



# University-industry interactions and innovative universities: models and measurement

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Keynote at roundtable “Governance of System Innovation:  
System Innovation Axes: Universities & Entrepreneurship”



Universiteit  
Leiden

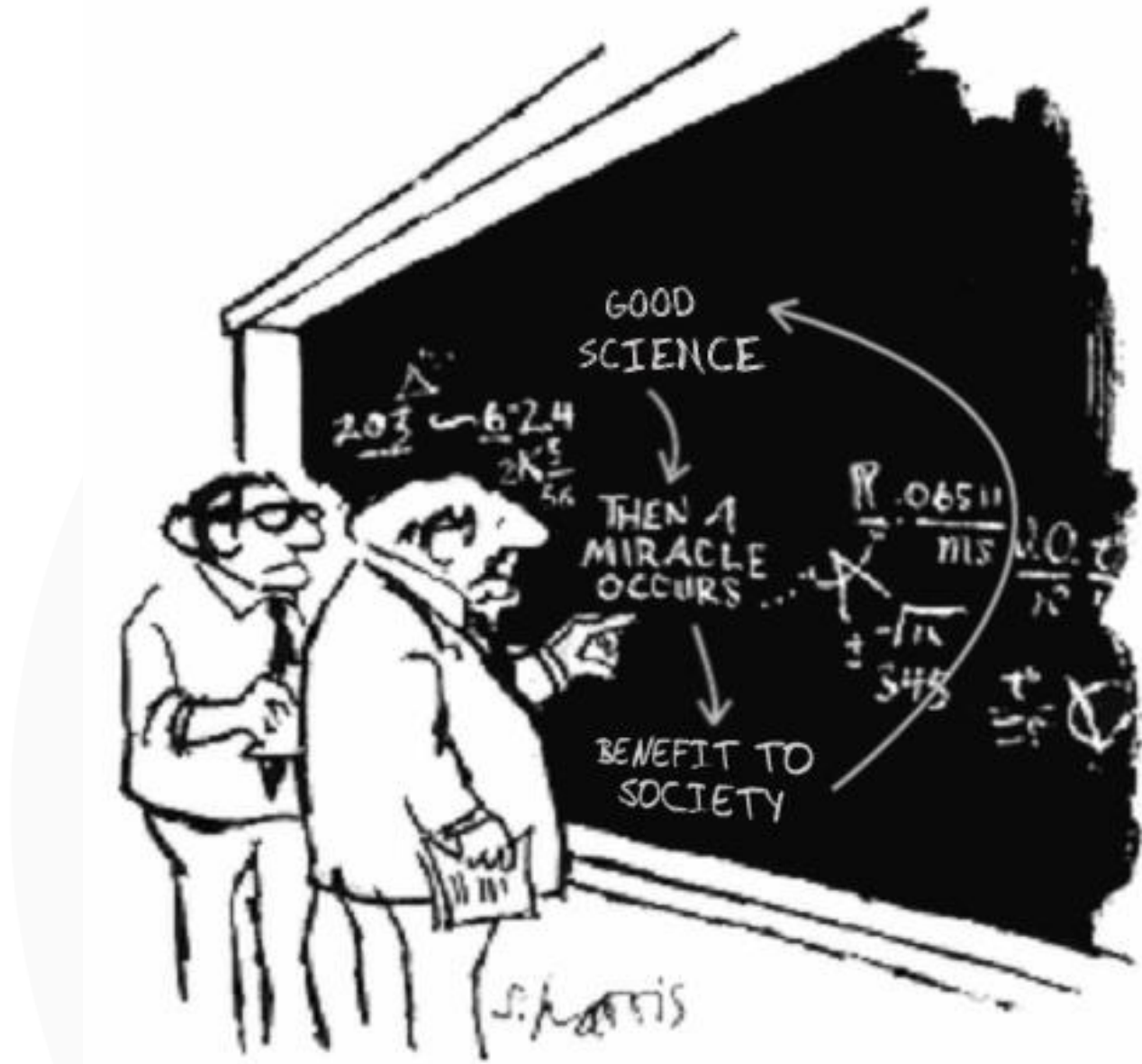
6 July 2017 (FAPESP, São Paulo, Brazil)

# Outline

- Models: dealing with complexity and uncertainty
- Measurement models and indicators of university-industry interactions
- Bibliometric analysis of Brazilian university-industry research cooperation
- Brazilian ‘innovative universities’
- Pasteur’s Quadrant model and innovative universities
- Discussion: models, measurement and evidence-informed policies

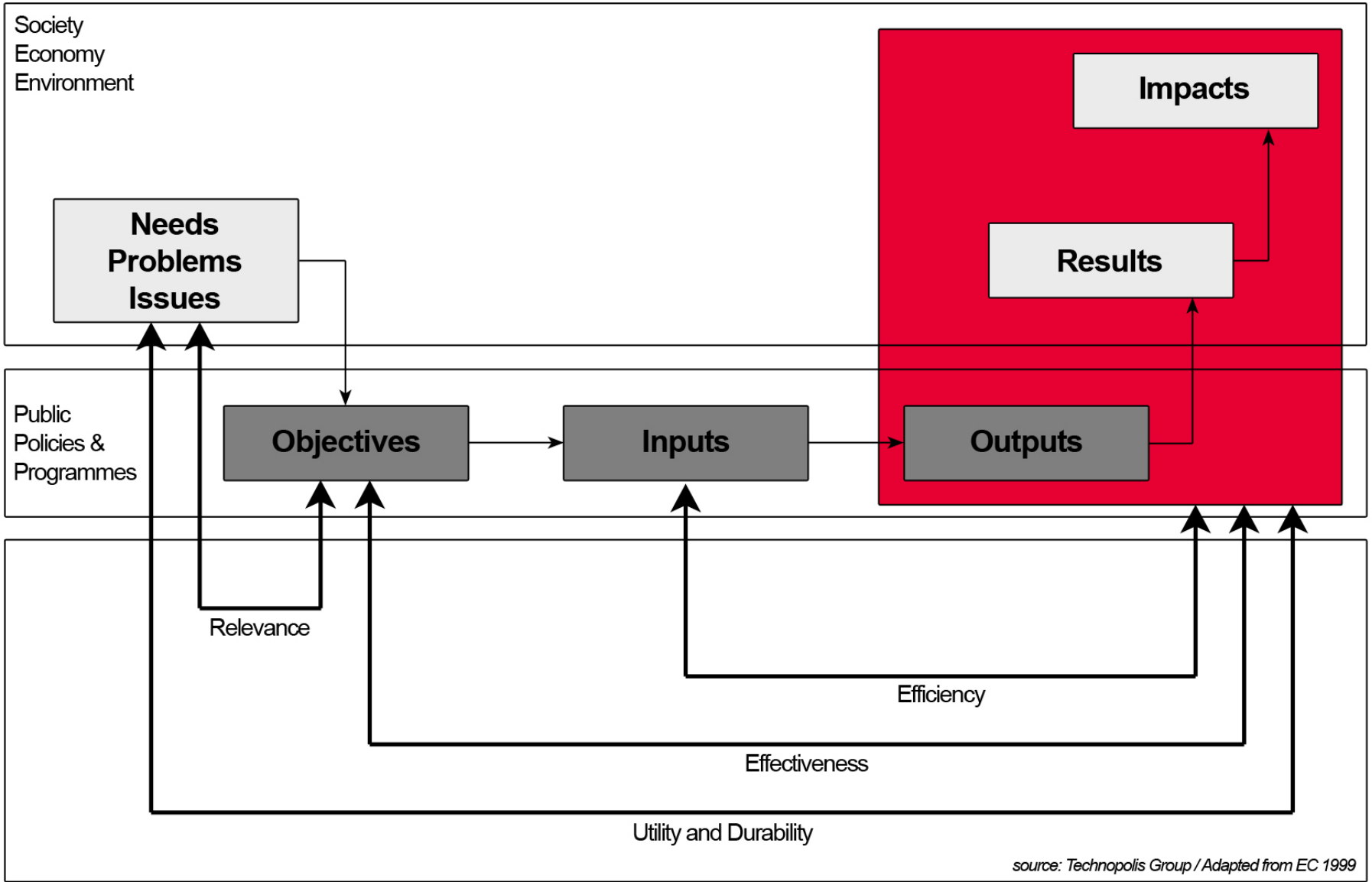
# Models: dealing with complexity and uncertainty





