Science and Innovation Policy Research - What Are the Factors Affecting Policy Impact?

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Structure

Scope of field of science & innovation policy research

What have we learned in 50 years?

20 major advances in understanding

Impact on management and on policy?

Factors affecting impact?

Some personal case-studies

Towards a model of interaction between policy research & policy-making/practice?

Where next?

Scope of field

Definition

- "Economic, policy, management and organisational studies of science, technology and innovation (STI) with a view to providing useful inputs to decision-makers concerned with policies for and the management of STI"

Primary focus

- Specific policy/management issues rather than theory

Nature of research

- Draws on wide range of disciplines
- Multi/inter-disciplinary – 'Mode 2'

Size

- Grown from a dozen researchers in 1950s to thousands today

Scope of field

Terminology changed over time

- Science/research policy, engineering/R&D management
- S&T policy, technology & innovation management
- Neo-Schumpeterian/evolutionary economics, innovation studies

'Science policy and innovation studies'

- Policy – science/research, technology, innovation
- Economics – science, technology, innovation
- Economic geography – e.g. clusters, reg systems of innovation
- Management – R&D, technology, innovation, knowledge
- Organisational studies – innovation, RBV of firm, org learning
- Sociology – e.g. diffusion of technology & innovation
  (but excluding 'science studies'/STS)
- History of technology and innovation, economic/business history
- Psychology – organisational psychology, psychology of creativity

Why is it important?

Science, technology and innovation (STI)

- Source of progress although some adverse consequences
- Major contributor to wealth of nations
- Not only more goods & services, but also ***new*** ones
- Enables people to do things never done before
- Changes to quality of life and environment – for better or worse

Globalisation + growing international competition

➔ Premium on knowledge and innovation

∴ STI increasingly important

- e.g. ICT, biotechnology, nanotech

But expensive and can bring risks/social costs

∴ Effective policies for STI essential

What have we learned?

Field now ~50 years old

What have we learned about the interaction between science, technology and innovation, and the nature of the innovation process?

What have been the key developments in our understanding?

What impact have these had on improving policies for, and the management of, STI?

Previous reviews

Reviews of literature in books, review articles

But most based on

- subjective assessment
- limited aspect/perspective

Tried to adopt

- rigorous approach to identifying main contributions
- global perspective on entire field of science policy & innovation studies

Identified 20 key advances in our knowledge

Methodology

Search for high-impact publications

- No obvious measure of impact on policy/practice
- Use HCPs as indicator of high academic impact, then subjectively assess impact on policy/practice
- Assumes most highly cited = most influential
- Also various problems and biases with *SSCI*

Starting point

- List of ~600 leading STI policy authors
- Surveyed ~90 journals
- Key word search

Identified ~200 publications with >300 citations

From these, synthesised 20 major advances

1. From individual entrepreneur to corporate innovators

Schumpeter (1934, 1939, 1942, 1950)

- One of few economists in early 20th C to recognise importance of innovation
- Distinction between 'invention' and 'innovation'
- 'Schumpeter Mark I'
  - stressed central role of individual entrepreneur
- 'Schumpeter Mark II'
  - gave increasing importance to collective innovative activities of large firms and in-house R&D
  - reflected changes in US industry in mid-20th C
- But still examples of Schumpeter Mark I (especially in IT)

2. From *laissez faire* to government intervention

Pre-WWII – limited involvement of govt in R&D & innovation, except in agriculture & medicine

WWII – Manhattan project, radar, cryptography, etc.

Post-WWII – major R&D programmes in defence, nuclear energy, space, health etc.

