2. Methodology of Technology and Innovation

2.1. What is technology economics?

- Technology as an entry point of economic analysis

  “ ... a number of important economic problems can be powerfully illuminated [by examining technologies] ... because the specific characteristics of certain technologies have ramifications for economic phenomena that cannot be understood without a close examination of these characteristics.”

Different world views

- Stationary (steady) state
  "A state that does not evolve with time"
  (in quantum mechanics)
- Pareto optimality

Creative destruction

" ... in dealing with capitalism, we are dealing with an evolutionary process. ... process of industrial mutation ... that incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one. This process of Creative Destruction is the essential fact about capitalism" (Schumpeter 1943: 82-83)

Neoclassical vs. Evolutionary economics

- Differences in priority in understanding the economy
- Different conceptualisation of technology

Production Theory

- Inputs → outputs
- Inputs
  - what are included?
  - which ones are more important?
- Outputs
  - what are they? ‘throughputs’?
- Transformation
  - management? technology?

Production function analysis

(1) Main objectives

- finding optimal resource allocation
- determinants

① relative prices between K and L

② the shape of the function

Production function analysis

(2) factor substitution vs. technological progress

- factor substitution separated from technological progress
- 'frictionless' substitution

"*Today's* factor substitution possibilities ... are the product of *yesterday's* technological explorations." (Rosenberg 1976: 64)

- tgcal progress = expansion of tgcal frontier

Production function analysis

(3) Explaining technological change

- movement of production function
  "What is the mover?" → ?
- readily available technologies?
- exogenous technological progress
- possible directions of tgcal progress
  : K-saving (L- augementing), L-saving (K-augmenting) …

Induced technological change

- Bias in innovation activities according to relative scarcity of factors
- "The real reason for the dominance of labour-saving inventions is surely …hinted at in our discussion of substitution. A change in the relative prices of the factors of production is itself a spur to invention, and to invention of a particular kind – directed to economizing the use of a factor which has become relatively expensive. The general tendency to more rapid increase of capital than labour which has marked European history during the last few centuries has naturally provided a stimulus to labour-saving inventions." (J.R. Hicks, *Theory of Wage*, quoted in Rosenberg 1976: 108-109)

Bias in reality?

" ... a firm always has an incentive to reduce any portion of its costs. The market mechanism provides no incentive to look for inventions which have any particular factor-saving bias. Indeed ... in competitive equilibrium it does not even make sense to speak of 'dear' labor or 'cheap' labor. After all, when each factor is being paid the value of its marginal product, then all factors are equally 'cheap' and equally 'dear' in the eyes of a competitive firm." (Rosenberg 1976: 109)

Bias in reality?

"If .. the theory [of induced inventions] implies that dearer labor stimulates the search for new knowledge aimed specifically at saving labor, then it is open to serious objections. The entrepreneur is interested in reducing costs in total, not particular costs such as labor costs or capital costs. When labor costs rise, any advance that reduces total cost is welcome, and whether this is achieved by saving labor or capital is irrelevant. There is no reason to assume that attention should be concentrated on labor-saving techniques." (W. Salter 1960, *Productivity and Technical Change*, quoted in Rosenberg 1976: 109)

Why L-saving technological progress then?

- Reactions to (threat of) increasing L costs …
- Easier to increase scale
- Higher possibility of innovations with more capital intensive technologies

  cf. division of L and productivity

Production function analysis

(4) Measuring technological change

- technology given outside
- no direct way to measure technological change

  $\rightarrow$ a 'residual' analysis

2.2. Growth Accounting and Measuring Technologies

‘Paper Tigers’?

