Chapter One

Reflections on the Dimensions, Applications and Implications of a Methodological Framework

Introduction

Broadly speaking, the fundamental aim of research is to generate new knowledge capable of improving our understanding of events in phenomena. Attempts to change lives for the better through well-designed technology policy initiatives would presumably follow. Systematic investigative efforts have unravelled patterns of regularity in the maze of classified data from which plausible inferences, reasonable judgements, or rationally defensible generalizations could be drawn. The generation of new knowledge, to policy makers, should be followed by welfare-improving technological applications and societal reforms. In this regard, policy research has hardly been treated as an end in itself, but rather as a means to enhance the human condition.

History has shown that human beings have, in relative terms, been more concerned with understanding *how* things work rather than *why* they work. The latter belongs to the realm of *science*, while the former belongs to the domain of *technology*. This drive to understand how things work largely explains the activeness of the human passion to generate knowledge in a bid to not only broaden the human horizons of thought, but also to enlarge the bounds of nature for purposes of welfare enhancement. The centrality of technology in provoking vast transformations and spearheading decisive economic changes the world over, is universally recognized. A number of influential writers have described technology as the prime motor or dynamo of the development process (Schumpeter, 1934). So pervasive has been its economic, social and political impact that fears are already abound intimating that humankind has lost control of technology and has since taken control of our lives (Norman, 1981). Whatever anxieties have been triggered by its ubiquitous influence, its contribution to the transformation of human society has been phenomenal.

It is not at all surprising that a phenomenon possessing such omniscient power, could command such awesome policy attention. Its pivotal role in the national and global scheme of things has stirred deep interest among leaders and men of affairs alike, as they have sought to understand how technologies are generated; What factors influence the rate and direction of technological change? How are innovations diffused or acquired? What interventions, mechanisms and policies would be necessary to stimulate viable technological processes?

These concerns, pose major policy and research challenges to development institutions and policy making structures in Sub-Saharan Africa (SSA). As such, if technology is to play an instrumentally decisive role in injecting growth-promoting dynamism in Africa's economies, the drive to furnish policy-oriented solutions to a diverse range of development challenges is a crucial priority. Hence, the need to pursue technology policy research. Embarking on such a research initiative would necessitate designing an appropriate methodological framework to guide investigative efforts. It is vital for technology policy researchers to appreciate and identify the relevant sources of information, what to look for in research endeavors, and how to search for data.

A methodological framework has, by nature, to be dynamic, ready to capture new informational demands and to reflect emerging research realities. Above all, it has to be sensitive to the canons of epistemological requirements and the rules of scientific objectivity. Only then will the research results assume validity and relevant applicability.

This paper explores these issues in the context of technology policy research for interested parties in SSA. It is structured as follows: Chapter two provides background information on the nature of technology policy and situates the discussion within the purview of methodological sensibilities, epistemological demands and scientific objectivity. Chapter three discusses the evolution of technology policy research by examining, first, the profound links that exist between conceptual categories and the configurations of methodological devices, and second, by describing how changes in research focus have over time led to non-trivial methodological shifts. Chapter four describes the elements and dimensions of a methodological framework.

Chapter five identifies priorities and the potential directions of future technology policy research. This part places a special premium on the imperative of relevance. The paper concludes by noting that the imperative of sustainable development has posed profound research and technology policy challenges to African researchers; challenges that are bound to influence the internal aspects of methodological devices.

Chapter Two

The Nature of Technology Policy Research: the Methodological and Epistemological Contexts

Any methodological framework worth its name would need to address at least five basic questions:

- *What* information and data is the research seeking to gather?
- *Where* would the researcher find such data?
- *How* will he obtain the information and data, or *which* approaches will he use to collect these?
- *What* are the limitations of the data?
- *When* will the research begin, and end?

Besides responding to these fundamental questions, technology researchers would also be required to *justify* the data and information they are seeking, the sources they plan to consult, the places they arrange to visit and the approaches they have chosen to employ. From the face of it, these matters may appear patently straightforward, but the reality is more complex than that. The issue under investigation may pose problems of aggregation or it may produce results that are so specific that extrapolations would only lead to a fallacy of composition. Moreover, the identified approaches would perhaps necessitate the construction of requisite, but relevant sampling designs.

While some of these elements and dimensions will be addressed later, it is crucial to point out here that the credibility of research results would depend largely on the scientific methodology used. Frankfort-Nachmias and Nachmias (1996) have put it aptly:

"Wherever a branch of what many people accept as factual knowledge is rejected by scientists, that rejection is always based on methodological considerations....For these reasons....science (would) mean all knowledge collected by means of the scientific methodology" (Frankfort - Nachmias and Nachmias, 1996).

Elsewhere, the authors make it plain that the

> *"....sciences...are not united by their subject matter but rather by their methodology. What sets the scientific approach apart from other modes of acquiring knowledge are the assumptions on which it is based and its methodology"*
> (Frankfort - Nachmias and Nachmias, 1996).

How does a scientific methodology look like? Here, we not only need to know the *meaning of science*, but also the *significance of epistemology* to methodological procedures. An overview of these issues would put us on a vantage pedestal in better appreciating the meaning of technology, technology policy and technology policy research.

The term science is derived from the Latin word *scire,* meaning "to know". Technically, it refers to organized, reliable and valid knowledge about phenomena generated by systematic and accepted techniques of inquiry. The knowledge possesses explanatory and predictive capacities in that it can be used to anticipate events and also ensure the realization of specific outcomes through regulation and control of certain circumstances. That is, the function of science is not only to discover regularities and describe relationships of events in phenomena, but also to improve the human condition. Francis Bacon (1561-1626) spoke of the instrumentality and strategic value of scientific knowledge when he stated that, it would expand the bounds of human nature by "effecting all things possible".

Unfortunately, science has often been confused with the *process* of inquiry i.e. the *scientific method*, comprising the stages of problem statement, observation, data collection, classification, analysis and conclusions. These systematic steps are only a *means* to a crucial end i.e. the generation of scientific knowledge. Stated differently, the stages of inquiry (or the scientific method) represent a *vehicle* that lead to the generation of systematized knowledge. In succinct terms, therefore, science refers to credible, reliable and valid knowledge, generated through systematized procedures and processes of inquiry.

A central concern to members of a research community has been the need to determine the reliability and basis of knowledge. Efforts to test the credibility of *knowledge claims* would inevitably plunge an investigator into the well charted sea of *epistemology,* a field that addresses not only the means by which knowledge is acquired, but also the establishment of standards by which to judge the truth or falsity of knowledge claims.

Technology policy research is a scientific endevour. It is an activity informed by a body of ideas that represents the structure of investigation. The latter consists of:

- Laws — statement of uniformities that explain events in phenomena; also defined as universal generalizations applicable across time and space
- Theories — generalizations that are potentially falsifiable and which continue to be repeatedly tested empirically
- Principles — laws and/or theories that serve as premises or organizing ideas from which are derived certain deductions or explanations about phenomena
- Facts — observation confirmed by many people
- Concepts — analytic categories that shape the overall outlook of an observer
- Procedures of an investigation — acceptable techniques of inquiry
- Empirical base — the potential availability and accessibility of relevant information and data
- Instruments of measurement and analysis (data processing) — tools that investigators can employ to carry out observations and fathom essential properties and relationships between distinct entities or events

These elements constitute the structure of a research system and form the core of that system.

Needless to say, the robustness of a researcher's investigative efforts and the quality of his end-product would be contingent upon the extent and degree of his familiarity with the elements of such structure. Knowledge of the laws, theories and concepts, scattered in available literature on science and technology policy is indispensable for researchers of technological phenomena. In functional terms, exposure to the real content of the elements of the research structure would broaden an investigator's perspectives on technology policy issues by sensitizing him to the boundaries of his investigatory domain. Sadly, the limited exposure of investigators to the relevant literature has been a notable deficiency. Clearly, this limitation poses a challenge to appropriate actors in the region.

Scientific research is not necessarily about the formulation of laws (i.e. universal generalizations applicable across time and space) though this would be the ultimate, desired goal of any systematic inquiry. Realising such an end would be the height of investigative achievement. The generation of laws has been a formidably difficult task for technology policy researchers. This has partly been due to methodological limitations owing to normative preoccupations influencing the formulation of research and sampling designs. In this respect, research conclusions from studies on technological phenomena have not been amenable to rigid classifications, capable of generating laws.

However, the evident failure of technology policy research to generate laws, does not mean that the investigative efforts are potentially unscientific. Despite the methodological shortcomings, technology research could still permit the formulation of plausible and reliable generalizations, if the scientific explanation is treated in *probabilistic* terms. Propositions of this genre state that particular technological events would occur with predictable frequency, if certain conditions obtain. Such a view can be defended on the premise that regularities of technological events do occur. It should be appreciated, however, that probabilistic propositions are not definitive statements about certain relationships, because to obtain such, one has to observe and classify all variables and events of technological phenomena.

