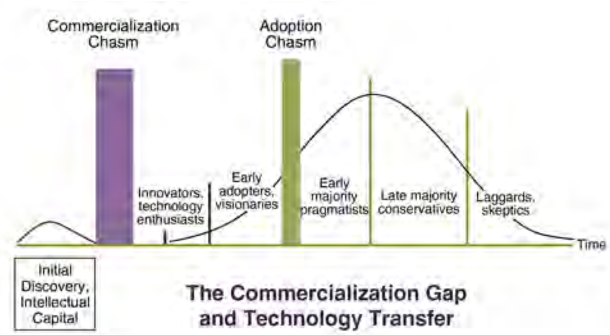
The cumulative adoption curves for various technologies show sigmoid curves, usually taking from 20 to 30 years before full adoption, or 10 to 15 years until adoption by half of the population. Recent examples of this pattern can be traced for the adoption of color TV, microwave ovens, personal computers, cell phones, and the Internet. While these curves are for the commercially available items, the research and discoveries that formed the basis of these products were generally performed years before any commercial offering, in some cases a decade or more before.

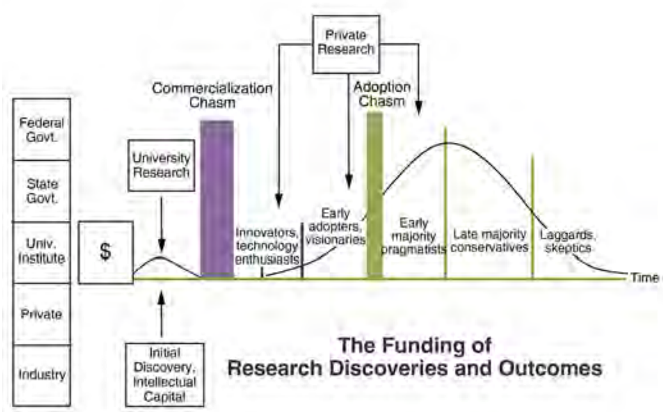
Others who have studied adoption patterns have proposed that new technologies can be adopted quickly by the first two groups, then there can be a delay, referred to as the “adoption chasm.” The innovators and early adopters, who want “technology and performance” are separated from the early and late majorities and skeptics, who want “solutions and convenience” by a period of months or years, increasing the time between discovery and adoption for almost half of the population.

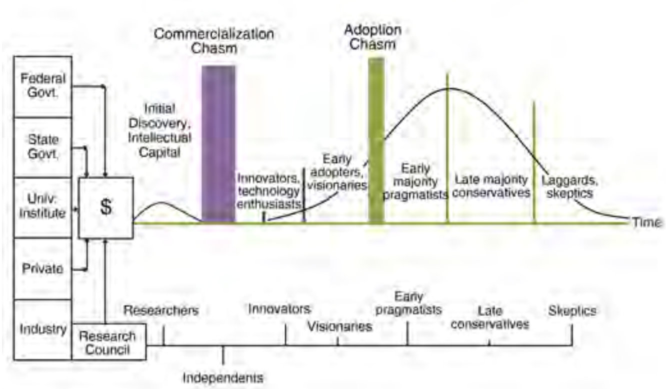
In a similar manner, the time required before new information and discoveries appear as commercial products can be delayed by what some call the “commercialization chasm” due to a need to establish new businesses, obtain distribution agreements, decide on the nature and pricing of the product, or just simply find someone who will take the risk to build the first prototype and commercialize the idea. There is then a further delay before the true adoption by various groups can begin.

Lead-Time and Time Scales from Research-to-Adoption

The time required for the development of a research proposal from an idea, the obtaining of research funding and the development of the discoveries, results, and information often predates the release of a commercial product by 3 to 5 years. It is important to realize that research-







Who would you choose to manage your research projects?

granting agencies should be comprised of forward-thinking people who understand that research needs will not be well-served by the "majority opinion," since it will likely be 5 to 10 years behind the forefront of science. This is especially true of industry commodity boards, which, while well-intended, are likely to be out of step with current scientific understanding and available technologies, sometimes by years. It is especially important that the attitudes displayed by the people on these boards be closer to the innovator and early adopter end of the curve instead of the late majority and skeptic end. There is little to be gained by asking someone who will be among the last to adopt something whether they think that you should start a research project that will lead to it.