Based on belief in 'linear model' of innov'n (Bush, 1945)

Basic res ➔ Applied res ➔ Tech devlpt ➔ Innovation

Simple, clear (and convenient!) model

1950-60s – Govt emphasis on supply-side policies

- Public investment in R&D
- Training of QSEs

2. From *laissez faire* to government intervention

Economic justification for govt intervention in STI based on ‘market failure’

Nelson (1959), Arrow (1962)

- Scientific knowledge a ‘public good’ – i.e.
  - ‘non-rival’
  - ‘non-excludable’
- Because they can’t appropriate all the benefits from their investment, private firms tend to under-invest in R&D
- To achieve socially optimal level of investment in S&T, govt ∴ needs to fund R&D
- Public funding thus expands the pool of economically useful knowledge

3. From 2 factors of prod'n to 3

Solow (1957)

- Econ growth not just ∵ changes in labour & capital
- A large 'residual' – attributed to tech change

Griliches (1957, 1958)

- High rates of return to R&D
- Social rate of return > private rate of return

Other important contributions by

- economists, e.g. Mansfield (1961, 1968), Schmookler (1966), Scherer (1965, 1970)
- economic historians, e.g. Gershenkron (1962), David (1975), Rosenberg (1976)
- Freeman and SPRU colleagues
  - *The Economics of Industrial Innovation* (1974 + later ed'ns)
  - 'Long waves' and economic development (1982)

4. From single division to multi-divisional efforts

Burns & Stalker (1961), *The Management of Innovation*

- Tech innovation influenced by different forms of org'n (e.g. mechanistic VS organic) with associated communication patterns
- Successful innovation requires integration of R&D with knowledge of market etc. – often hindered by internal divisions in the firm

Zaltman et al. (1973), *Innovations and Organisation*

Allen (1977), *Managing the Flow of Technology*

- Importance of communication flows
- Certain organisational structures enhance innovation

5. From technology adoption to innovation diffusion

Coleman et al. (1957, 1966)

- individ's/org'ns respond to innov'n opportunities in different ways

Rogers (1962 + later editions), *Diffusion of Innovations*

- diffusion of tech'y & innovation often follows logistic 'S-curve'
  - slow diffusion, rapid growth, growing saturation, then slow-down
- different categories of innovators
  - early adopters, early majority, late majority, laggards

Vernon (1966)

- four-stage model of the product cycle
  - new goods (i.e. innovations) generally developed 1st in industrialised countries, then diffused to LDCs as product matures

Model formalised by Krugman (1979)

6. From sc push to demand pull

Science-push model – Bush (1945)

- Provided rationale for govt funding
- Favoured by scientists

Demand-pull model – changed market demand 'calls forth' innovation

Mkt demand ➔ App res ➔ Tech devlpt ➔ Innovation

- Often attributed to Schmookler (1966)
- Model picked up by e.g. Myers and Marquis (1969)
  - Study of >550 innovations in 5 industries
  - "Recognition of demand is a more frequent factor in innovation than recognition of technical potential"

2 models have very different policy implications, so various empirical studies to investigate (e.g. Hindsight, TRACES)

Mowery & Rosenberg (1979) review – both demand and supply side influences crucial

