Finance, Innovation & Growth

Antoine Godin
antoine.godin@ul.ie

University of Limerick

Schumpeter vs Romer. A case of technological change.

Outline

Capitalism

Capitalism and growth

Capitalism needs growth in order to be sustainable, growth in GDP or GDP per capital, growth in living standards, etc. One of the main driver of growth lies in technological change or innovation.

A brief historical consideration of technological progress

- Neoclassic theory
  - Classics vs Marginalists, increasing vs decreasing return to scale
  - Kaldor's critique
  - Solow's growth model
  - Solow's residuals
- Romer: Endogenous Growth Theory
- Stiglitz and market imperfections
- Schumpterian economics
- Perez and the Technological Revolutions

Neoclassic theory I

Increasing return to scale

The notion of increasing return to scale is one of the main points of the classical theory of economics. Based on Smith's division of labor which improved productivity.

Enters Ricardo

On the other hand, the marginalist theory is based on decreasing return to scale. The idea is that at first you use the most productive land and then use the other, less productive, until no profits can be made (that is until the marginal productivity is equal to 0). Thus only technological progress also allows you to evolve.

Neoclassic theory II

The Kaldorian critique

It is difficult to distinguish between movements *along* the production function and movements *of* the production function because capital accumulation is not neutral with respect to the evolution of technological know-how.

> *The use of more capital per worker [...] inevitably entails the introduction of superior techniques which require inventiveness of some kind*

There is thus a feedback between capital accumulation and technological progress and vice versa. This leads to the so-called Kaldor-Verdoorn Law (1949) based on learning by doing.

Neoclassic theory III

The neoclassic answer: Solow (1956)

- Cobb-Douglas production function with constant return to scale: $X(t) = A(t)K^{\alpha}N^{1-\alpha}$
- Elasticity of Substitution equal to one: thus it is always possible to replace one of the factor of production by the other one.
- Hicks neutral progress, that is the technological progress increase proportionally the productivity of both factors of production

Results:

- While you might have short term fluctuation, in the long run the economy reaches a steady state where savings are equal to the depreciation of capital
- Changes in the propensity to save or the depreciation rate will impact levels of savings or investment but not the steady state growing rates
- Without technological change, there is no growth

Neoclassic theory IV

Solow's residual

The only way to improve household's welfare, according to Sollow, is to increase either *technological efficiency* or *capital stock per capita*. Hence the need of Solow's decomposition and Solow's residual, which is the increase in output that is not explained by the increase of capital or labor used in the production process. In the case of a Cobb-Douglas with constant return to scale:

$$SR = g_x - [\alpha g_K + (1-\alpha) g_L] \tag{1}$$

Neoclassic theory V

Criticism of Total Factor Productivity

- The use of Cobb-Douglas production function
- *The Cambridge controversy*: aggregation of capital doesn't make sense
- Solow's Residual are a *measure of our ignorance*
- The residuals depend on fiscal and monetary policies
- etc...

Outline

Various approaches

Externalities

The economic growth is guaranteed by the presence of externalities that enter in the production function, even with production factors that have decreasing marginal productivity. Thus, no change in the neoclassical assumptions and theories, just add these positive externalities that have increasing return to scale.

Some examples

- Knowledge incorporated in physical capital thanks to learning by doing, that can be imitated by other firms (Romer, 1986)
- Human Capital (Lucas 1988)
- Stock of ideas out of R&D (Romer 1990)
- Infrastructures and public Services (Barro 1991)

Romer 1990: Endogenous Technological Change I

Paper setup

1. Technological change is the driver of economic growth
2. Technological change arise due to intentional actions of people
3. Technology related to raw material is different from that of other processes: once the blueprint exists, it can be used again and again at no additional cost

Rivalry and Excludability

- A purely *Rival* good implies that if it is used by someone it cannot be used by someone else
- An *Excludable* good implies that the owner can prevent its use by someone else

Romer 1990: Endogenous Technological Change II

Soooo

- Point 3 implies that Technology is non rival
- Point 2 implies that Technology has to be at least partially excludable
- Point 1 implies that growth is driven by the accumulation of a good that is non rival and partially excludable

Example: Ability to create spreadsheets vs Design of a new computer

- Is it rival?
- Cost of replicating the object in question?

Implications

1. Non rival goods can be added without limit: *Unbounded growth*
2. Treating knowledge as a non rival good allows to address spillovers (incomplete excludability): *Incomplete appropriability*

Romer 1990: Endogenous Technological Change III

Implication for the production function

Suppose that a firm can invest 10,000 hours of engineering time to produce a design for a 20-megabyte hard disk drive for computers. Suppose that it can produce a total-of 2 trillion megabytes of storage per year (i.e., 100,000 units of the drive) if it builds a $10 million factory and hires 100 workers. If it merely replicates the rival inputs-the factory and the workers-it can double its output to 4 trillion megabytes of storage per year.