*Are there any workable analytical models !?*

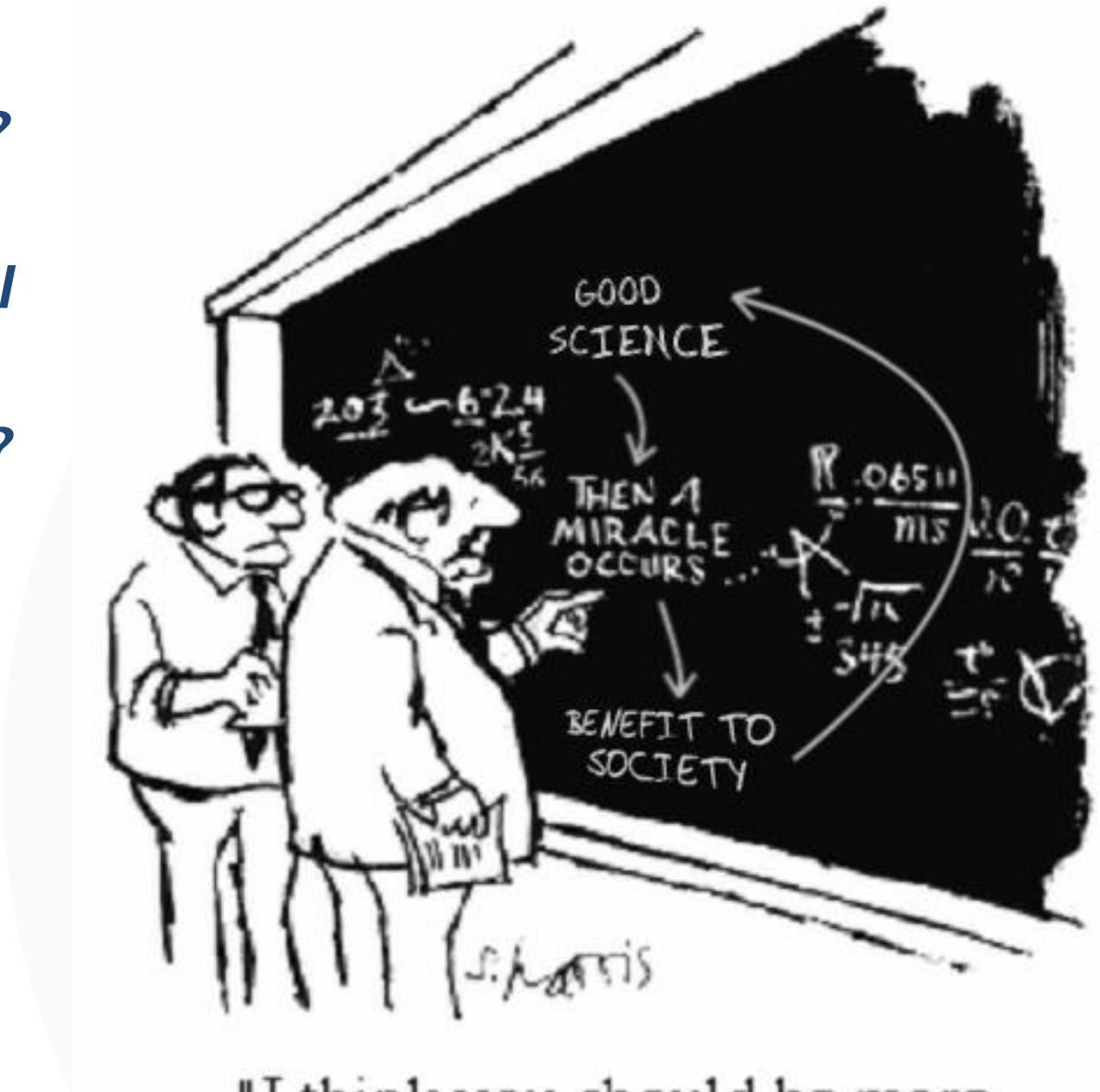
"I think you should be more explicit here in step two."



*Is this a workable analytical model !?*

*Is there any useful empirical data and information !?*

*How to deal with chance events?*



"I think you should be more explicit here in step two."