From the foregoing, it would be worth recapitulating two points: First, that science is a body of organized knowledge generated through robust methodological procedures and validated by systematic epistemological modalities. Second, that what distinguishes scientific from non-scientific knowledge is whether the investigative process employs the scientific methodology.

Against this background, we are now in a position to discuss the meaning of science policy, technology, technology policy, and technology policy research. I would define science policy as the deliberate, but discretionary manipulation of macro and micro-variables and aggregates, to influence the rate and direction of incentive in an economy. Now, if science is systematized knowledge, then technology is knowledge related to some application e.g. production, organization and communication. Technology comprises four parts:

- *technoware* — the equipment and hardware
- *humanware* — the requisite human skills
- *infoware* — the information in manuals, blueprints and documents, essential for operation, repair, maintenance, and manufacture of hardware facilities
- *orgaware* — the requisite institutional structures and organizational mechanisms essential for productive activities to take place (Figure 1)

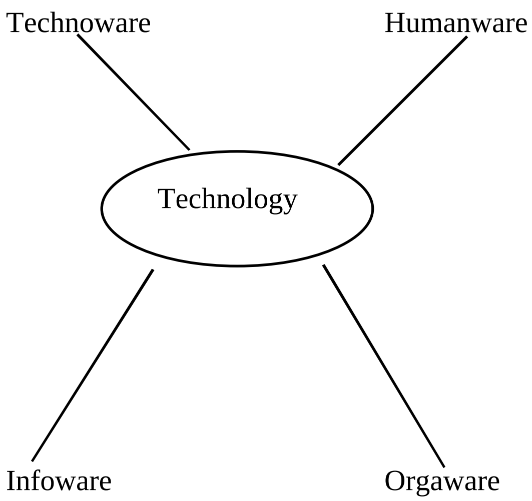

Figure 1: Schematic Representation of Technology.

When an economy or firm acquires or generates technology, it would be expanding its knowledge base and productive capacity. The significance of technology stems from the fact that it is able to improve the following:

- Productivity
- Economic growth
- Income levels and distribution
- Investment potential
- Employment potential
- Trading performance
- The quality and delivery of goods and services
- Communication
- Rate of progress

If the realization of these impacts is deemed desirable, then the basic objective of technology policy would be to influence the *rate* and *direction* of technological change in an economy. Thus, technological change would refer to the growth in the stock of knowledge related to applications. In this respect, I would define technology policy as the deliberate, but, discretionary manipulation of macro and micro variables and aggregates to stimulate, promote and/or deepen the process of productive technological change.

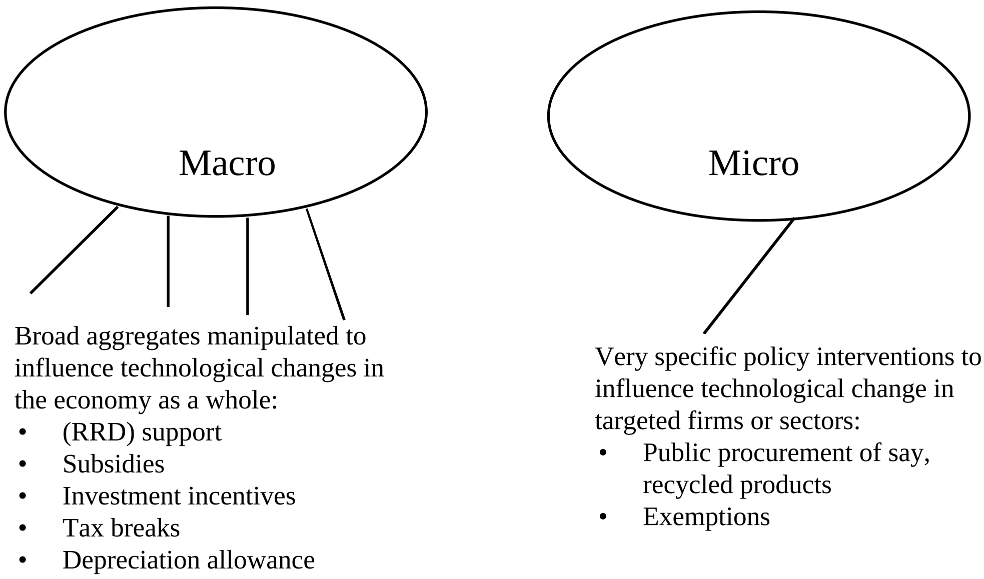

Figure 2: Technology Policy Targets.

A *technology policy framework* would refer to a broad set of mutually reinforcing and internally consistent policies, designed to facilitate technological change. It is a structure underpinned by a guiding philosophy, namely, a value system that can inspire policymakers to articulate measures capable of promoting the evolution and utilization of domestic technological capabilities (including the use of resource-based inputs in economic activities).

The formulation of technology policies and the designing of a technology policy framework are activities of great strategic value. To this end, their capacity to evolve and remain relevant would depend on how technology policy information from research is reflected in the framework. I would define *technology policy research* as the application of systematic scientific procedures in a bid to:

- investigate technological phenomena by fathoming the processes and dynamics of technological change
- generate reliable and credible knowledge of policy relevance and utility
- suggest further areas of policy research with direct implications for technology policy

Technology policy research has to generate credible and reliable knowledge. Such knowledge should be rationally and/or empirically defensible according to scientific canons of validation and criteria of legitimation. This is where *scientific methodology* looms into relevance. If research is a process of inquiry, then what constitutes reliable objective knowledge has to emerge from the use of a scientific methodology.

Table 1 summarizes a range of technology policy instruments that a technology policy framework can accommodate.

Knowledge produced through technology policy research is *reality-based* and is part of human experience for all practical purposes. Therefore, we use the terms "rationally defensible" to refer to systematic methodological procedures employed in the generation of knowledge and not the mode of rationalism associated with discourses on logic and philosophy of science. In the latter cases, rationalism assumes that:

- certain forms of knowledge exist *a priori* and are independent of human experience, and
- the human mind is capable of comprehending events and relations, independent of observable phenomena, i.e. by relying on pure reason.

From the foregoing, it is clear that *technology policy research is a scientific process* that employs *scientific methodological procedures* to generate credible and reliable knowledge. The investigative endeavor would need to conform to the formal rules and assumptions of systematic research.

Table 1: Technology Policy Instruments

Policy Tool	Examples
Public enterprise	Innovation by publicly owned industries, setting up of new industries, pioneering use of new techniques by public corporations and participation in private enterprise.
Scientific and technical	Research laboratories, support for research associations, learned societies, professional associations and research grants.
Education	General education, universities, technical education, apprenticeship schemes, continuing and further education and retraining.
Information	Information networks and centres, libraries, advisory and consultancy services, data bases and liaison services.
Financial	Grants, loans, subsidies, financial sharing arrangements, provision of equipment, buildings or services, loan guarantees and export credits.
Taxation	Company, personal, indirect and payroll taxation and tax allowances.
Legal and regulatory	Patents, environmental and health regulations, inspectorates and monopoly regulations.
Political	Planning, regional policies, honours or awards for innovation, encouragement of mergers or joint consortia and public consultation.
Procurement	Central or local government purchases and contracts, public corporations, research and development (R&D) contracts and prototype purchases.
Public services	Purchases, maintenance, supervision and innovation in health services, public building, construction, transport and telecommunications.
Commercial	Trade agreements, tariffs and currency regulations.
Overseas agents	Defence sales organizations.

Source: Rothwell, 1983.

Chapter Three

Evolution of Technology Policy Research: Perspectives on Methodological Currents

To what extent have conceptual frameworks influenced the methodological content of technology policy research? If worldviews have changed over time, have these transformations spurred requisite changes in a researcher's methodological base? How significant have been these changes to fathoming technological phenomena?

In this section, we shall examine these concerns in a bid to shed light on the links between conceptual categories and methodological systems in technology policy research.

Conceptual Categories and Methodological Frameworks: the Imperative of Congruence

A useful starting point in our methodological excursion would be to discuss the methodological impact of neoclassical theory on technology policy research. This backdrop is important for at least three fundamental reasons:

- the framework has advanced a narrow conceptualization of technological phenomena by drawing inspiration from a very simplistic view and definition of technology.
- mainstream economics has treated technology as an *exogenous* constant, which firms can reach for and obtain from a ready and waiting technological shelf.
- the neoclassical worldview has propounded a theory of the firm that advanced a very shallow view of technical change. All these dimensions have had major methodological implications on technology policy research. I shall address these issues later, but first, it would be instructive to discuss how worldviews influence a researcher's methodological orientation.

The use of conceptual devices in technology policy research has, by and large, been made implicit by the choice of topic made by the researcher. Indeed, a researcher's investigative pursuits would be greatly facilitated if the research topic is specified in concise and succinct terms. This would enable one to locate the clearly defined line of inquiry within an appropriate worldview i.e. a constellation of mutually reinforcing ideas, values and beliefs integrated in a system of thought that informs, guides and influences one's thinking. Writers like Thomas

Kuhn (1962) have referred to such broad-based models of thought as paradigms. A paradigm could be defined as a conceptual framework within which events in a phenomenon are described, interpreted, explained and predicted.

