THE USE OF RESEARCH PORTFOLIOS IN SCIENCE POLICY

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RESEARCH PORTFOLIO

Definition: Set of research activities supported by a funding and/or research-performing organization or a group of organizations.

- In large technology-intensive companies, portfolio-wide perspective to R&D management has long been applied to better align research project investments with the firm's overall strategic goal of economic return maximization (Schilling, 2017).
- In contrast, with relatively few exceptions (Ruegg, 2007; NIH Office of Portfolio Analysis), public R&D management still bases selection processes on the scientific excellence of individual projects according to peers rather than considering the merits of the whole portfolio (Linton and Vonortas, 2015; Linquiti, 2015).
- Research portfolio appraisal is challenging and more so in the public sector. Besides the usual inertia and the resistance by scientists trusting the peer review process, serious concerns include:
  - multiple objectives
  - project interdependency
  - difficulty to monetize or value

OPPORTUNITY

In the past couple of decades, major improvements in:

- ✓ Data processing and visualization techniques (Börner et al., 2003; Van Eck and Waltman, 2014)
- ✓ Conceptual developments in research and analytical methods better handling risk (Lo Nigro et al., 2016; Luehrman, 1998; Vonortas and Desai, 2007)

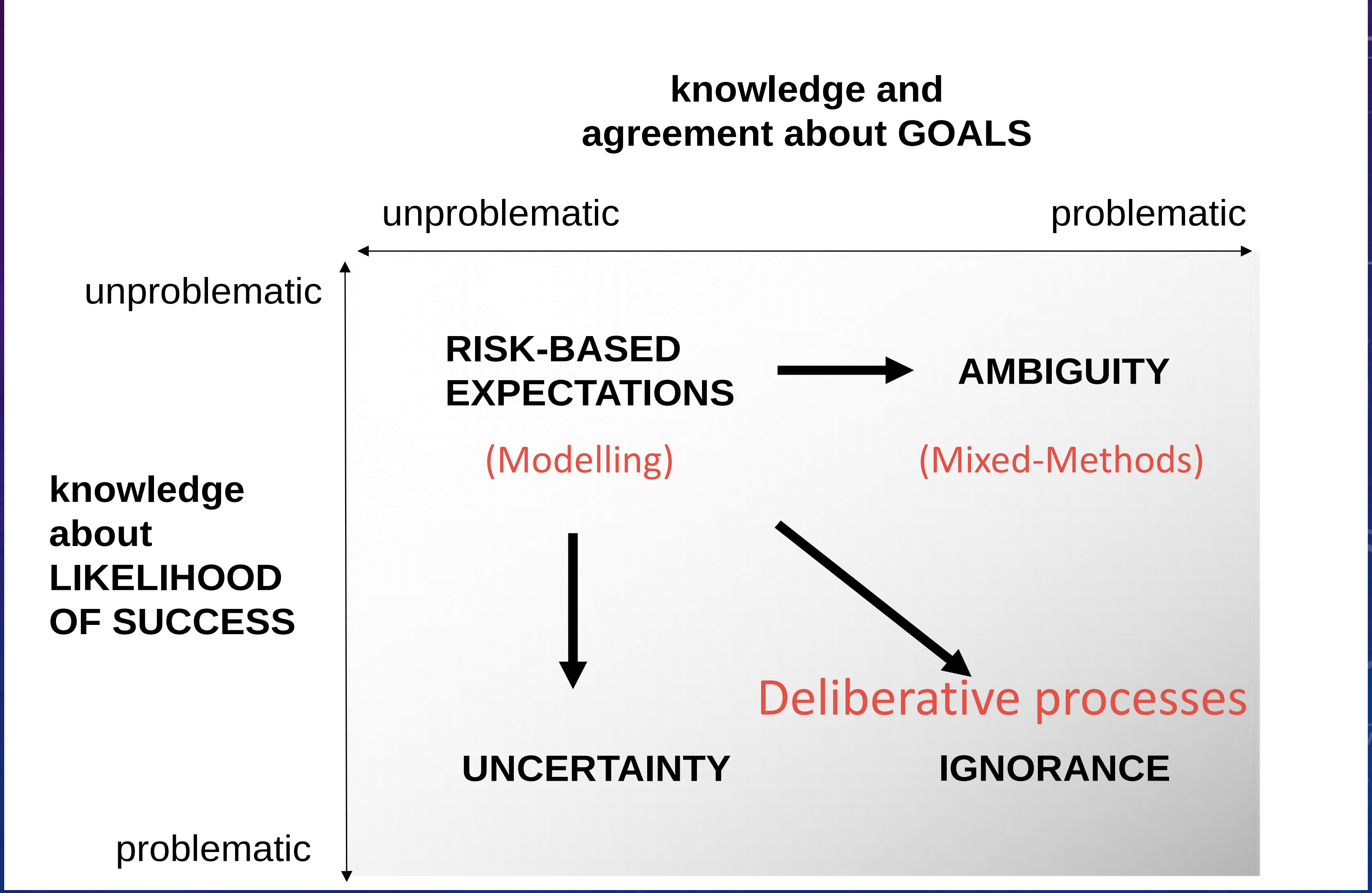
Modern research portfolio approaches offer a realistic possibility of improving the performance of R&D programs by identifying gaps and opportunities.

