What's in YOUR Tool Box?
Best Practices in R&D Prioritization, Management, and Evaluation: A Science of Science Policy Workshop

Building the Knowledge Economy – How to measure performance?

Patrick Cunningham

Chief Scientific Adviser to the Government

Washington DC, 28-29 October, 2009

John Holdren

Presidential Science Adviser

“between 50 and 85 percent of the growth of the U.S. economy over the past half-century -- and two-thirds of our productivity gains in recent decades -- are directly attributable to scientific and technological advances.”

Testimony to Congressional Committee, February 2009

President Obama

“We will devote more than 3 percent of our GDP to research and development.”

Addressing the National Academy Of Sciences, April 2009

Lisbon Agenda (2000)

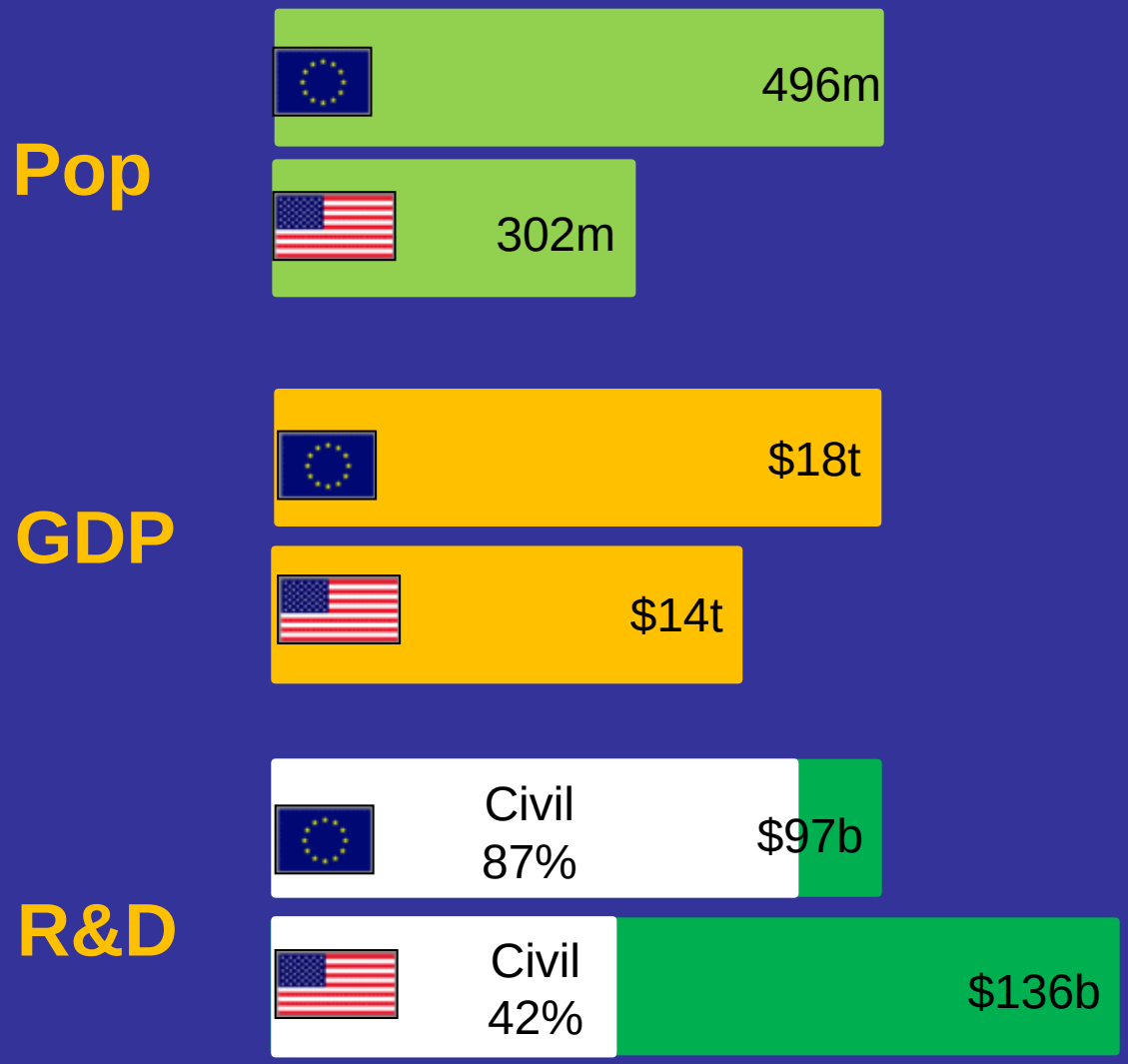
"to become the most competitive and dynamic knowledge-based economy in the world, capable of sustainable economic growth with more and better jobs and greater social cohesion."

- ***3% of GDP on R&D***
- ***1/3 public; 2/3 business***

SSTI vision (2006)

