Donald B. Anthony, ScD.

President and Executive Director
The Council for Chemical Research

Biography

Donald B. Anthony, Sc.D., became President and Executive Director of the Council for Chemical Research in January 2004.

Prior to that, he served as President and CEO of NineSigma, Inc., President of Bailey Controls and ABB Process Automation, Vice President of Technology for Bechtel Petroleum and Chemicals, and Vice President of R&D for BP America and Standard Oil of Ohio. He was also Assistant Professor and Director of MIT's School of Chemical Engineering Practice.

Don earned his Sc.D. and S.M. in Chemical Engineering from MIT. He received his B.S. in Chemical Engineering from the University of Toledo.

THE COUNCIL FOR CHEMICAL RESEARCH

AIChE-ACS Management Conference

Cincinnati, OH
November 2, 2005

CCR Phase II Study

"Measuring Up: Chemical R&D Counts for Everyone"

Donald B. Anthony, Sc.D.
President & Executive Director

Council for Chemical Research

The Council for Chemical Research (CCR) was created in 1979 to improve trust and collaboration between the public and private research sectors.

"CCR's purpose is to benefit society by advancing research in chemistry, chemical engineering, and related disciplines through leadership collaboration across discipline, institution, and sector boundaries."

CCR Membership & Goals

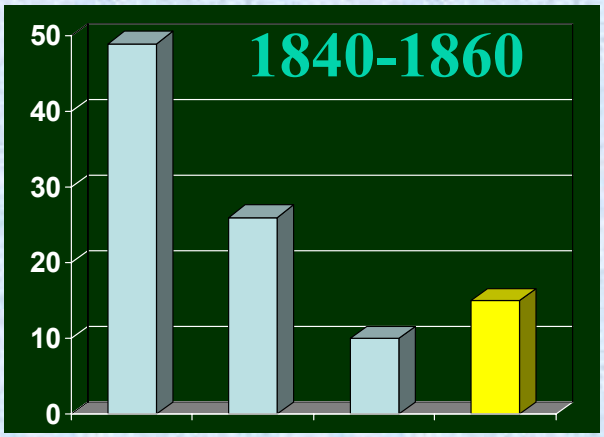
- **Represents research leadership in 3 sectors**
  - Industrial (27 corporations)
  - Academic (134 research universities)
  - Governmental (10 national labs and 1 international affiliate)
- **Goals**
  - Advance research collaboration
  - Advocate research investment
  - Enrich graduate education
  - Address long-range issues

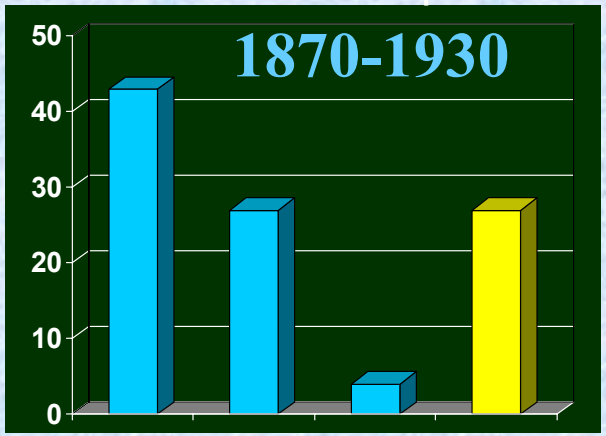
1987 Nobel Prize

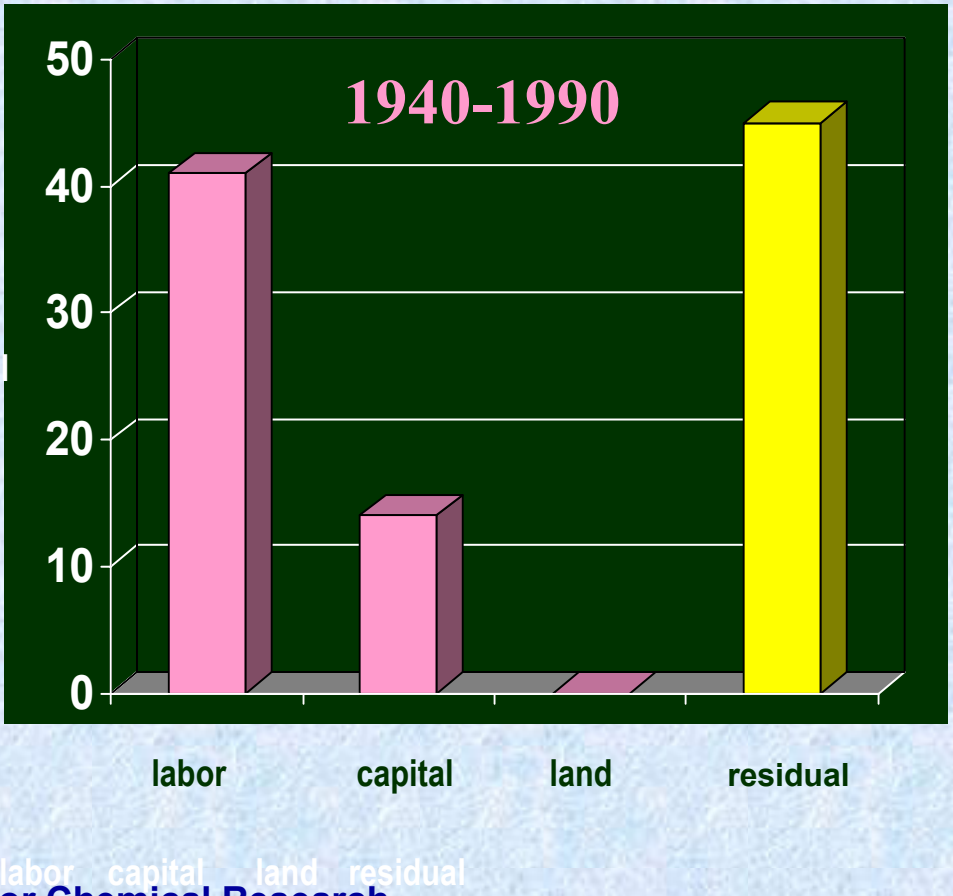
Robert M. Solow, a professor at the Massachusetts Institute of Technology, was awarded the 1987 Nobel Prize for Economics for identifying technological change as the chief factor underlying economic growth.

His 1957 article, *"Technical Change and the Aggregate Production Function,"* showed that half of economic growth cannot be accounted for by increases in capital and labor. He then demonstrated that technological change—ignored by mainstream theory—is responsible for that unaccounted-for portion of economic growth—now called the "Solow residual."

Measuring the "Solow" Residual







CCR Study

In the Fall 1999, the CCR commenced a special study with the objective:

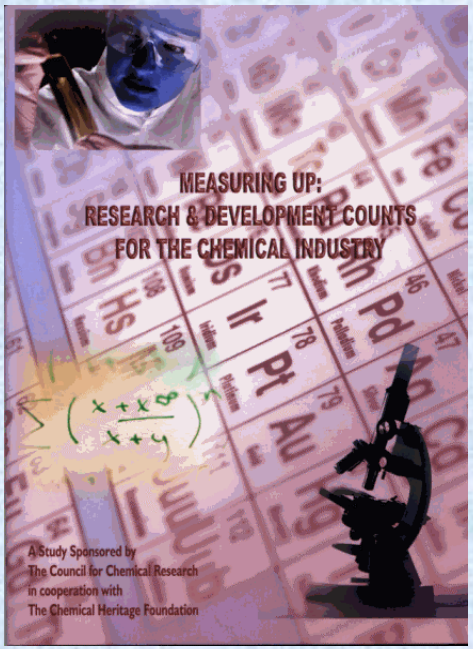
Measure the impact (return or payoff) of chemical research and development

- **Provide comprehensive and quantitative results**
- **Use leading edge methodologies**
  - **Econometric production function (Dr. Baruch Lev, NYU)**
  - **Bibliometric analysis (Dr. Francis Narin, CHI Research, now ipIQ)**