Modern research portfolio approaches also help making more transparent the multiple goals of most public R&D programs. They thus facilitate the alignment of research with its various welfare, environmental, security and economic missions (Wallace and Rafols, 2015).

RESEARCH PORTFOLIO, UNCERTAINTY AND AMBIGUITY

Modeling becomes problematic under conditions of:

- High degree of uncertainty
- Lack of agreement on outcomes, i.e. on needs or options to prioritize



Based on Stirling and Scoones (2009)

I. R&D PORTFOLIO MODELING

- The classic approach to appraise economic returns to an investment is the net present value (NPV) (cash flow model) and the related internal rate of return (IRR). The model is expressed by the well-known function

$$\mathrm{NPV} = \sum_{t=0}^{T} \frac{F_t}{(1+r)^t},$$

- Link and Scott (2013) summarize a set of seventeen laboratory-based economic impact analyses of this type. Some portfolio characteristics (effects through value chain). Misses many others.

- Good example of explicit R&D portfolio analysis using an extended NPV methodology is National Research Council's study to estimate ex ante the net benefits of six cases of applied energy (DOE) R&D projects (NRC, 2005; 2007).

I. NRC DOE STUDY (2007)

- *Study examined all three perceived primary effects of DOE programs: (1) technical risk reduction; (2) market risk reduction; (3) acceleration of technology market introduction*.
- Decision trees describe the technical and market uncertainties and the impact of DOE support in overcoming them. The acceleration effect represented either by the change in the likelihood of a project to attain the program goals of completion by a critical date, or by the acceleration of their benefits vis a vis technology developing in the absence of the government program (counterfactual).
- Expert panel reviews of the DOE R&D programs used.
- Expected economic, environmental, and energy security benefits in three different global economic scenarios estimated.
- Scenarios were built with the help of NEMS forecasting the likely energy cost savings through 2030 from the deployment of the new technology generated by the program.
- The overall benefit of the DOE R&D program is given as the difference between the expected net benefits with DOE support and the expected net benefits without it (counterfactual). The expected benefits correspond to a probability-weighted average of the benefits in specific technical and market outcomes, within common scenarios and under common assumptions.
- The traditional discounted cash flow framework (NPV) was used for these calculations.

I. REAL OPTIONS FOR R&D

The Options approach allows one to estimate the maximum funding level that could be spent on the R&D initially....

followed by a clear quantitative estimate of how much funding would be acceptable for the second, third, etc…. stages of the Program before it goes into the market for commercialization.

In effect, at every stage one determines the option for the next stage.

The ‘real options’ valuation method draws on developments in finance to realistically account for:

(a) Technical risk

(b) Market risk

(c) The optimum funding for conducting R&D at each stage of a project

Its relative strengths are particularly important for the ex ante appraisal of highly risky, long-term R&D investments.

I. PORTFOLIOS OF R&D OPTIONS

- The idea of R&D portfolio analysis goes back to principles in finance and, in particular, the idea that assets should not be selected solely on the basis of their individual merits. Markowitz (1952) demonstrated that risks are not additive; neither are returns of financial assets. Evaluation of an asset's return should be in relation to other assets in the portfolio and overall market fluctuations.

$$E\left(R_p\right) = \sum_i w_i E\left(R_i\right) \ ,$$

Where E is expectation, R_p is the return on the portfolio, w_i are weights on individual assets' returns, R_i.

- The risk associated with individual investments is managed through diversification: the portfolio combines assets that will be profitable as a group despite the uncertainties of individual assets and of the overall market.
- Much of the basic thinking of financial asset management applies to R&D project management. R&D project portfolio diversification enables achieving complex – and often conflicting – goals of an R&D strategy that cannot be attained by any single R&D project.

I. PORTFOLIOS OF R&D OPTIONS

"…[T]he certain absence of risk additivity in all investment portfolios, the frequent absence of return additivity in R&D portfolios, the value of purposively trading off risk and return, and the complex interaction of investments with conditional payoffs are all persuasive reasons to analyze and value not only individual R&D projects, but also the R&D portfolios they comprise." (Linquiti, 2015, p.63-64).