A paradigm is like a pair of glasses; if the shades are blue, then everything you see is bluish. If the shades are red, what you see looks reddish. In other words, a paradigm or conceptual framework *colours* ones perspectives. A Marxist, for instance, would explain the rise in crime in terms of obscene expropriation of surplus value by the capitalists and the poor remuneration of the workers. The exploitative pressures unleashed by the owners of production on the proletariat would drive the latter to the margins of existence. Their aggressive claim to the fruits of their labour would manifest itself as crime. So the Marxist's would view crime as a manifestation of the class struggle borne out of the gross injustices unleashed by capitalist exploitation.

Now, a serious Christian would dispute this line of argument. His analysis and interpretation of the crime situation would be informed by the Christian worldview. He might state, for instance, that the rise in crime stems from the abandonment of religious values as manifested by decadence and the entrenchment of secularist tendencies. Therefore, a Christian fundamentalist would call for a re-assertion and widespread inculcation of basic Christian teachings if crime levels are to drop or disappear altogether.

From the two simple examples cited above, it is evident that events in a phenomenon would be understood, interpreted, explained and predicted, depending on which conceptual category one subscribes to. In this sense, a conceptual framework is a mental device protagonists invoke to comprehend the world around them.

A methodological framework, on the other hand, refers to a procedural structure or format that spells out the techniques, instruments, and approaches which an investigator would employ to generate data for hypothesis testing, pursuing research objectives, and undertaking quantitative and/or qualitative analysis. It is a plan that specifies the type of data to be gathered and the appropriate methods to be used in this respect. In essence, it facilitates a researcher's investigative efforts by indicating to him *where to look*, *what to look for* and *how to proceed*.

A paradigm would exert a generic influence on a methodological framework for all intents and purposes. In other words, such a framework cannot be conceived independently of the problem being investigated and the conceptual category that underpins the whole study. A simplified version of the relationship between the broad components of technology policy research is given in Figure 3.

The connections are not necessarily linear; a researcher would be obliged to move back and forth as reading expands. In the process, the research topic can be sharpened and the objectives refined to achieve greater focus.

What becomes clear is that the paradigm, from whose foundations the study draws philosophical guidance, would secure a firm hold or will be replaced by a better one, on account of a researcher's extensive exposure to relevant literature. Where the paradigm informing the investigation offers a view inherently incompatible with the thrust of the topic and the study's objectives, the methodological framework would turn out to be restrictive and of limited research value. The congruence and theoretical harmony between the research topic, conceptual device and methodological framework, is of critical import to the outcome of research. We shall illustrate the significance of such correspondence in this chapter.

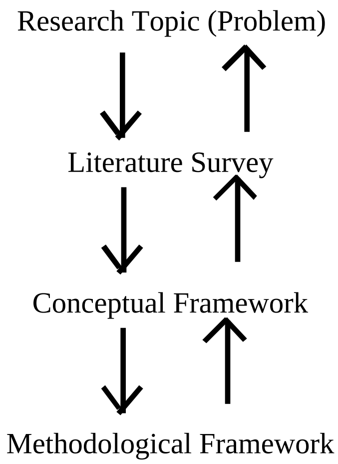

Figure 3: The Relationship Between the Broad Components of Technology Policy Research.

Understanding the role of conceptual categories is crucially significant to technology policy researchers, given the profound interconnections between such categories and methodological framework. When an investigator conceptualizes technology in neoclassical terms, the methodological device he constructs would be shaped by that particular worldview. Invariably, the conceptual scheme would influence, if not dictate, the type of data to be sought. To illustrate this with an example, consider how the neoclassical conceptual framework defined the boundaries of technology research before the seminal, path-breaking study by Solow (1957) and Abramovitz (1956) appeared on the scene. The neo-liberal paradigm conceptualized technology in terms of capital (K) and labour (L) combinations. The relationship between these key factors was captured by an isoquant (Q) where shifts in the curves (Q1,Q2,Q3, etc.) represented technological progress (OT). The neoclassical conceptualization is summarized later.

Such a narrow conceptualization of technological change restricted the scope of a researcher's methodological framework. His investigative efforts were confined to, and limited by, the slender and skeletal data (in this case K and L combinations), stipulated by the neoclassical worldview. Not surprisingly, technical change was explained in terms of *capital augmenting* or *labour reducing* processes. The Cobb-Douglass function became the standard model for fathoming technological phenomena.

This brief example illustrates how a conceptual framework *conditions* the configuration and boundary limits of a methodological framework. In the main, the neoclassical paradigm could not possibly excite researchers to ask pertinent questions such as: How are technologies produced? What role do firms play in generating those technologies? What goes on inside the very firms themselves?

Dosi et al. (1988), for instance, have reminded us that the central assumptions of equilibrium theory and neoclassical economics, cannot be reconciled with empirical research on technical innovation and institutional change. In particular, the authors state that the main epistemological weakness of this theory stem from the fact that it pays:

> *"…inadequate attention to social learning processes, particularly technological accumulation and the institutions affecting these processes"* (Dosi, G. et al., 1988).

Following a dramatic turn of theoretical events, the neoclassical model suffered a major blow in the mid-1950s when research by Solow (1957) and Abramovitz (1956) showed that only 18 % of increased output could be accounted for by the additional units of K and L. So, where did the 82 % increase in factor productivity stem from?

The ground-breaking studies concluded that the large "residual" in factor productivity stemmed from significant improvement in workers' skills, minor or incremental technical innovations, and time-saving improvements. In a very profound way, these conclusions pointed to a far-reaching methodological implication. It became clear that there was more to technology research than just the mere collection and analysis of data on K-L combinations only. Significantly, the studies led to the appreciation that, to understand the technological phenomenon more broadly, there would be need to include a wider data base, far beyond the traditional variables of capital and labour.

Rosenberg (1982) recognized the methodological limitation of the approaches used by both Abramovitz and Solow. He observes:

> *"….the extremely large residual with which to measure the growth in output per capita that was attributable for rising inputs per capital, encompassed a wide range of possible causes of improved efficiency other than technological change. In fact, the methodologies were such that the residual captured all causes of rising output per capita. The unexplained growth in resource productivity….is a 'measure of ignorance' which turned out to be surprisingly large"* (Rosenberg, 1982).

Research on technological change can be broken down into various genres, sometimes overlapping, each genre specifying the type of additional data or information required for analysis and, hence, in deepening understanding of technological phenomena. The *first-generation* studies, employed the Cobb-Douglas production function. The large residual factor was seen as representing technological change though later works attempted to decompose the residual into a number of possible influences on productivity growth. The research by Denison (1962) was particularly important in this regard.

Clearly, these first-generation studies confined the investigative efforts to collect data (time series) on capital, labour and the factors making up the residual. Note also that the unit of analysis was the economy as a whole. This had implications on the methodological framework.

After these early efforts, a second-generation studies began to appear on the scene in the 1960s. The latter category focussed on processes and activities that expand the stock of knowledge, the key factor in this respect being research and development (R&D). Researchers treated R&D expenditures as a distinct input into the production process. The Cobb-Douglas model was thus modified to reflect the role of inventive activity on technological advance as follows:

$$Q_t = Ae^{\lambda t} C^{y}_t K^{\alpha}_t L^{\beta}_t$$

Here, C represented the weighted sum of past R&D expenditures. The methodological implications of these second-generation studies are enormous. First, the unit of analysis could be a firm, an industry or the whole economy. Second, a comparative exercise between countries could be undertaken to show how a firm's R&D activities affected productivity performance. This kind of analysis requires cross-sectoral data (Stoneman, 1987).

The point worth emphasizing here is that the configurations and boundary limits of a methodological framework are, by and large, conditioned by the conceptual worldview invoked by a researcher.

The way a technology is defined would condition a researcher's methodological path. The neoclassical worldview has embraced the antiquated notion that technology is the application of science. Therefore, a researcher interested in issues on technological change would, by implication, be conditioned, to look for data in domains that serve as theatres of scientific inventiveness. No wonder, neoclassical economists began to turn to R&D departments for analytical inspiration.

As will become clear later, the so-called second-generation studies (which explored technological issues), discussed the relationship between R&D expenditures at the level of firm, industry or economy. The way the models of these studies were framed (which, most crucially, conditioned the type of data collected) left no doubt regarding the conceptual framework that informed the research thrust. Nearly all researchers who contributed to the second-generation studies seemed to be of neoclassical persuasion. Griliches (1984), Mansfield (1968), Pakes and Schankerman (1984), and Cuneo amd Mairesse (1984), appeared to have been influenced by the view that technological change is a product of scientific inventiveness. Methodologically, the idea that technology is derived from science tends to limit studies on technology to examining scientific inputs such as R&D. In an important sense, then, how technology is conceptualized conditions the type of data to be gathered and the direction of the research thrust.