# Impacts of science

## Science

- Knowledge
- Research activities
- Graduate training

## Technology

- Products and processes
- Services

- Know-how

## Economy

- Production
- Financing
- Investments
- Commercialization
- Budget

## Culture

- Knowledge
- Know-how
- Attitudes
- Values

## Society

- Welfare
- Discourses and actions of groups

## Policy

- Policy-Makers
- Citizens
- Public programs
- National security

## Organization

- Planning

## Work organization

- Administration
- Human resources

## Health

- Public health
- Health systems

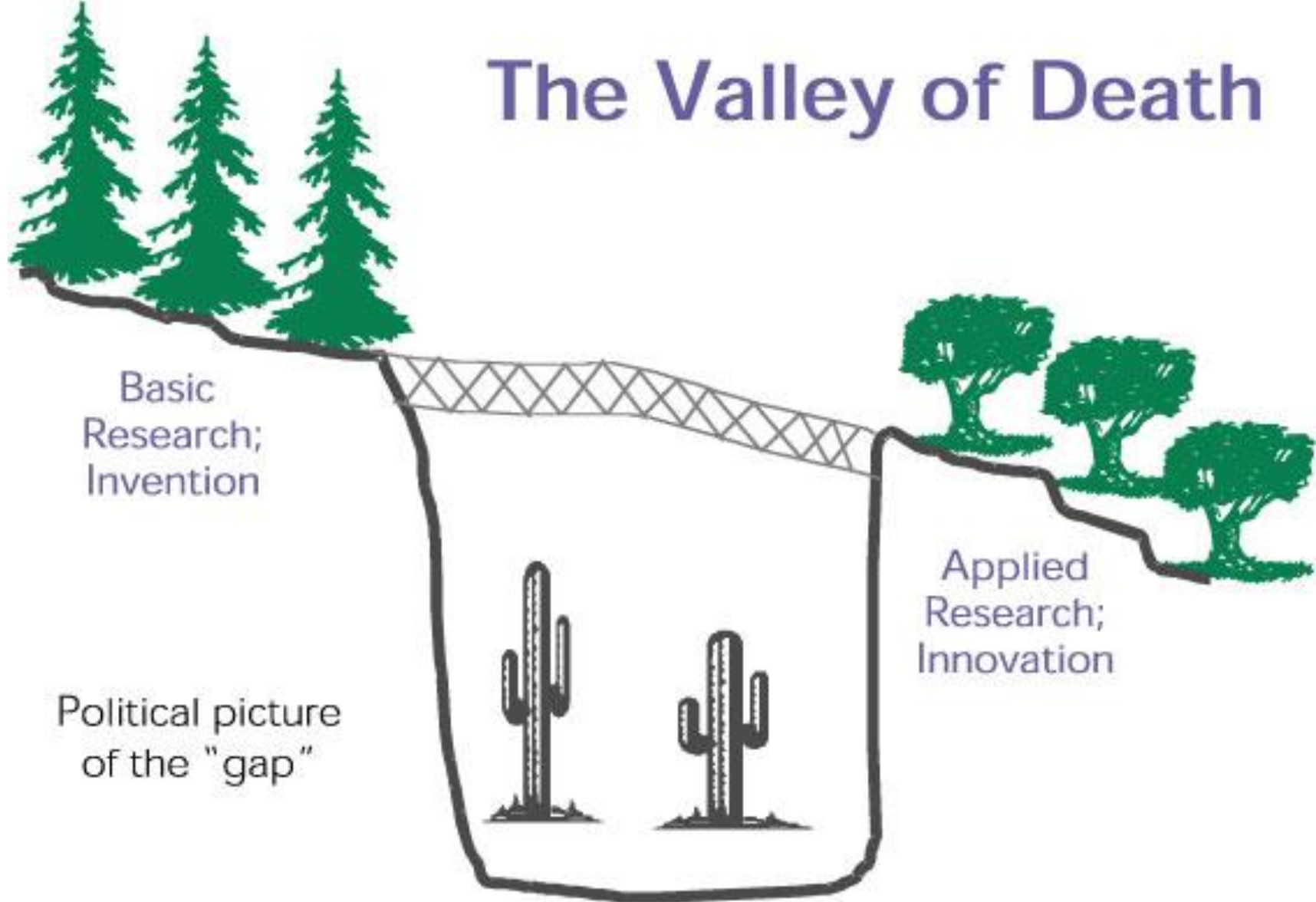
## Environment

- Management of natural resources and the environment
- Climate and meteorology

## Education

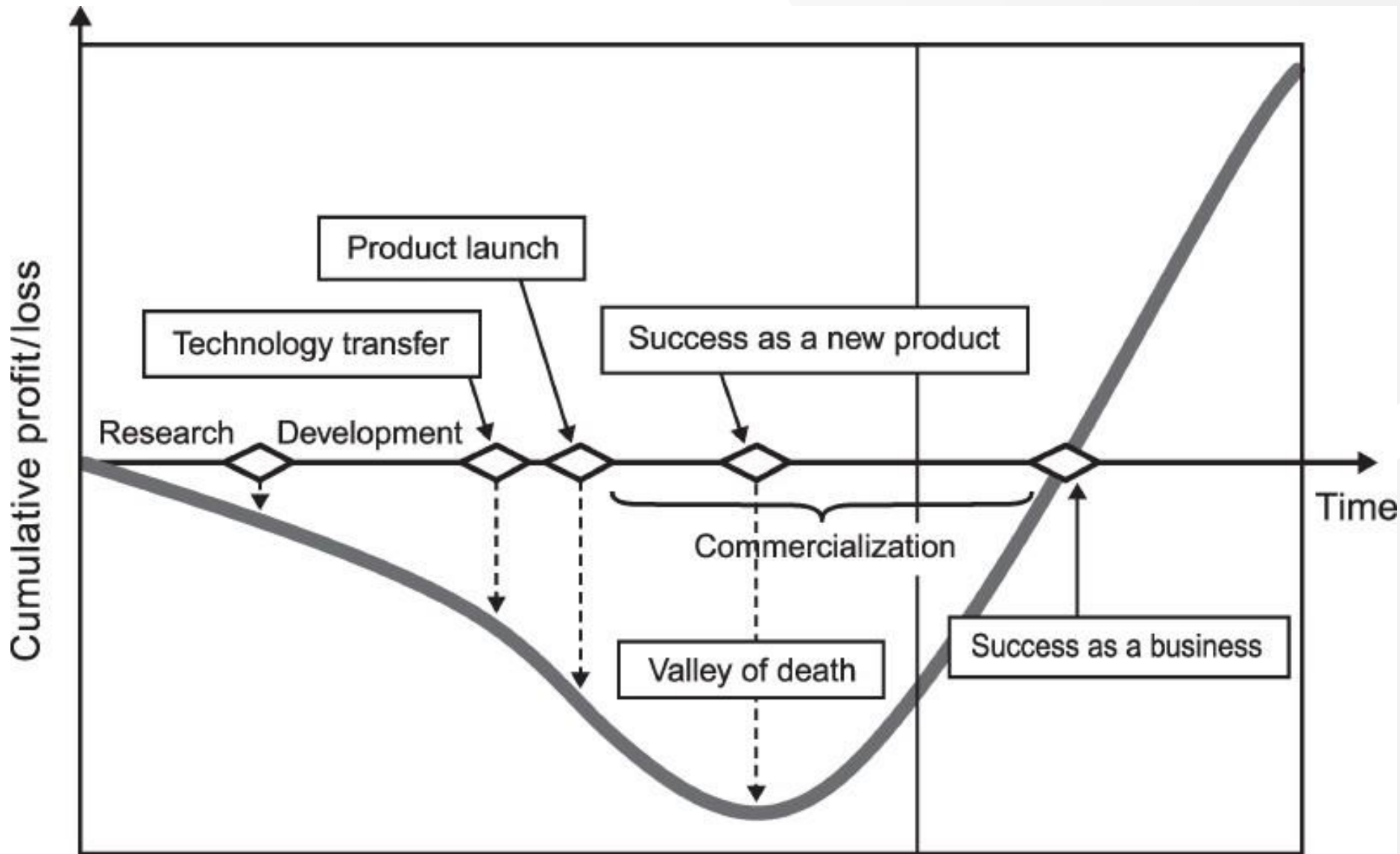
- Curricula
- Teaching tools
- Qualifications
- Insertion into the job market
- Fitness of training/work
- Careers
- Use of acquired knowledge

# The Valley of Death

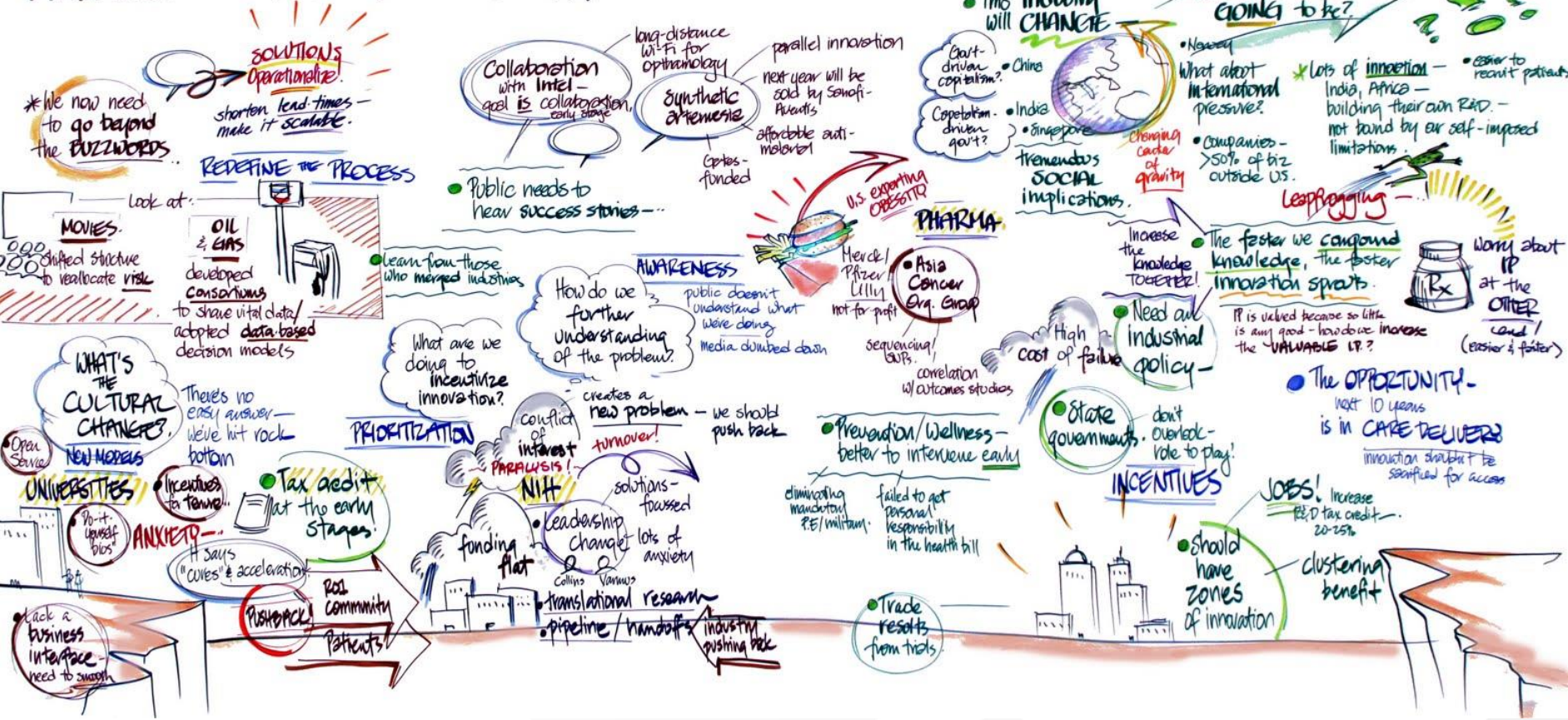


"Valley of Death"