7. From single factor to multifactor explanations of innovation

Early studies – focus on ***successful*** innovations

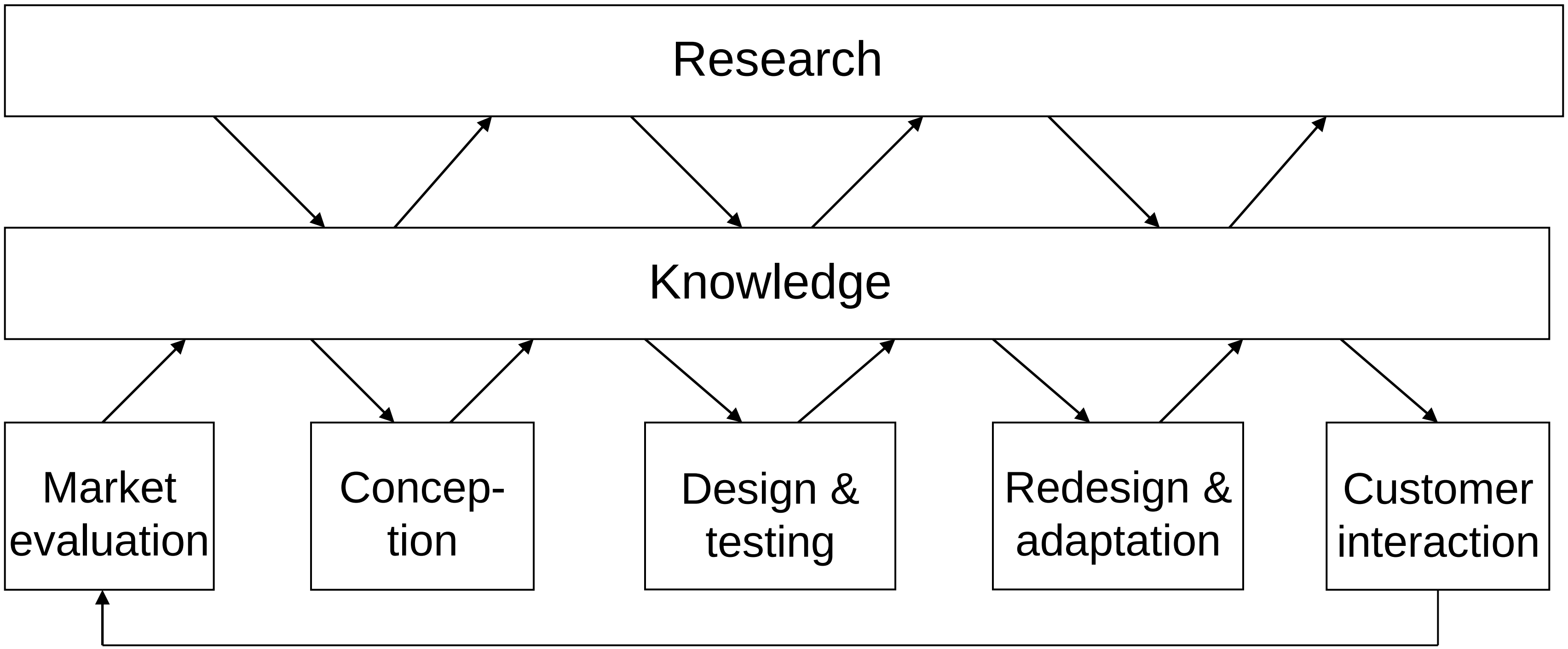
Project SAPPHO (Rothwell et al., 1974)

- 43 matched pairs of successful & unsuccessful innovations
- Most important factor = 'user needs understood'
- Other significant factors include
  - attention to marketing
  - support of senior 'product champion'
  - size of project team
  - coordination of R&D, production & marketing
  - good communication with ext sc'ic community
- Success not greatly affected by
  - R&D organisation, incentives, academic qualifications of staff, size of firm, no. of QSEs, project planning, growth rate of firm

Subsequent work on how best to manage & exploit innovation

- e.g. Hayes & Wheelwright (1984), Abernathy & Clark (1985), Teece (1986), Womack et al. (1990), Clark & Fujimoto (1991), Utterback (1994), Christensen (1997)

8. From the linear model to the interactive ‘chain-link’ model



Adapted from Kline & Rosenberg (1986)

A better representation of (complex) reality

- But harder to use for policy/management purposes

STI researchers keep ‘slaying’ ***the*** linear model

- But what happened to the other linear model?

9. From a static to a dynamic model of innovation

Abernathy & Utterback (1975 & 1978) – dynamic model of product & process innovation

- Initial period dominated by radical product innovation
- Attracts new entrants ➔ several competing designs
- Process innovations then become more important
- Emergence of a dominant design (e.g. QWERTY typewriter, Model T Ford, Hoover, Boeing 747, IBM PC, ipod)

10. From one innovation process to several sector-specific types

From earlier empirical studies, clear that sources & nature of innovation process vary with sector

Pavitt (1984) – analysed sectoral patterns

- SPRU database of ~2000 innovations
- Taxonomy of sectors
  - supplier-dominated
  - scale-intensive
  - specialised equipment suppliers
  - science-based
- Taxonomy resolves some earlier differences in empirical findings re
  - S&T push VS demand pull
  - product VS process innovation
  - relationship between firm size and innovation

Recent work shows this sectoral approach too static

11. From neo-classical to evolutionary economics

Nelson & Winter (1977)

- ‘In search of a useful theory of innovation’
- Existing economic literature fundamentally flawed