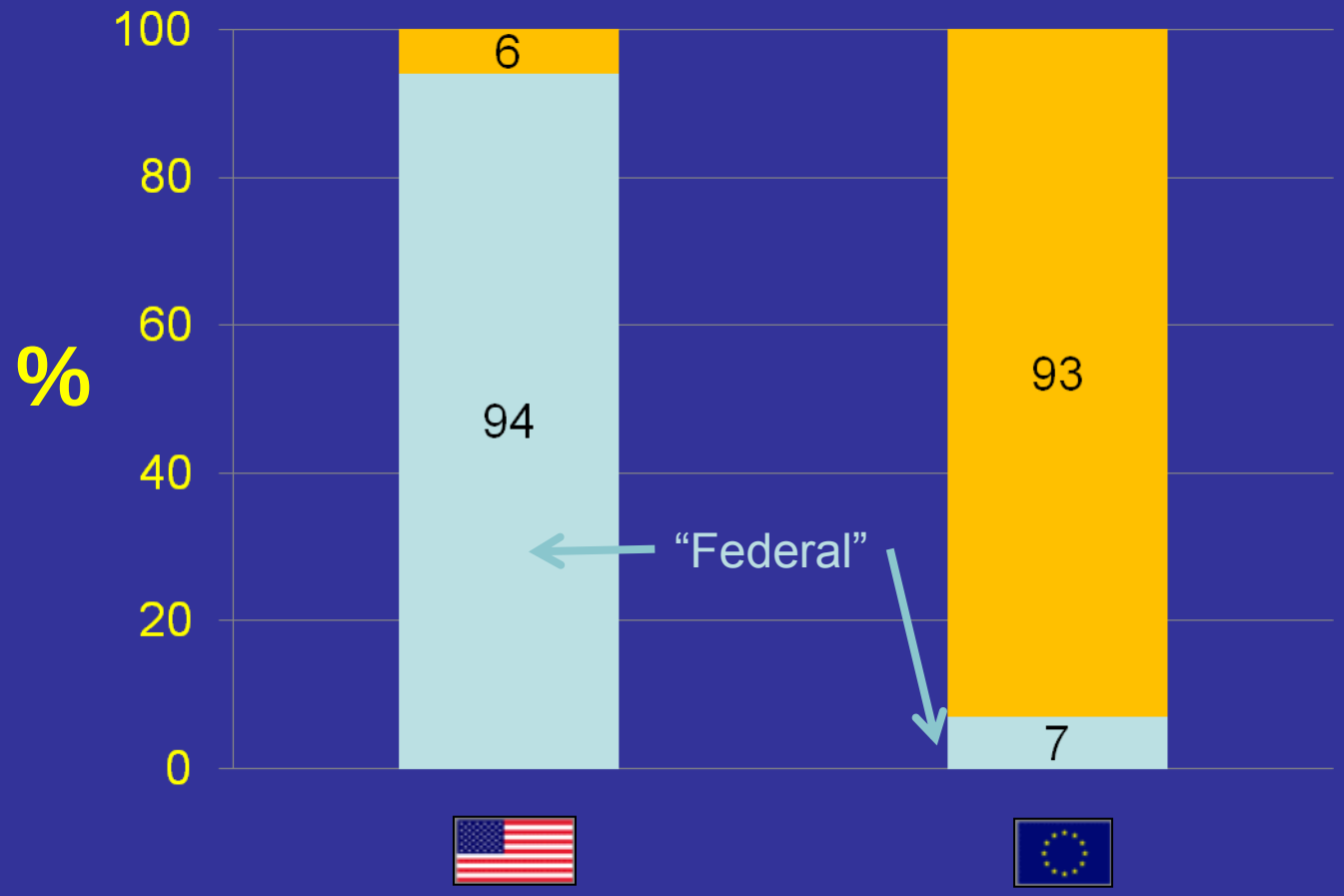
"Ireland by 2013 will be internationally renowned for the excellence of its research, and will be to the forefront in generating and using new knowledge for economic and social progress, within an innovation driven culture."

How We Compare



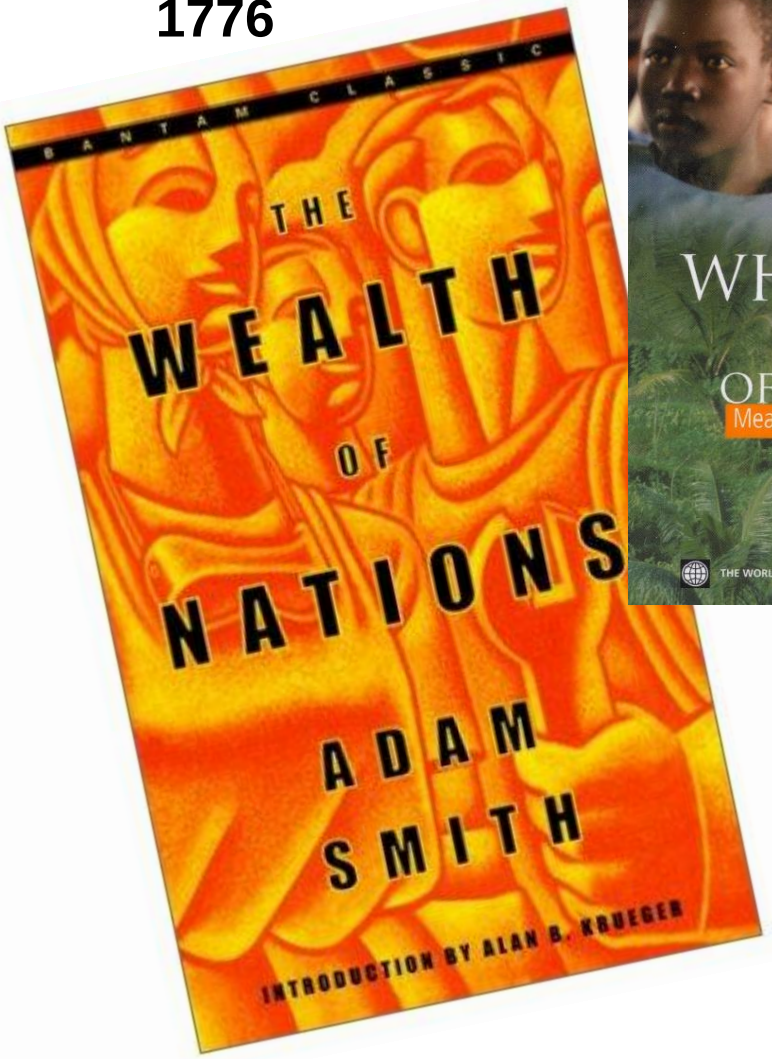
Sources: World Bank, 2008; OECD 2006.