Suppose that the firm could have invested 20,000 hours of engineering time in the design work instead of 10,000 hours and, by doing so, could have designed a 30-megabyte hard disk drive that could be manufactured with the same factory and workers. When the firm doubles all its inputs, it uses a 20,000-hour design, two factories, and 200 workers and produces 6 trillion megabytes of storage per year, three times the original output.

The model I

inputs

- *Labor* (L) skills available from any worker: rival
- *Human capital* (H) education or training: rival
- *Technology* (A): nonrival
- *Capital goods* (K): rival

Sectors

- *Research* uses human capital and existing knowledge to produce new knowledge
- *Intermediate-good* uses design from research and saved output to produce durable goods
- *Final-good* uses durable goods, labor, human capital to produce final outputs
- *Capital goods* (K): rival

The model II

Assumptions

1. Population and labour supply are constant
2. Total stock of human capital is fixed
3. Technology to produce capital goods and final goods are identical
4. Research is very human capital intensive

The model III

Conclusions

1. *The return to investing human capital in research is a stream of net revenue that a design generates in the future. If the interest rate is larger, the present discounted value of the stream of net revenue will be lower. Less human capital will be allocated to research, and the rate of growth will be lower.*
2. *Although all the research is embodied in capital goods, a subsidy to physical capital accumulation may be a very poor substitute for direct subsidies that increase the incentive to undertake research.*
3. *a second-best policy would be to subsidize the accumulation of total human capital.*
4. *an economy with a larger total stock of human capital will experience faster growth.*

Outline

How do firms' perception of risk impact production decision?

Shock diffusion

Risk might impact firms' net worth and thus impact their willingness to produce which in turns impact the demand curves of other firms and propagate into the economy.

How do firms' perception of risk impact production decision?

Shock diffusion

Risk might impact firms' net worth and thus impact their willingness to produce which in turns impact the demand curves of other firms and propagate into the economy.

Model assumptions

- No new equities, fixed dividend per share
- Perfect loan market, manager adverse to bankruptcy
- No future market and inputs must be paid before any output is sold

Real wages, nominal wages and marginal productivity

Let output be a function of labor only: $q = \phi(l)$, where $\phi' > 0$ and $\phi'' < 0$, then we have that, in a perfect market, $P = \frac{w}{\phi'}$ where w is the nominal wage. Dividing both sides by P, gives $MC = \frac{w}{P \cdot \phi'}$.

Real wages, nominal wages and marginal productivity

Let output be a function of labor only: $q = \phi(l)$, where $\phi' > 0$ and $\phi'' < 0$, then we have that, in a perfect market, $P = \frac{w}{\phi'}$ where w is the nominal wage. Dividing both sides by P, gives $MC = \frac{w}{P \cdot \phi'}$.

The puzzle

In recession, l is reduced dramatically and thus we should have that real wages $\frac{w}{P}$ should increase proportionally.

Real wages, nominal wages and marginal productivity

Let output be a function of labor only: $q = \phi(l)$, where $\phi' > 0$ and $\phi'' < 0$, then we have that, in a perfect market, $P = \frac{w}{\phi'}$ where w is the nominal wage. Dividing both sides by P, gives $MC = \frac{w}{P \cdot \phi'}$.

The puzzle

In recession, l is reduced dramatically and thus we should have that real wages $\frac{w}{P}$ should increase proportionally.

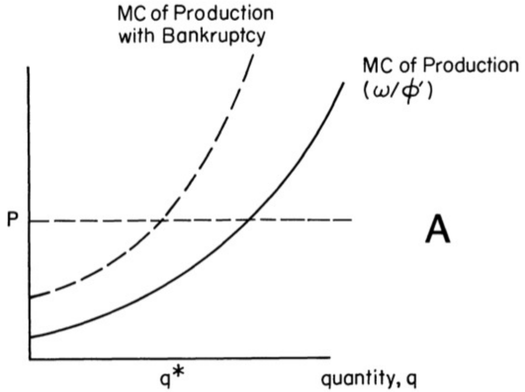
Three answers

1. Production function is a function of time, and in recession, there is a technical regress implying a reduced marginal productivity of labor.
2. Data gives only nominal wage and not real (marginal) wage. But marginal wage should include overtime which are more important in booms and in recession, the puzzle is thus even thicker.
3. Markets are imperfect and price should be $P = \frac{\frac{w}{\phi'}}{1-\frac{1}{\eta}}$, where η is the elasticity of demand. But mark-ups are likely to decrease in recession.