Nelson & Winter (1982), *An Evolutionary Theory of Economic Change*

- Tech change and innovation central – generate ‘*variation*’ in form of new products, services etc.
- Firms compete with these products/services – market provides ‘*selection*’ mechanism
- Products/services strongly influenced by ‘routines’ within firms – provide ‘*self-replication*’ mechanism
- i.e. analogy with biological evolution and ‘survival of the fittest’

12. From old to new growth theory

Solow (1956) – neo-classical economic growth theory

- Technology treated as exogenous

David (1985), Katz and Shapiro (1986) – technology adoption ➔ network externalities

Romer (1986, 1990) – 'New growth theory' (NGT)

- Neo-classical economics – does not explain rate of growth – depends on exogenous factors e.g. rate of savings, rate of tech change
- Human capital and new technologies crucial – latter can generate 'increasing returns' (Arthur, 1989)
- R&D can create important 'spillovers' (Jaffe, 1986)
- Investment in education & R&D can boost growth, as can other incentives to innovate (e.g. patents)
- ➔ investment in 'intangibles' cf. previous emphasis on investment in 'tangibles' such as capital goods

NGT further developed by Grossman & Helpman (1991) and Aghion & Howitt (1992, 1998)

13. From the optimising firm to resource-based view of the firm

Neo-classical economists

- Firm = an optimising organisation, with perfect information & rationality

Resource-based view of firm (RBV)

- e.g. Wernerfelt (1984), Grant (1991, 1996)
- Firm = a collection of resources (human, physical, etc.)
  - e.g. brand names, tech knowledge, equipment, skilled personnel, trade contacts, efficient procedures, capital
- Built on earlier work by Coase (1937) and Penrose (1959)

Subsequent work on e.g.

- core competences (Prahalad & Hamel, 1990)
- the learning organisation (Senge, 1990)
- dynamic capabilities (Teece et al., 1997; Eisenhardt & Martin, 2000; Zollo & Winter, 2002)

14. From individual actors to systems of innovation

Freeman (1987) – success of Japan heavily dependent on wider national system of innovation (NSI)

Lundvall (1988, 1992), Nelson (1993) – extended to other countries

NSI definition

> "that set of distinct institutions which jointly and individually contribute to the development and diffusion of new technologies and which provides the framework within which governments form and implement policies to influence the innovation process. As such it is a system of inter-connected institutions to create, store and transfer the knowledge, skills and artefacts which define new technologies." (Metcalfe, 1995)

How effectively a NSI operates depends not just on the strength of the individual actors (companies, gov't labs, universities etc.) but more particularly on ***the strength of the links*** between them

15. From market failure to system failure

Nelson (1959) & Winter (1962)

- Private firms tend to under-invest in R&D
- To overcome this 'market failure', government needs to fund R&D

cf. new rationale – govt needs to overcome system failures & develop/strengthen links in NSI

- From 'picking winners' to building/strengthening links
- e.g. via networks, collaboration, strategic alliances etc.
- Technology Foresight as a means of 'wiring up the national system of innovation'

16. From one to ‘two faces’ of R&D

Cohen & Levinthal (1989 & 1990) – two roles (or ‘faces’) of in-house company R&D

- to develop new knowledge internally
- to identify potentially useful external knowledge, access and quickly exploit it

Concept of ‘absorptive capacity’ – crucial for

- combining technologies (see below)
- successful open innovation (see below)

Jaffe and others – R&D generates ‘spillovers’

- firms need to be in position to exploit effectively spillovers generated by others

17. From Mode 1 to Mode 2?

Gibbons et al. (1994), *The New Production of Knowledge*

- Mode 1 – discipline-based, largely in academic institutions, primarily concerned with furthering knowledge, subject to internal scrutiny
- Mode 2 – transdisciplinary, in variety of institutions, pursuing knowledge 'in the context of application', subject to ext accountability
- Shift over time from Mode 1 to Mode 2 (?)