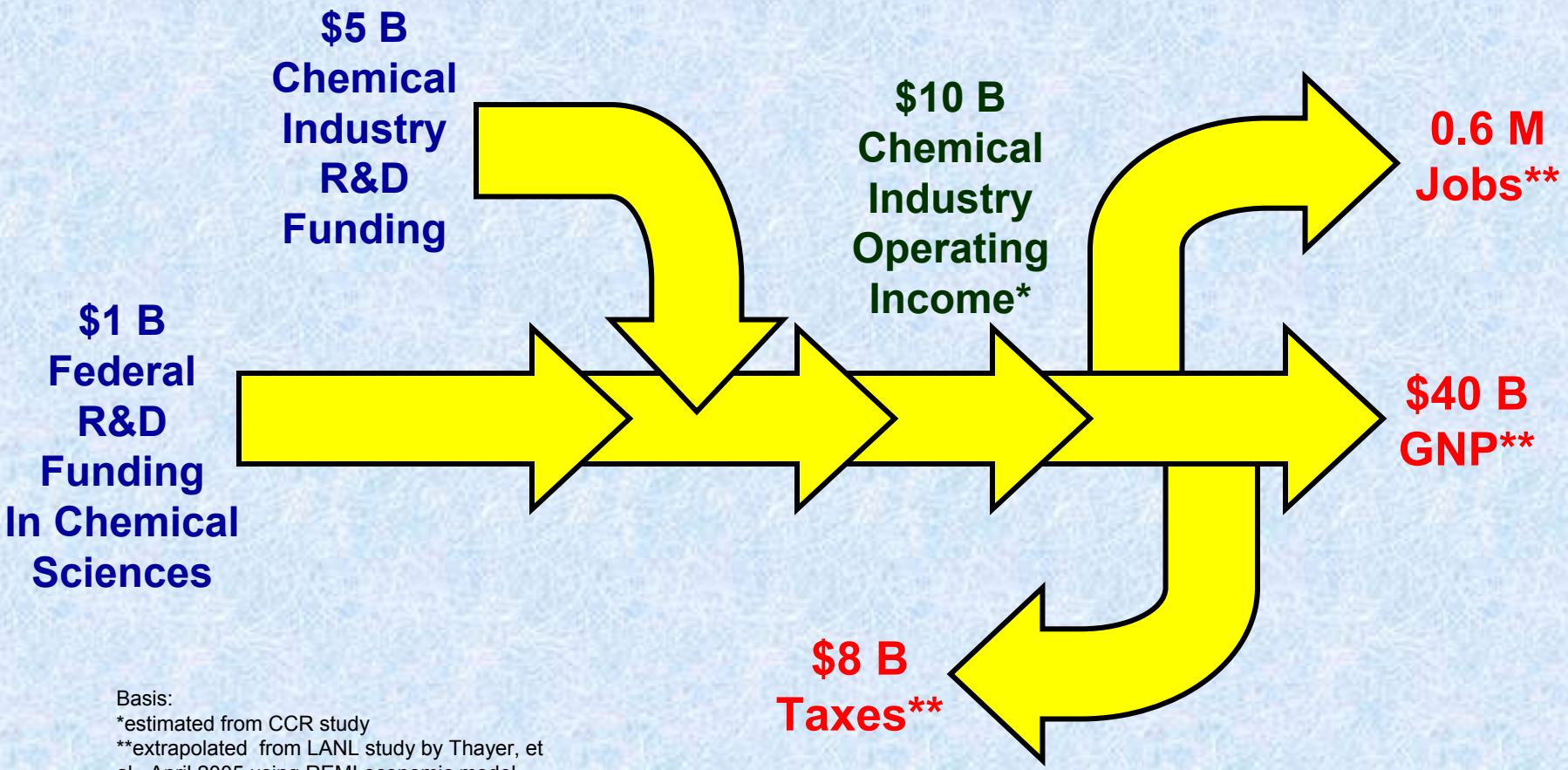
Phase I Results

- $2 Operating income per $1 R&D invested
  - 17% after tax return
- Publicly funded science links highly to chemical patents, 6 citations per patent
- Published Summer, 2001:

"Measuring Up: R&D Counts for the Chemical Industry"



Macroeconomic Implications



Basis:
*estimated from CCR study
**extrapolated from LANL study by Thayer, et al., April 2005 using REMI economic model

Phase II Results

- **To be published December 2005**

"Measuring Up: Chemical R&D Counts for Everyone"

Phase II

- What are the financial payoffs for technology quality, innovation speed and strong scientific links?
- What industries are significantly impacted by the chemical sciences?
- How long does it take for public funded science to yield commercial innovation?

Phase II

- What are the financial payoffs for technology quality, innovation speed and strong scientific links?
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Approach to Question 1

- Determine any correlations between chemical companies' patent holdings and their financial performance
- Financial measures included:
  - Sales
  - Market to book value
  - Stock price
- Bibliometric methodology (Patrick Thomas and Michael Albert, iplQ)

Patent Portfolio Indicators

Current Impact Index (CII)

– a measure of the impact of a company's patents, based on how frequently its patents are cited by subsequent patents

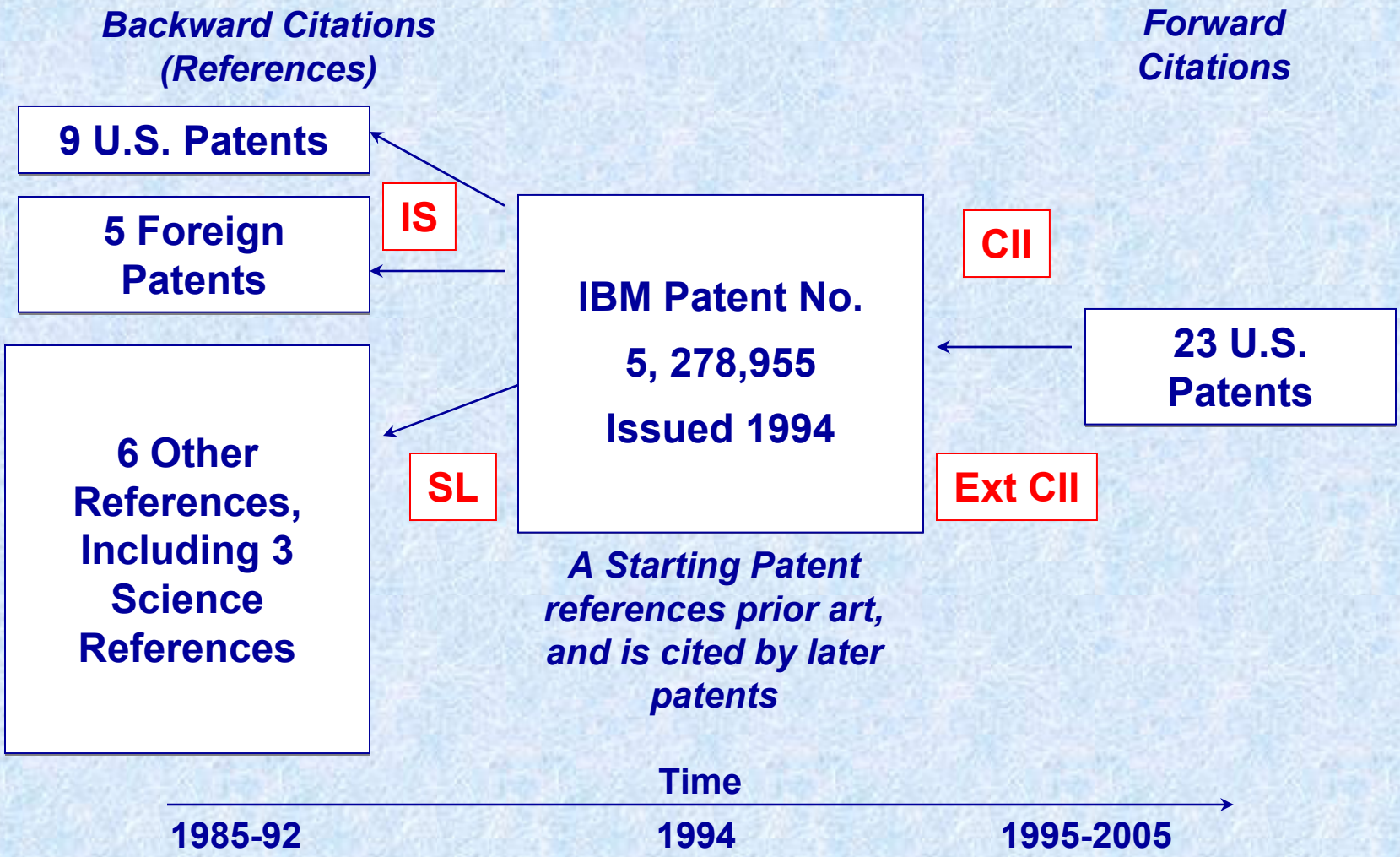
Science Linkage (SL)

– average number of citations a company's patents make to scientific papers, a measure of its links to scientific research

Innovation Speed (IS)