“Federal” *versus* “State” R&D Funding

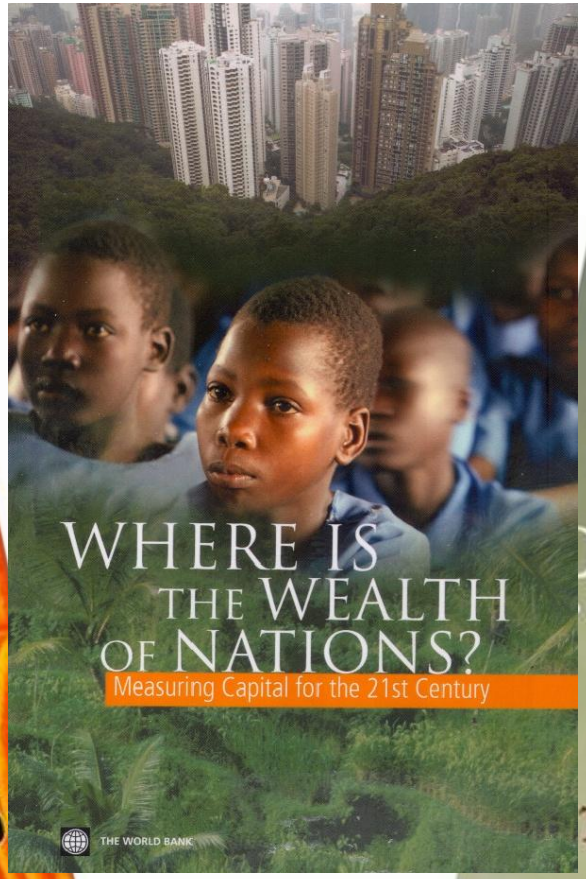


Sources: InfoBrief, NSF, 2008; Main S&T Indicators, OECD 2009.