- The application of financial portfolio theory to R&D project analysis is subject to difficulties:
  - Financial options are linked to traded financial securities. In contrast, R&D projects and their outcomes (underlying assets) are very seldom traded in the market and there is little information about the project's inherent value and expected future returns (on which the option valuation depends). Returns may arrive far into the future, they may relate to defense, security of natural resources, improvement of the natural environment, regulation, or reputation. Monetary returns may not even be an important decision variable for R&D project selection.
  - Financial assets are typically assumed to behave in a Gaussian manner. Experts argue that this is not entirely appropriate for R&D projects where long tails may be the norm in the distribution of returns.

- Nonetheless, there have been efforts to monetize such effects. See, for instance, the aforementioned studies of NRC (2005, 2007). Here is a need for further research.

II. MIXED-METHOD APPROACHES TO MODELING

A diverse set of alternative non-parametric methods to draw up real asset portfolios (including R&D) have been developed to account for multiple, difficult to monetize, and often conflicting program and project goals.

- Some of the better known methods include:
  - *Peer review score*. Classic technique, it involves experts affixing a score on individual projects against a series of merit criteria. Projects are then rank ordered and the top projects selected.
  - *Analytic Hierarchy Process (AHP)*. Technique to organize and analyze complex input from various sources. It helps structure a problem in terms of various quantifiable elements organized logically so that they can be measured against overall goals and alternative solutions.
  - *Data Envelopment Analysis (DEA)*. Non-parametric methodology to estimate a frontier by estimating the relative efficiency of a number of producers. Efficiency is defined as the ratio of the sum of weighted outputs to the sum of weighted inputs.
  - *Balance Scorecard (BSC)*. A model for analyzing strategy and performance information for all types of organizations. Widely adopted in the private sector to plan and align strategic initiatives, clarify and translate vision and strategy into action, and enhance strategic feedback and learning.

RESEARCH PORTFOLIO, UNCERTAINTY AND AMBIGUITY

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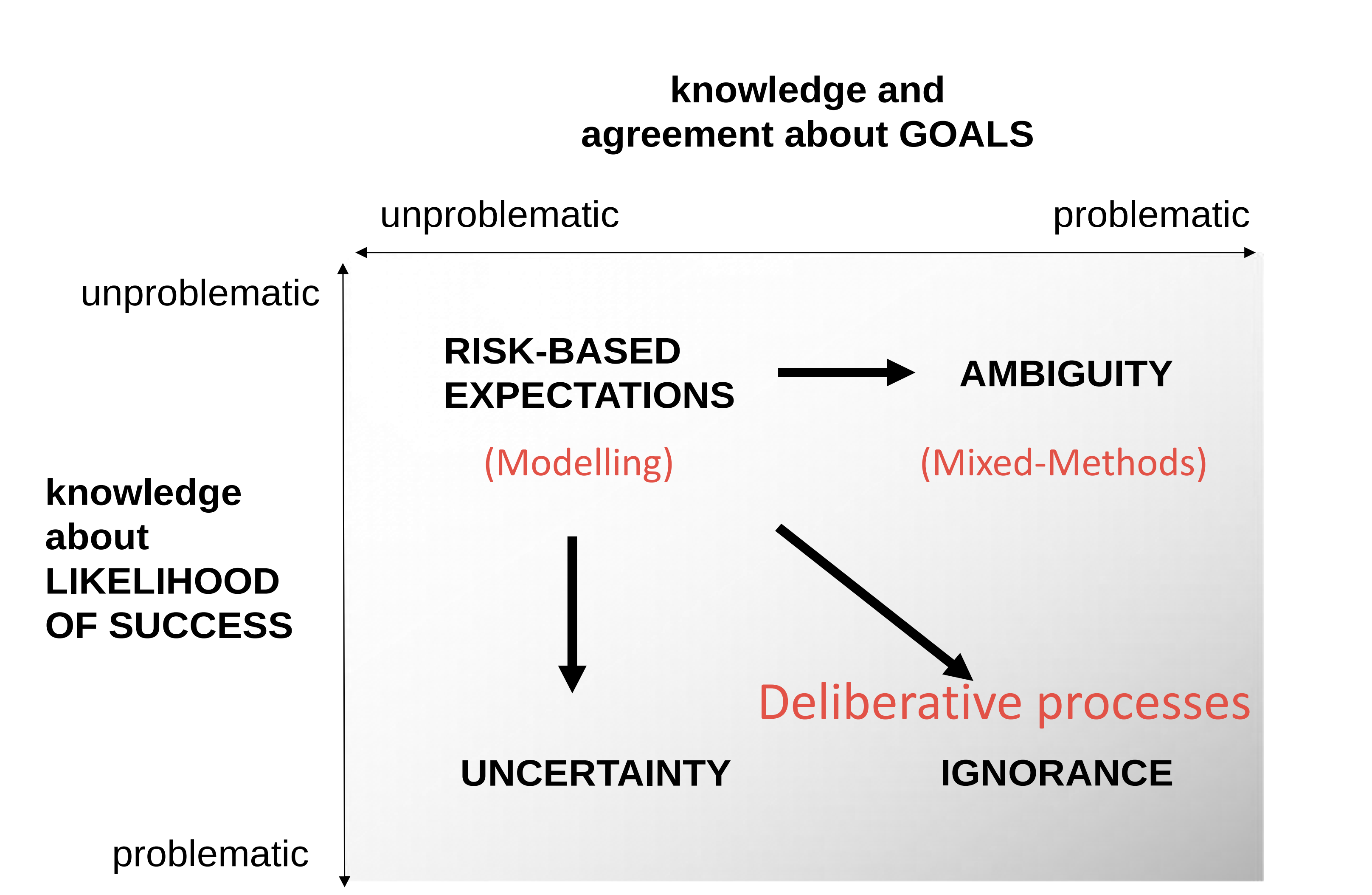