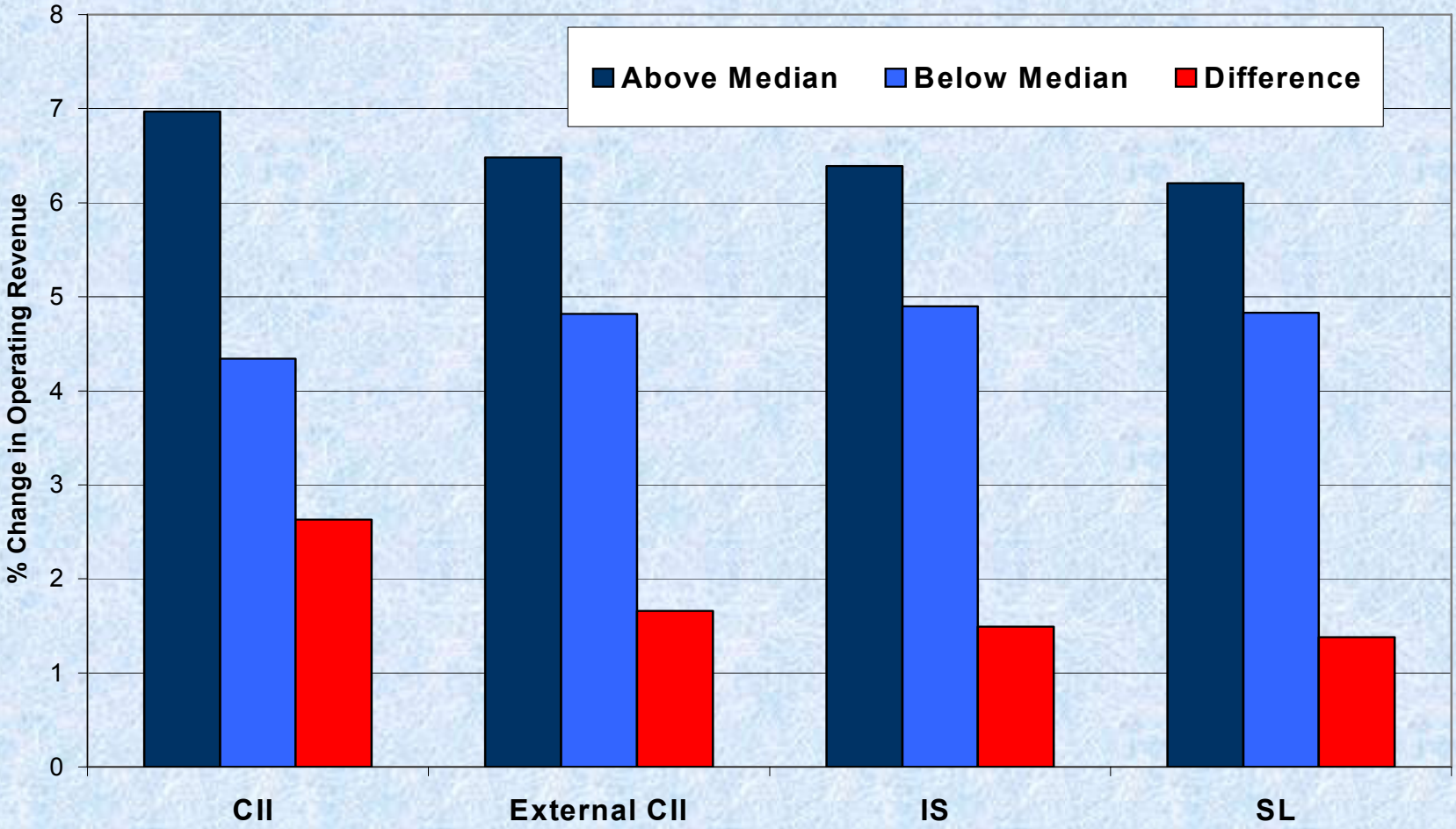
– measures median age of the patents cited by a company's patents, an indicator of its speed of innovation

Introduction to Patents and Patent Citation Analysis



Strong Patent Portfolios Correlate with Higher Sales Growth

Two year percentage change in operating revenue for chemical companies, divided based on being above and below median on different technology indicators



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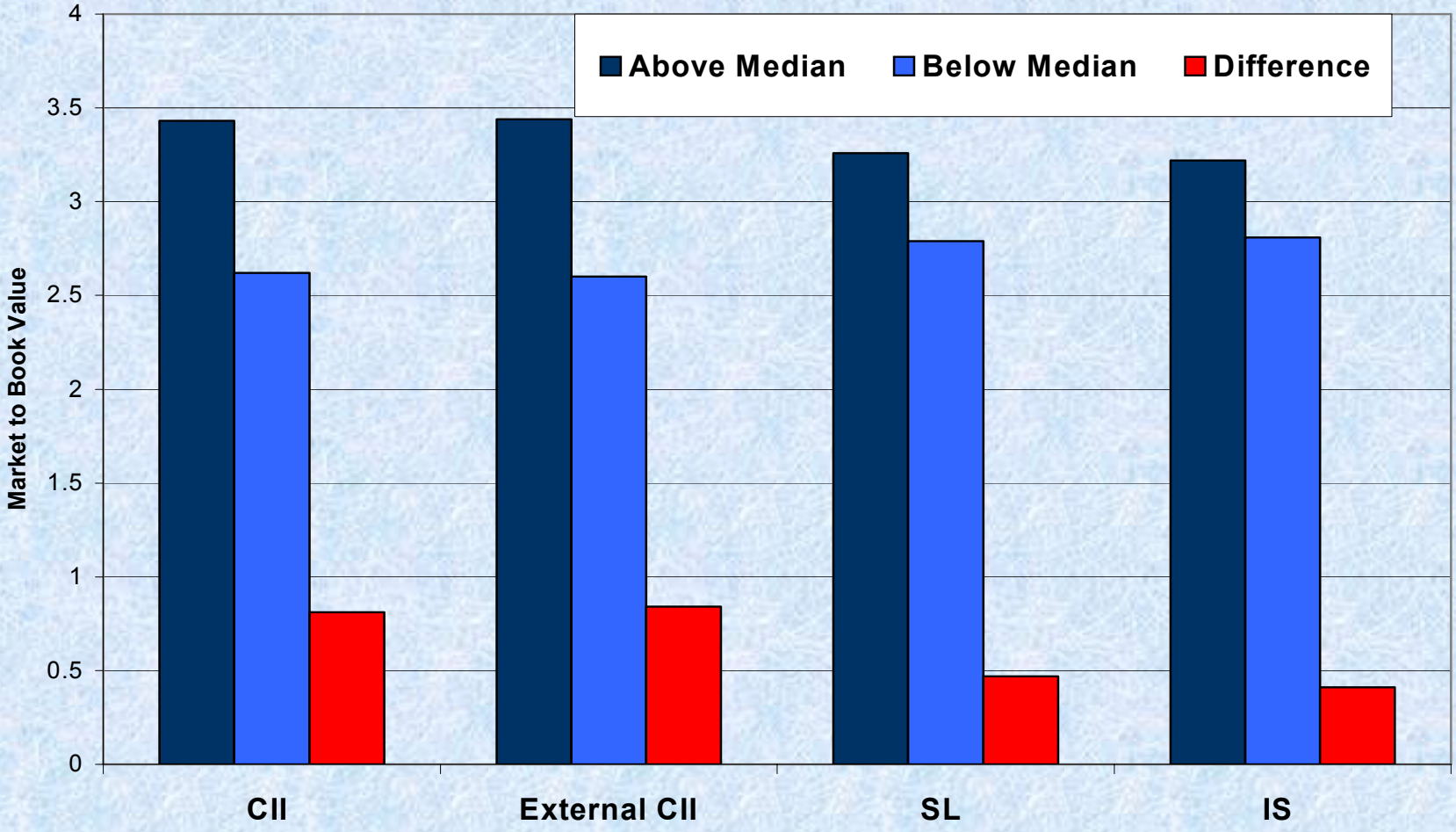
Strong Patent Portfolios Correlate with Higher Market to Book Values