This paradigm shift took a decisive turn following these studies, but an effort to engender a re-conceptualization of the technological phenomenon had been initiated decades earlier by Schumpeter (1934). His definition of a technological innovation was elaborated by Stoneman (1983) to refer to:

- *" ... new processes, by which is meant new ways of using existing resources to produce existing products*
- *new products, encompassing the use of existing processes and materials to produce completely new or changed versions of existing goods and services*
- *new sources or types of raw materials, covering discoveries of new sources of supply or changes in the raw materials available (one may reasonably extend this category to include improved intermediate inputs into production)*
- *new markets, either in a geographic sense or in the sense of applications of existing products to new uses*
- *new organizational methods, that is, new means of controlling and organizing productive inputs."*

This conceptualization was a departure from the marginalist treatment of technology in economic production. By conceptualizing technology in this broad-minded fashion, Schumpeter had given notice of the existence of new methodological horizons to be explored. Yet, his definition did little to dethrone or even critically challenge the neoclassical conceptual framework until much later.

Such a conceptualization lay behind the debate that grappled with issues concerning the genesis of technological innovations. Initially, Schumpeter (1934) regarded endevours of individual scientists as the sources of inventive activity. His later work (1943), tended to locate such sources in R&D departments of companies. The view that treated inventive activity as exogenous was christened Schumpeter Mark I, while the later conception, dubbed Schumpeter Mark II, viewed such activity as endogenous and stemming from the formal institutionalization of R&D programmes. Methodologically, research endevours on science and technology policies tended to direct the energies of investigators towards scientists and R&D establishments.

The methodological orientation of technology researchers began to shift somewhat in the wake of the controversy over whether technological development was demand-driven or technology-pushed. Schmookler (1966) established that, in general, inventive activity proceeded upswings in demand, a conclusion he reached after observing a synchronous relationship between investments and patents (inventive activity), following a time-series analysis of railroad, petroleum refining, agriculture and papermaking industries in the USA. This study led to the suggestion that Schmookler propounded the demand-led theory of innovation though it would be fair to note that he acknowledged the existence of other determinants of inventive and innovative activity.

A variant of the technology push view was advanced by David (1975) and Arrow (1962) in their attempts to comprehend the sources of inventive and innovative activity. The authors observe that these activities have, at times, emerged without any allocation of R&D resources. In fact, they contend, firms experience technological learning from internal processes involving *learning by doing*. These experiences enable firms to develop similar techniques in time.

Coombs et al. (1987) have intimated that attempts to understand the role of science in stimulating technological change posed a profound methodological challenge. They noted:

> *"What was required was a detailed analysis of how the process of innovation took place in firms and industries. An analysis of this type could not be conducted within established disciplinary boundaries. Neoclassical economics dealt with technological change in an implicit way, making it almost impossible to understand how a shift between two different production functions took place. In the innovation studies of this period a more empirical approach was developed. One of the main features of these studies was the belief that any approach which studied a large sample of innovations might reveal some patterns or general laws which might aid understanding of this complex process"* (Coombs et al., 1987).

Another landmark contribution that offered new methodological directions and insights as regards technology policy research was that of Freeman (1974). The focus of Freeman's endeavor revolved around the processes and activities of technological change that occurred inside a firm. Methodologically, and in the level of detail and issues involved, no study had gone this far before.

Paradigmatically, Freeman's study tended to foster and popularize a relatively narrow view of the Science – Technology (S – T) relationship, one that underscored the impression that technology is a product of science. By and large, this conceptualization that technological innovations stem from science-based, research and development (R&D) efforts, has influenced technology researchers to tackle policy issues within the purview of a highly restricted scope of data requirements. That said, Freeman's own study, while located in the broad tradition of the S – T conceptualization, is profoundly remarkable in that it has discussed firm-level activities far beyond the K – L treatises of neoclassical economists.

One of the salient, but methodologically limiting features of the neoclassical worldview is the theory of the firm. A major assumption of this theory is that technologies are an exogenous constant, infinitely available to firms in a ready and waiting technological shelf. At any given time, firms choose from among the infinite array, the technique that defines its production function. The natural corollary of this underlying assumption is *that firms do not generate technologies* from within. As such, the idea of endogenous technological change does not arise, is not entertained and does not exist in the vocabulary of neoclassical theory.

The methodological implications of this static theory of the firm are clear. First, a researcher is expected to appreciate technical change only from the standpoint of a firm securing a technique of production from an exogenous source. Consequently, research should concentrate on K – L combinations. Second, the theory gives the researchers no cause to expect endogenous dynamic activity and therefore analyze these internal developments for theoretical illumination and for understanding of firm behaviour.

Evidently, the neoclassical worldview fails to accommodate the role a selection environment plays in a firm's innovative processes. Indeed, the theory's description of the firm's decision-making behaviour hinges on the far-fetched assumption that firms operate under conditions of certainty and perfect information. As we shall observe when discussing the product cycle theory, information about a newly introduced innovation is usually limited and imperfect during the early time periods when it is being adopted and used. Therefore, since innovations are associated with bursts of new information that is asymmetrically distributed, the environment becomes fraught with uncertainty. These characteristics of information-impactedness and uncertainty, contradict the neoclassical assumption of perfect information and certainty, thereby explaining the deficiency of mainstream economics to model endogenous technological change.

Again, the capacity of technology policy research has been methodologically constrained by such a narrow conceptual and theoretical device.

Undoubtedly, then, a realization of endogenous technological change at the firm level could be well captured if investigative efforts on a firm's innovative behaviour are viewed in the context of selective dynamics of the operating environment. In this regard, and from both the conceptual and methodological viewpoint, the model that broadened our perspectives on new data requirements with respect to technology policy research, was the evolutionary theory of the firm as promulgated by Nelson and Winter (1982). The theory of the firm as outlined by mainstream economics is epistemologically weak in addressing issues of technological change (Clark, 1985).

According to the evolutionary model, firms operate in a competitive environment characterized by uncertainty and imperfect information. Pressures and threats from this environment excite in them strategic and tactical responses in their struggle for existence. Driven by the instinct of self-preservation, firms would employ established endogenous mechanisms and resources at their disposal in facing competitive challenges. Every firm has a repertoire of idiosyncratic abilities, which it resorts to when threatened. These internal mechanisms, as requisite endowments, could be likened to genes, which encode behaviour-defining information. The usual day-to day operations of survival could be regarded as "institutional routines." Other inherent capacities, such as "search routines," empower them to outcompete rivals. Those with successful strategies survive, while the weaker ones fall by the wayside. Nelson and Winter have invoked the Darwinian paradigm to describe the behaviour of firms.

One key determinant of competitive behaviour is investment in technological change. Here, firms seeking to outdo rivals and establish a competitive edge would proceed with innovative initiatives and institutionalize R&D activities. The general path, which defines the industry's orientation of production, historical and potential, is known as the *technological trajectory*. Each firm would operate within the confines of a technological paradigm, but would exhibit its own distinctiveness on the basis of its own requisite endowments e.g., diversity in skills, experience, expertise and patents.

What is crucial for our discussion is the fact that the evolutionary model offers far better insights about firm behaviour and internal efforts, to stimulate technological change. Compared to the neoclassical paradigm, this model imposes a demanding, but more valuable methodological requirement. The types of data that a technology policy researcher would call for are wider in range and more illuminative in value.

To conclude, methodological devices are conditioned by the conceptual frameworks that broadly inform the technological issue under investigations.

Alongside the second-generation studies, evolved a third genre stream that was pregnant with possibilities of defining new research and methodological directions.

The immediate concern of researchers such as Hollander (1965) and Enos (1962), whose works we will examine shortly, was the subject of technical change. Research efforts on technical change have offered sterling insights on significant sources of productivity and growth. Rosenberg (1982) has pointed out that, while technical progress represents knowledge that could be utilized to "….produce (a) a greater volume of output or (b) a qualitatively superior output from a given amount of resources" (Rosenberg, 1982), economists have expanded relatively more energy addressing the *cost-reducing* aspects of technological *processes* than in attempting to examine improvements in the final *product*
itself. He puts it in the following terms:

> *"Technical progress is typically treated as the introduction of new processes that reduce the cost of producing an essentially unchanged product – to ignore product innovation and qualitative improvements in products is to ignore what may very well have been the most important long-term contribution of technical progress to human welfare"* (Rosenberg, 1982).

Traditionally, economists researching on technological change have, by and large, directed their sights on process innovations, namely, new machinery and equipment used in production.

As mentioned earlier, this focus stemmed from their interest in understanding the cost-reducing impact of technical change. Infact, the most immediate preoccupation was in addressing the factor-saving bias, in particular, labour-saving devices, because labour was getting relatively more dearer. From the point of view of investigations, therefore, the tendency to explore cost-reducing innovations (where a relatively expensive factor would be reduced in a production set-up), was partly concerned with identifying the *direction of technical progress*. Yet, research efforts have also been directed at discerning the *rate of technical progress.* Here investigators have grappled with such questions as: Why have some societies (communities) been more innovative than others? What accounts for the differences in innovative activity and what factors (economic, political and social) have been responsible for pronounced receptivity and potential capacities in technology acquisition by one society relative to another?

