4. Taxonomy of Innovations and Techno-Economic Paradigm Shift

4.1. Taxonomy of innovations

- Incremental innovations

  * Innovations along technological trajectory

  “They may occur, not so much as the result of any deliberate research and development activity, but the outcome of inventions and improvements suggested by engineers ... in the production process ... or users.” (Freeman & Perez 1988: 46)

Incremental innovations

- Includes scaling up of plants and equipment

  - economies of scale cannot be achieved without accumulation of production knowledge in smaller-scale production
- Small improvement individually, but their combined effect is highly important economically

  eg 1. Horndal effect

  eg 2. Du Pont rayon plant in the 1950s

Incremental innovations

- Subject to diminishing returns in some stage

  → 'Wolff's Law: 'laws of retardation of progress'

  "...the scope of improvement in any technology is limited, and that the cost of incremental improvement increases as the technology approaches its long-run performance level" (Freeman 1982: 216)

  → increasing cost for additional minor improvements

Radical innovations

- Mensch's 'basic innovations'

"... no matter how many stage coaches you put together you will not get a steam locomotive or a railway systems" (Schumpeter, quoted in Freeman 1992: 79)

eg 1. candle light vs. electric light

eg 2. train vs. automobiles

eg 3. vacuum tube vs. transistor

eg 4. LP vs. CD (DVD, MD...)

eg 5. fixed-line phone vs. wireless phone

Radical innovations

- Requiring a new types of facility for their production and/or new markets
- Induce technological progress in related areas

$\rightarrow$ development of 'new technology systems': clustering

eg 1. the case of electric light

cf. 'linkage effects', 'inducement mechanisms'

Radical innovations

- Changes in productivity

 - initial productivity gain is slow

 - require incremental innovations along the new technological trajectory

"Major and prolonged productivity increases are likely to be achieved during the main *improvement* phase [of] a radical innovation, but not in the early *introduction* phase, when the scale of production is too small to achieve scale economies, when standardisation of supply of new materials and components has not yet taken place and when designs of both product and process are still in flux. .... The *potential* leap to much higher levels of productivity from a radical innovation may become a reality only when it is complemented by a wide range of other innovations, including especially organisational, managerial and social innovations." (Freeman 1992: 81)

Eg. Albert Fishlow's study of productivity in the American railroad system (Quoted in Rosenberg 1982: 69-70)

- $1.3bn cost reduction during 1870-1910
- $50 mil. → radical innovations like air brake and automatic coupler
- $479 million → substitution of steel rails for iron
  - → rapid adoption: 80% in 1890
- $749 mil. → improvement in the design of locomotives and freight cars

 - freight car capacity more than trebled

 - locomotive force more than doubled

4.2. Techno-economic paradigm shift and business cycle

Changes in techno-economic paradigm

"Some changes in technology systems are so far-reaching in the effects that they have a major influence on the behaviour of the entire economy. ... A vital characteristic of this ... type of technical change is that it has *pervasive* effects throughout the economy, i.e. it not only leads to the emergence of a new range of products, services, systems and industries in its own right; it also affects directly or indirectly almost every other branch of the economy, i.e. it is a 'mega-paradigm." (Freeman & Perez 1988: 47)

'Key factor' inputs and long waves

- Three characteristics of key factors
  - falling costs
  - rapidly increasing supply
  - pervasive applications

Table 1.3 Successive waves of technical change

Long waves or cycles		Key features of dominant infrastructure			
Approx. timing	*Kondratieff waves*	*Science technology education and training*	*Transport communication*	*Energy systems*	*Universal and cheap key factors*
First 1780s–1840s	Industrial revolution: factory production for textiles	Apprenticeship, learning by doing, dissenting academies, scientific societies	Canals, carriage roads	Water power	Cotton
Second 1840s–1890s	Age of steam power and railways	Professional mechanical and civil engineers, institutes of technology, mass primary education	Railways (iron), telegraph	Steam power	Coal, iron
Third 1890s–1940s	Age of electricity and steel	Industrial RD labs, chemicals and electrical, national laboratories, Standards laboratories	Railways (steel), telephone	Electricity	Steel
Fourth 1940s–1990s	Age of mass production ('Fordism') of automobiles and synthetic materials	Large-scale industrial and government RD, mass higher education	Motor highways, radio and TV, airlines	Oil	Oil, plastics
Fifth 1990s–?	Age of microelectronics and computer networks	Data networks, RD global networks, lifetime education and training	Information highways, digital networks	Gas/oil	Microelectronics

Impacts of key factor inputs

- New product mix
  - towards intensive utilisation of the key factor
- New skill profile in labour force
- New pattern in the location of investment
- New pattern of consumption

Impacts of key factor inputs

- Tendency of large firms to concentrate in those branches where key factor is produced and most intensively used

$\rightarrow$ creating ‘engine of growth’ in the new wave

Impacts of key factor inputs

- New ideal type of production organisation

- new ‘best practice’ form of firms, plants...
  cf. Fordism, Post-Fordism

‘Structural crisis’ and structural unemployment

- Involves ‘upheavals’ in all sectors
  - a process of ‘creative destruction’
- Takes time for actors to adjust to new imperatives

A comparison with the Marxian system

- The relations between technology system and economic system
- ‘Productive forces’ vs. ‘productive relations’