Based on Stirling and Scoones (2009)

III. MAPPING ALINGMENTS BETWEEN SCIENCE SUPPLY AND SOCIETAL NEEDS/DEMANDS

- **Problem:** perceived mismatch between type of research outcomes produced and societal needs/demands

“Are we doing the right type of science?”

- Across diverse areas: perceived underinvestment in some type of research in health (disease), agro (crops), energy (techs)
- Lock-in, institutional dynamics and vested interests might shape research priorities towards “sub-optimal” configurations.

III. IMPROVEMENTS IN DATA AVAILABILITY, PROCESSING AND VISUALIZATION OF PORTFOLIOS

Data availability and infrastructure

- Increasing access to project funding data (e.g. StarMetrics, UberResarch) and funding acknowledgements in publications (e.g. in PubMed and WoS) and combinations (e.g., Digital Science)

Data processing and classifications

- Increasing availability of bottom-up topic classification of publications or grants based on semantic approaches (e.g. topic modelling) or individual-article clustering.

Visualization

- Accessible visualisation tools such as Gephi and VOSviewer
- Rendering portfolios analysis more intuitive

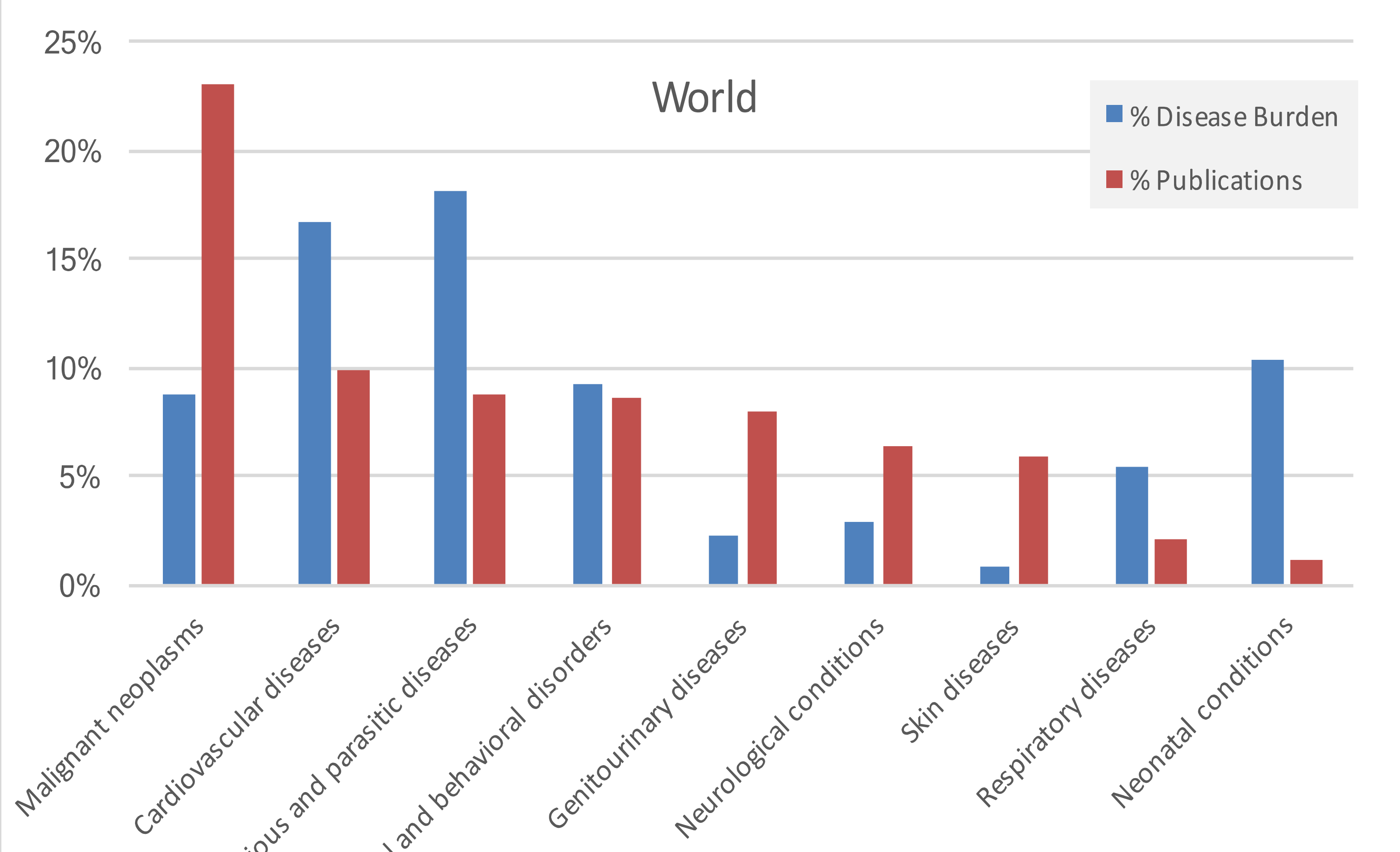
III. PRIORITY SETTING BETWEEN DIFFERENT PROBLEMS

Comparison to facilitate deliberations on priority setting by experts or stakeholders.

In global health, under-investment in Infectious Diseases.

In developed countries, under-investment in Cardio-Vascular or Respiratory Diseases.

NIH – dedicated website.