However, technical progress has also been associated with the development of new products and new industries which appear discontinuously and at discrete intervals. It was Schumpeter (1943) who first recognized the phenomenon of creative disruption. These changes, referred to as radical innovations, tend to shift economic dynamism to a new and higher level.

The phenomenon of technical progress encompassed a lot more following Schumpeter's characterization of what constitutes an innovation. Apart from new products and processes, he included the opening of a new market, the discovery and utilization of a new source of raw materials, and the structural and managerial reorganization of industry as innovations. Research on technical progress was thus incorporating a much wider data range than ever before.

Citing Usher (1954), Rosenberg notes further that technical progress would also draw attention not only to

> *"….elements of continuity but also to the cumulative significance, in the inventive process, of large numbers of changes, each one of small magnitude"* (Rosenberg, 1982; Usher, 1954).

It needs to be pointed out that the issue of technical change has been so significant in technology policy research that the subject was revisited more conscientiously in 1980s.

The study of minor innovations and their impact on cost reductions have at times included a comparative cost analysis of such incremental improvements with the major ones introduced initially. In his study to fathom the sources of increased efficiency in Du Pont's rayon plants, Hollander (1965) showed that cost reductions stemming from cumulative minor innovations were far greater than cost reduction brought about by the introduction of the major innovation (Hollander, 1965). In the same vein, Enos (1962) arrived at a similar conclusion from a study of petroleum refining industry. He noted that the cumulative impact on cost reduction of subsequent minor innovations was far greater than the cost reductions that emanated from the initial introductions of the four major innovations, namely, thermal cracking, polymerization, catalytic cracking and catalytic reforming (Enos, 1962).

This brief overview on the issue of technical progress raises fundamental questions about methodology and the relationship between a researcher's breadth of understanding of the concepts, terms and definitions employed in research and the type and scope of data he would look for. In the specific cases considered earlier, the implication is that *how we define and characterize technical progress* influences a researcher's orientation towards data identification and selection.

A further example showing the extent to which conceptual devices restrict a researcher's selection of data, besides limiting his boundaries of exploration, can be demonstrated using the epidemics model. Analysts of technological change have shown keen interest in understanding the dynamics and mechanisms associated with the spread of technological innovations. Once a new technology is introduced in an economy, the prospect for other potential users to adopt it would be a function of many factors. Central to the calculus of a potential adopter would be how promising the innovation is likely to be in generating high returns and in producing supernormal profits. Stoneman (1983) devised a mathematical relationship to capture the factors that influence a prospective firm towards generating or commercializing an invention, but such a model could well be representative of an adopter's imitative potential. He expressed it as follows:

$$G = px - cx - E$$

WhereG	=	profit
P	=	price of a unit of output from an innovation
X	=	level of output of the innovation
X	=	$\frac{SaM}{P}$
Sa	=	market share of the adopter
M	=	size of the entire market
C	=	cost of manufacture of one unit of output
Ea	=	expected cost of adopting the innovation

Now, I indicated earlier that one key factor that could motivate a potential adopter to utilize an innovation is profit. So, a mark-up element will have to be introduced. Stoneman (1983) captures this feature for an invention in the following terms:

$$G = S.M\,(I - K) - E$$

Where $K = \frac{C}{P}$

This model could perhaps be located within a much broader conceptual framework that can describe, interpret and predict the phenomenon of diffusion of technological innovations. Initially, when an innovation bursts into the scene, not only would information about it be limited, but risks associated with it will be high. However, as firms adopt the innovation, information about it spreads, while the high degree of risk declines. This increases the innovation's rate of diffusion. With the passage of time, the proportion of firms adopting the innovation would rise as the number of potential adopters declines. Evidently, the rate of diffusion falls progressively until the whole process comes to a halt.

Such a dynamic can be summarized using a *logistic diffusion curve* and reflected in a mathematical form as shown in Figure 4.

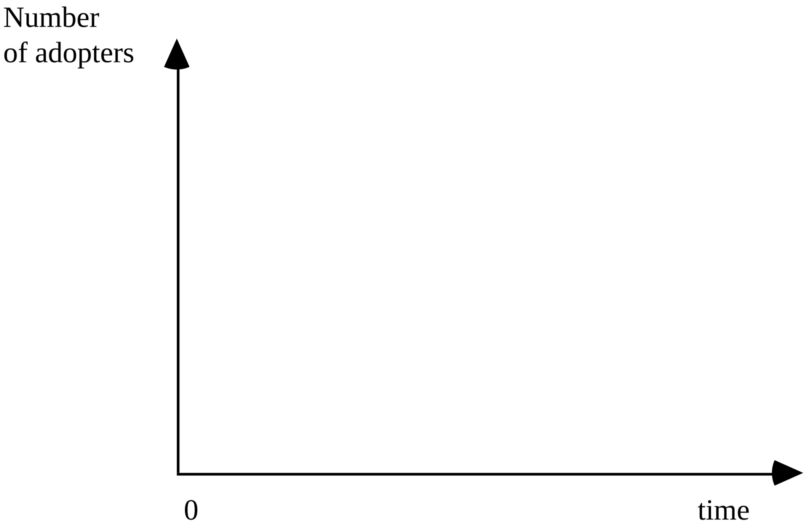

Figure 4: Model Logistic Diffusion Curve.

The rate of diffusion will depend on the proportion of adopters x at time t, and this can be captured by the *rate of change* $\frac{dx_t}{d_t}$. But it will also be a function of the proportion of potential adopters (I – Xt).

Hence,

$$\frac{dx_t}{d_t} = ß\, x_t\, (I - x_t)$$

Where ß = constant

From the epidemics model, it is clear that a researcher would be required to collect data on the specific times different firms adopt an innovation.

This conceptual model raises some crucial methodological concerns. It fails to capture vital information on any significant improvements in technological innovations as time progresses and the process of diffusion increases, decreases or stops. Moreover, since the passage of time would inevitably be accompanied by changes in the policy and operating environment, the dynamics of diffusion would be affected. In addition, this model addresses the *demand-side* of technological change, but lacks the ability to handle information on technology suppliers and the process of generating technological innovations. Therefore, diffusion studies that invoke such a conceptual apparatus in attempting to understand the patterns of technological change tend to be of limited technology policy value (Stoneman, 1983).

To conclude this section, it is vital to appreciate the extent to which conceptual categories condition the configurations of a methodological framework. The greatest folly of technology policy researchers would be to invoke the neoclassical framework in conceptualizing technological phenomena. Indeed, economists with orthodox backgrounds still cling to all sorts of neoclassical variants in such research endeavors. Yet, from a conceptual point of view, most become methodologically indisposed since neoclassical approaches fail to address "…some of the crucial problems of technical and institutional change" (Rosenberg, 1982).

Methodological Shifts and Their Relevance to Post-1970s Research

From the late 1960s, another shift in research focus gave birth to a new genre of technology scholarship with expanded methodological requirements. These addressed issues of technology transfer and diffusion. The former preoccupying the minds of development economists mainly in the Third World and the latter engaging energies of technology researchers in the developed countries. Both these research preoccupations brought in their wake not only fresh demands for gathering new types of data, but also the construction of relevant methodological procedures compatible with the new research orientation.

To appreciate these new methodological demands, it would be instructive to discuss a traditional model originally invoked to understand the process of technology diffusion and transfer. A major methodological limitation of the diffusion conceptual model becomes apparent when the issue of technology transfer is examined at the level of international trade. We shall discuss this aspect with respect to a related conceptual model of technology diffusion, the *product-cycle* theory. The idea was first put forward by Posner (1961) and later modified by Vernon (1961). It is a model that invokes Schumpetarian notions of product imitation and replication. According to the model, technological innovations are introduced into the market place by firms in advanced economies, which possess requisite infrastructure, resources and policy environment for stimulating inventive activity and commercializing discoveries. At this stage, both the innovative firm and economy enjoy a monopolistic advantage as the new product fetches high rents. This outcome is sustained by a combination of high prices and phenomenal growth in output and sales. Hence the configuration of the curve (stage I) shown in Figure 5.

The innovator's monopoly position is eventually challenged on expiry of patent protection as imitators copy the technology and penetrate the market. This marks stage II of the product cycle which begins at time t_z. The growth of competitive entrants eat into the innovator's market share, causing the latter's rate of profit to fall. Some new entrants would operate large-scale facilities and benefit from economies of scale, but would be driven by market pressures to improve upon the technology in a bid to secure a competitive edge. This stage could also witness investments in overseas locations and, hence, the internationalization of production.

With the passage of time, the product achieves maturity as knowledge about the technology becomes widespread and standardized. This marks stage III of the product cycle and takes off from time t_z. At this stage, competition is so intense that firms experience notable falls in output and decline in prices to competitively low levels. These conditions tend to raise the prospects of developing country economies to obtain the now affordable technology. In other

Output

Stage I Stage II Stage III

0 t1 tz time

Price

Stage I Stage II Stage III

0 t1 tz time

Figure 5: The Product Cycle.

words, the new dynamics would engender a state of affairs that would improve the Third World's comparative advantage towards investing in production technology.