'Pasteur's Quadrant' – Stokes (1997)

- Research that is aimed **both** at increasing knowledge **and** at generating useful results – cf.
- Bohr's Quadrant – aimed solely at increasing knowledge
- Edison's Quadrant – aimed solely at generating useful results

'Triple Helix' (Etzkowitz & Leydesdorff, 1997)

- Growing 3-sided interaction of universities, industry and government
- 'The second academic revolution' – adoption of '3rd Mission' ➔ emergence of 'the entrepreneurial university'

18. From single-technology to multi-technology firms

Many major innovations involve bringing together previously separate streams of technology

- ‘technology fusion’ (Kodama)

Granstrand, Patel & Pavitt (1997)

- Technological diversity of growing importance to innovation
- In some sectors, firms need to combine several technologies
- ➔ Need for strategic alliances, links with universities etc.

19. From national to multi-level systems of innovation

NSI concept extended to other dimensions

- ***Regional system of innovation*** – e.g. Saxenian, Cooke, Jaffe, Audretsch & Feldman, Morgan
- ***Sectoral system of innovation*** – e.g. Malerba, Breschi, Orsenigo, McKelvey
- ***Technological systems*** – e.g. Bijker & Hughes, Carlsson

Regional system of innovation also influenced by e.g. cultural factors

- R Florida – cities/regions with more cultural diversity & 'bohemian' lifestyles more creative/innovative?

Firms need to have effective links with all these different levels of systems if to benefit fully

20. From closed to open innovation

Knowledge required for innovating becoming more organisationally dispersed (?)

Locus of innovation shifting from within the firm to networks, alliances, collaborations etc. – i.e. innovation increasingly co-produced with partners (suppliers, users, universities etc.)

Variously characterised (e.g. by Powell et al., Chesborough, von Hippel etc.) as

- open innovation
- networked innovation
- distributed innovation
- interactive innovation
- democratic innovation

Firms need good links with external knowledge sources + ability to exploit these promptly & effectively

20 advances in science/innov'n policy

From individual entrepreneur to corporate innovator

From *laissez faire* to government intervention

From 2 factors of production to 3

From single division to multi-divisional efforts

From technology adoption to innovation diffusion

From science push to demand pull?

From single factor to multi-factor explanations of innovation

From static to dynamic model of innovation

From linear model to interactive 'chain-link' model

From one innovation process to several sector-specific types

From neo-classical to evolutionary economics

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Impact on T&I management

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Factors affecting policy impact?

Little research on this – largely tacit knowledge

Lessons from some personal examples

- Research assessment
- Science indicators
- Comparisons of government funding of research
- Technology Foresight
- Economic benefits of publicly funded research

1. Research assessment

1978 – SPRU 10 year review, Gov't report

➔ 'Big science' project

- ~65% of SRC budget devoted to big science labs
- What benefits to UK?

Developed methodology for assessing

- scientific contributions
- technological spin-off etc.
- skills-related benefits

Assessment of scientific contributions based on

- bibliometric indicators
- extensive peer-review

1. Research assessment

SPRU study one of first

- to use bibliometric indicators for institutional evaluation and a specific policy purpose
- to stress that ‘partial indicators’ only
- to combine bibliometric indic’s with extensive peer review
- to use HCPs as indicators of more radical scientific advances (cf. ‘normal’ science)
- to show that peer review may break down in ‘big science’ (no neutral peers)
  - Cambridge and Jodrell Bank
  - Rutherford and Daresbury Labs
  - RGO/INT

1. Research assessment

Hostile reaction from

- scientists – threat to autonomy & monopoly of peer review
- Directors of 2 of the 'big science' labs
- science studies community

Sceptical reaction from most policy-makers

Lessons

Demand-pull important as well as science-push

Innovative science policy research ➔ opposition

Need to find a 'product champion'

- B Oakley (SRC)
- Alvey Prog evaluation (eventually ➔ Technopolis)

Need for perseverance – continual 'marketing'

- Subsequent diffusion to RC's, DTI etc.

2. Science indicators

Extension to international comparisons

Prior to 1980s, little more than anecdotal evidence

- e.g. UK scientists claiming that in decline

SPRU 1985 study – 'The decline of British science'

- UK's % share of publications & citations in decline
- Significant impact (e.g. House of Lords, Horizon)
- Welcomed by scientists!
- i.e. stronger 'demand'

Several subsequent studies to diffuse (e.g. BESST)

1995 visit to SPRU by new Chief Scientist

- Quickly becomes 'product champion'
- But ignored caveats
- 1997 paper in *Science* – UK No.2, but Fr & G suffering as much research in separate institutes
- To criticise or not to criticise?