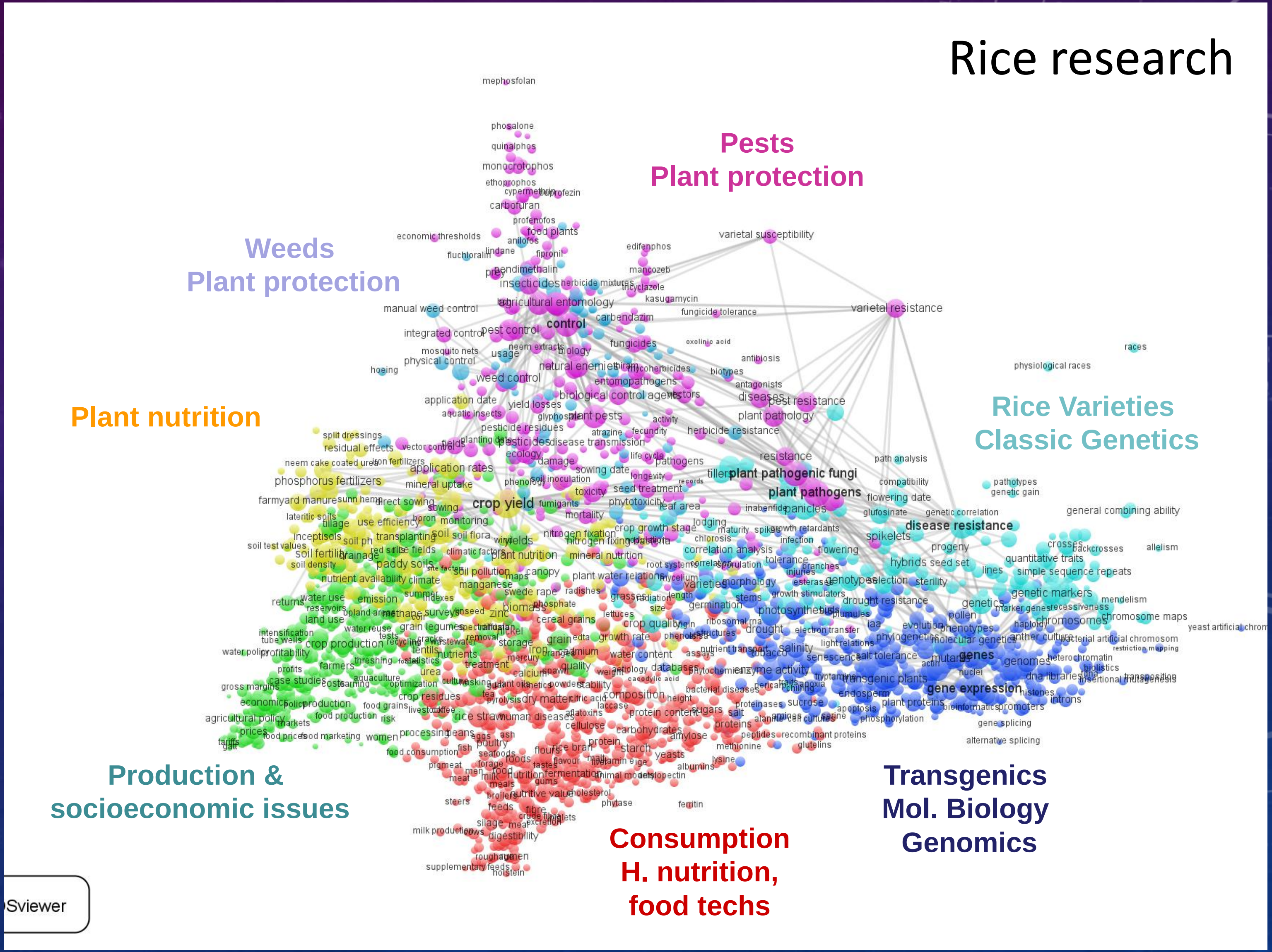


Rafols and Yegros (2018)

III. PRIORITY SETTING BETWEEN RESEARCH OPTIONS

Comparison to facilitate deliberations on priority