This conceptual device has traditionally been invoked to describe and understand the process of technology transfer from industrialized economies to developing countries. However, it is a device that poses severe methodological difficulties. Researchers guided by this model might readily assume that the transfer of technology between the North and South would be inevitable once innovations produced by the former reach maturity. As such, technology studies may ignore data that would reveal the difficulties developing countries continue to face in their efforts to industrialize (Perez and Soete, 1988). In particular, investigators may overlook information on the historical context, institutional framework, and the developmental constraints impinging on the process of technology imitation and transfer (Perez and Soete, 1988).

Several studies on technology transfer had emerged in the 1960s, but it was in the 1970s and 1980s that a research deluge became apparent. This development was marked by a new research agenda that incorporated new research issues, defined new data requirements, and necessitated the formulation of an appropriate methodological design.

It is not often remembered that a large number of early technology studies were heavily biased towards examining *macro-patterns* and understanding *broad technological changes* in economic systems (Solow, 1957; Denison, 1962; Manfield, 1968). Research efforts focusing on firm level case studies were a rarity. This was generally true even though seminal, path-breaking but in-depth firm level studies were revealing consistencies and precedents of great theoretical and policy value (Hollander 1965; Enos, 1962). In fact, some of the most exciting yet deeply informing works of this genre were done by economic historians (Landes, 1969).

Since these specialists have not traditionally been enjoying the kind of respectable profile relished by neoclassical economists, their novel conclusions had not enjoyed extensive popularization in mainstream economic departments. Technology discourses by the latter breed of experts tended to attract and command inordinate attention, hence, the case-study research efforts were apparently peripheral and trivial.

The study by Freeman (1974), though continuing this tradition of general studies, was significantly outstanding, in that it also embodied considerable chunks of information from *qualitative* research. It proceeded to document in detail processes of technical change at both the industry level and the wider economy as a whole. The broad patterns of change at these levels were deduced from a profound analysis of process innovations, in particular, on oil refining, synthetic materials, electronics (radio, television, radar and computer) and electronic components. Freeman's contribution had significant methodological ramifications. In an important sense, it defined a new path in the study and exploration of technology issues. The innovative directions delineated and suggested by his unique approach, precipitated new demands for data — both in scope and depth.

While these early macro studies were of theoretical and intellectual value to development economists and men of affairs alike in developing countries, it is the effort to fathom the complexities of the technology transfer process that broadened the investigative agenda of technology policy research in the 1970's. Initially, and for almost a decade, the approach was macro and general in tone, content and orientation. The studies by Vaitsos (1973) on patents and the role of Multinational Corporations (MNCs) in technology commercialization (1974), were *sectoral or country case studies*. Further, other efforts by, say, Cooper (1974), Cooper and Sercovitch (1971), and (UNCTAD, 1975) were essentially broad-based. The UNCTAD technology transfer series brought to the fore the range of research issues which engaged the energy of researchers, but again the methodological approach was either macro or sectoral. In short, these early studies shaped the methodological landscape, both in terms of data content and procedures used for technology policy research from the 1970s onwards.

An overview of the issues that defined such research is in place here. In general, objectives addressed:

- International market for technology
- Technology transfer process
- Terms and conditions underpinning the process
- Impact of such transfer on technological development of recipient countries.
- Role of developing country governments in stimulating technological change
- Technology transfer and local R&D.

Research literature identified various forms of technology transfer such as patents; licenses, software, blueprints, manuals, technology supplier skills, expertise and information; also equipment, instruments and machinery. The dominant vehicle for technology transfer was the multinational corporation, while the main channel of this flow was direct foreign investment. Most technology transfer arrangements were associated with various terms and conditions, some clearly specified, while many were applied informally. They included:

- Transfer restrictions
- Market restrictions
- Volume restrictions
- Recognition of the licensor's intellectual property regime
- Limitations imposed on licenses in the use of technology after expiry of agreements
- Restrictions on competing products
- Restrictions on choice of sites and locations of production
- R&D restrictions
- Tie-in restrictions which limit a licensee's sources in the procurement of inputs
- Grant back condition which necessitated that transfer of rights over improvement and innovations to transferred technology.

The studies also covered the following:
- Sources of technology
- Descriptions of technology (process or product)
- Nature of transfer arrangements and elements of the technology package
- Modalities of technology search and evaluation
- Rights retained, demanded and expected by supplier.

It is evident that the methodological challenges were massive both in terms of information sources and scope of categorization. On the latter, what constituted "technology" had to be specified. The definition advanced by Teece (1977) was considered representative, namely, decomposing technology into embodied (physical) and unembodied forms. The former comprised of equipment, machinery, instruments, materials, components and blueprints. The latter embraced knowledge and skills on organization, production procedures, operation, maintenance, repair and quality control. In addition, it includes knowledge and skills on consulting and engineering services such as the range of pre-investment services, and project execution and implementation services (e.g. supervision of plant design and installation, precommissioning and plant commissioning capacities).

These technology studies had an interesting angle. Even though the research efforts were sectoral (industry-specific) or country-oriented (country case studies), the survey methods included *firm level visits and data collection.* Whether the orientation was sectoral or country wide, specific methodological decisions had to be made. To begin with, it was obvious that not all industries could be investigated. As such, the endeavours narrowed their sample to examining selected case study industries.

The selection process had to proceed on the basis of clear-cut criteria — consistently and uniformly applied. The following considerations could loom large in the selection effort:
- The size (level of sales per year) or growth rate potential
- The numerical strength or abundance of firms
- The level of technological intensiveness i.e. the extent to which future industrial progress is heavily R&D dependent.Willingness of industries to participate in the research programme (e.g. providing data access)
- Inclusion of locally-owned firms.

Information could be obtained through surveys using postal questionnaires (stage I) and firm visits to conduct direct interviews (stage II). The stages involved securing *different* types of information. The first could seek *general* company information on performance and technology transfer activities, while the second could be detailed and more specific (firm level experiences on technology acquisition). Yet, a third stage could involve making visits to overseas technology suppliers. Here, the motive would be to understand technology transfer issues from their point of view.

Finally, researchers conducted interviews with several representatives of domestic technology agencies. The seniority of the interviewees had to be resolved. The rationale of this stage would be to generate data on what governments have specifically done to promote technology transfer and development by local industries. Moreover, the information would demonstrate the effectiveness or otherwise of government initiatives and measures in this regard. There would then be sufficient basis to suggest policy options to promote effective technology transfer.

This brief overview outlines the methodological drift of technology policy studies that examined technology transfer issues in the 1970s and 1980s. As noted earlier, the focus was largely macro in nature i.e. it was sectoral (industry-specific) or country-wide. However, the investigative process itself relied heavily on firm-level evidence from where broad generalizations were made.

Firm-Level Case Studies: A New Focus in Technology Policy Research?

In the 1980s, the large volume of research output (on technology concerns) that flowed, exhibited a marked tendency, namely, the orientation of many of its investigators to focus on specific firms as distinct units of analysis.

This micro-thrust was becoming a dominant feature of technology policy research. What led to this new drive is not so obvious. Perhaps the main reason stems from the observation that very few studies had been produced along these lines. If the deeply illuminating works of Hollander (1965) and Enos (1962) were anything to go by, then more studies of this genre would expand our horizons of thought and deepen our understanding of technological process. In any case, the neoclassical model was singularly deficient in comprehending critical aspects of technological phenomena, especially regarding the question of what goes on inside firms. Yet, strategic insights could be furnished by zeroing in on firm level evidence on technological change.

But Khalil (1992) offers a different reason for this bias towards firm level case studies.

"Firm level evidence provides a large array of information that increases understanding of technological achievements as well as patterns of technological change in a firm or industry. Results from such studies avoid the kind of methodological problems associated with national and sectoral level studies, which frequently encounter difficulties of insufficient and unreliable data (Hoffman, 1986). Evidence of technological change at the firm level is likely to be more promising if it considers all aspects of the firm. Technology studies at the firm level unearth important details that are almost always overlooked in more general studies. This study

accepts as a basic premise the diverse behaviour of firms. There is an element of individuality about each firm. To capture this essence, it is necessary to proceed on a case by case basis.

Peculiarity and idiosyncrasy as attributes of firms are also indicative of the wider internal forces that shape their functioning, survival and growth in time and space. Unique characteristics endogenous to a firm may require systematic examination in order to reveal specific tendencies. Indeed, it is possible for a firm, with totally unconforming behaviour, to overwhelm an industry in terms of diversity of responses and strategic orientation. What is considered as a sub-optimal case, may after all, provide the evolutionary drive and hence pervasively transform economic space (Allen, 1986). It is this factor of identity, individuality and particularism that needs to be fathomed."

In this section, I shall examine some of the pertinent developments in this regard. I shall discuss a few methodological implications of this shift in focus, and conclude by noting that technology policy research has been significantly enriched by it.