“Asian growth has so far been mainly a matter of perspiration rather than inspiration - of working harder, not smarter (Paul Krugman, ‘What Ever Happened to the Asian Miracle?’ *Fortune*, Aug. 18, 1997)”

TABLE 3.1: CRUDE ESTIMATE OF TOTAL FACTOR PRODUCTIVITY GROWTH

Hong Kong							
Time Period	Growth of:			Average Capital Share	Percentage Contribution of:		
	Output	Labour	Capital		Labour	Capital	Tech. Δ
71-76	0.406	0.165	0.447	0.330	0.27	0.36	0.36
76-81	0.512	0.253	0.527	0.386	0.30	0.40	0.30
81-86	0.294	0.095	0.388	0.421	0.19	0.55	0.26
86-90	0.260	0.036	0.237	0.414	0.08	0.38	0.54
71-90	1.472	0.549	1.599	0.384	0.23	0.42	0.35
Singapore							
Time Period	Growth of:			Average Capital Share	Percentage Contribution of:		
	Output	Labour	Capital		Labour	Capital	Tech. Δ
70-75	0.455	0.247	0.992	0.521	0.26	1.14	-0.40
75 80	0.455	0.256	0.487	0.501	0.28	0.54	0.18
80-85	0.300	0.069	0.651	0.465	0.12	1.01	-0.13
85-90	0.582	0.252	0.284	0.447	0.37	0.35	0.30
70 90	1.592	0.825	2.413	0.489	0.26	0.74	-0.01

Young

"Singapore is a victim of its own targeting policies, which are increasingly driving the economy ahead of its learning maturity into the production of goods in which it has lower and lower productivity." (Young 1992: 5)

Krugman

"Singapore's growth has been based largely on one-time changes in behavior that cannot be repeated. Over the past generation the percentage of people employed has almost doubled; it cannot double again. A half-educated work force has been replaced by one in which the bulk of workers has high school diplomas; it is unlikely that a generation from now most Singaporeans will have Ph.D's. And an investment share of 40 percent is amazingly high by any standard; a share of 70 percent would be ridiculous. So one can immediately conclude that Singapore is unlikely to achieve future growth rates comparable to those of the past. ... all of Singapore's growth can be explained by increases in measured inputs. There is no sign at all of increased efficiency." (Krugman 1994)

Growth accounting and its applications

- Shaky methodological foundation
- Poor understanding of the process of technological progress

Various Measurements of Technological Progress

(1) Labour productivity

- historically the most widely employed measurement

cf. capital deepening

(2) Capital productivity (capital efficiency)

- ICOR, ROE, ROA ...
- long-term trend in catching-up countries: decline

Various Measurements of Technological Progress

(3) Total factor productivity (TFP)

- multi-factor productivity (MFP)

: output increase relative to all factors

- a common concern of many economists interested in growth

* J.S. Mill

"The increase of production ... is a result of the increase of the [inputs] themselves, or of their productiveness." (quoted in Abramovitz 1989: 13)

$Q = F(K,L,t)$

The Solow Model and Residual

- Objective of the Model
  - a steady state growth

  "To see if there is always a capital accumulation path consistent with any rate of growth of the labor force" (1956, p. 68).

  → 'Stable full employment growth path'

The Solow Model and Residual

(1) $\boxed{Q = F(K,L,t)}$

(2) $\boxed{Q = A(t)F(K,L)}$

Assumption (1): Neutral technological progress

A(t), the cumulated effect of shifts in the production function over time which includes technological progress as well as "slowdowns, speedups, improvements in the education of labor force, and all sorts of things" (Solow 1957, p. 312)

The Solow Model and Residual

(3) $$\frac{\dot{Q}}{Q} = \frac{\dot{A}}{A} + w_k \frac{\dot{K}}{K} + w_l \frac{\dot{L}}{L}$$

(w_k and w_l are the relative shares of capital and labour)

Assumption (2): F(K,L) is constant returns to scale

Assumption (3): MP = MC (maintaining equilibrium)

TFP

- Residual

: What is left out in output growth after contributions of capital and labour accumulation are accounted for

"Some sort of measure of our ignorance about the causes of economic growth" (Abramovitz 1956: 11)

→ What can we say with what we do not know?