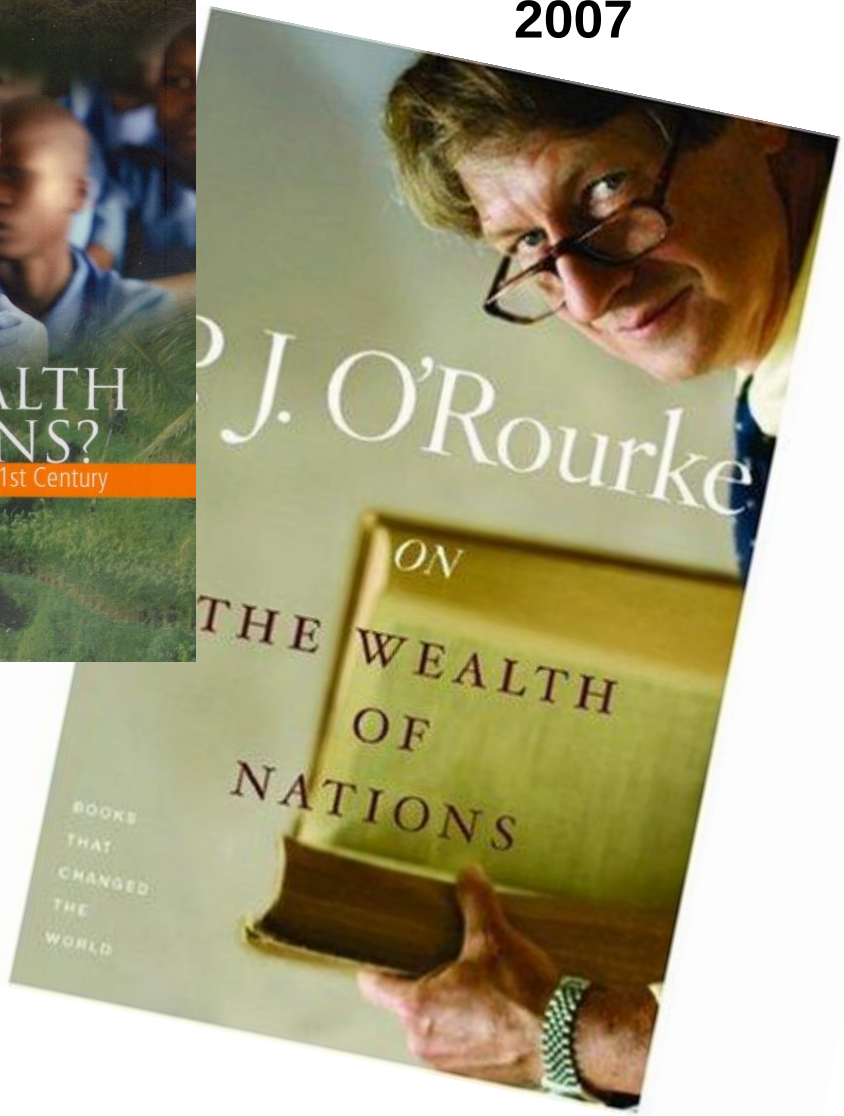
1776



2006



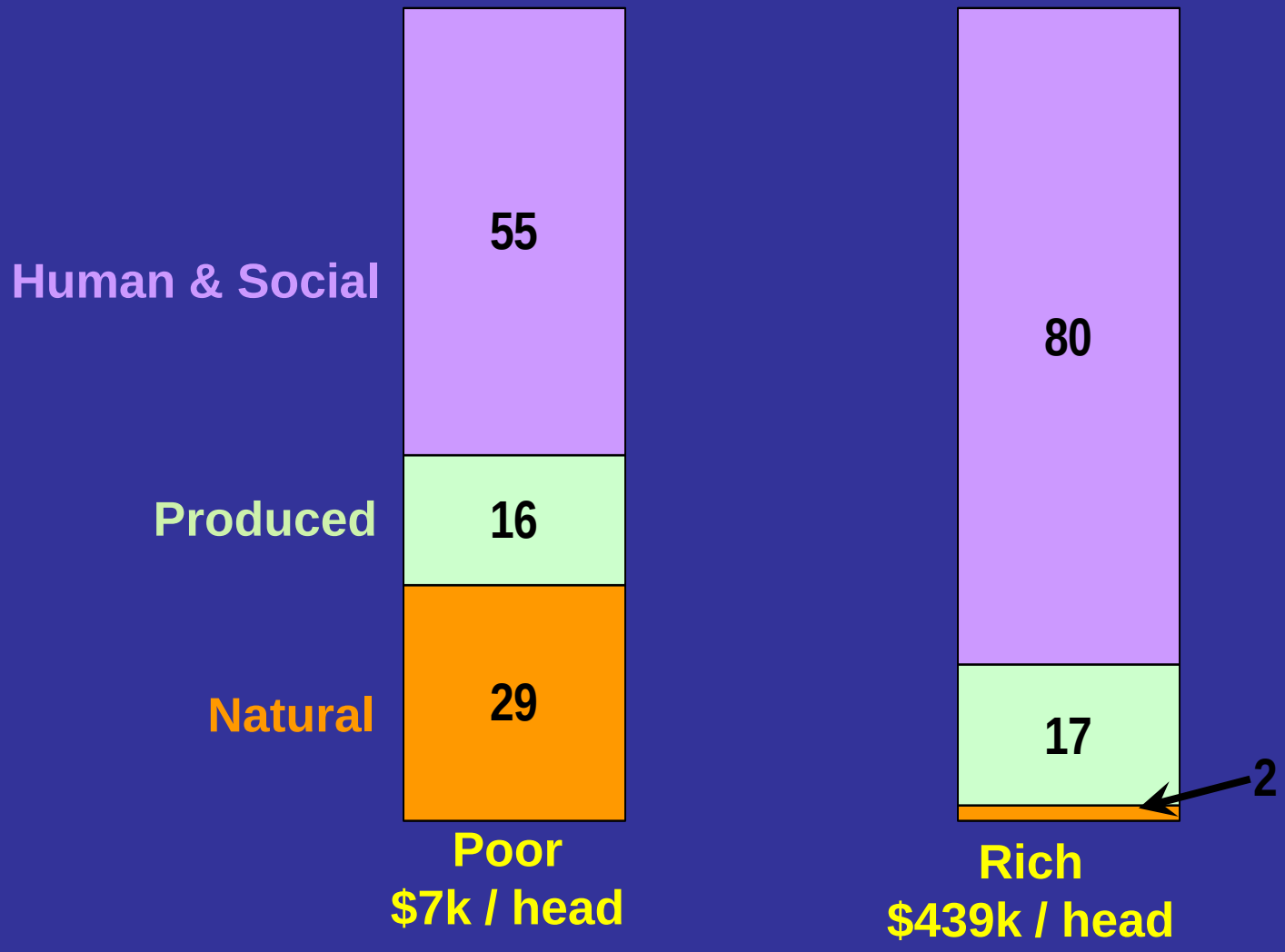
2007



The Wealth of Nations: capital per person

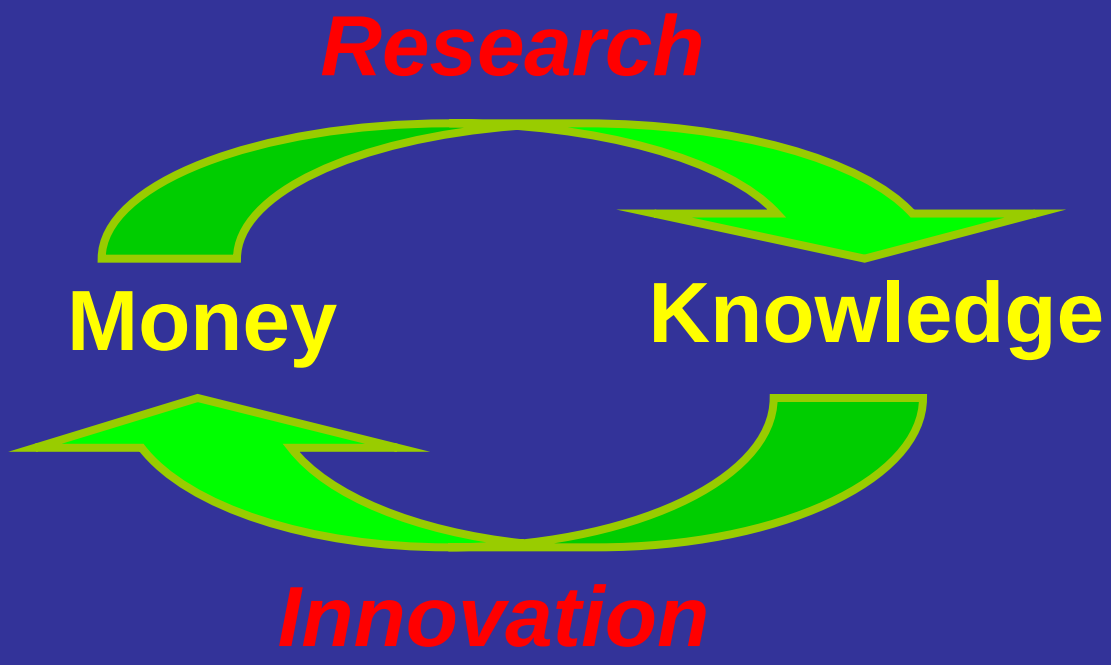
Source: Where is the Wealth of Nations? World Bank , 2006.