Adding bankruptcy risk

Marginal bankruptcy costs

Bankruptcy is costly and should be included in the cost fuction, we thus have $P = \frac{w}{\phi'} + MBC$, where MBC is the marginal bankruptcy cost. This allows to draw a different marginal cost of production curve.



Conclusion of the model

- Price and wage flexibility might exacerbate problems in recession
- Stabilization policies have dual effects:
  - More stable environment induce firms to take more risks (Minskian cycle) and thus the economy is more vulnerable to shock
  - Welfare gains should be computed in terms of reduced volatility and increased output due firms' decisions

Conclusion of the model

- Price and wage flexibility might exacerbate problems in recession
- Stabilization policies have dual effects:
  - More stable environment induce firms to take more risks (Minskian cycle) and thus the economy is more vulnerable to shock
  - Welfare gains should be computed in terms of reduced volatility and increased output due firms' decisions

But

No connection between technological change and finance, market imperfections and risk behaviours are an explanation for the puzzle of reduced productivity. No endogenous theory of technological change.

Outline

Schumpeter: Credit creation as the monetary complement of innovation

The carrying into effect of an innovation involves, not primarily an increase in existing factors of production, but the shifting of existing factors from old to new uses. [...] If innovation is financed by credit creation, the shifting of the factors is effected not by the withdrawal of funds - canceling the old order - from the old firms, but by the reduction of the purchasing power of existing funds which are left with the old firms while newly created funds are put at the disposal of entrepreneurs: the new order to the factors comes, as it were, on top of the old one, which is not thereby canceled. (Schumpeter, 1939, pp. 110-111)

Some schumpeterian definitions I

Dynamic space for the study of technical change

- *innovation* commercial introduction of a new product
- *invention* science and technology definition
- The space of inventions is much larger than the space of innovations
- *trajectory* or *paradigm* is the rhythm and direction of change in a given technology
- Dynamics of innovation often follow the rhythm of a logistic curve: small and slow start, followed by a steel increase which slows down again as the innovation comes to maturity (notion of *dominant design*)
- But need to define also the direction, that is the *technical paradigm*
- These notions pinpoints the concept of *incremental innovation* following a *radical innovation*

Some schumpeterian definitions II

Trajectory of an individual technology

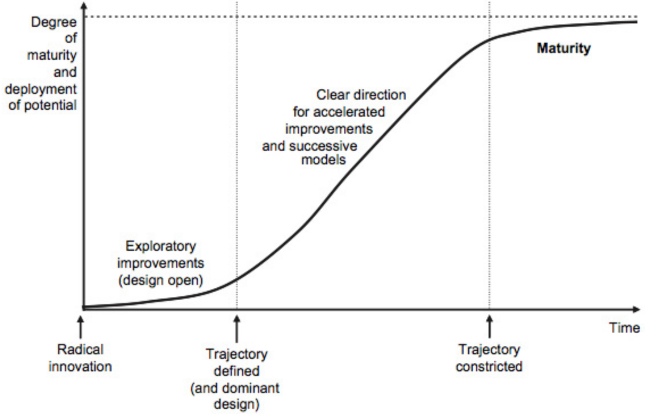


Fig. 1. *The trajectory of an individual technology.*
Source: based on Wolf (1912), Utterback and Abernathy (1975), Nelson and Winter (1977), Metcalfe (1979), Dosi (1982), Arthur (1988), Malerba (1992) etc.

Some schumpeterian definitions III

5 revolutions

Table 1. *Five successive technological revolutions: 1770s to 2000s*

Technological revolution	Popular name for the period	Big-bang initiating the revolution	Year	Core country or countries
First	The Industrial Revolution	Arkwright's mill opens in Cromford	1771	Britain
Second	Age of Steam and Railways	Test of the *Rocket* steam engine for the Liverpool–Manchester railway	1829	Britain (spreading to Europe and USA)
Third	Age of Steel, Electricity and Heavy Engineering	The Carnegie Bessemer steel plant opens in Pittsburgh, PA	1875	USA and Germany forging ahead and overtaking Britain
Fourth	Age of Oil, the Automobile and Mass Production	First Model-T comes out of the Ford plant in Detroit, MI	1908	USA (with Germany at first vying for world leadership), later spreading to Europe
Fifth	Age of Information and Telecommunications	The Intel microprocessor is announced in Santa Clara, CA	1971	USA (spreading to Europe and Asia)

Source: Perez (2002).

