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EC4372 – Learning (Week 4)

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Tutorial W3

1. Utilities of Trajectories in Understanding Technological Change

Technological trajectories are blueprints that map the expected path of innovation for a piece of new technology that is powerful enough to open up a wide range of possibilities through new combinations (Nelson and Winter, 1982). It core utility is in controlling innovation. Trajectories allows the best use of known attributes and trends to reduce the level of uncertainty so as to allow decision making to occur under bounded rationality. This helps to ensure technologies are developed in the best manner we can comprehend and foresee. An example of this is a trajectory known as Moore's Law in the area of semiconductors where innovation moves along density doubling of transistors.

Moving past innovation, trajectories are important at the stage of diffusion in technological change. There is only so much that a well innovated new idea can do. Most ideas only blossom when applied to a wide ranging set of marketable products or services. When the Advanced Research Projects Agency Network was first created, the age of packet swapping networks left behind the traditional, one to one, circuit switching connections. Its transformation from military use into the internet is largely based on its trajectory set by a multitude of computer scientists such as Lawrence Roberts, and Robert Taylor. These men worked within the technological paradigm of packet switching and contributed extensively in its diffusion to produce the world's largest network (Markoff, 1999). Packet swapping is now applied in nearly all forms of networking such as local networks and Bluetooth connectivity. Thus, trajectories allow effective swarming to take place via user end products.

Trajectories can roughly pinpoint when it is time to begin an entirely new search (Dosi, 1988) or veer off to a radical innovation as the stages of incremental innovation and diffusion hit diminishing returns. NAND Flash memory, an example of diffusion of semiconductors, has in itself undergone the stages of innovation and diffusion and has reached the hands of multiple consumers as memory cards (SD Cards / Compact Flash Memory) and more recently as solid state drives. Researchers have recently updated its guidepost predicting its demise. Microsoft Research announced that flash memory would hit a road block at 6.5nm. Current trajectories point to increasing densities but past 6.5nm, it is said to be "unstable" and a new search must be started. Such trajectories predict even a rough date when such diminishing returns to increasing densities will occur – 2024 (Grupp, 2012). With this, searches have been called for new inventions, radical innovations and even new paradigms to replace NAND flash memory once it undergoes Wolf's Law.

We cannot view technological growth without a series of capital injections and investments. Trajectories bring confidence to firms and investors to pump both monetary and non-monetary efforts to developing a new technology. The search for renewable forms of energy has created an abundance of trajectories sent to governments and firms. Based on these trajectories, funding is injected to the technology thought to be best solution. This is largely based on the projection given by the said trajectory whether be it in wind or solar power, etc. Thus, trajectories provide sufficient investor confidence to ensure that a piece of technology has the necessary funding to be developed.

However, not all trajectories are powerful. There are limitations to the benefits of trajectories in understanding technological change. Trajectories do not depict linkages between different innovations. A movement from point to point in one trajectory may require innovations in linked goods. For example shrinking a die from 32nm to 22nm in Intel's move from Sandy Bridge CPUs to its Ivy Bridge series required a refined technique on the fabrication plant's end (Tri-Gate fabrication process) (Intel, 2005). Thus, additional innovations are not accounted for by trajectories. (Dosi, 1982)

It has been established above that trajectories are largely useful for an overall understanding of technological change. However, the mechanisms driving such trajectories can only be made clear by looking at the different forms of learning.

2. Learning by Doing, Using & Interaction – A Comparison

Learning allows a firm to move from point to point within a trajectory. These forms of learning have both in theory and practice changed since Schumpeter's initial concept of bright entrepreneurs (Freeman, 1992). Its general direction moves from learning at the source of production (doing) to multi way information flows between all involved in the product (interaction).

Locus of Innovation: Learning by doing is limited to the inventor and others at the point of production. There is only so much that the drawing board can provide. It takes the act of creating the product or service to find and iron out the kinks. This draws the boundary of learning tightly at the point of production. Learning by using shifts the spotlight to users. However, for a product or service to be profitable, it must be a good fit to what the end consumer desires. Firms were initially oblivious to consumer feedback, focusing on refining the production process (doing) rather than ensuring that the process was producing what consumers want. This form of learning is user-orientated and ensures that the final product increases utilities of consumption (Rosenberg, 1982). Companies have moved to this approach with large expenditures in market surveys. It has reached a level in which consumer survey and satisfaction are now hailed as corner stones in product design and innovation (Bergman, 2003). Unlike 'doing' and 'using', learning by interaction involves both agents at once. It focuses on continual communication where discussions can take place instead of one way feedback. This increases both information flow and complexity.

Information Flows: Learning by doing and using features a flow of information in a largely single direction. In 'doing', information stays within the producers. 'Using' sees feedback flowing from users to producers. In contrast, learning by interaction stands out as being a continual multi directional information flow between different types of users and multiple tiers of people within the production process. Big firms have embraced this form of interaction and this can be seen in Microsoft's development of Windows 8. They share their thoughts and personally respond to feedback to a wide range of competencies from developers to end users. Thus, information flows for 'interaction' are multi directional and quantitatively higher due to a wider casting net.