setting by experts or stakeholders.

For a given issue, which research options should be prioritised?



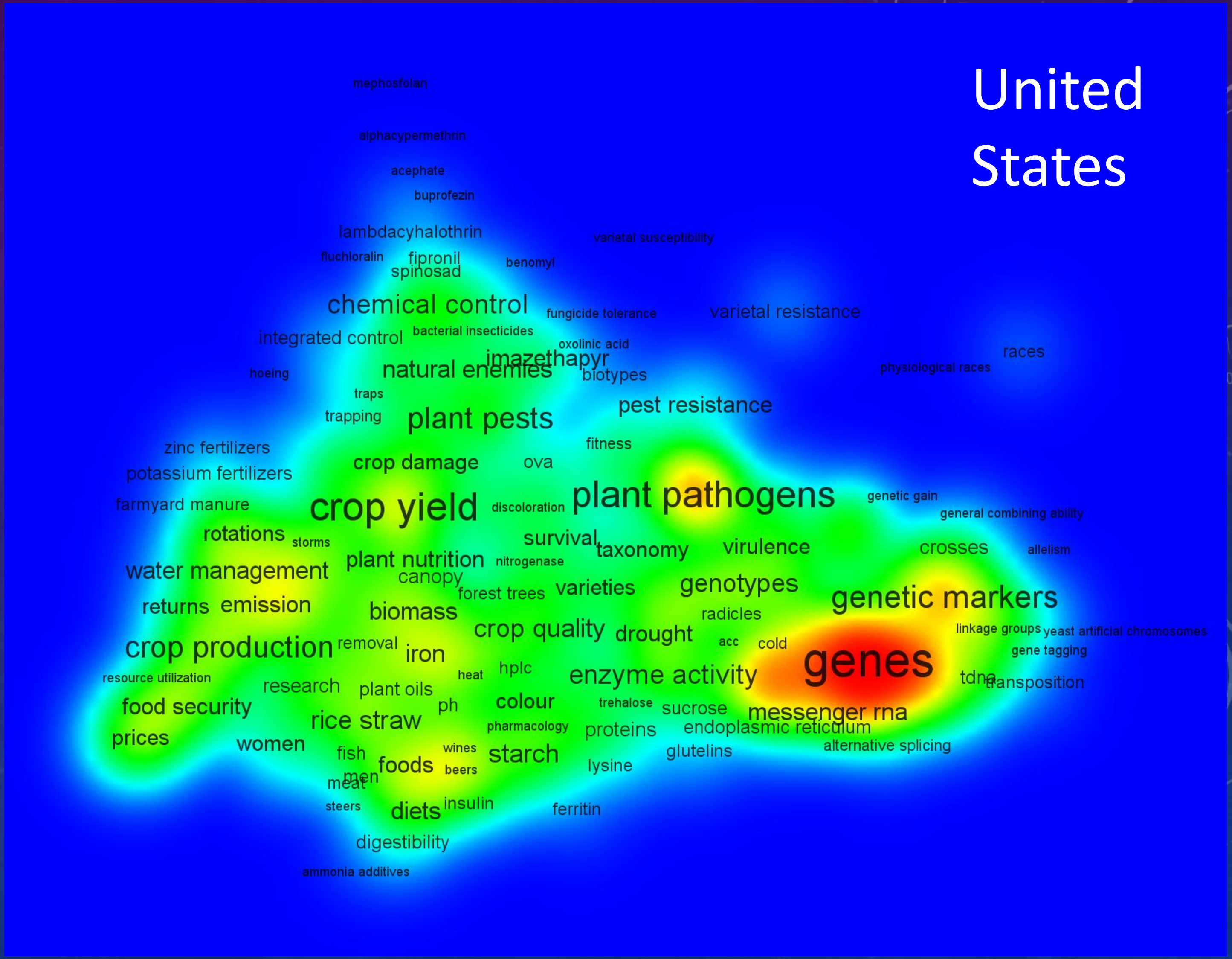
Ciarli and Ràfols (2017)