3. Comparisons of govt funding

ABRC study (1984-86)

- ‘experiment where we knew the answer’
- revealed problems with official OECD data
- political pressures (e.g. France)
- initial impact limited?

ABRC/NSF study (1987-89)

- extended, updated, more rigorous
- near end, Irvine met Minister (Jackson)
  - Mrs T: “We’d better give them an extra £100 million”
  - Result from 2nd study?

Moral dilemma!

- Present in all science policy research
- Engage and compromise VS objectivity & integrity
- Appropriate balance?

4. Technology Foresight

1983 – Cabinet Office & ACARD

- ITT – how to identify exploitable areas of science?
- SPRU bid – title? 'Project Foresight'

Focus on France, Germany, US & Japan

Report to ACARD

- Learn from others, especially Japan
- Launch small-scale Foresight experiment

Transformed into book, *Foresight in Science*

- Choice of subtitle – wrong!

This + emphasis on Japan ➔ largely ignored by Thatcher Govt – belief that could 'leave to the market'

i.e. political circumstances not right – no 'demand'

4. Technology Foresight

1987-89 – study for Dutch Govt – major impact

1992 – phone call from Cabinet Office

Small project

- Focussed on G & US (not J)
- Set out range of options
- 60-page report

New Cabinet Minister (Waldegrave)

- Preparing White Paper
- Need 2-page brief on TF
- The briefing
- “Yes, Minister!”

1993 White Paper

- Launched TF
- Opted for most ambitious form!

4. Technology Foresight

Lessons

- Be attuned to political context
  - In 1993, chose G & US as exemplars, not J
- Go in at right level
  - ‘Level 5’ civil servants – actually do the work, keen to make name
- Find a product champion
  - Waldegrave – “my idea”
  - Stewart – ran TF programme very efficiently
- *Carpe diem* (Horace)
  - “***Luck*** is what happens when ***preparation*** meets ***opportunity***.” (Seneca)
- Be prepared to take on other roles
  - Practitioner
  - Even missionary!

5. Benefits of publicly funded research

Treasury – sceptical re benefits from research

1996 ITT – do as ‘loss leader’?

Moral dilemma – give Mansfield answer (RoR = 29%)?

- Politically convenient
- But methodologically dubious & too simplistic

Identified 6 ‘channels’ – all ➔ substantial benefits but most not easily quantifiable

Report ➔ briefing at Treasury – influence on CSR?

2010 Roy Soc Rep’t ➔ extra £350M for science

Lessons

- Opportunism
- ‘Loss leader’ can sometimes pay off
- Balance between simplicity & complexity in message
- Govt – short collective memory ➔ more work!

Towards a model of interaction between policy research & policy-making

In 50 years, science & innovation policy research made some important contributions

Several instances of significant impact on policy

But not a simple linear 'science push' process

Need

- demand-pull – likely to need 'market research', demand articulation, marketing etc.
- 'product champion'
- absorptive capacity