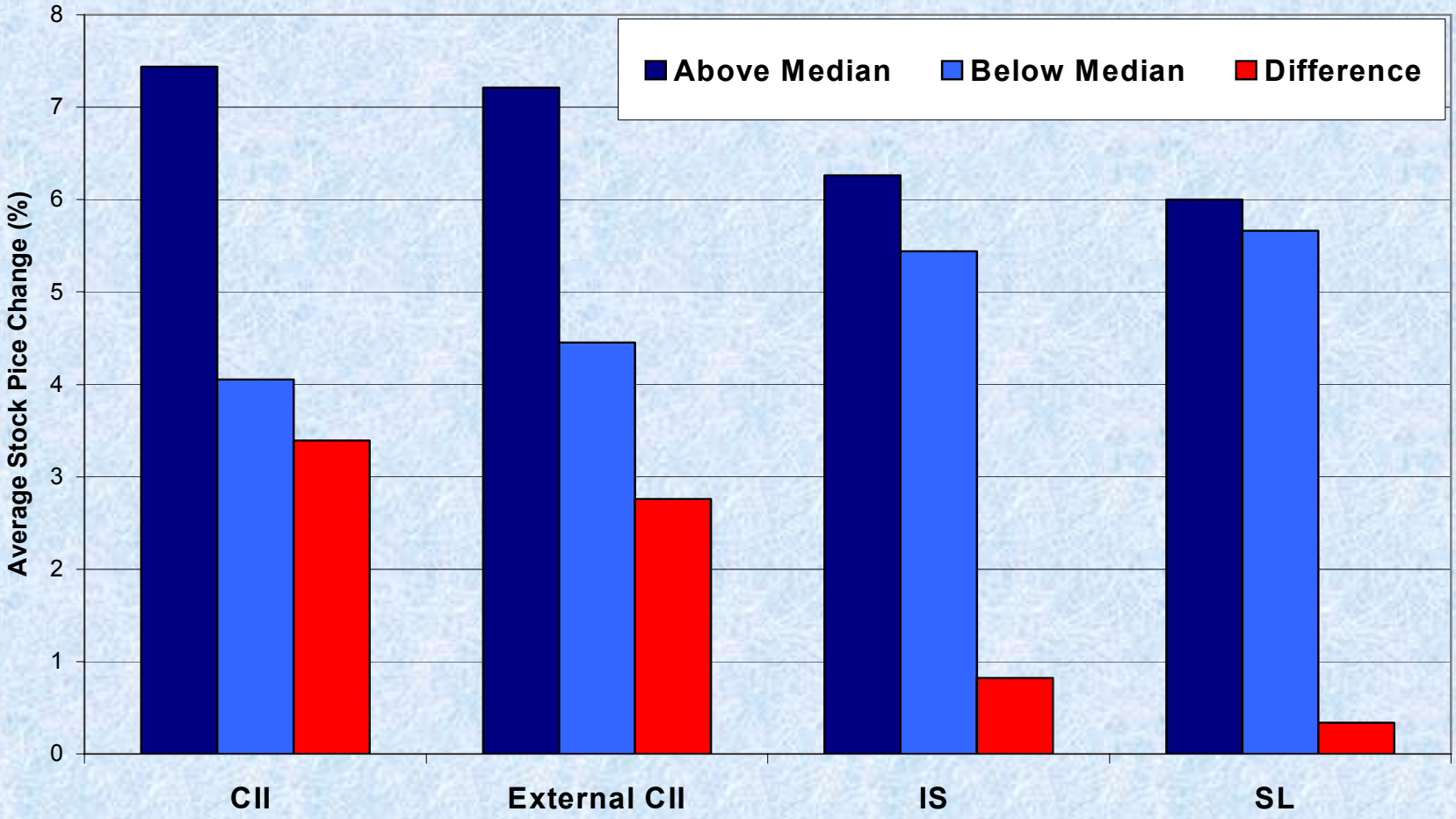
Market to Book values of chemical companies,
divided based on being above or below median values on different technology indicators



The Council for Chemical Research

Strong Patent Portfolios Correlate with Higher One Year Stock Price Growth

Average one-year stock price changes of chemical companies,
divided based on being above or below median values on different technology indicators



The Council for Chemical Research

Conclusion: Strong Technology Pays Off

Chemical companies with strong patent portfolio indicators tend to exhibit consistently strong financial performance, such as higher stock market valuations (35-60% higher on average)

- Correlation between CII (patent impact) and financial performance is particularly strong
- Correlations between financial performance and SL (science linkage) and IS (innovation speed) are also positive

Phase II

- What are the financial payoffs for technology quality, innovation speed and strong scientific links?
- What industries are significantly impacted by the chemical sciences?
- How long does it take for public funded science to yield commercial innovation?

Approach to Question 2

- **Examine patent database to determine which industries**
  - **Patent chemical technology vs. other technologies**
  - **Reference chemical technology patents vs. other technology patents**
  - **Reference chemical science literature vs. other sciences**
- **Bibliometric methodology (Michael Albert, Diana Hicks and Peter Kroll, ipIQ)**

The 15 Industries (1151 companies)

- Automotive* (90)
- Biotechnology* (41)
- Chemicals* (143)
- Computers & Semiconductors* (164)
- Electrical & Electronics* (116)
- Energy (34)
- Engineering, Oil Field Services (5)
- Food, Beverage & Tobacco* (28)
- Forest, Paper, Textiles* (37)
- Health Care (78)
- Instruments & Optical (49)
- Materials (24)
- Metals & Mechanical (238)
- Pharmaceuticals* (58)
- Telecommunications* (46)

* - denotes names that are very similar to the names of a technology

The 29 Technologies

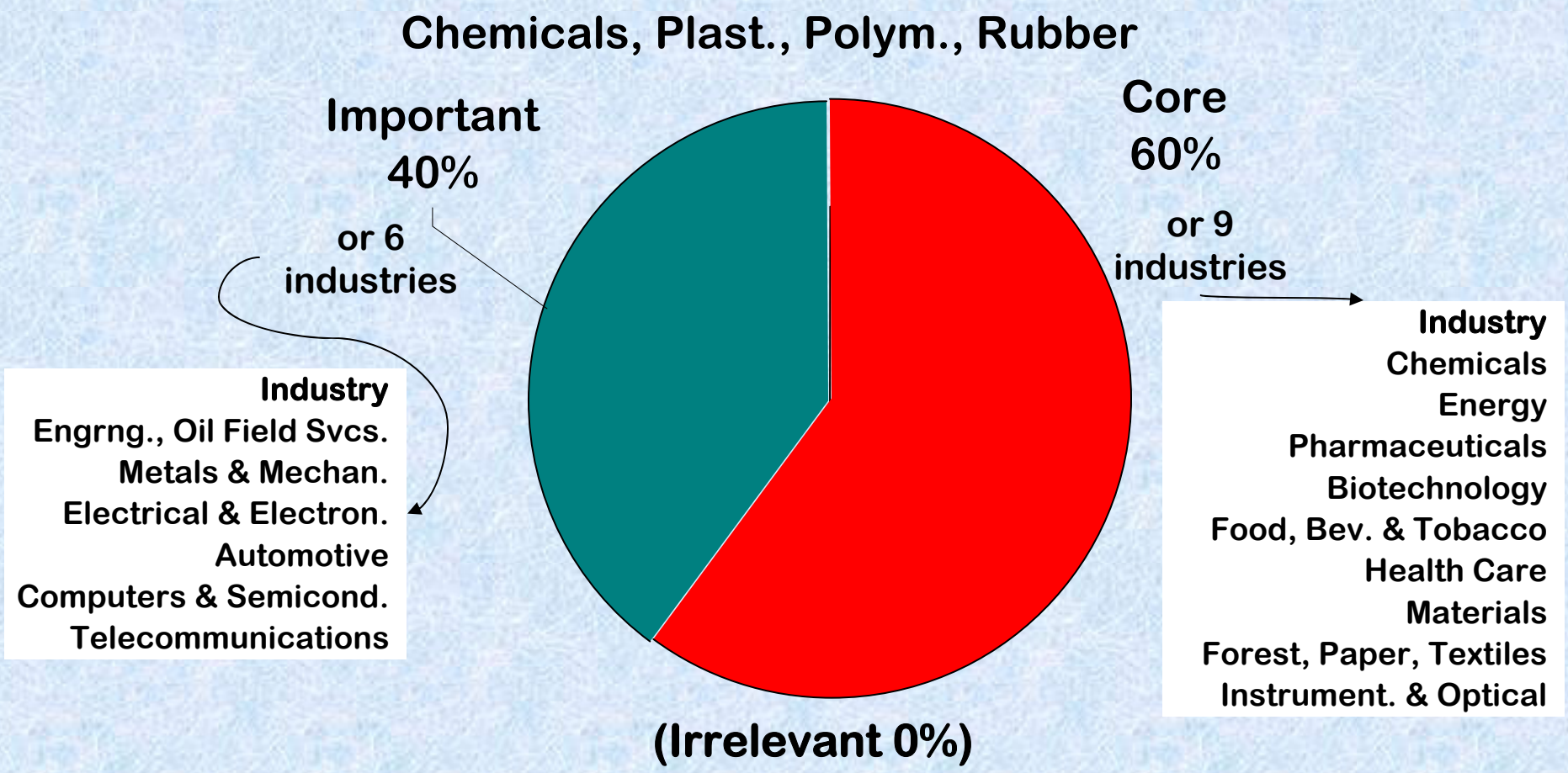
- Aerospace & Parts
- Agriculture
- Biotechnology*
- Chemicals, Plastics, Polymers & Rubber*
- Computers & Peripherals*
- Electrical Appliances & Components
- Fabricated Metals
- Food & Tobacco*
- Glass, Clay & Cement
- Heating, Ventilation & Refrigeration
- Industrial Machinery & Tools
- Industrial Process Equipment
- Measurement & Control Equipment
- Medical Electronics
- Medical Equipment
- Miscellaneous Machinery
- Motor Vehicles & Parts*
- Office Equipment & Cameras
- Oil & Gas, Mining
- Other
- Other Transport
- Pharmaceuticals*
- Power Generation & Distribution
- Primary Metals
- Semiconductors & Electronics*
- Telecommunications*
- Textiles & Apparel*
- Wood & Paper*