III. PRIORITY SETTING BETWEEN RESEARCH OPTIONS

Rice research

Comparison between
Research portfolios
of countries

Against different
national needs due to
local contexts
(culture, nutrition, farming
practices, etc.)



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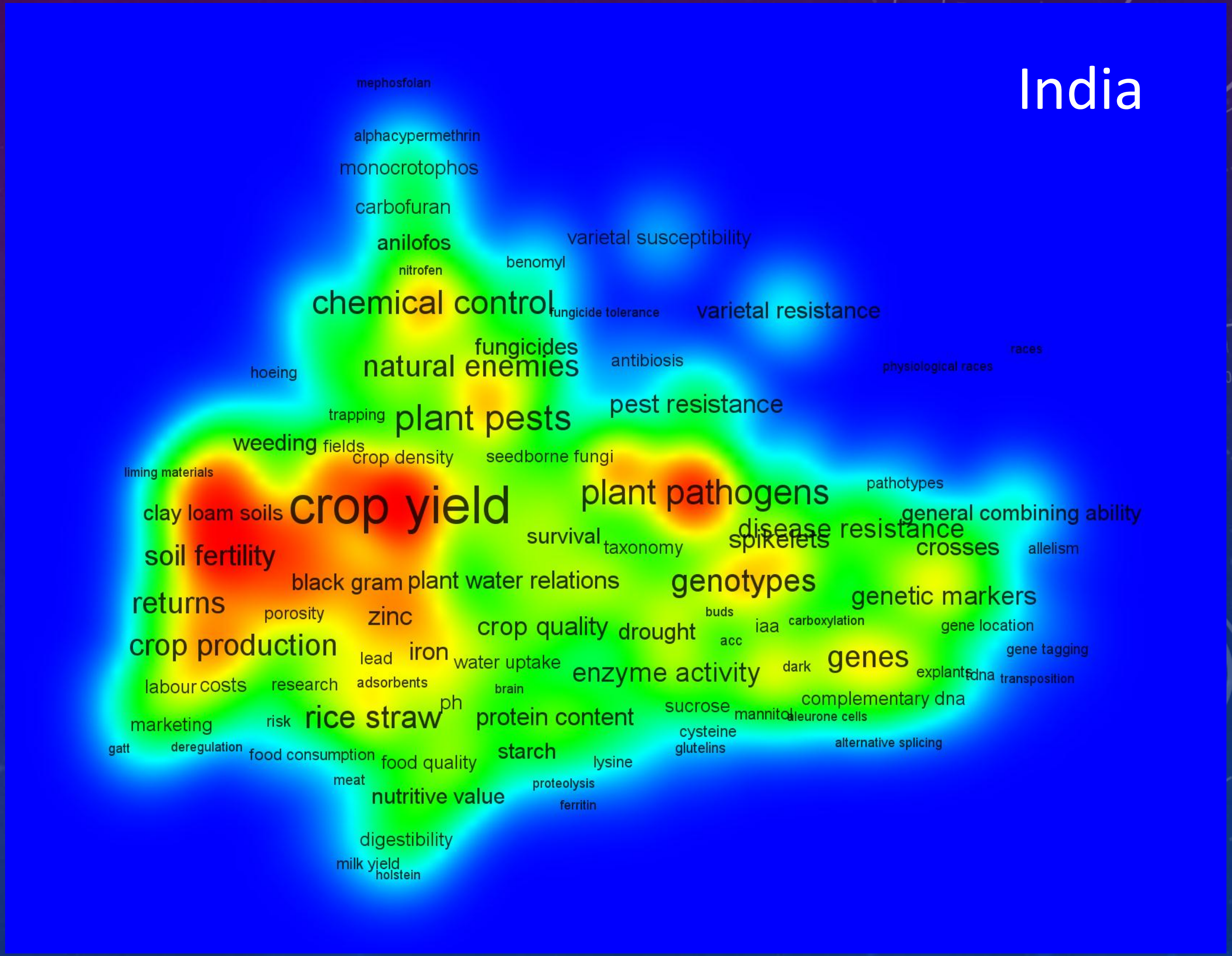