# MAPPING THE VALLEY OF DEATH



# Diabolical dilemma's of complex systems



- Science and innovation policies, and policy initiatives, are always embedded in **complex adaptive systems**
- To design, manage, monitor and evaluate policies we need **useful models** and **timely and relevant information**
- Complex dynamic systems can **never be fully captured** by models (no available information of individual parts; specific outcomes or impacts are **difficult to isolate** from other determinants or factors; **causality and attribution** problems)



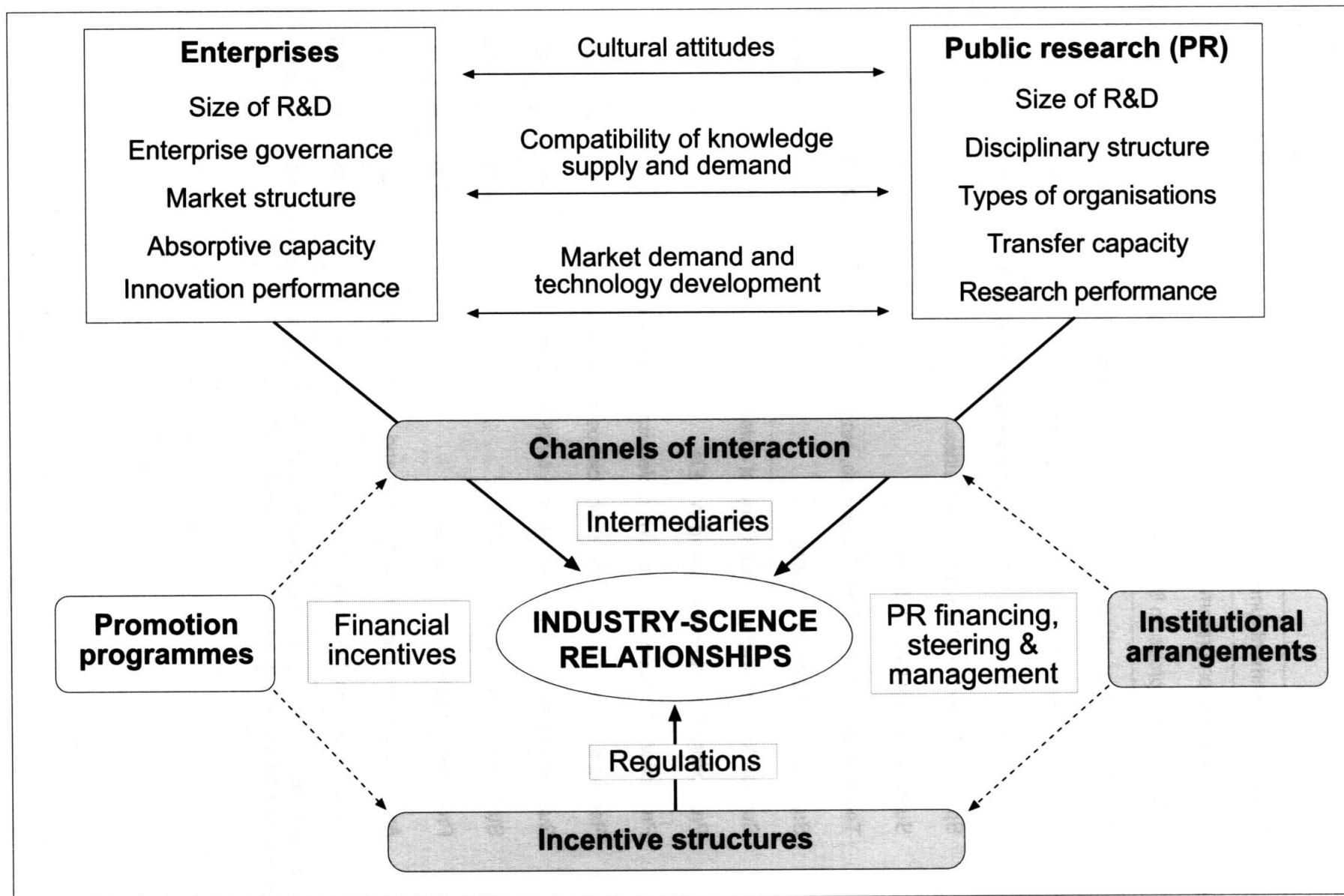
# Diabolical dilemma's of complex systems



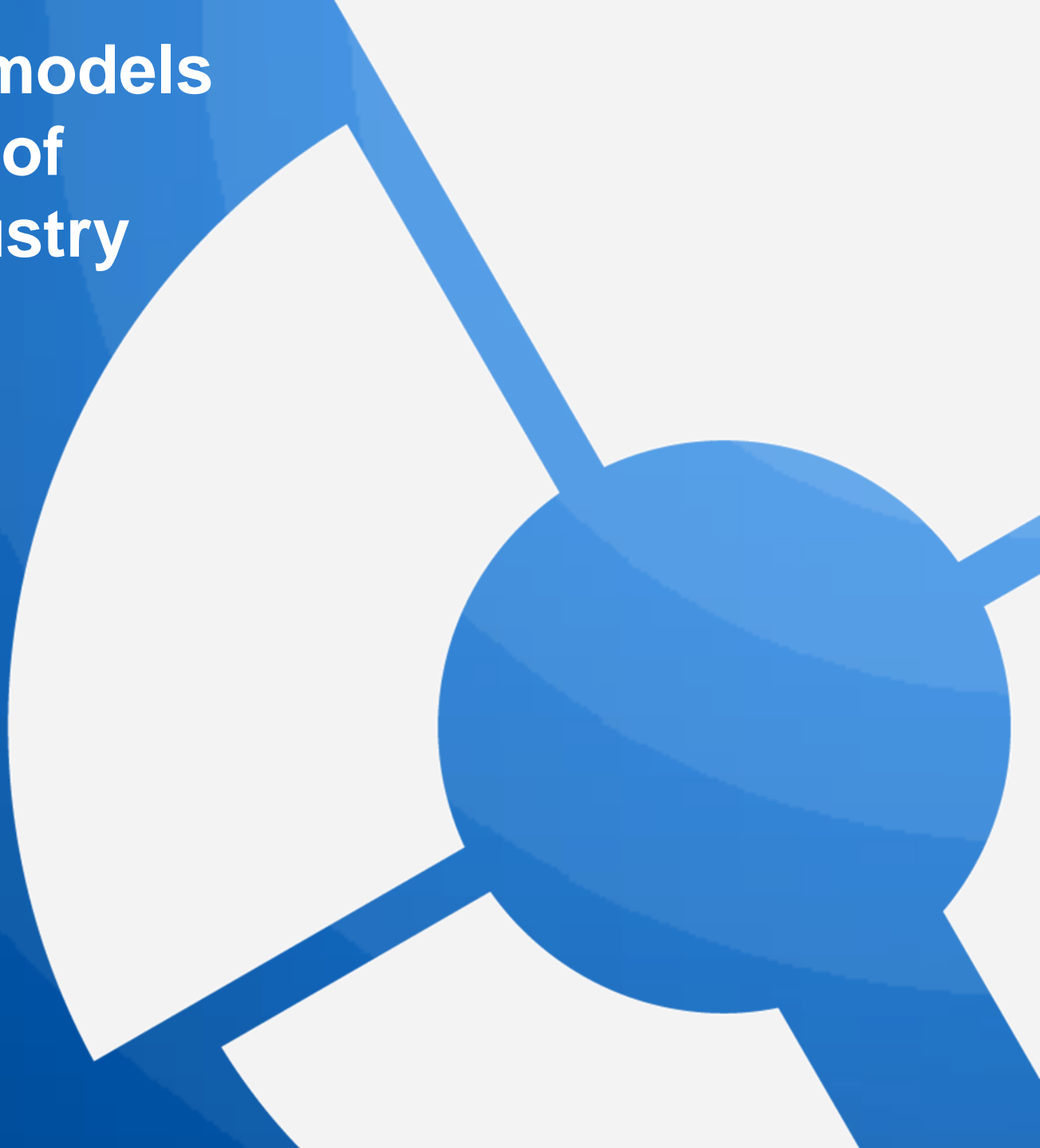
Performance measurement is usually based on:

- crude estimates of model parameters
- proxy measures of inputs, outputs, results and impacts

# A conceptual framework for assessing industry-science relationships



# Measurement models and indicators of university-industry interactions





Indicators are a trade-off between **simplicity and complexity**

Indicators are usually either **model-driven** or **data-driven**

| Measurement Framework                             | Indicators                           |   |
|---|--------------------------------------|---|
| Innovation Impact                                 | Economic Performance                 | productivity                            |
|   |                                      | employment growth                       |
|   |                                      | economic well-being                     |
| Innovation Performance                            | Research and Education               | skilled graduates                       |
|   |                                      | research publications                   |
|   | Technology Development and Transfer  | patents                                 |
|   |                                      | university technology transfer          |
|   | Commercialization                    | product innovation                      |
|   |                                      | high-wage employment                    |
| firm entrants and exits                           |                                      |   |
| Innovation Capacity                               | Higher Education and Public Research | highly cited scientists                 |
|   |                                      | stock of public sector R&D personnel    |
|   |                                      | level of collaboration                  |
|   | Linkages and Support Companies       | stock of industry R&D personnel         |
|   |                                      | employment by industry clusters         |
| creative economy                                  |                                      |   |
| leading R&D companies                             |                                      |   |
| Innovation Investment                             | Public Investment                    | gross expenditures on R&D               |
|   |                                      | federal and provincial research support |
|   |                                      | research infrastructure                 |
|   | Private Investment                   | business R&D                            |
|   |                                      | venture capital investments             |
| investments in ICT, machinery and other equipment |                                      |   |