At the outset, it would be crucial to delineate the range of issues that characterized research on firm-level technological change. The new genre of research efforts flowed following an appreciation of the view that technology or technological capabilities can be derived or built from existing technologies. The relationship could be thus:

T1 - T2 - T3 etc.

Such a conceptualization of technological change spawned a large number of research initiatives replete with vastly different data requirements and methodological approaches. These studies raised a multitude of new questions, on how firms or economies *acquire* technologies, and what conditions and initiatives lead to the evolution or generation of domestic technological capabilities. The new research directions elevated technology policy research to a new level.

Let us review several case studies of this genre to appreciate the demands for requisite data and the methodological innovations necessitated by the new research endeavours. The means or processes used to enhance technological capabilities at firm or individual levels have been the focus of attention of numerous technology policy researchers. The growth in skills and knowledge has not only been a time-dependent process, but has also involved deliberate efforts and investments in the accumulation of technological capacity. According to Bell (1984), the accumulation has been achieved through various forms of learning such as learning:

- by operating
- through the pursuit of technical change
- by training
- by hiring
- by searching
- through feedback mechanisms

Writers like Ranis (1984) have argued that the ability of firms to apply technology depends on the quality of indigenous technological activity. This is a function of:

- the ability to choose available technologies wisely and cost effectively
- the ability to improve and make adjustments
- the capacity to channel and diffuse information and technologies

Ranis (1984) proceeds to examine the determinants and consequences of indigenous technological activity by distinguishing between the supply factors such as the prevailing human and/or organizational and institutional abilities, and demand factors, such as the different dimensions of an economic environment. Research issues may include analyzing:

- the configuration of the educational system (primary and secondary) on stimulating the cognitive processes and in engendering a problem-solving capacity.
- technical literacy and skill levels
- attitude towards technology of polytechnic level technical personnel
- nature of infrastructural investments by governments in education and agricultural research and extension services.
- information gathering potential of local institutions
- science and technology institutional infrastructure
- public policy changes that foster an information/diffusion/adaptation network
- the extent of integratedness of firms in industry
- subcontracting incentives
- choice of batch production system over continuous production lines, the former encouraging the search for product and process change more readily than the latter
- the nature of the legal system that promotes the enhancement of local abilities
- a reasonably competitive environment
- nature of foreign aid
- nature of the transportation network
- the size of the domestic market

It has been noted that technological search efforts have been critical in enhancing the process of technological accumulation. Katz (1984) has identified a range of technology policy research issues in this regard such as:

- firm-specific variables such as bottlenecks and imbalances in product designs and plant lay-out, which generate the sort of compulsive sequences (Rosenberg, 1982).
- the competitive dynamics of a market environment that induce firms to pursue cost reducing technological search efforts.
- the role of micro and market specific variables e.g. an increase in the cost of capital equipment would dissuade firms from pursuing new investments. This would compel the firms to pursue output-stretching technological search efforts.A pronounced growth in demand would stimulate firms to pursue technological search efforts designed to expand physical capacity
- an increase in the rate of interest would compel firms to seek information which, on application, would ensure cost reducing innovations e.g. simplifying product design, reduction of handling time and effective management of inventories.

These few examples illustrate the decisive change in focus of technology policy research from the 1980s onwards. Available literature is abundantly rich in material and on issues relevant for investigation. What should be appreciated is that firm level studies generate conclusions that are bound to be exclusive and therefore not amenable to generalizations. A researcher can only proceed with such extrapolations under very restrictive qualifications.

Chapter Four

Elements and Dimensions of a Methodological Framework

It would be too presumptuous on my part to pretend that this section will discuss the entire gamut of methodological issues that could conceivably impinge on technology policy research. Literature on research methods, both general and specialist, is voluminous and it is beyond the scope of this effort to review the numerous features of a methodological structure. With that in mind, I will proceed on a selective basis by briefly:

- summarizing related work on methodological models
- discussing the features of a research design relevant to technology policy research
- reviewing components of a sampling design
- reviewing approaches to data gathering

There exists a large body of literature appearing either as general introductory texts for social scientists or as specialized books on research methods for exclusive use by researchers in various disciplines. Nearly all cover topics such as elements of research, research designs, and data collection, processing and analysis. Various features of methodological procedures are invariably discussed and where possible, examples are furnished to serve as illustrations. In the main, most texts would provide a reader with insights on how to proceed with research activities.

In this section, we shall discuss generally, albeit briefly, some of the salient elements of methodological import. The aim of this overview is to shed light on the main data collection methods employed in research as well as point out some of their limitations. The overall goal here is to set the stage for a more comprehensive discussion of methodological approaches, which a technology policy researcher can draw guidance from.

An early ATPS study on methodology for science and technology policy research was written by Adeboye and Clark (1996) to assist African researchers come to grips with issues of investigative concern. The study makes reference to the limitations of the neoclassical framework in capturing the technological phenomena in all its diversity. It then mentions the progressiveness of the Schumpetarian tradition in enriching our understanding of innovative developments by exposing the deficiency of the market framework in promoting technological change. In the same breath, the study places a special premium on the concept of technological capacities and calls for a more proactive role by governments to catalyze the growth of these capacities. This issue of policy proactiveness has been explored by Khalil (1995) in the context of weighing Africa's prospects for technological evolution amid the pressures unleashed by market reforms and globalization. More recently, Chang and Cheema (2001) have revisited the market versus public policy debate and noted that proactive interventions are a manifestation of, and a necessary condition for running a successful technology policy in developing countries.

Adeboye and Clark (1996) then devote a considerable part of the paper discussing the methodological significance of this concept in re-orienting technology policy research. Four approaches are examined in this regard, namely:

- The Lall (1992) model
- The Charles Weiss Jr. (1993) approach
- The Bell-Pavitt (1993) approach
- The Ernst, Mytelka and Ganiatsos et al. (1994) model

What these models do is to emphasize the direction the technology policy research has taken over a decade or so. Finally, the study suggests some methodological guidelines in a bid to not only strengthen African research efforts, but also to improve the quality of results that could potentially influence the contents and scope of technology policy.

While the book has shed useful light on some critical issues on methodology, it suffers several drawbacks:

- It is silent over the methodological demands posed by firm level case studies. Its overall orientation appears sectoral, industry-wide, or national. The unit of analysis chosen has far-reaching methodological implications.
- The study does not discuss the various types of research designs that could be relevant to various forms of policy research.
- The study has taken an omnibus view of the concept of technological capability. No real attempt was made to show how, say, studies on technical change, or investigations on pre-investment capacities, demand tailor-made methodological approaches.
- The study cites the limitations of the neoclassical framework in fathoming technological phenomena, but fails to provide examples on how the different conceptual categories have conditioned the methodological scope of technology policy research. Related to these is the criticism that the study has taken a very limited historical perspective, thereby failing to capture the changing emphasis, which characterized inter-temporal shifts. In this context, there was no discussion on how methodological requirements reflected the new realities.
- The study failed to discuss the various sampling procedures in light of their suitability (or otherwise) or appropriateness (or otherwise) to technology policy research. What procedure would be relevant in one case and not another, and when and under what circumstances one sampling design would be selected as opposed to others, are questions not explored by Adeboye and Clark (1996).
- The study has ignored the profound epistemological questions which methodologies need to take on board to ensure the generation of reliable and valid knowledge.

Most of these issues have already been covered in detail in the earlier sections of the book. My treatment of these matters has proceeded in the context of not only exposing the methodological deficiencies of the conventional research approaches, but also in suggesting new methodological directions.

In their review of the various models, Adeboye and Clark (1996) have distilled the following types of technological capabilities:

- Production
- Investment
- Innovation
- Linkage
- Minor change
- Strategic marketing

This study (Adeboye and Clark, 1996), as well as many previous ones, have failed to identify three other crucial technological capabilities. Khalil (1992) has acknowledged the existence of the following:

- pre-investment
- project execution
- project implementation

These capabilities can be broken down as follows:

- pre-investment stage:

(i) opportunity cost studies
(ii) screening of project ideas
(iii) market studies
(iv) technical requirement studies
(v) techno-economic feasibility studies
(vi) technical evaluation of project
(vii) economic and financial evaluation
(viii) location studies
(ix) evaluation of means of financing.

- Project execution stage:

(i) process and product design
(ii) architectural and structural design
(iii) design and layout of machinery and equipment
(iv) evaluation of bids
(v) supervision of construction and equipment installation
(vi) purchasing, inspection and testing of materials and equipment
(vii) quality control.

- Project implementation stage:

(i) production activities
(ii) technical personnel training
(iii) maintenance

The reality is that most research endeavours on technology policy have not addressed these capacities in all their diversity. The methodological questions that could arise are:

- Which firms undertook these activities?
- From whom did they acquire the capacities?
- How did they go about building these capacities?

Often, a focus on these capacities by technology policy researchers has been ignored largely because they constitute a tiny proportion (usually less than 5%) of the total project costs. Yet, they are the foundations upon which crucial technologically-oriented decision making in subsequent phases are made. These particular service capabilities are the critical building blocks of future technological direction.