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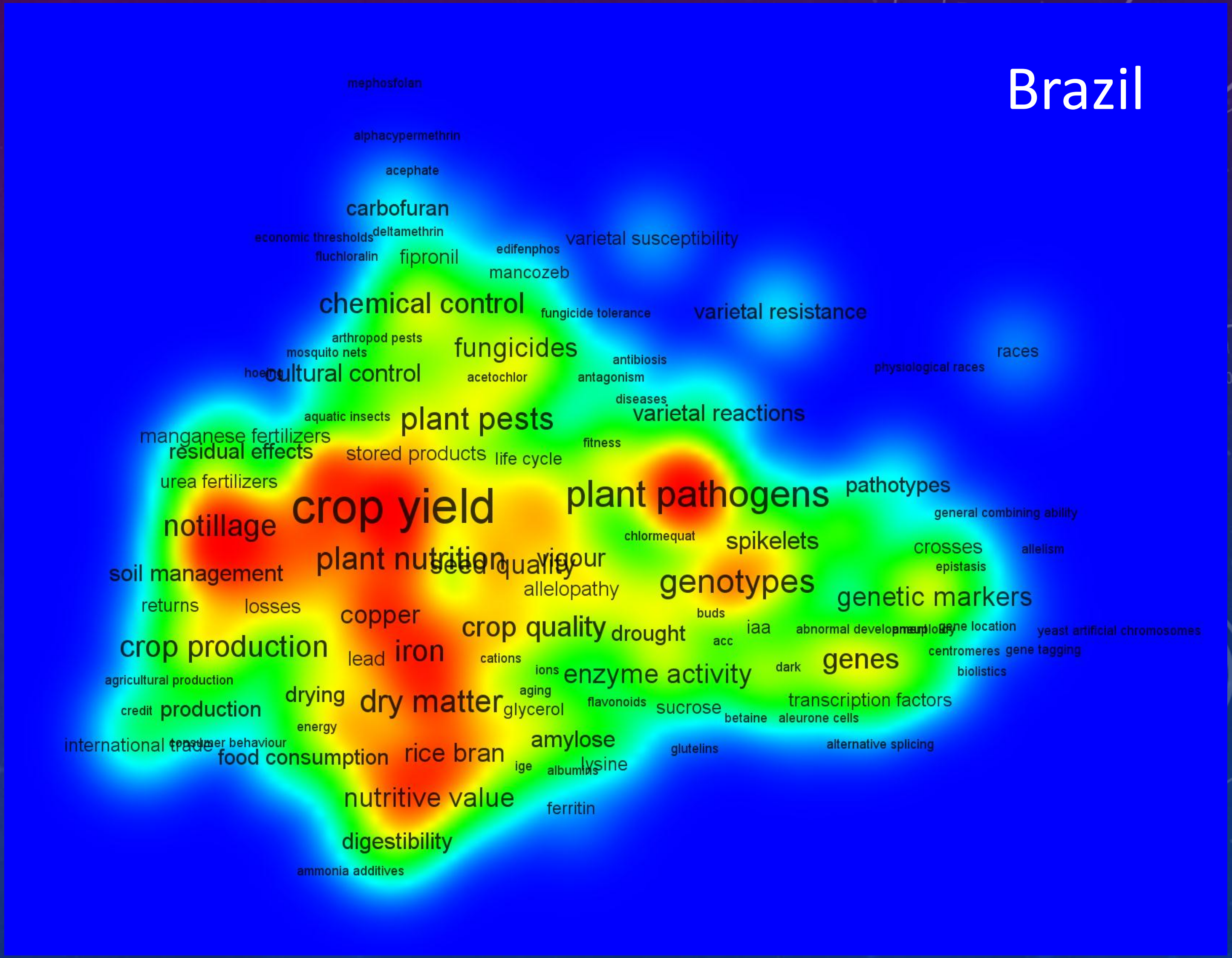

Ciarli and Ràfols (2017)

CONCLUSIONS

- Use of data reporting and visualization methods of research portfolios is generally recommended.
- Modeling of research portfolios is recommended for cases of agreement on program goals where value estimates are possible (presence of risk, but low uncertainty)
- Portfolios can be a useful tool to assist in deliberative processes aimed at aligning science supply with social needs or demands.