# European Innovation Scoreboard

2016



CREAT **I** VITY  
K **N** OWLEDGE

TECH **N** OLOGY

**E U R O P E**

IN **V** ESTMENT

RESE **A** RCH



COMPETI **T** IVENESS

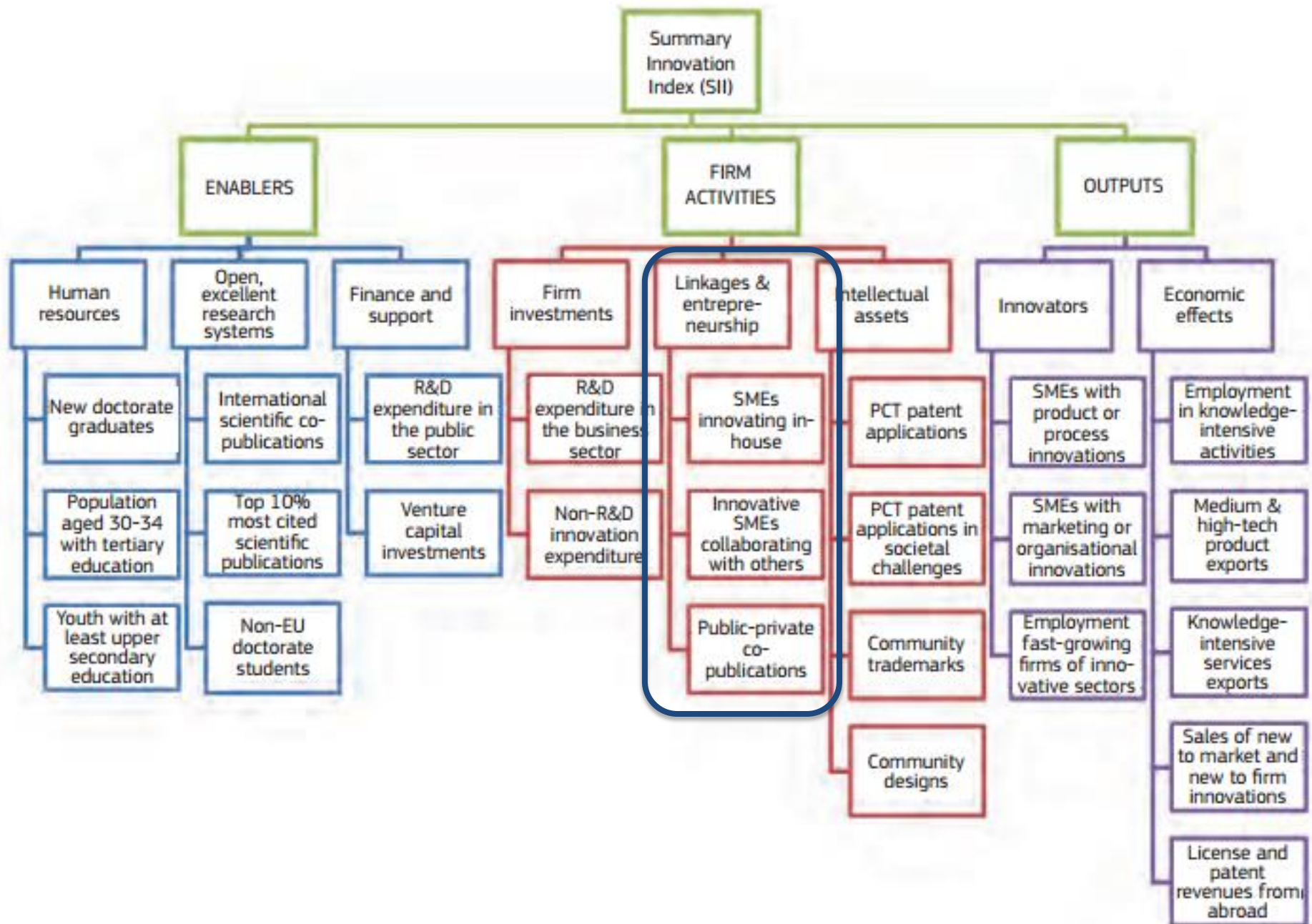


SK **I** LLS

COLLAB **O** RATION

GROWTH **A** **N** D JOBS

Figure 2: Measurement framework of the European Innovation Scoreboard



**Table 3: Indicators used in the international comparison**

| <b>MAIN TYPE / Innovation dimension / Indicator</b>   | <b>Data source</b>   | <b>Years included</b> |
|---|--|-----------------------|
| <b>ENABLERS</b>   |  |                       |
| <b>Human resources</b>  |  |                       |
| 1.1.1 New doctorate graduates (ISCED 6) per 1000 population aged 25-34  | OECD   | 2006 - <u>2013</u>    |
| 1.1.2 Percentage population aged 25-64 having completed tertiary education  | OECD, World Bank, Eurostat   | 2007 - <u>2014</u>    |
| <b>Open, excellent and attractive research systems</b>  |  |                       |
| 1.2.1 International scientific co-publications per million population   | Web of Science (data provided by CWTS as part of a contract to DG Research and Innovation) | 2008 - <u>2015</u>    |
| 1.2.2 Scientific publications among the top 10% most cited publications worldwide as % of total scientific publications of the country                                      | Web of Science (data provided by CWTS as part of a contract to DG Research and Innovation) | 2006 - <u>2013</u>    |
| <b>Finance and support</b>  |  |                       |
| 1.3.1 R&D expenditure in the public sector as % of GDP  | OECD, UNESCO Institute for Statistics  | 2007 - <u>2014</u>    |
| <b>FIRM ACTIVITIES</b>  |  |                       |
| <b>Firm investments</b>   |  |                       |
| 2.1.1 R&D expenditure in the business sector as % of GDP  | OECD, UNESCO Institute for Statistics  | 2007 - <u>2014</u>    |
| <b>Linkages &amp; entrepreneurship</b>  |  |                       |
| 2.2.3 Public-private co-publications per million population   | Web of Science (data provided by CWTS as part of a contract to DG Research and Innovation) | 2008 - <u>2014</u>    |
| <b>Intellectual assets</b>  |  |                       |
| 2.3.1 PCT patents applications per billion GDP (Purchasing Power Parity in international dollars (PPP\$))   | OECD, World Bank   | 2006 - <u>2013</u>    |
| 2.3.2 PCT patents applications in societal challenges per billion GDP (Purchasing Power Parity in international dollars (PPP\$)) (environment-related technologies; health) | OECD, World Bank   | 2005 - <u>2012</u>    |
| <b>OUTPUTS</b>  |  |                       |
| <b>Economic effects</b>   |  |                       |
| 3.2.2 Medium and high tech product exports as a % of total product exports  | United Nations   | 2007 - <u>2014</u>    |
| 3.2.3 Knowledge-intensive services exports as % total service exports   | United Nations   | 2007 - <u>2014</u>    |
| 3.2.5 License and patent revenues from abroad as % of GDP   | World Bank   | 2007 - <u>2014</u>    |

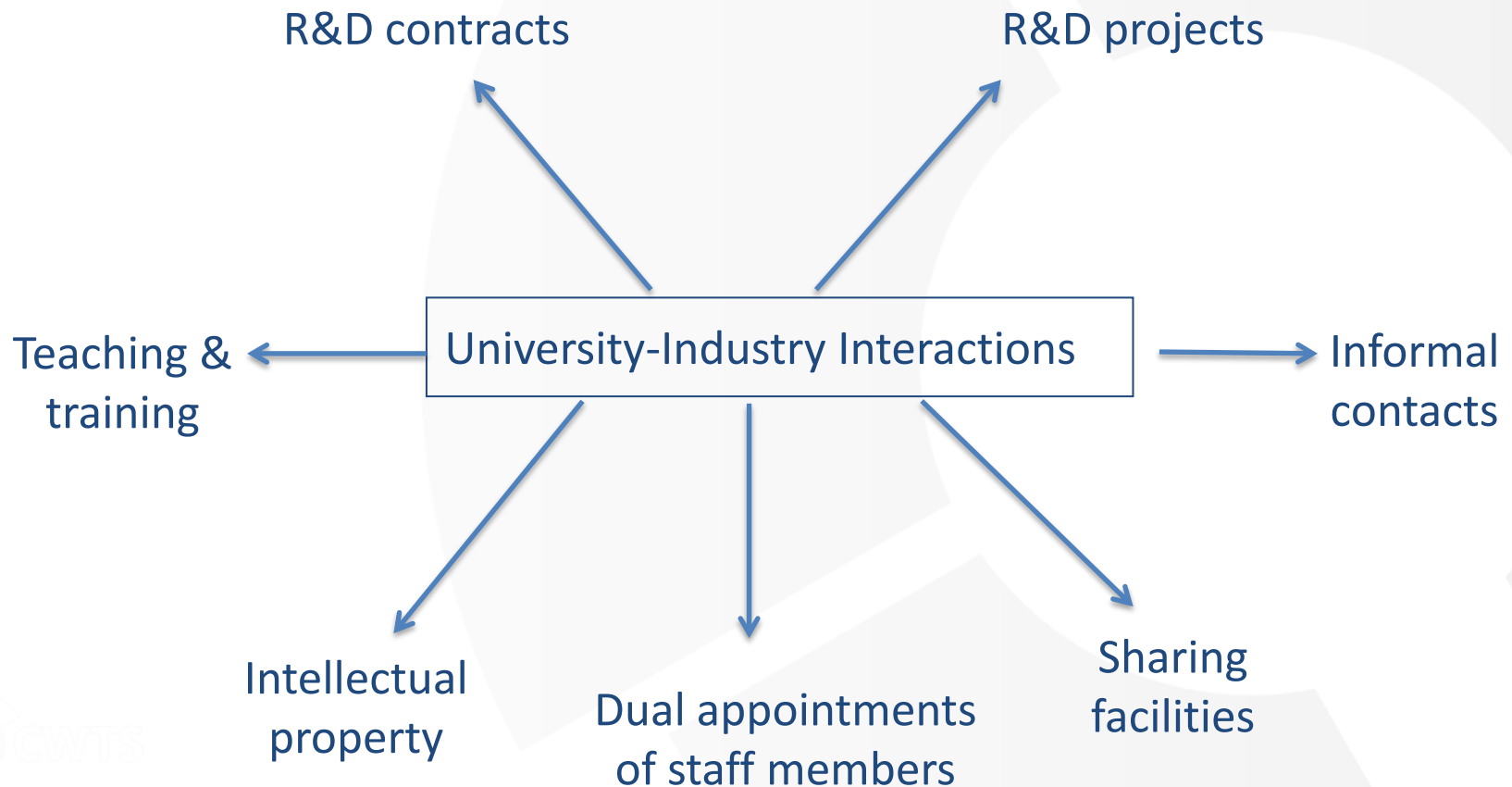


In order to be useful and generally acceptable, information derived from indicators should be – at the very least - **meaningful and convincing**

# Defining 'industry-science relationships' and 'university-industry interactions'

## Extremely broad definition:

Any interaction, connection or communication between a university staff member (or student) and a staff member of a business enterprise located somewhere worldwide



| Measurement Framework         | Indicators                           |   |
|-------------------------------|--------------------------------------|---|
| <b>Innovation Impact</b>      | Economic Performance                 | productivity<br>employment growth<br>economic well-being  |
| <b>Innovation Performance</b> | Research and Education               | skilled graduates<br>research publications  |
|                               | Technology Development and Transfer  | patents<br>university technology transfer   |
|                               | Commercialization                    | product innovation<br>high-wage employment<br>firm entrants and exits   |
| <b>Innovation Capacity</b>    | Higher Education and Public Research | highly cited scientists<br>stock of public sector R&D personnel<br>level of collaboration                       |
|                               | Linkages and Support Companies       | stock of industry R&D personnel<br>employment by industry clusters<br>creative economy<br>leading R&D companies |
| <b>Innovation Investment</b>  | Public Investment                    | gross expenditures on R&D<br>federal and provincial research support<br>research infrastructure                 |
|                               | Private Investment                   | business R&D<br>venture capital investments<br>investments in ICT, machinery and other equipment                |





# Operationalizing 'university-industry interactions'

## **Extremely narrow definition:**

Tangible output as a result of successful research-based collaboration between an academic researcher and R&D staff employed by a local business enterprise

## **Available empirical data for large-scale studies:**

National Innovation Surveys among business enterprises

Surveys among individual academic researchers and/or corporate R&D staff

University-Industry Co-authored Publications (UICPs)

| Measurement Framework                             | Indicators                           |   |
|---|--------------------------------------|---|
| Innovation Impact                                 | Economic Performance                 | productivity                            |
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| Innovation Capacity                               | Higher Education and Public Research | highly cited scientists                 |
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| creative economy                                  |                                      |   |
| leading R&D companies                             |                                      |   |
| Innovation Investment                             | Public Investment                    | gross expenditures on R&D               |
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|   |                                      | research infrastructure                 |
|   | Private Investment                   | business R&D                            |
|   |                                      | venture capital investments             |
| investments in ICT, machinery and other equipment |                                      |   |