Complexity & Diversity: Learning by doing is the easiest to carry out as all engineers speak a standard working language that makes collaboration easy and learning efficient. With good familiarity and a common understanding of the production techniques to create the product, this basic form of learning allows innovations to be quickly applied. Learning by using heightens the bar of complexity. When a consumer makes a feature request, it may be done in a manner that engineers and product designers do not understand. For example, consumers have often made requests for TVs to do more than display one way content. They do not specify how they want it to be executed, because they are neither designers nor engineers. The result is poorly executed 'Smart TVs' rolled out by big name manufacturers with subpar graphical user interfaces that has seen poor demand (Wilcox, 2011). Thus, the gap in competency and the lack of standards in communication are large hurdles when expanding to learning by using. Unlike learning by using, interaction has the highest complexity due to multi layered flows of information. It carries over the problems associated with learning by using. However, this time it is on a massive scale. This may result in inefficiencies in learning where important information may be overlooked or misunderstood due to high volume. Producers must be able to conduct its interaction well by sieving out important information. This is especially difficult when a technology is raw and uncertainties abound. Thus, it is often easier to first begin with learning by doing before pushing on to using and lastly interaction, so that the firm has garnered sufficient knowledge to facilitate an efficient interaction.

Time & Cost: The progression from 'doing' to 'interaction' is matched with increasing costs. Learning by doing is relatively a byproduct of production, requiring little additional time and cost. 'Using' can be seen to be equivalent to stress testing (Rosenberg, 1982), something that the short production span of 'doing' cannot reveal. As such, 'using' requires a longer time period and higher expenditure. In comparison, 'interaction' takes the longest duration and is costliest due to the increased density of information exchanged that requires more time and effort to execute and glean useful lessons.

Consumer Dependency: The progression of 'doing', 'using' and 'interaction' sees an increasing level of dependency placed on consumers. 'Doing' is relatively free from consumer influence while 'using' opens up a firm to one way feedback. Learning by interaction represents the highest level of dependency on user-producer relations. Such interactions can now be seen as an important factor of production (Lundvall, 1988). This increasing dependency results in powerful implications that will be explored later.

The section on learning above has put in focus the actual steps in the process of innovation. While trajectories are golden rules shared by different firms, it is the unique techniques of learning that separate different firms in their growth process.

3. Implications of Learning – Technological Progress & Firm Growth

What can one take away from the different forms of learning? Firstly, the uniqueness that each firm executes its learning means that it is near impossible to model technological progress even with classic definitions. Unlike technological trajectories that can give a rough gauge of how progress should be made, learning is specific to the type of industry, product, and company-user culture. The large numbers of unique variables make it unrealistic to attempt to model technological progress. As such, there is no ‘golden rule’ of learning. Instead, Lundvall (1988) asserts that firms must be dynamic and creative to adapt, innovate and exploit with little guidelines. This tends the argument towards a Schumpeterian firm where creative destruction provides a more wholesome explanation as compared to classic price competition (Micheal, 1990).

An extension to the argument above is that labor cannot be viewed solely as a form of static input because it has further capabilities that can be unlocked and utilized only through learning (Penrose, 1995). This is in contrast to classic models of a firm where additional inputs to labor (or capital) are required for firm growth (Micheal, 1990). Thus firms may experience endogenous sources of growth by exploiting initially untapped resources within their current labor pool.

With this in mind, labor management is now a delicate process. Learning increases the value and productivity of labor. Retention of key labor inputs is important. Certain engineers and designers like Jonathan Ive of Apple fall in such categories and are retained for their wealth of tacit knowledge coming from learning over the years. This is also especially true for managerial positions. Firm growth requires confidence under uncertainties and such confidence comes from people they can trust to make the right judgments for the firm (Penrose, 1995). A managerial team is a unique complement of strengths where each member cannot be easily replaced. Thus, a firm must retain its management team and best engineers who have gained value via the learning process.

However, as mentioned in part one, growth is not just incremental. At certain points, radical innovations may be required and might lead to larger growth spurts. Moving to radical innovations may require a change in labor personnel, as currently available labor may have their learning directions already skewed in a direction that the firm is initially comfortable with. Current managerial knowledge may also shape future searches and hinder radical innovations. Thus, the firm might have to undergo organizational innovation (Penrose, 1995). Certain firms create new wings taking an ambidextrous form. A new wing will face less resistance from possibly creating a disruptive radical innovation. Bell systems incorporated such a structure that allowed them to embrace and carry out the learning process efficiently (O'Reilly, 2004). In contrast, Kodak's film department hindered the disruptive radical innovation of digital photography leading to the firm's demise. (Pachal, 2012)

It has been established that learning is key for both incremental and radical innovations. Thus, it is imperative to refine the learning process. Firms must be able to build a renewable user feedback group that it can trust not to leak both product information and learned techniques to competitors (Lundvall, 1988). Also, refining information flows is important for efficient learning and must be handled so that important information is implemented and not overlooked (Dosi, 1988). This is especially difficult at the starting point where the appropriate routes of learning are unknown and user incompetence might tarnish the process.

Innovated outputs crafted by learning have already become highly prized. Companies like Google are acquiring firms (Motorola) mainly to obtain their patent portfolio (Ovide, 2011). Also, various tactics such as 'patent parking' have entered the scene due to the immense value of innovations (Lemley, 2009). As such, the growth of firms hinges not just on making most of learning, but also on protecting what they have learnt.

In extension, the importance of effective producer-user relationships and patent administration requires a moderate level of government intervention. The focus should be encouraging linkages and the creation of institutions to enable and enhance information channels (Lundvall, 1988). As mentioned above, there also exists a large role in ensuring patents are managed well. While protection is necessary, overprotection can hinder further innovation (Lemley, 2009). Also, it should encourage inter firm, industry and university linkages filling the gaps where firms do not have the incentive to do so. This allows economy to capture positive externalities of learning (Nelson, 1990).

4. Conclusion

Schumpeter's core contribution in defining the technological process of invention-innovation-diffusion is fleshed out with an overview provided by technological trajectories. While such trajectories are largely useful and beneficial, it is the mechanism of learning that key players (firms, consumers and governing authorities) should hone. For the best employed learning processes are likely to produce the best firms; and with the best firms – a progressed economy.

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