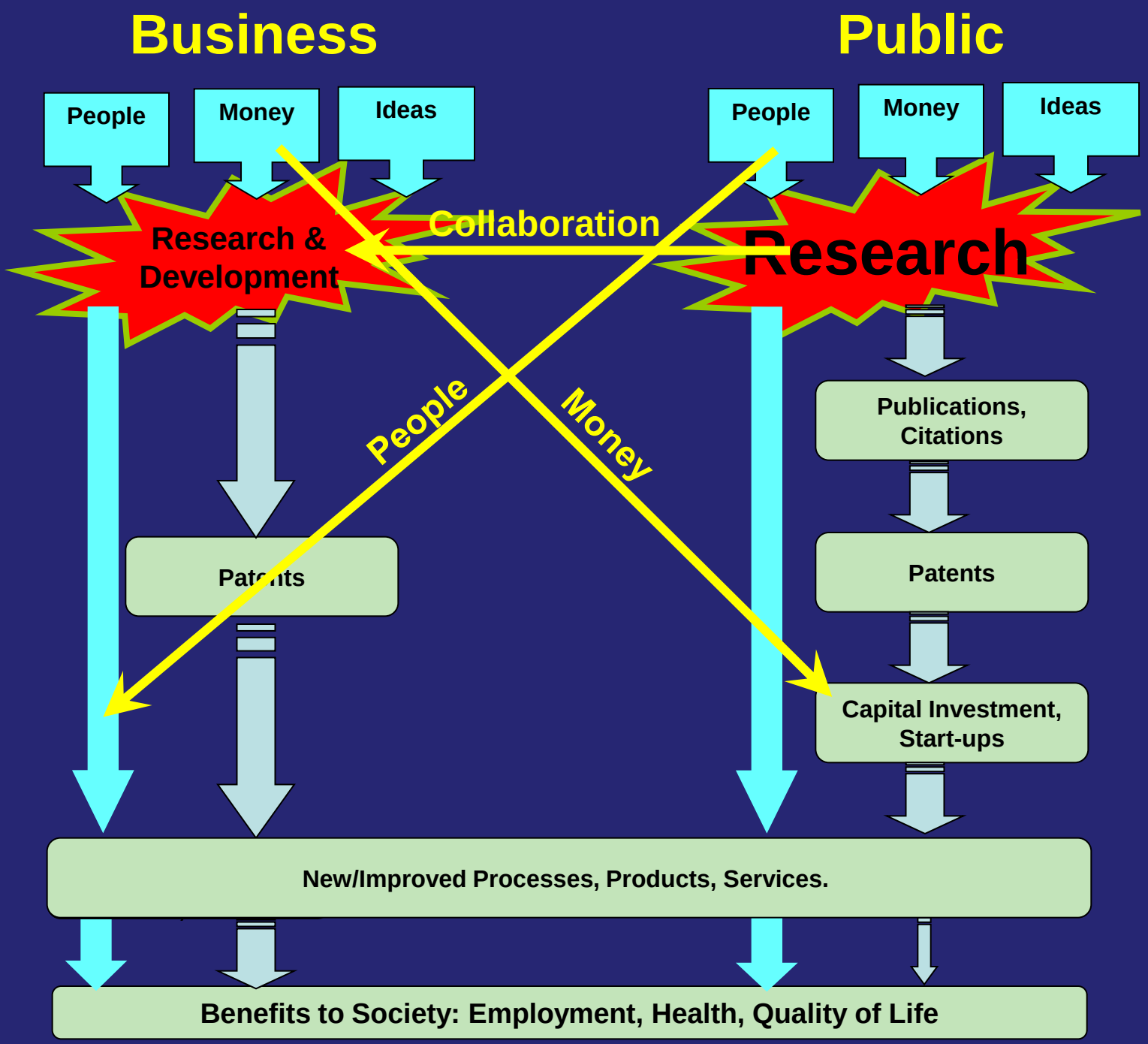
The Wealth of Nations



Source: Where is the Wealth of Nations? World Bank , 2006.

A Virtuous Circle




Business
Public
People
Money
Ideas
People
Money
Ideas
Research & Development
Collaboration
Research
People
Money
Publications, Citations
Patents
Patents
Capital Investment, Start-ups
New/Improved Processes, Products, Services.
Benefits to Society: Employment, Health, Quality of Life

Metrics

OECD	**Main Science and Technology Indicators** **(138 indicators)** **Science, Technology and Industry Scoreboard** **(88 indicators)**
World Bank	**World Development Indicators** **(15 indicators)** **Knowledge Assessment Matrix** **(80 indicators)**
UNESCO	**Science and Technology and Indicators** **(12 indicators)**
WEF	**Lisbon Review** **(68 indicators)**
EU	**European Innovation Scoreboard** **(29 indicators)**

European Innovation Scoreboard - *Inputs*

Human Resources

- S&E, SSH Primary Graduates
- S&E, SSH PhD Graduates
- Pop. with Tertiary Education
- Life-long Learning
- Youth Education Attainment

Finance & Support

- Public R&D Expenditure
- Venture Capital
- Private Credit
- Firms with Broadband

Firm Investments

- Business R&D Expenditure
- IT Expenditure
- Non-R&D Innovation Expenditure

Linkages & Entrepreneurship

- SMEs Innovating In-house
- Innovative SMEs Collaborating
- Firm Renewal
- Public-Private Co-publications

Throughputs

- EPO Patents
- Community Trademarks
- Community Designs
- Technology Balance of Payments