* – denotes names that are very similar to the names of an industry

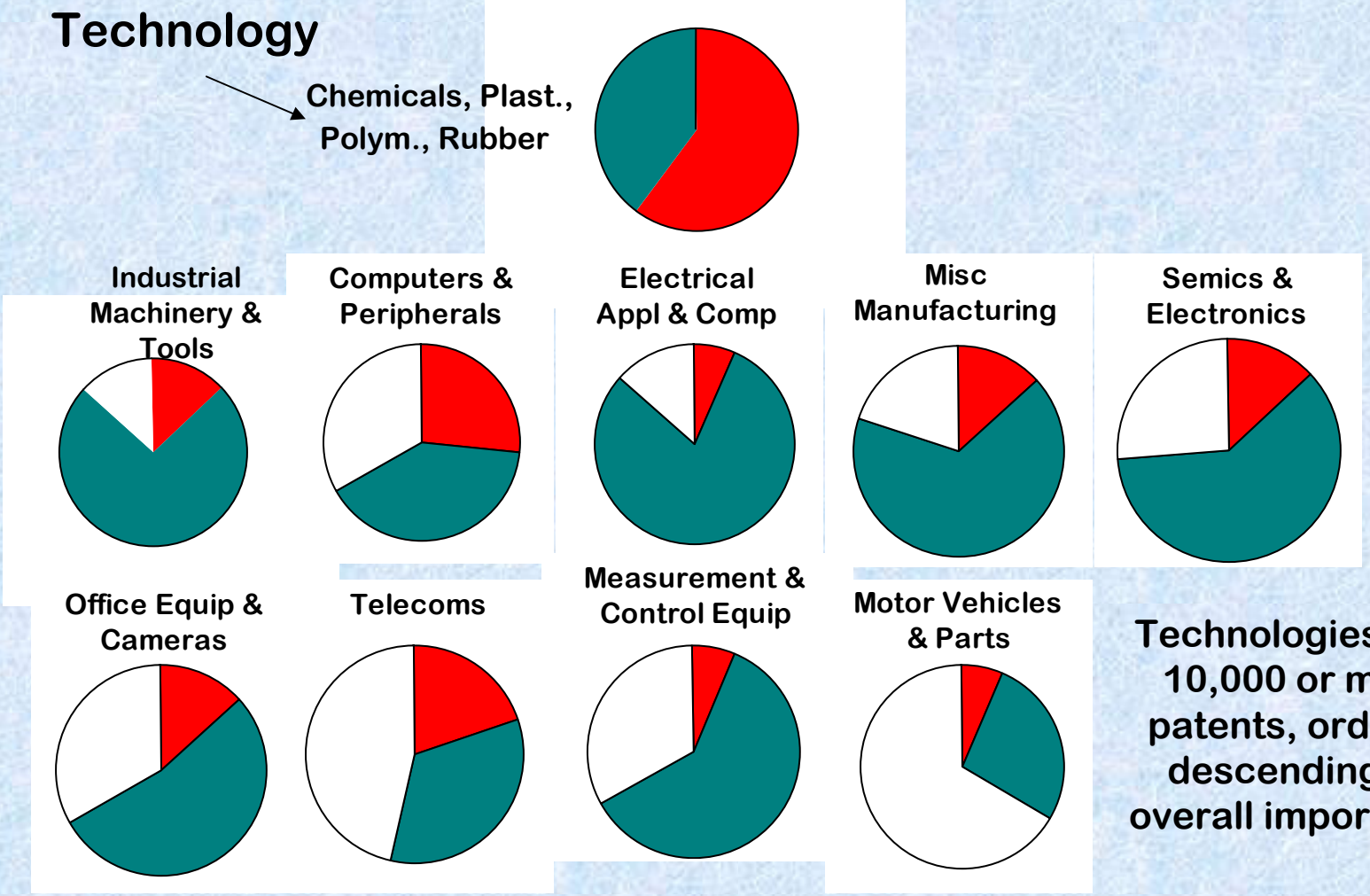
How many industries build on chemical technology?

- **Definitions:**
  - ■ Core technology: Technology accounts for at least 10% of patents or citations for an industry
  - ■ Important technology:Technology accounts for between 1% and 10% of patents or citations for an industry
  - □ Irrelevant technology: Technology accounts for less than 1% of patents or citations for an industry

Chemical technology creation is core or important in all 15 of the industries



No other technology comes close

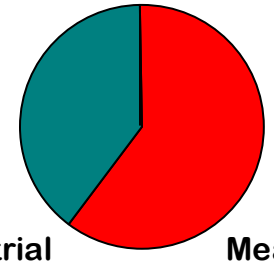


Technologies with 10,000 or more patents, ordered descending by overall importance

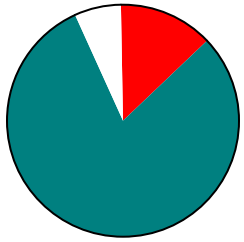
Again, no other technology comes close

Cited Technology →

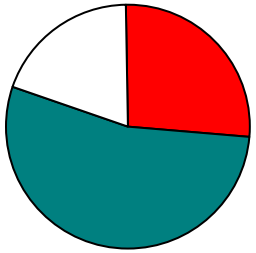
Chemicals, Plast., Polym., Rubber



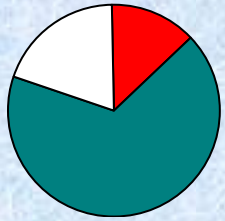
Misc. Manufacturing



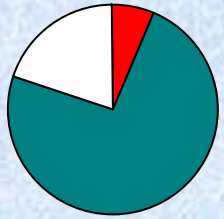
Computers & Peripherals



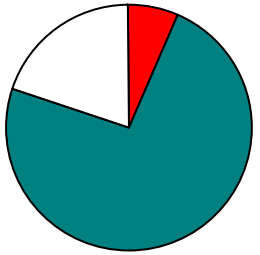
Industrial Machinery & Tools



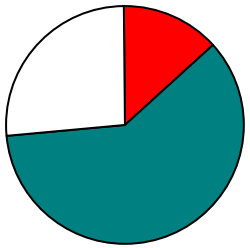
Measurement & Control Equip



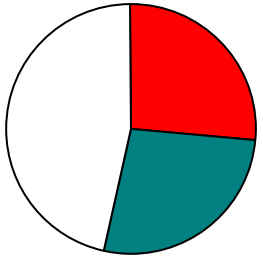
Electrical Appl & Comp



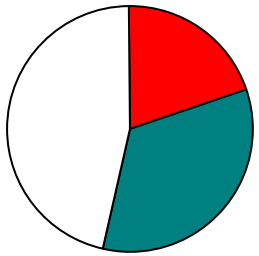
Semics & Electronics



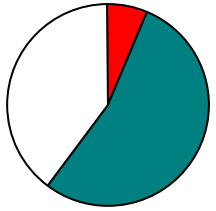
Telecoms



Medical Equipment



Office Equipment & Cameras

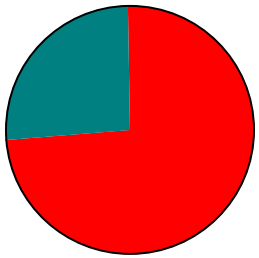


Technologies whose patents earned at least 60,000 citations, descending by overall importance