Core industries I

Motive branches

produce the cheap inputs with pervasive applicability: semiconductors today, oil and plastics in the previous surge, cheap steel in the third, coal in the second and water power (for water wheels and canal transport) in the first.

Carrier branches

these are the most visible and active users of the inputs and represent the paradigmatic products of the revolution, carrying the word about the new opportunities: computers, software and mobile phones today, automobiles and electrical appliances in the fourth, steel steam ships in the third, iron steam engines in the second and textile machinery in the first.

Core industries II

Infrastructures

The infrastructures, which are part of the revolution in terms of technology and whose impact is felt in shaping and extending the market boundaries for all industries: internet today, roads and electricity in the fourth, the world transport network in the third (transcontinental railways and steamship routes and ports), national railways in the second and canals in the first.

Core industries III

Induced branches

A fourth category of induced branches may be added to encompass a set of industries that are not necessarily revolutionary in technological terms but that may be seen as indispensable to facilitate the maximum diffusion of the core industries. They may have existed before but they are modernised and take on a different role. Such was the case of the construction industry that made suburbanisation possible during the mass production surge. The multiplication of housing at the edges of cities constantly expanded the market for automobiles and electrical appliances and created a whole technology system of stand- ardised building materials and several other suppliers of goods and services for suburban construction and living. In the current world of globalised trade and internet shopping, a similar role is being played by the courier servicesand all the other systems of transport of goodsthat have experienced explosive growth and profound transformations to facilitate complex global and local logistics.

5 Techno-economic paradigms, I

Table 2.3 A different techno-economic paradigm for each technological revolution, 1770s to 2000s

Technological revolution Country of initial development	*Techno-economic paradigm 'Common-sense' innovation principles*
FIRST *The 'Industrial Revolution'* Britain	Factory production Mechanization Productivity/time keeping and time saving Fluidity of movement (as ideal for machines with water-power and for transport through canals and other waterways) Local networks
SECOND *Age of Steam and Railways* In Britain and spreading to Continent and USA	Economies of agglomeration/Industrial cities/National markets Power centers with national networks Scale as progress Standard parts/machine-made machines Energy where needed (steam) Interdependent movement (of machines and of means of transport)

5 Techno-economic paradigms, II

THIRD *Age of Steel, Electricity and Heavy Engineering* USA and Germany overtaking Britain	Giant structures (steel) Economies of scale of plant/vertical integration Distributed power for industry (electricity) Science as a productive force Worldwide networks and empires (including cartels) Universal standardization Cost accounting for control and efficiency Great scale for world market power/'small' is successful, if local
FOURTH *Age of Oil, the Automobile and Mass Production* In USA and spreading to Europe	Mass production/mass markets Economies of scale (product and market volume)/ horizontal integration Standardization of products Energy intensity (oil based) Synthetic materials Functional specialization/hierarchical pyramids Centralization/metropolitan centers–suburbanization National powers, world agreements and confrontations
FIFTH *Age of Information and Telecommunications* In USA spreading to Europe and Asia	Information-intensity (microelectronics-based ICT) Decentralized integration/network structures Knowledge as capital/intangible value added Heterogeneity, diversity, adaptability Segmentation of markets/proliferation of niches Economies of scope and specialization combined with scale Globalization/interaction between the global and the local Inward and outward cooperation/clusters Instant contact and action/instant global communications

Production and Financial Capital

Schumpeter: complementary

Financial capital follows a pecking-order theory, as for productive capital. Furthermore, criteria are influenced by techno-economic paradigms.

Production and Financial Capital

Schumpeter: complementary

Financial capital follows a pecking-order theory, as for productive capital. Furthermore, criteria are influenced by techno-economic paradigms.

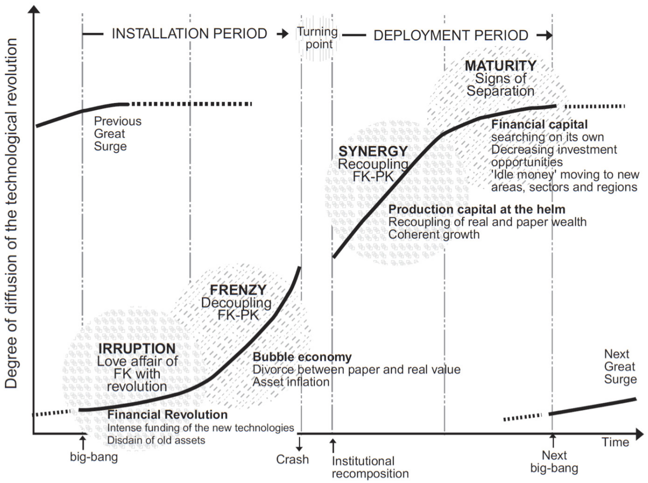
Fundamental differences

- Path-dependency for productive capital and is intrinsic to the techno-economic paradigm. Long-term horizon
- Financial capital is "footloose, flexible, and mobile". Distribution of wealth in order to obtain financial returns on the short term.