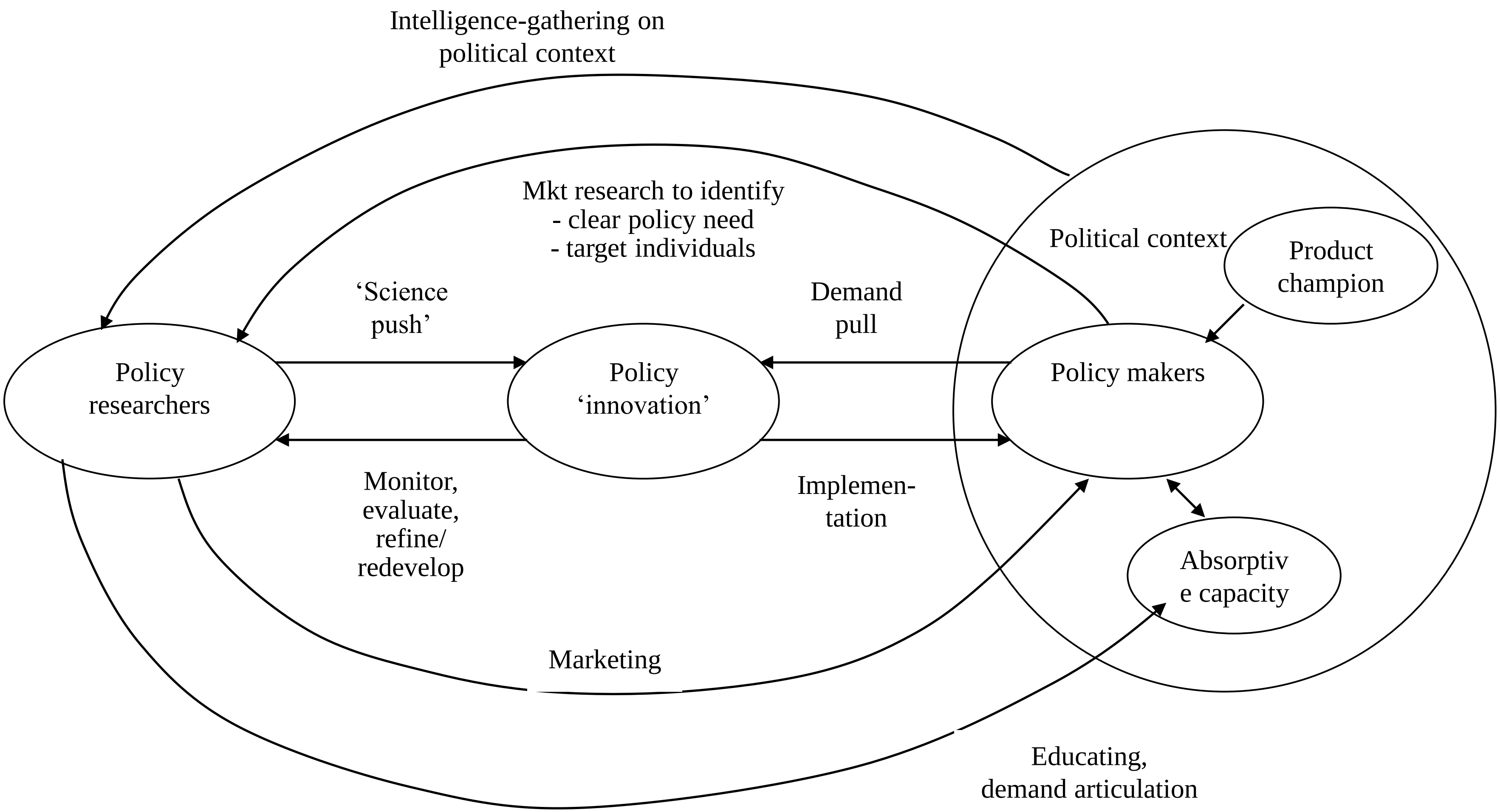
cf. the innovation process itself

Towards a model of interaction between policy research & policy-making

Researchers also need

- to identify clear policy need
- to understand wider political context
- to go in at right level
- to seize opportunities
- to deliver on time

A model of the interaction between policy research and policy-making



Towards a model of interaction between policy research & policy-making

Also need

- to identify clear policy need
- to understand wider political context
- to go in at right level
- to seize opportunities
- to deliver on time

To achieve this, may well need

- to compromise – balance between engagement and integrity
- to simplify – balance between sophistication and accessibility
- to persevere – ‘knowledge creep’ VS ‘direct hit’

Where next?

Have we kept up with our changing world?

Or are we

- like generals, still 'fighting the last war'?
- like politicians, "in the thrall of the ideas of some long-dead economist"?

Focus of many innovation studies still reflects central issues of previous decades – e.g.

- innovation in manufacturing (especially hi-tech 'boys' toys') rather than services & other sectors
- innovation for productivity rather than sustainability
- innovation for wealth creation rather than wellbeing or quality of life

Need to address new challenges

- '20 challenges for innovation studies' (Martin, 2013)

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