Science Base Across Industries: Chemistry Ranks First

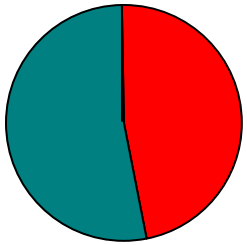
Scientific field →

Chemistry

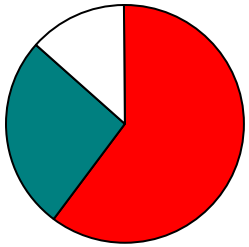


■Core
■Important
□Irrelevant

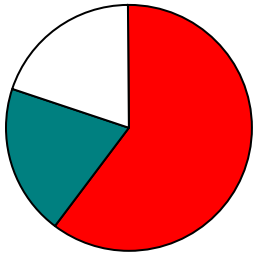
Biomedical Research



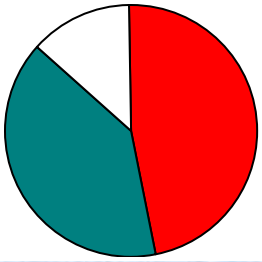
Engineering & Tech



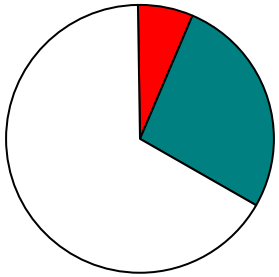
Physics



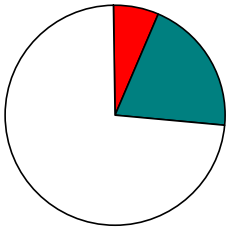
Clinical Medicine



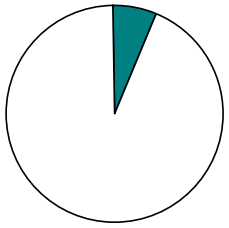
Biology



Earth & Space



Mathematics



Small fields with <3% total citations

Fields ordered descending by overall importance

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Conclusion: Chemistry is the most enabling science / technology

More than any other technology:

- **All industries create chemical technology.**
  Evidence: patent counts
- **The underpinning of all industries' technology relies on chemical technology.**
  Evidence: industry-to-technology patent citations
- **Chemistry is an important part of the science base of all industries.**
  Evidence: patent-to-paper citations

Phase II

- What are the financial payoffs for technology quality, innovation speed and strong scientific links?
- What industries are significantly impacted by the chemical sciences?
- How long does it take for public funded science to yield commercial innovation?

Approach to Question 3

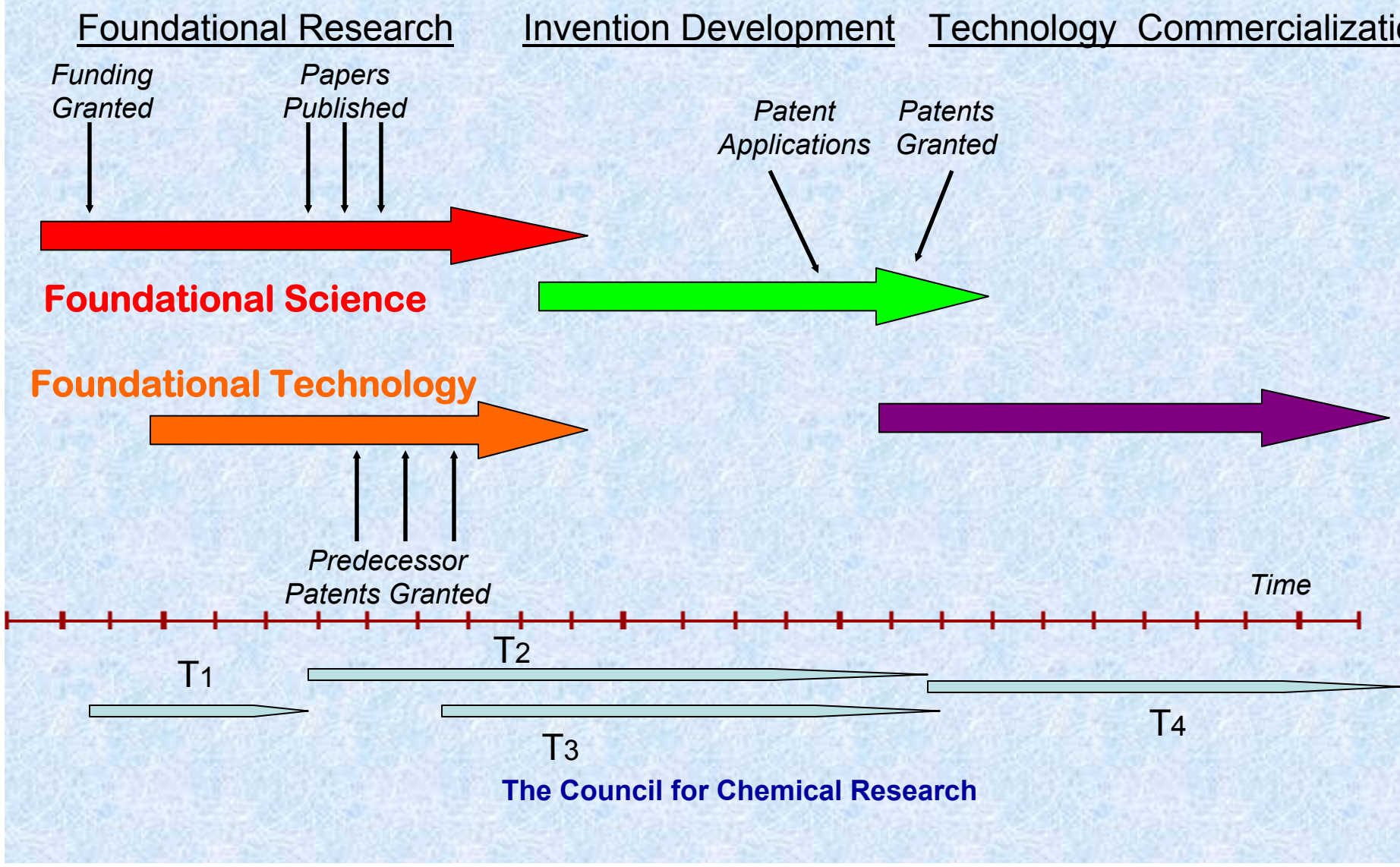
Trace the average time spans from successful commercial innovations back to originating patents and scientific literature citations. Determine start of funding from literature acknowledgements.

Time intervals to determine:

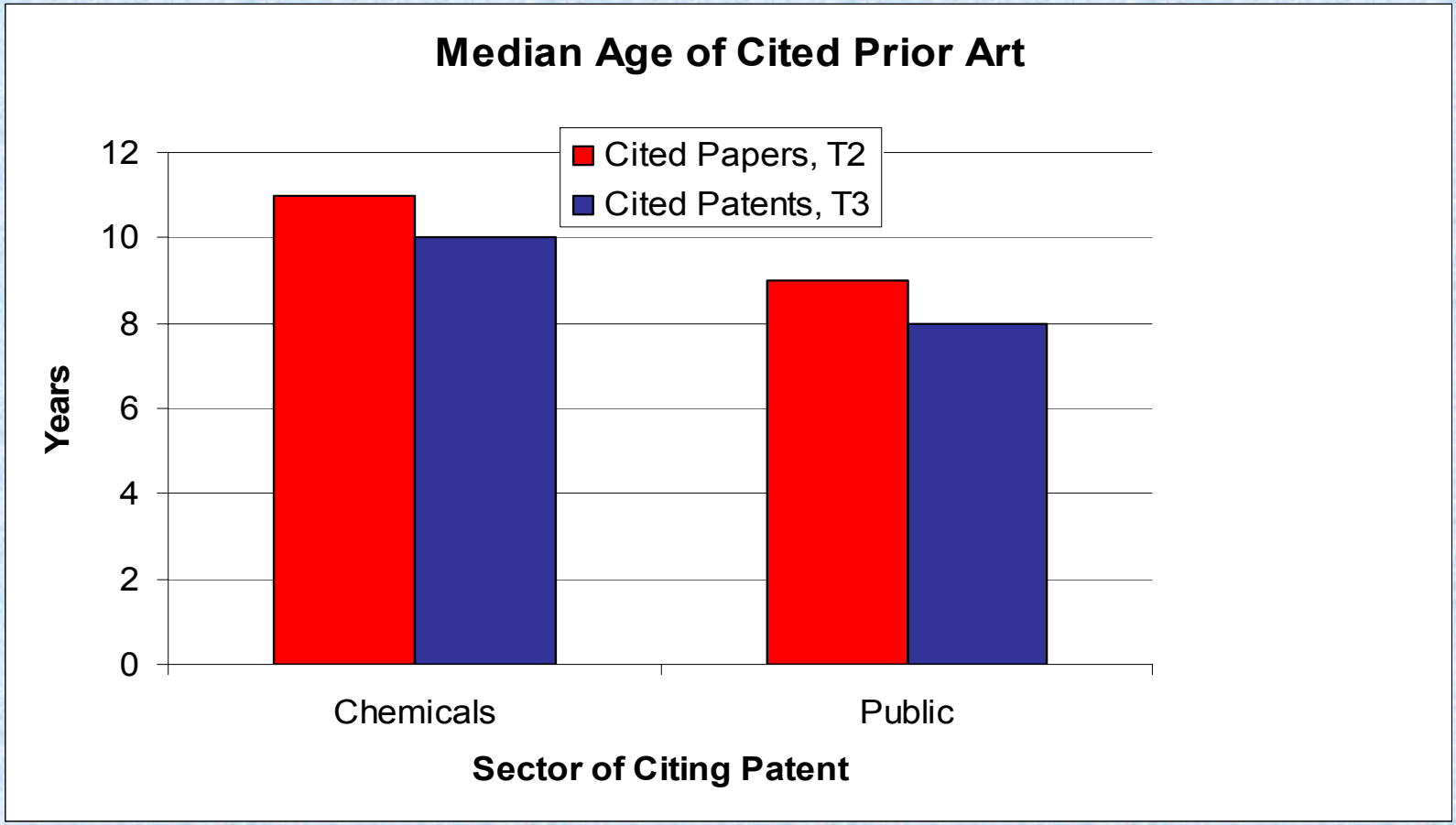
- **T_1 = time from grant funding to paper publication**
- **T_2 = time from paper publication to citing patent grant date (Science-to-Technology Cycle Time)**
- **T_3 = time from predecessor patent issuance to patent grant date (Technology Cycle Time)**
- **T_4 = time from patent issuance to product commercialization**