Interpretation of TFP

- The sheer size of the residual in advanced countries
  - "the most important source of growth" (51% in Dennison)

Table 1.1. *Sources of growth in labor productivity, Denison's estimates, 1948–79*

	Percentage points per year	Percent of total growth rate
1. National income per person employed	1.81	100
2. Hours per person	−0.41	−23
3. Capital stock per person[a]	0.43	24
4. Total factor input (lines 2 + 3)	0.02	1
5. Total factor productivity (= primitive residual) (line 1–4)	1.79	99
6. Labor quality	0.53[b]	29
a. Efficiency offset	0.05	3
b. Age–sex	−0.16	−9
c. Education	0.41	23
d. Other	0.22	12
7. Adjusted total factor input (lines 4 + 6)	0.55	30
8. Adjusted total factor productivity (line 1–7)	1.26	70
Resource allocation	0.24	13
Scale	0.31	17
Intensity of demand	−0.13	−7
Other	−0.08	−4
Knowledge and n.e.c. (final residual)[c]	0.92	51

[a]Includes land.
[b]Total does not equal sum of components because of rounding.
[c]n.e.c. = not elsewhere classified.
Source: Denison (1985), Table 8.3. Figures are weighted arithmetic averages of growth rates for 1948–73 and 1973–79.

Interpretation of TFP

- Modest interpretation
  - the sheer size of our ignorance
  - → continual efforts by scholars to reduce the size of TFP by manipulating parameters
  - → still large size of TFP

Table 1.2. *Sources of growth in total national output, 1948–79: comparison of estimates by Edward Denison and Dale Jorgenson*

	Percentage points per year		Percent of total growth rate	
	Denison	Jorgenson	Denison	Jorgenson
1. Output[a]	3.49	3.42	100	100
2. Total labor hours	0.93	0.68	27	20
3. Labor quality	0.53	0.37	15	11
4. Capital stock[b]	0.77	1.15	22	34
5. Capital quality	–	0.40	–	12
6. Total labor input (lines 2 + 3)	1.46	1.05	42	31
7. Total capital input (lines 4 + 5)	0.77	1.56	22	46
8. Total factor input (lines 6 + 7)[c]	2.23	2.61	64	76
9. Total factor productivity (line 1–8)[c]	1.26	0.81	36	24

[a]Denison output is net national income; Jorgenson output is gross value added.
[b]Includes land.
[c]Sums of lines do not necessarily equal totals due to rounding.
Sources: Denison (1985), table 8.1. Figures are weighted arithmetic averages of growth rates for 1948–73 and 1973–79. Jorgenson, Gollop and Fraumeni (1987), table 9.5.

Interpretation of TFP

- Popular (strange) interpretation

  - capital accumulation and labour force growth do not fully account for economic growth

  $\rightarrow$ technological progress is the ultimate source of economic growth

Problems with measuring TFP

- Uncertain and arbitrary estimates

  - Net or gross capital?

  "The answer makes a small difference to the measured growth rate of capital stock. It makes a very large difference to the weight attributed to the growth of capital stock."

  - Should depreciation include obsolescence?

  cf. Denison: net national income

  Jorgenson: gross value added

Unrealistic assumptions in TFP

(1) Neutral technological progress

(2) Technological progress is separated from changes in capital and labour.

→ Assuming only 'disembodied' technological progress

- Technology and K: learning-by-doing, economies of scale
- Technology and L: education,
- K and L: K provide new job opportunity

Unrealistic assumptions in TFP

(3) CRS

- no increasing returns in the system

(4) Always maintaining equilibrium growth path?

Other Growth Theories

- New growth theories
  - endogenising technological progress by allowing interaction between factors
  - growth accounting falls apart once IR is introduced
- Keynesian growth theories
  : the capital accumulation view

→ embodied technological progress

How do we measure technological progress then?

- Obsessions with measurements
- Living with imperfections
  - Being imperfect is better than being misled