Given the time scale of adoption alone, researchers should be working on innovations 20 to 30 years before the slowest adopters will want to accept them. If you add to that the time to write a proposal, assemble the research capability (people, facilities and instrumentation), get the grant, and complete the project, then the lead time needs to be another five years ahead.

Some Wine-Related Examples of Commercial Adoption

To illustrate the time taken for certain commercial products to be widely adopted, it will be helpful to consider several examples of systems or developments that provide improvements in winemaking or delivered wine quality. The original studies of the application of cross-flow filtration to juice and wine clarification in the United States date back to 1976, and today almost every winery has or uses a filter of this kind. The adoption curve is essentially complete, but it really only began to take off in the early 1990s, with about a 50% adoption by 2000. These filtration units have been commercially available since the early 1980s, so there was no development time or commercialization gap in this case that would delay the beginning of adoption. This is an example of a decade of lag and then almost 30 years for complete adoption. It is reasonable to ask "Why did it take so long?"

The application of pressure transducers to follow wine fermentation progress was first demonstrated in 1982 at the Charles Krug Winery in St. Helena, using an existing commercial sensor and an early HP computer to produce a display of a Brix curve on a screen. While there has been a proliferation of computers in everyday activities, the adoption of fermentation monitoring has barely reached a 5 to 10% adoption level today, possibly due to a commercialization chasm of the related software, not the availability of sensors or computers, possibly due to a scarcity of IT companies who are willing to work with wineries. The delay in adoption might be interpreted as due to a relatively low level of interest in the advantages of computer systems and fermentation technology to winemaking, in general, but it is also partly due to poor commercialization of the idea or its value, not only in the United States but also globally.

The quantitative fouling test for microbial membrane filters, developed and published in the mid-1980s, is barely at 50% adoption, probably again due to a commercialization chasm for a reasonably priced commercial test system. This is generally considered one of the most expensive filtration steps and the most crucial in terms of wine microbial protection. This example might be further complicated by the thinking that membrane filter companies should be involved in overcoming the commercialization gap, but it is clear that a conflict of interest exists in that better prediction of filter performance will result in a loss in sales of membrane filters.

The commercial availability of screwcaps and the research indicating wide variation in cork properties has been around for more than 25 years. While adoption of wines bottled with screwcaps in Australia and New Zealand is close to 95%, in the United States it is barely 20%. This is clearly not a commercialization limitation, but rather a wine producer choice in the U.S. market when the same is not true for many imported wines and in other markets, such as the United Kingdom, Asia, and many parts of Europe.

The Adams-Harbertson tannin assay was first published about 15 years ago, and yet barely 10% of wineries use the assay to track tannin extraction in red wines, even given the importance of these values. Similarly, the tracking of temperature, time, and location in bottled or bulk wine shipments has been possible for more than five years with commercially available data boxes and memory chips, but less than 5% of wine transport is monitored in this critical stage of delivery.

There is a secondary effect due to the speed of adoption. Industries and companies that are slow to adopt will soon be relegated to among the last groups to be approached with new developments and technologies, ensuring that they will be among the last groups to have the opportunity to adopt them. Finally, a research funding program that does not support the development of analytical methods and new technologies and process systems results in fewer new ideas being developed, less growth of intellectual capital, and fewer results that can be commercialized for the adoption cycle to begin.

Summary

The link between innovation and intellectual capital is controlled by the level and effectiveness of research activities. The most effective way to grow intellectual capital is through research, with both human and structural capital being grown, in university graduate student and postdoctoral research programs. A compound research function was used to show how all aspects of research activity need to be sufficiently funded for effective research outcomes to be obtained.

Most nations and leading global corporations invest at least 1% of sales in research and development and have 1.5 scientists and engineers per thousand employees. Comparable targets for grape and wine research funding should be 1% of value, or $5000 per employee. These are conservative standards which provide a basis for discussions of what might be required to create an effective research activity for this industry.

The research gap between the level of investment in wine research in Australia versus that in California is $14M per year, with an accumulated deficit over the last 35 years approaching $100M. This is from an industry essentially half the size of the U.S. wine industry.

The time scales of research activity, commercialization of new ideas, and adoption by half of the likely adopters is at least a decade, with complete adoption often taking from 20 to 30 years.

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