European Innovation Scoreboard - *Outputs*

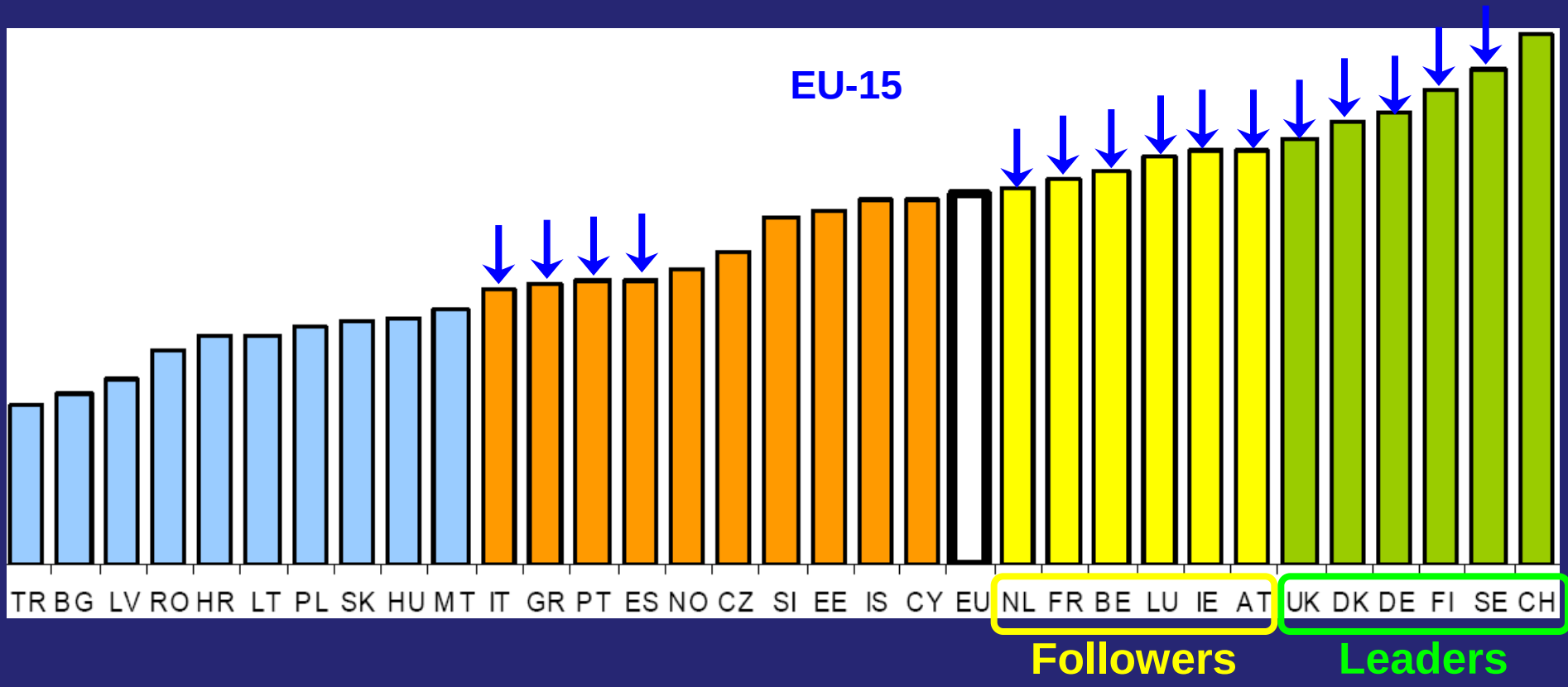
Innovators

- SME Product / Process Innovation
- SME Marketing / Organ. Innovation
- Resource Efficiency Innovators

Economic Effects

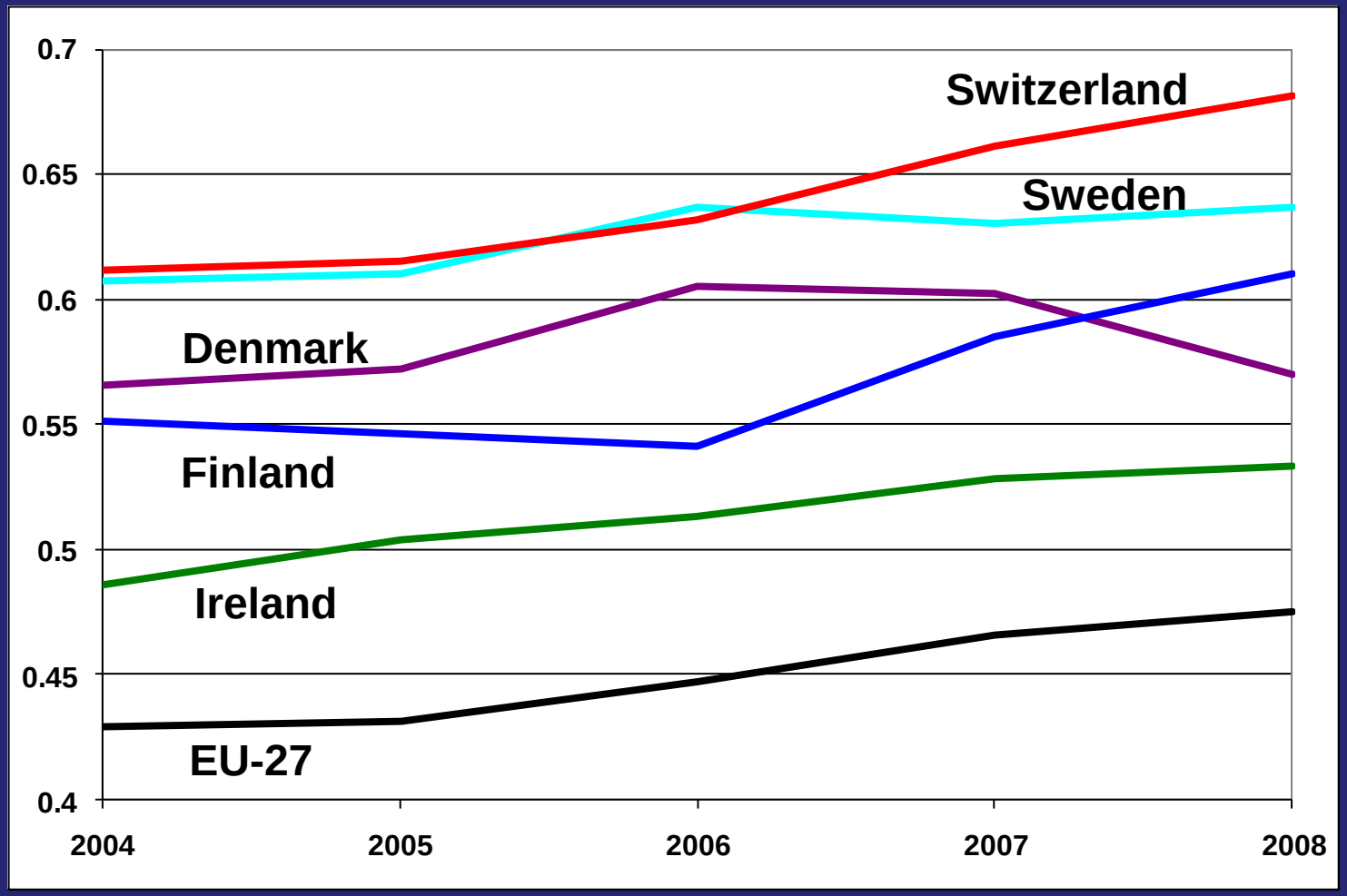
- High-tech *Manuf*. Employment
- Knowledge-Intensive *Serv*. Employment
- High-tech *Manuf*. Exports
- Knowledge-Intensive *Serv*. Exports
- New-to-market Sales
- New-to-firm Sales