Bibliometric methodology (Peter Kroll, ipIQ)

Timeline from Conception to Market



Age of Cited Prior Art



A Sample of Cited Science References (Papers) Was Examined in Detail

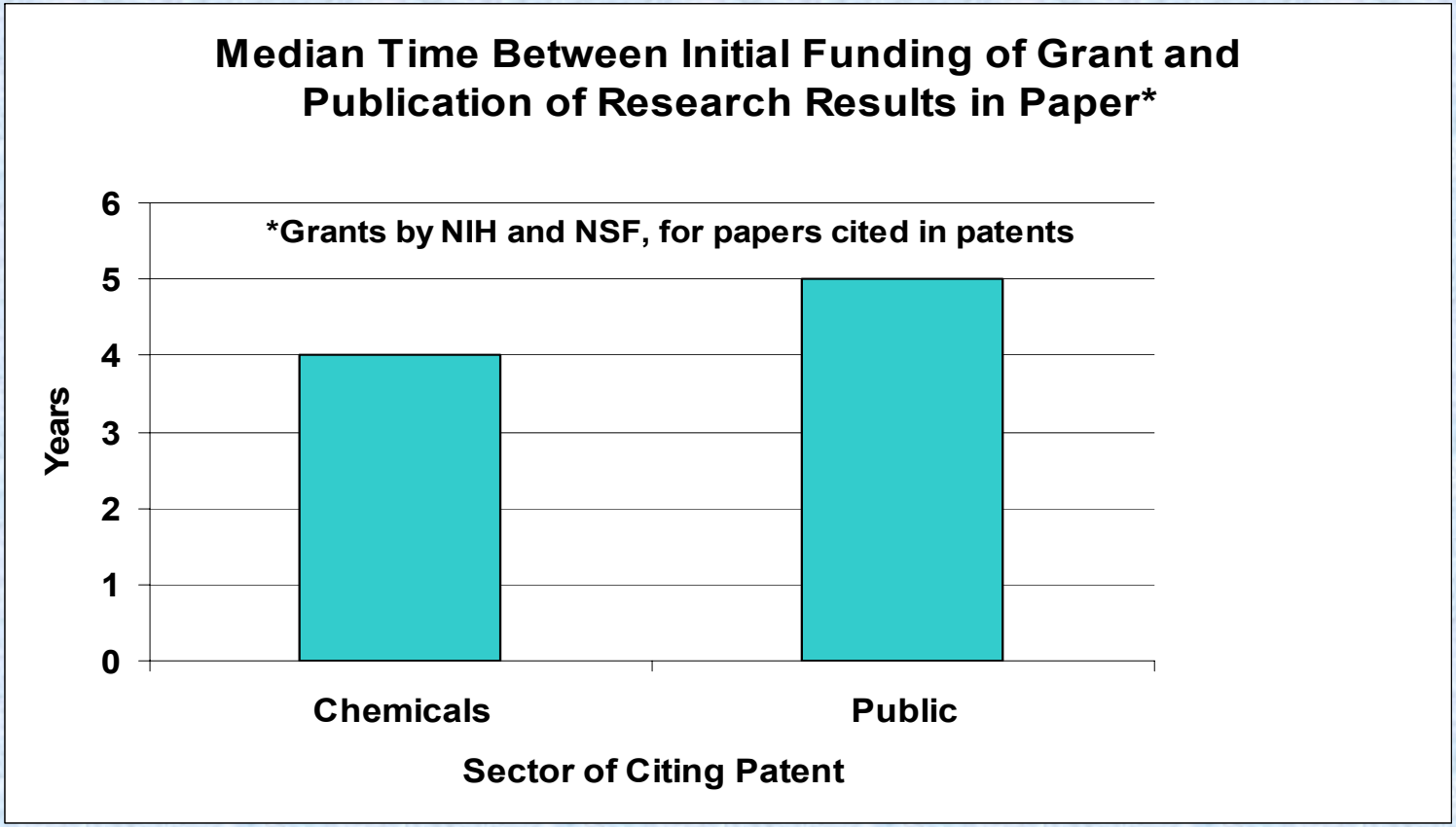
1. 355 papers cited by Chemical Industry patents,
   395 papers cited by Public Sector patents

2. In library, identified (if possible) each paper's
   - Grant identifiers, where funding was acknowledged
   - Author institution sector

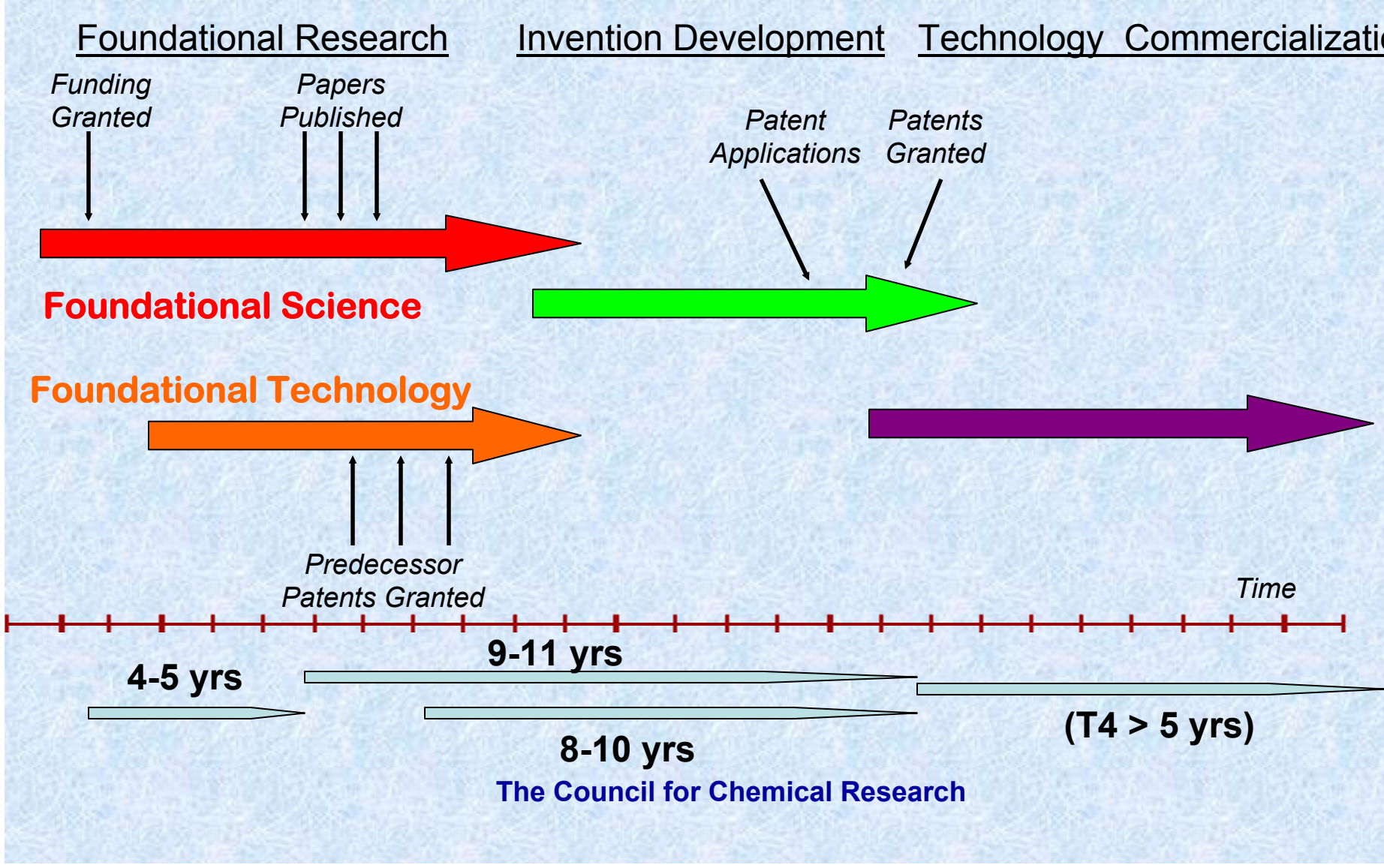
3. Determined date of grant from grant identifier
   - only for NIH and NSF grants