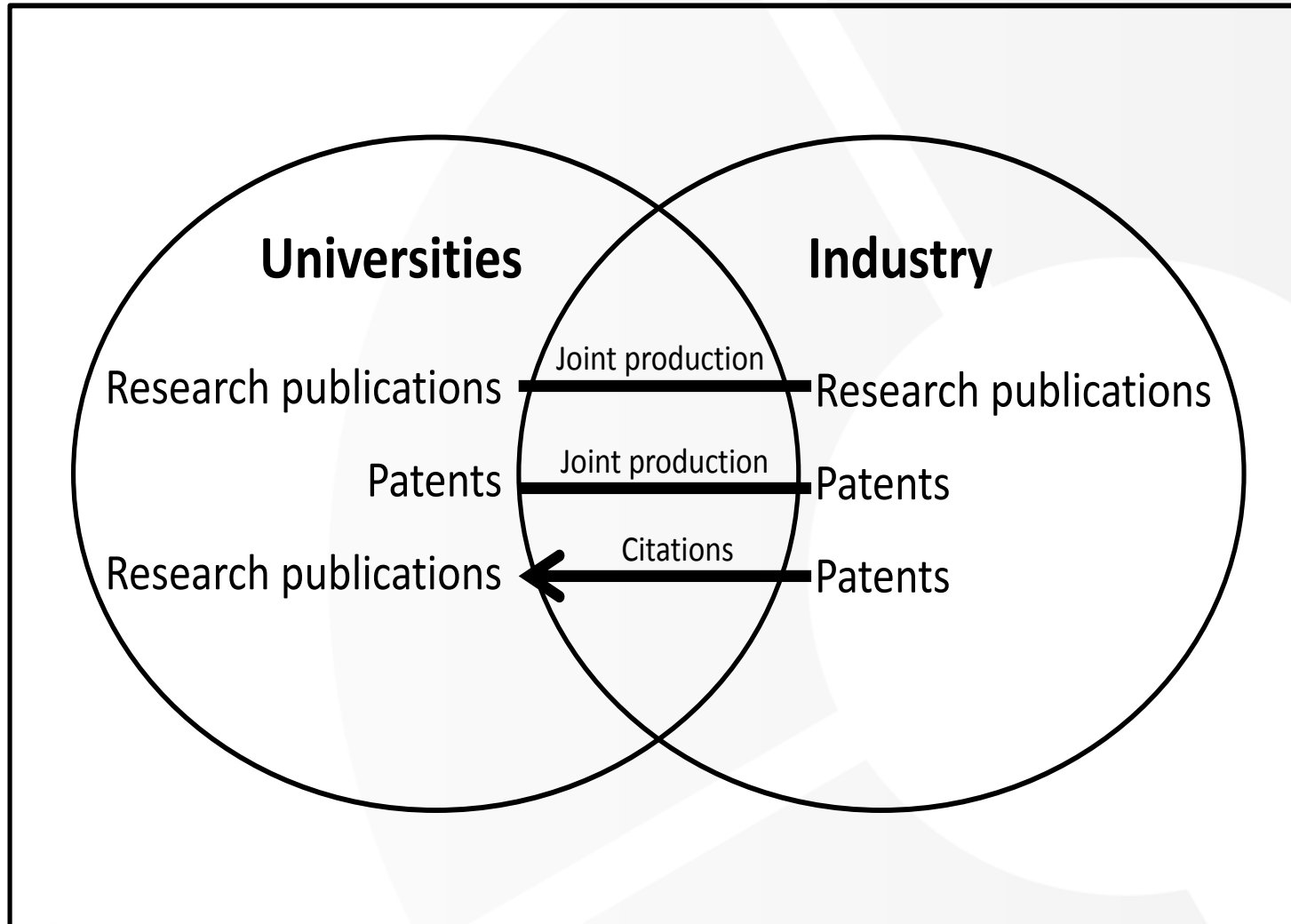


# Knowledge flows from university science to industrial R&D

## Performance indicators:

- Staff movement and mobility between academia and industry
- Dual appointments/employment of staff
- Patents
- Citations in patents to research publications
- University-Industry Co-authored Publications (UICPs)

# Bibliometric model of university-industry interactions



**Case study:  
Brazilian 'innovative  
universities'**





# Reuters Top 100: The World's Most Innovative Universities - 2016



By David Ewalt



# 'Innovation performance' metrics

**Publication volume:** total number of research articles indexed by Thomson Reuters *Web of Science* database

**Patent volume:** total number of patents filed at the *World International Patent Organisation* (WIPO)

**Patent success:** ratio of patent applications to WIPO granted patents

**Patent citations:** patent-to-patent citation impact (patent count)

**Patent citation impact:** patent-to-patent citation impact

**Patent-to-article citation impact:** relative citation impact citation from patents to research publications

**Industry article citation impact:** citation impact from industry-produced publications

**Industry collaborative articles:** percentage of university-industry co-authored publications

Time period: 2012–2015 Type of indicators: Collaboration

Field: All sciences Indicators: P, P(industry), PP(industry)

Region/country: Brazil Order by: P

Min. publication output: No minimum

| University                             | P     | P(industry) | PP(industry) |
|--|-------|-------------|--------------|
| 1 Univ São Paulo                       | 29026 | 629         | 2.2%         |
| 2 Univ Estadual Paulista               | 10217 | 104         | 1.0%         |
| 3 Univ Campinas                        | 9993  | 247         | 2.5%         |
| 4 Univ Fed Rio de Janeiro              | 9394  | 320         | 3.4%         |
| 5 Fed Univ Rio Grande do Sul - UFRGS   | 8302  | 181         | 2.2%         |
| 6 Univ Fed Minas Gerais                | 6934  | 157         | 2.3%         |
| 7 Univ Fed São Paulo                   | 6014  | 139         | 2.3%         |
| 8 Fed Univ Santa Catarina - UFSC       | 4052  | 91          | 2.2%         |
| 9 Univ Fed Paraná                      | 3694  | 79          | 2.1%         |
| 10 Fed Univ Pernambuco - UFPE          | 3441  | 59          | 1.7%         |
| 11 Fed Univ São Carlos - UFSCar        | 3171  | 54          | 1.7%         |
| 12 Univ Brasília - UnB                 | 3135  | 52          | 1.7%         |
| 13 Univ Fed Fluminense - UFF           | 2907  | 90          | 3.1%         |
| 14 Univ Fed Ceará                      | 2810  | 32          | 1.1%         |
| 15 State Univ Rio de Janeiro - UERJ    | 2682  | 59          | 2.2%         |
| 16 Univ Fed Viçosa                     | 2487  | 41          | 1.6%         |
| 17 Univ Fed Santa Maria                | 2362  | 35          | 1.5%         |
| 18 Fed Univ Rio Grande do Norte - UFRN | 2247  | 24          | 1.1%         |
| 19 State Univ Maringá                  | 1844  | 23          | 1.2%         |

## Time period, field, and region/country

Time period:

Field:

Region/country:


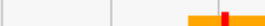



































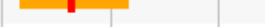


Min. publication output:

## Indicators

Type of indicators:

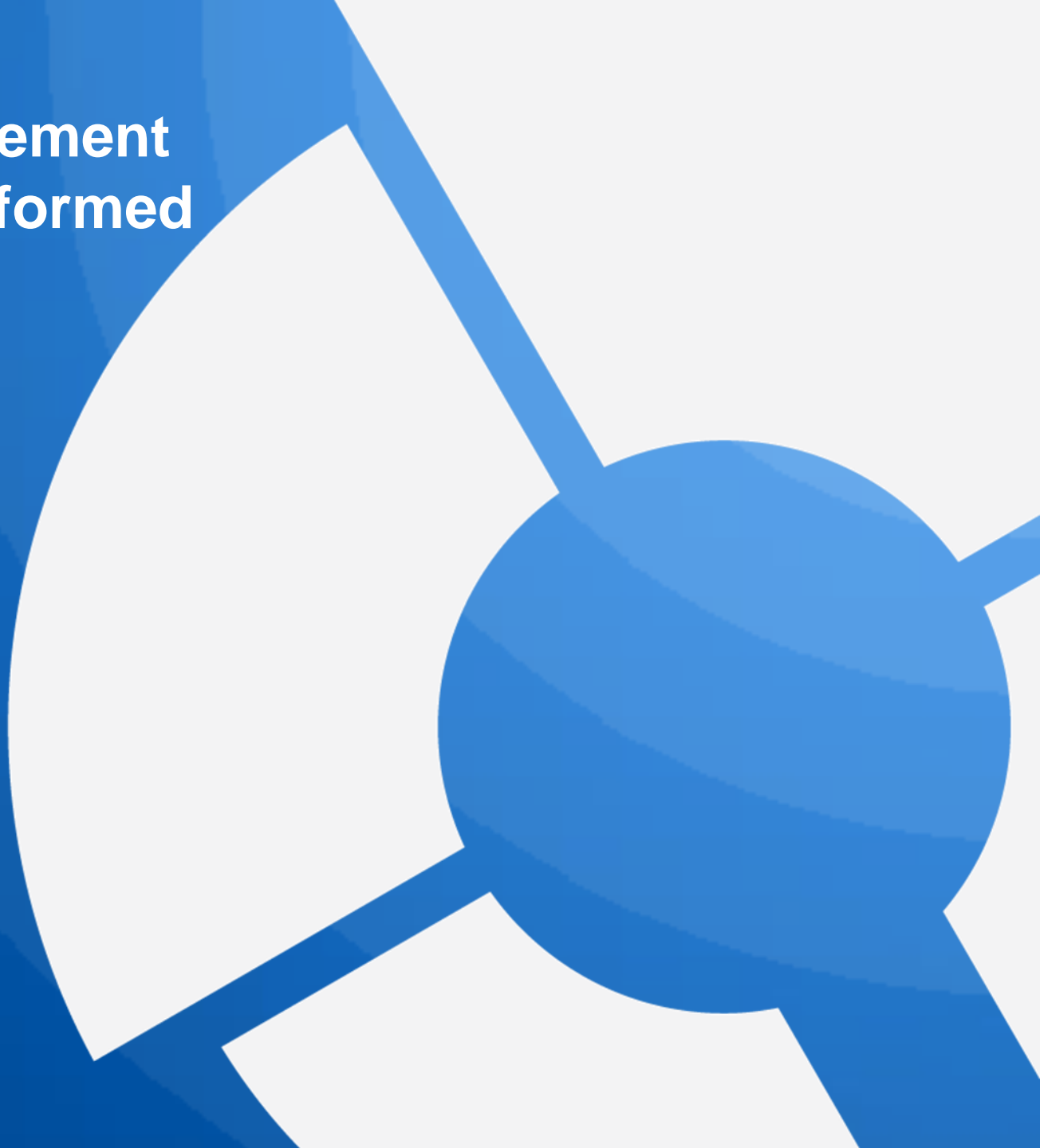
Indicators:

Order by:

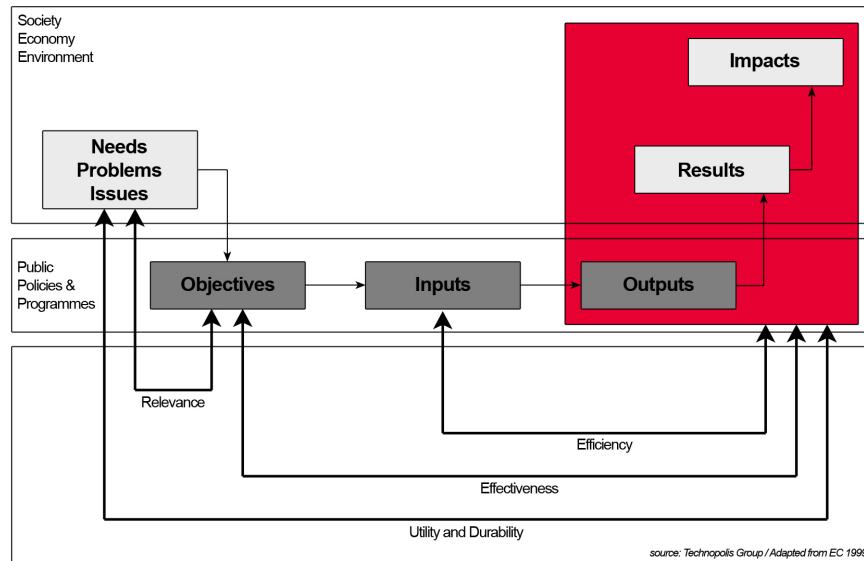
|    | University                         |   | P     | P(industry) | PP(industry) |   |
|----|------------------------------------|---|-------|-------------|--------------|---|
| 1  | Univ Fed Rio de Janeiro            |    | 9394  | 288         | 3.1%         |    |
| 2  | Univ Chile                         |    | 5407  | 151         | 2.8%         |    |
| 3  | Pontificia Univ Católica Chile     |    | 4897  | 114         | 2.3%         |    |
| 4  | Univ Fed São Paulo                 |    | 6014  | 139         | 2.3%         |    |
| 5  | Univ Fed Minas Gerais              |    | 6934  | 157         | 2.3%         |    |
| 6  | Fed Univ Santa Catarina - UFSC     |    | 4052  | 91          | 2.2%         |    |
| 7  | State Univ Rio de Janeiro - UERJ   |    | 2682  | 59          | 2.2%         |    |
| 8  | Fed Univ Rio Grande do Sul - UFRGS |    | 8302  | 181         | 2.2%         |    |
| 9  | Univ Campinas                      |    | 9993  | 215         | 2.2%         |    |
| 10 | Univ Fed Paraná                    |    | 3694  | 79          | 2.1%         |    |
| 11 | Univ São Paulo                     |   | 29026 | 593         | 2.0%         |   |
| 12 | Univ Fed Fluminense - UFF          |  | 2907  | 58          | 2.0%         |  |
| 13 | Univ Nacl Colombia                 |  | 2453  | 47          | 1.9%         |  |
| 14 | Univ Buenos Aires                  |  | 7374  | 141         | 1.9%         |  |
| 15 | Univ Concepción                    |  | 2430  | 43          | 1.8%         |  |
| 16 | Fed Univ Pernambuco - UFPE         |  | 3441  | 59          | 1.7%         |  |
| 17 | Fed Univ São Carlos - UFSCar       |  | 3171  | 54          | 1.7%         |  |
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**Discussion:  
models, measurement  
and evidence-informed  
policies**



# Capturing dynamic and open science and innovation systems



Current models are able to capture some relevant processes, outputs and impacts

Some performance indicators may provide useful comparative empirical information

Brazilian university-industry R&D is linked to global innovation systems; large differences in performance levels among Brazilian universities and firms

Causality and attribution problems render it (almost) impossible to assess effectiveness, efficiency, or determine rates of return

# Contextualization is essential

Add information from local (Brazilian) sources:

- SciELO database of research publications;
- Lattes database on individual researchers
- Information from organisational databases (university administration)
- Validation and verification studies with experts and stakeholders (**'numbers with narratives'**)

Utilize **university rankings**, and underpinning performance indicators, as an **transparency tool** and a 'way in' to create common elements in a **comparative empirical evidence base**

Produce persuasive **'narratives with numbers'** (avoid false precision of 'statistical facts') as input for policy debate

# Some STI policy questions

- Which **policy-relevant analytical frameworks** (if any) can help better understand university-industry interactions (and forecast their outcomes?)
- How could **macro-level and meso-level** policy oriented studies and **micro-level** analysis of activities (projects, individuals) supplement each other ?
- Who are **key R&D staff** – within the public sector institutes, universities and firms - engaged in those interactions; what are their major R&D achievements and research-based innovation goals?
- What **challenges confronted by public sector researchers** when engaging with the business sector, during university-industry collaboration activities and research commercialization?
- What are the main contributions of **private sector intermediates and investors** ?