Summary Innovation Index 2008
(29 Indicators)



Source: European Innovation Scoreboard 2008, UNU-MERIT, Maastricht , Jan 2009

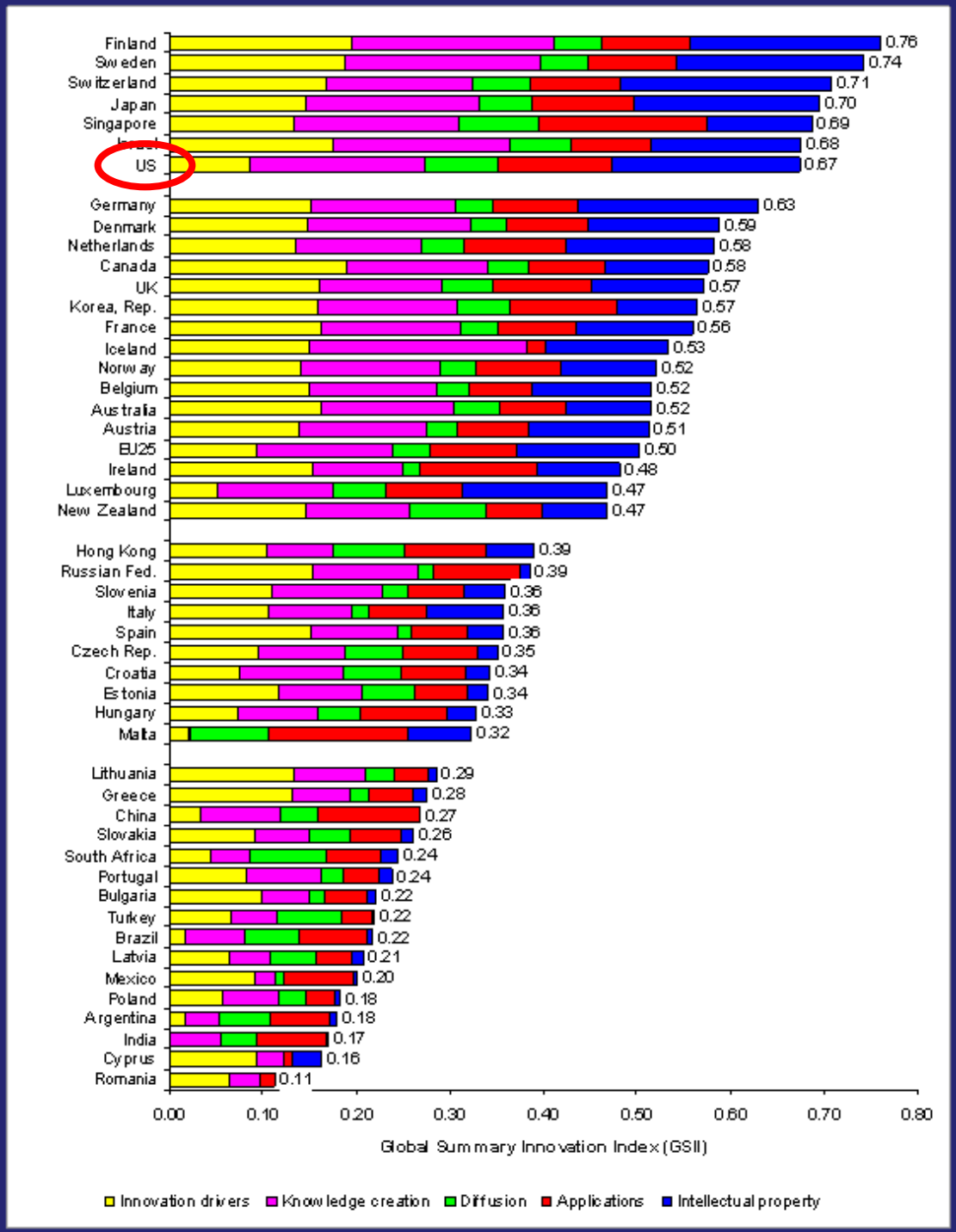
EIS ("2008 methodology") Time Series



Source: European Innovation Scoreboard 2008, UNU-MERIT, Maastricht , Jan 2009

Global Innovation Scoreboard

(12 Indicators)



Source: UNU-MERIT, Maastricht, 2006

Is there a better way?

The *Selection Index* approach

14 Inputs

INNOVATION DRIVERS

1. S&E graduates per 1000 population
2. Population with tertiary education
3. Participation in life-long learning
4. Youth education attainment level

KNOWLEDGE CREATION

5. Public R&D expenditures
6. Business R&D expenditures
7. Share of medium-high-tech and high-tech R&D
8. Share of enterprises receiving public funding for innovation

INNOVATION & ENTREPRENEURSHIP

9. SMEs innovating in-house
10. Innovative SMEs co-operating with others
11. SMEs Innovation expenditures
12. Early-stage venture capital
13. ICT expenditures
14. SMEs using organisational innovation

Table 1

3 Outputs = *Economic Effects*

1. Employment in high-tech manufacturing
2. Employment in high-tech services
3. Exports of high tech products as a share of total exports

Aim

To invest in inputs so as to maximise output (defined as GDP)

GDP = private consumption +
gross investment +
government spending +
exports – imports.