2.3. The Schumpeterian dynamics

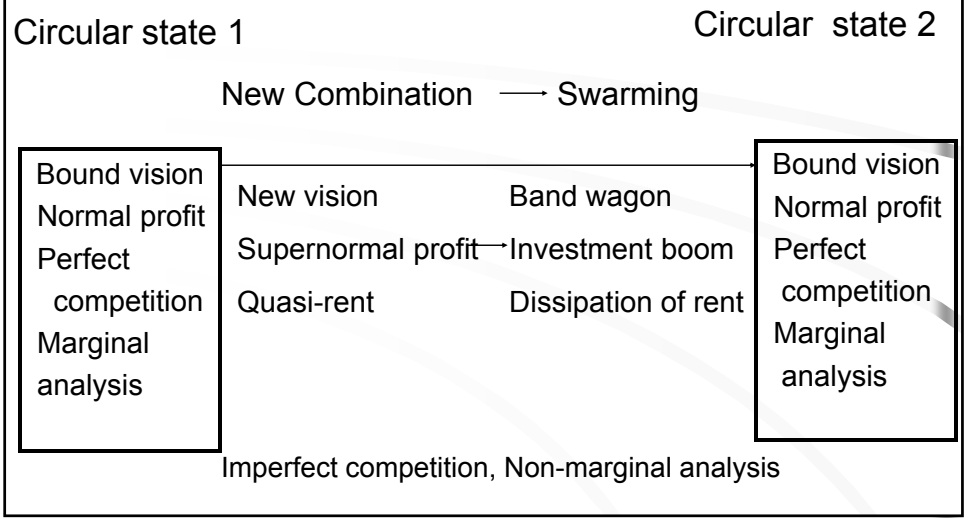
Why Schumpeter?

- “If, as Alfred North Whitehead once noted, the history of western philosophy may be adequately described as a series of footnotes upon Plato, it may equally be said of the study of technological innovation that it still consists of a series of footnotes upon Schumpeter.” (Rosenberg 1982: 106)

Characterisation of innovation: 'New combinations'

(1) new (consumer) goods (or new quality of goods): product innovation
(2) new method of production: process innovation
(3) the opening of new market
(4) new source of supply of raw materials or half-manufactured goods
(5) new organisation of industry (including creation of monopoly position or breaking the monopoly)

Schumpeterian Dynamics



Sources of change

- “ ... in dealing with capitalism, we are dealing with an evolutionary process. ... Capitalism ... is by nature a form or method of economic change and not only never is but never can be stationary. ... The fundamental impulse that sets and keeps the capitalist engine in motion comes from the new consumer goods, the new methods of production or transportation, the new markets, the new forms of industrial organization that capitalist enterprise creates. ... (continued)

… [New combinations] illustrate the ... process of industrial mutation ... that incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one. This process of Creative Destruction is the essential fact about capitalism” (1943: 82-83)

Schumpeterian dynamics

- Profit motivation within capitalism

  → looking for 'super-normal profit', not satisfied with normal profit

  → competition for innovation

  → evolutionary process of change (changes from within)

Impact of innovation: 'bombardment"

" [Forces of new competition form New Combinations] ... commands a decisive cost or quality advantage and ... strikes not at the margins of the profits and the outputs of the existing firms but at their foundations and their very lives. This kind of competition is as much more effective than the other as a bombardment is in comparison with forcing a door, and so much important that it becomes a matter of comparative indifference whether competition in the ordinary sense functions more or less promptly." (1943: 84-85)

Dynamics between forerunners and latecomers

- Diffusion process

  : providing new vision → swarming (clustering of innovations)

- "... whenever a new production function has been set up successfully and the trade beholds the new thing done and its major problems solved, it becomes much easier for other people to do the same thing and even to improve upon it. ... [I]t becomes easier not only to do the same thing, but also to do similar things in similar lines .. First, ... innovations do not remain isolated events, and are not evenly distributed in time, but that on the contrary they tend to cluster, to come about in bunches, simply because first some, then most, firms follow in the wake of successful innovation …(continued)

…Second, ...innovations ... tend to concentrate in certain sectors and their surroundings. ... Industrial change is never harmonious advance with all elements of the system actually moving, or tending to move, in step. ... Progress .. not only proceeds by jerks and rushes but also by one-sided rushes ... the evolution is lopsided, discontinuous, disharmonious by nature ... the disharmony is inherent in the very *modus operandi* of the factors of progress. Surely, ... the history of capitalism is studded with violent bursts and catastrophes ...” (1939: 100-102)

Contiual creation and dissipation of rents (quasi-rents)

- “It disciplines before it attacks. The businessman feels himself to be in a competitive position even if he is alone in his field ... In many case, though not in all, this will in the long run enforce behavior very similar to the perfectly competitive pattern.” (1943: 85)

What is left by Schumpeter?

- A schematic picture of process of innovation
- What are details of this process?

eg. Which firms or nations are successful in innovation? How can they do that?

Neo-Schumpeterian contribution

- Delineating technological aspects of innovation
- Elaborating on the Schumpeterian dynamics