4. Calculated time from grant issuance to paper publication

Time from Grant to Paper



Timeline from Conception to Market



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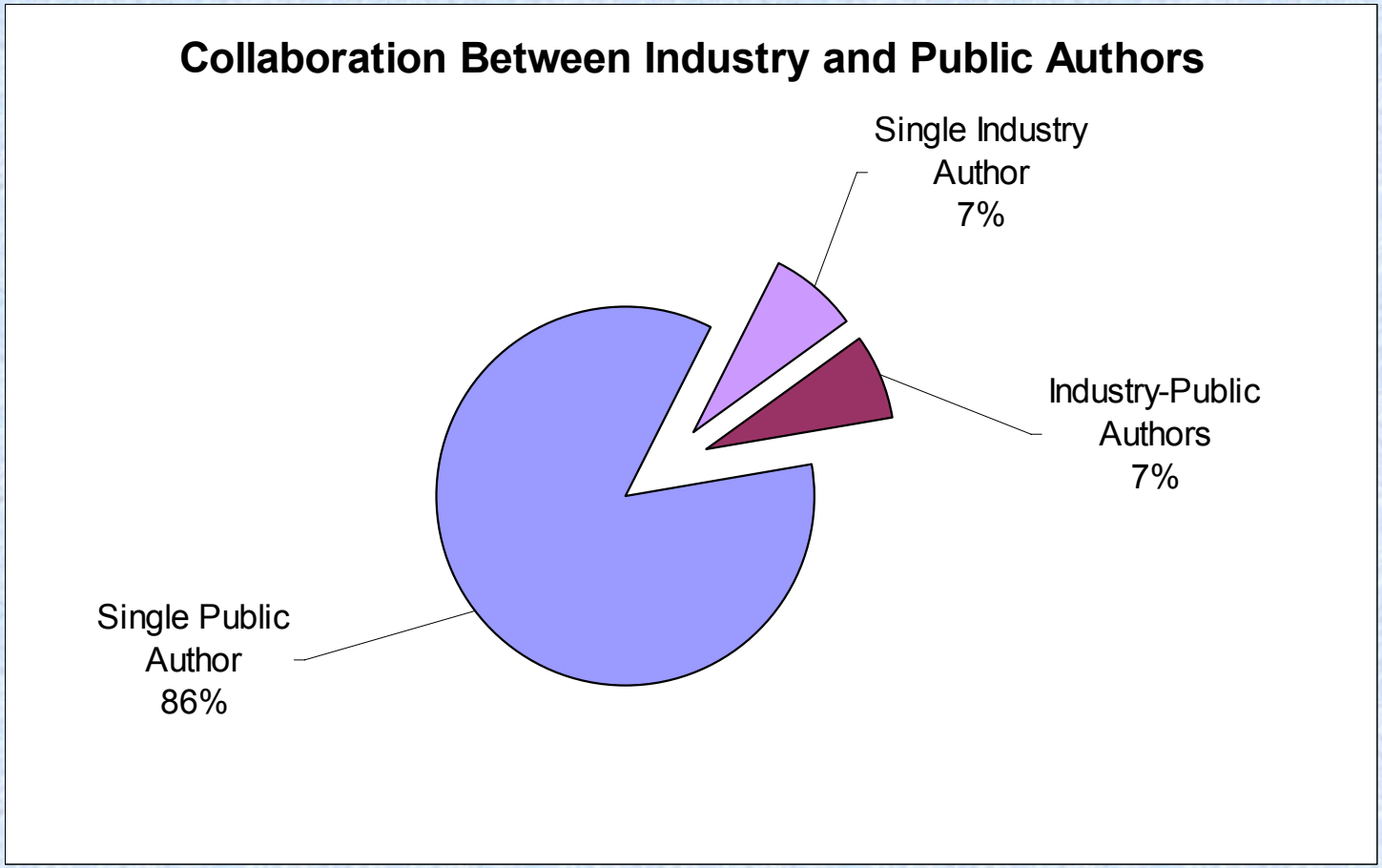
Findings

- The time for the results of basic research to reach the stage of patented invention may typically take 13-16 years from the time funding is provided by a support agency.
- On average, the lag to commercialization from patent is additional 5+ years providing an overall cycle time of 18-21+ years.

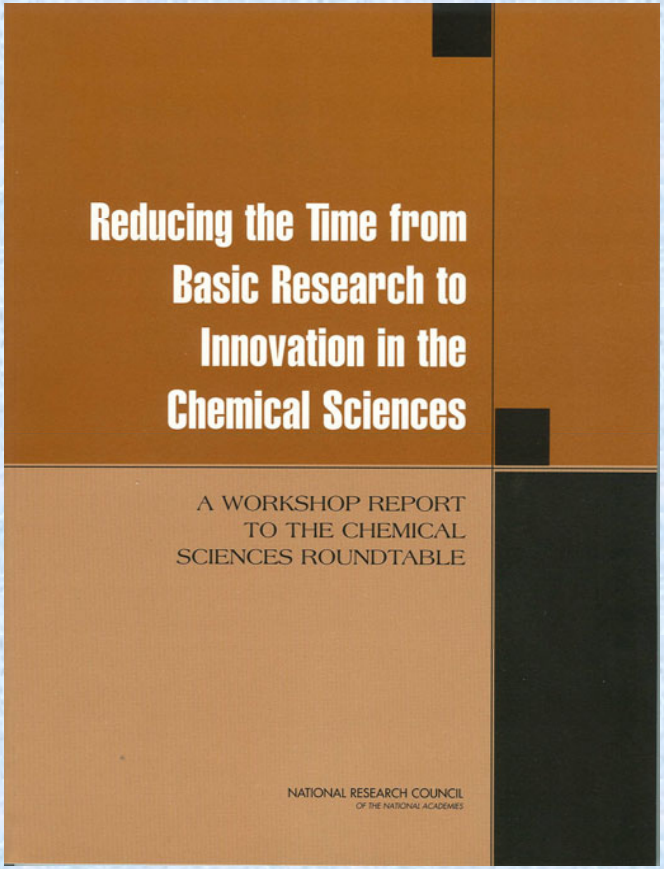
Limited Collaboration in Cited Papers



NRC Workshop

"Reducing the Time from Basic Research to Innovation in the Chemical Sciences"

- June 4, 2002
- 54 participants
- Workshop report to Chemical Sciences Roundtable, Board on Chemical Sciences and Technology



Conclusion: Big Opportunity to Reduce Innovation Cycle Time

- Industry focused on later stages of innovation, in particular, applied research and patenting to commercialization
- Limited collaboration at basic research stage
- Significant upside financial value if 20 year innovation cycle is shortened

Overall Conclusions

- Chemical companies get $2 of operating income for every $1 of R&D invested; that's a 17% after tax return.
- Technology quality, innovation speed and strong scientific links deliver greater shareholder value.
- Chemical technology is highly dependent on publicly funded chemical science research
- All industries are significantly impacted by the chemical sciences. It is the most enabling science and technology.
- The big opportunity is to reduce the 20-year innovation time lag from initial public research funding to commercialization.

Acknowledgements

Funding provided by

- National Science Foundation
- National Institutes of Health
- CCR member organizations