Assigning Economic Value to Outputs

Employment

1% increase in high-tech employment gives

$$v_1 = \frac{n_L G_H - n_H G_L}{n_L (G_H + G_L)}$$

% increase in GDP.

Where, n_H, n_L are the numbers employed in high-tech and low-tech industry, and G_H, G_L are the GVA for high-tech and low-tech industrial sectors.

Exports

1% increase in high-tech exports E_H gives

$$v_3 = \left(\frac{E_H}{GDP} \right)$$

% increase in GDP.

Need to discount outputs for time delay:

$$d = \left(\frac{1}{1+r} \right)^{y}$$

where

y = no. years delay to outputs,

r = discount rate.

Objective is now to maximise outputs:

$$d_1 v_1 E_1 \quad + \quad d_2 v_2 E_2 \quad + \quad d_3 v_3 E_3$$

where

E_1 , E_2 **are % change in high-tech employment in manufacturing & services, respectively;**

E_3 **is % change in high-tech exports;**

v_1, v_2, v_3 **are economic values calculated through impact on GDP; and**

d_1, d_2, d_3 **are time discount factors.**

- There are 14 inputs (Table 1).
- These are inter-related and linked to the output elements E_1 , E_2 , E_3.
- These relationships can be estimated from variances and covariances observed across countries.
- Table 2 shows estimates of these from the latest EIS database.

Covariance Matrix

Table 2

1523.4	572.3	1194	144.9	502.3	597.8	23.7	-238.2	233.8	723.2	341.9	970.9	-57.6	162.5	91.4	323.9	-326.2
572.3	1802.6	2008	158.9	891.5	1875	87.8	910.1	517.4	1301.9	271.4	1193.3	94	456.2	-434.2	848.9	414.9
1194	2008	8239.8	48.5	2177	4459	290.5	1513.5	1132.3	2937.1	787.6	4120.4	125.5	1049.5	128.4	2115.6	917.3
144.9	158.9	48.5	276.7	11.7	118.5	26.4	26.3	-66.4	181.4	121.4	-197	59.6	-129.1	148.6	10.2	-245.5
502.3	891.5	2177	11.7	1332.1	1799.6	116.5	44.4	296.7	926.2	407.6	640.1	-78.8	311.9	21.3	890.8	-285.8
597.8	1875	4459	118.5	1799.6	5104.9	350.4	1853.9	1347.3	1911.9	844.7	1528.4	114.1	1224.2	565.9	[illegible]	1463
23.7	87.8	290.5	26.4	116.5	350.4	[illegible]	[illegible]	97.7	163.4	58.5	263.5	35.1	114.9	101.9	158.8	122.9
-238.2	910.1	1513.5	26.3	44.4	1853.9	[illegible]	[illegible]	1765.1	1848.3	434.3	80.5	-1068.8	2397.7	-1063.8	[illegible]	[illegible]
233.8	517.4	1132.3	-66.4	296.7	1347.3	[illegible]	1765.1	1296.7	993.7	431.2	336.7	-97	1252.3	-67.4	407.1	897.2
723.2	1301.9	2937.1	181.4	926.2	1911.9	163.4	1848.3	993.7	2858.7	896.5	1078.3	-100.8	1254.1	-315.1	933.1	645.5
341.9	271.4	787.6	121.4	407.6	844.7	58.5	434.3	431.2	896.5	1228.1	167.6	-212.3	681.8	19.9	182.4	-312.2
970.9	1193.3	4120.4	-197	640.1	1528.4	263.5	80.5	336.7	1078.3	167.6	6898.6	375.4	216.8	-459.9	946.7	1943.7
-57.6	94	125.5	59.6	-78.8	114.1	35.1	-1068.8	-97	-100.8	-212.3	375.4	525.6	-345.3	-121.8	-12.8	301.7
162.5	456.2	1049.5	-129.1	311.9	1224.2	114.9	2397.7	1252.3	1254.1	681.8	216.8	-345.3	1589.7	-184.1	[illegible]	1127.3
91.4	-434.2	128.4	148.6	21.3	565.9	[illegible]	[illegible]	-67.4	-315.1	19.9	-459.9	-121.8	-184.1	1364.9	[illegible]	6
323.9	848.9	2115.6	10.2	890.8	1973.4	[illegible]	[illegible]	407.1	933.1	182.4	946.7	-12.8	331.9	170.1	[illegible]	573
-326.2	414.9	917.3	-245.5	-285.8	1463	[illegible]	[illegible]	897.2	645.5	-312.2	1943.7	301.7	1127.3	6	[illegible]	4596.3

P G G' C

The weighting of the different inputs which will maximise the output function is the solution to the equations

$$P\,b = G\,v$$

where *b* is a vector of 14 weights and
***v* is a vector of 3 discounted economic values.**

The contribution of each of the elements in the outputs to overall gain is

$$\frac{b'G_j}{b'Pb}(v_j)(100)$$

The relative contribution of each input to the overall gain is given by

$$100-\sqrt{\frac{b'Pb-\frac{b_i^2}{P_{ii}^{-1}}}{b'Pb}}(100)$$

Illustrative Results
(with equal economic weights)

Input	Contribution
S&E graduates per 1000 population	-
Population with tertiary education	5
Participation in life-long learning	-
Youth education attainment level	-
Public R&D expenditures	-
Business R&D expenditures	22
Share of medium-high-tech and high-tech R&D	-
Share of enterprises receiving public funding for innovation	-
SMEs innovating in-house	2
Innovative SMEs co-operating with others	-
SME Innovation expenditures	8
Early-stage venture capital	5
ICT expenditures	-
SMEs using organisational innovation	3

Illustrative Results
(with equal economic weights)

Output	% of total
Employment hi-tech manufacturing	**13**
Employment hi-tech services	**24**
Hi-tech Exports	**63**

Thank you