Production and Financial Capital

PK and FK interconnectedness

The recurring sequence in the relationship between financial capital (FK) and production capital (PK)



Periodization of a techno-economic paradigm I

1. Installation period (20-30 years)

1. *Irruption phase* Finance enables the reallocation of available funds from mature technologies-industries to the emerging ones. New ways of finance related to new ways of production. Technological innovations thus foster financial innovation. This phase usually overlaps with the exhaustion of the previous waves of development.
2. *Frenzy-decoupling phase* Innovative sectors-technologies success induces excitement in the financial world. Speculation and infinite trust in the *new economy*. However, this phase, which represents a necessary stage of the structural change process induced by the emergence of a new technological paradigm, inevitably ends with a major bubble collapse. Empirical evidence showing that stock price volatility increases during the early stage of a new innovative sector and during period of radical technological change.

Periodization of a techno-economic paradigm II

2. Collapse and recession: the turning point

- Re-alignment between real and financial values
- Creative destruction
- Important recomposition of the social-institutional framework, leading to more regulation of finance and more intervention of the state.
- *Phase did not happen in 2000 (New Economy) nor in 2007 (Great recession)*

Periodization of a techno-economic paradigm III

3. Deployment period

1. *Synergy phase*
    - The recently established economic paradigm gets more and more embedded in all spheres of society, becoming "Conventional Wisdom" (Galbraith, 1998).
    - Easy access to new infrastructures, adequate distribution channels, education of workers and consumers create huge inclusion mechanisms that stimulate incremental innovations compatible with the new technological paradigm.
    - Control of investment passes from financial to production capital.
    - The new technological paradigm at this point has succeeded in redefining the economic and institutional context, turning into a techno-economic paradigm.
2. *Maturity-exhaustion phase*
    - The technological base of the techno-economic paradigm has been totally exploited and the system experiments a slow-down.
    - With an increasing amount of idle money originated by the drop of profit opportunities, the conditions for the emergence of a new cluster of radical innovations are created.

Soci-economic feedback I

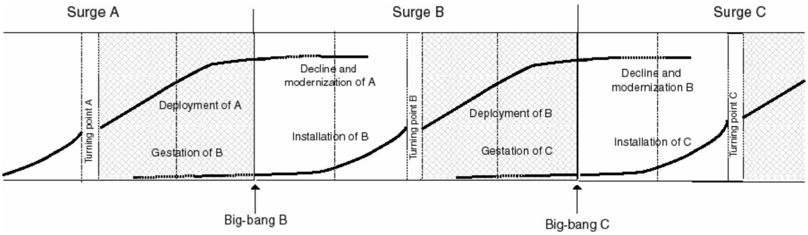
Conclusion

The concept of techno-economic paradigm unveils the fundamental role played by the socio-institutional context. Institutions evolve in an adaptive way under the pressure of the structural change process taking place in the economic system. However it takes a long time for social institutions to change and the lack of and adequate institutional framework during the incubation and installation periods is usually a key factor preventing the full exploitation of the possibility embedded in the new technologies. The long term process of technological diffusion and the transformation in the socio-economic context thus go hand in hand influencing each other.

Soci-economic feedback II

Overlapping

Figure 3 The overlaps in the gestation, diffusion and decline of successive surges[30]



The double bubble at the turn of the century I

Major technology bubble

Bubble linked to the end of the installation period of the techno-economic paradigm based on ITC. Thus new technology bubble. *Opportunity pull*

Easy liquidity bubble

Housing sub-prime bubble linked to large amount of liquidity on the market. *Easy credit pushed*.

The double bubble at the turn of the century II

What happened?

No regulation after the 2000 bubble, as prevented in the theory

- Bubble confined to NASDAQ
- Foreign demand out of emerging economies re-launched the economy
- FED: negative real interest rates
- Higher household debt
- Housing bubble
- New finance + ICT: CDS, HFT, etc...

The double bubble at the turn of the century III

Conclusion

There can be, however, little doubt that this second major bust and its consequences are likely to follow the script and facilitate the necessary institutional recomposition to unleash the deployment period of the current surge. The massive revelations of irresponsibility, incompetence, outright fraud and illegitimate enrichment of many of the actors involved make a sufficient indictment of unregulated finance and the unfettered free markets under which they operated to create an atmosphere of widespread indignation that puts pressure on politicians to act. (Perez 2010, p.800).