Normally, pre-investment, project execution and project implementation services for government projects receiving funding from abroad have invariably been undertaken by overseas consulting firms. The strong bonds that have existed between these firms and foreign technology suppliers have tended to maximize overseas content on the one hand, and deepening of technological dependence of clients on the other (Khalil, 1992).

Some repetitions are worth their while. In our context, it is the reemphasis that the services offered during the preinvestment, and project execution and implementation phases, that constitute strategic technological capabilities that need to attract the attention and resources of technology policy researchers.

Research Problem and Design, and the Sampling Design

When a technology policy researcher has identified a *research problem* whose investigation is aimed at producing policy-oriented results, the next step constitutes the methodological phase. It would entail sharpening the focus of the research question, selecting a research design, identifying the variables, forging research instruments and generating a sample. The origins of one's interest to tackle a particular research problem may vary from individual to individual, but in our context, the stimulus has to stem from a practical concern to generate technology policy solutions to satisfy a palpable need. One's curiosity could have been aroused after reading local or national newspaper, assessment reports and specialized literature (journals and books). Since at the start one would conceptualize the problem in a general way, the next step would involve defining the research issue more concisely. One way of achieving this would be to discuss the matter with friends, colleagues and officials in relevant institutions. Another would involve consulting appropriate literature and reading reports and publications written on the subject. Libraries and documentation centres would be useful in this regard.

Other sources would include visiting search engines and requisite websites on the internet. These search efforts would expand the horizons of knowledge of the potential researcher, which along the way would help him clarify and narrow his research problem.

Methodologically, therefore, this stage is crucial in that the configuration of the research design would depend on how well the researcher has succeeded in focusing the research problem. The latter would be reduced to a single, but brief statement. It should be self explanatory, appreciably comprehensive and unambiguous. It can appear in the form of a hypothesis, an objective or a research question. However, a researcher may have to begin the focusing process by framing several hypotheses, objectives and research questions. Needless to say, the imperatives of clarity and conciseness in formulation of the research problem are strategically instrumental in effectively designing the methodological phase.

Once this exercise is reasonably through, a researcher will be confronted by several questions: How would one proceed? Who shall be studied? What will be the unit of analysis (firm level, sectoral and national)? What variables will need to be selected and what shall be observed? When will the observations be made and how will the data be collected? When will the study begin and end?

This is where both a *research design* and a *sampling design* would loom into relevance. A research design is a plan, which an investigator devises to guide his research and help him generate results that would serve as, or empower him to derive technology policy solutions to the research problem. The first question "How do I proceed?" would require a researcher to determine, with the help of say, similar studies done elsewhere, whether his unit of analysis will be the firm, industry, sector, nation or region. Moreover, he will be required to decide whether the investigation would involve a comparative analysis of firms (or industry) at a particular point in time or across time? Table 2 summarizes some of the basic types of research design.

In technology policy studies where causal influences are being addressed (for example, the impact of economic reforms on technological change), three factors need to be borne in mind: covariation, nonspuriousness and time order. Covariation refers to a situation where two or more variables or events vary together. The essence here is to establish whether one phenomenon causes another. Nonspuriousness is said to characterize a relationship between events when this relationship cannot be explained (impinged or impacted upon) by other variables. Time order establishes the temporal direction of influence in that the assumed cause is shown to occur prior to the assumed effect. Clearly, such studies impose specific methodological demands on a research exercise.

As to what variables will be selected will depend on the topic under investigation and the research design adopted. If the research topic is technology transfer and a firm level case study is the unit of analysis, then the variables to be investigated could include an entire gamut shown earlier. Alternatively, one could justify the use of some choice variables and not others. In any case, a researcher's capacity to identify the relevant variables would be greatly enhanced if an extensive review of literature on the subject is done. The point to remember is that selecting variables is not as straightforward as it sounds. It poses a challenge, since the investigator has to justify the relevance and conceptual utility of such indicators. Questions like "How good or valid is the variable and how adequately does it capture the essence of the study?" are crucial to raise when undertaking a selection. In the main, the variables must not only reflect the empirical interests of the research, but also contribute overwhelmingly to addressing the hypotheses, objectives and research questions.

Table 2: The Five Basic Types of Research Design

Type of design	**Time laps**	**Question asked**
Simple case study A		What is happening?
Longitudinal study Time 1	A Time 2	Has there been a change in A?
Comparison A B		Are A and B different?
Longitudinal Comparison A B	A B Time 2	Are A and B different through time?
Experiment Experimental group A	A	Is there difference between A and B due to a change (in the independent variable?)
Control group B Time 1	B Time 2	

Source: Bouma and Atkinson, 1987.

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The choice of particular variables prepares the researcher's frame of mind regarding what he should observe or look for when collecting data. It confers cost-effectiveness to the research process by enabling him to optimize on resources and economize on time. This latter aspect brings us to the issue of when the study should begin and is planned to end. The temporal horizon of the technology policy research should be specified. It is evident that the study's duration would be conditioned by the defined scope and depth of the research endeavour, resources available and the availability of relevant officials/staff (on leave or away on assignment). Surely, the delineation of time scale would also be contingent upon the means chosen to gather data and the complexities of addressing the components of a sampling design.

Now, whatever means a researcher uses to gather data, he has to determine the sample size i.e. the number of firms, industries or sectors he plans to include in his study. This determination is necessary if the study is not to be bogged down by the inordinate demands of an all-inclusive, exhaustive undertaking. A sampling exercise confers key advantage, it makes the research effort manageable. In fact, if the sampling process is handled carefully, then the results of research could be generalized for the whole population. This extrapolation of validity would only hold if the sample is an accurate reflection of the whole population, i.e. representative. Again, achieving this is neither easy nor simple. It should be borne in mind that the way a sampling design is constructed, determines the extent to which a study's findings can be generalized. Thus, sampling poses a major challenge to technology policy researchers.

In many instances, sampling has been an important feature of technology policy research. In general, policies are supposed to apply to wider situations though authorities may also formulate specific policies designed to target exclusive cases. Sectoral or nation-wide studies have most often relied on samples to generate policy findings with wider applicability.

However, random sampling may not always be necessary. If the population being considered is finitely small, then the entire group could be studied. In such instances, the whole population is embraced by the survey. One must therefore be careful to limit conclusions of the study to the very group covered.

Two generic sampling procedures need to be appreciated to a technology policy researcher: random and non-random. The methods under these broad categories will be introduced briefly rather than discussed in detail. I will subsequently indicate which procedures have most often been used by technology policy researchers.

As the name implies, random sampling procedures refer to methods that give each element (e.g. group or type of firm), an equal chance of being selected. This category comprises four types: simple random, systematic, stratified random, and cluster sampling. In simple random sampling, the first step is to identify the population from where the sample will be derived.

Then, each element (e.g. solar firms) of the population is listed. Finally, a system is devised that ensures that each element has an equal chance of being selected.

So, if a country has 100 firms producing solar panels and 30 need to be studied, then all the firms will have to be listed and enumerated. The selection of the sample firms could proceed using a table of random numbers. Alternatively, each firm could be represented by the assigned number (fixed during enumeration) or name posted on a piece of paper. These are placed in a container, mixed thoroughly and one drawn out at random. The number or name of the lucky draws would represent the successfully selected candidates. The only thing to bear in mind is that the selected piece of paper should be returned to the container before repeating the exercise. This process continues until 30 firms are selected.

In systematic sampling, selection proceeds randomly , but the sample will be made up of every fourth item on the list. In our case, every third firm (100 firms ö 30 = 3.33, so 3 is the nearest whole number) would constitute the sample. The only condition with this procedure is that the first selection must occur randomly. This starting number could be determined by making a draw from the container. If the number is, say 5, then the next selection will be 8, 11 and 14, until a sample size of 30 is reached.

The main advantage of these procedures is that a researcher's preferences or prejudices are ruled out.

Stratified random sampling refers to the sub-division of a population into distinct classified groups, which are then identified and enumerated. Manufacturing firms in the export sector of the medical and scientific equipment industry, could be stratified according to the size of their operations (e.g. production output). The particular basis for classification would be determined by the objective or hypothesis of the study. Once the stratification is done, then the random selection of firms will proceed. If the stratified groups are three, then each stratum will have 10 firms randomly selected in the manner discussed earlier.

This procedure is suitable for technology policy research, for sectoral, industrial, national studies intended to use statistical or econometric techniques to analyze data.

Finally, a word about cluster sampling. This multistage procedure consists of a series of random selections and is applied when an unmanageably large population is subject to investigation. The method involves dividing the population into segments, followed by the random selection of a specified number of segments. All firms in this randomly selected, but segmented population are identified and enumerated. The sampling process concludes when a specified number of randomly selected firms reach the sample size. If, 30 firms are to constitute the sample and the segments are 60, then each segment will have two firms randomly selected from it (60 - 30).

Again, this sampling procedure would apply to broad-based sectoral or national studies which intend to use statistical techniques to analyze data.

As noted earlier, random sampling procedures are normally applied when research conclusions from a studied sample are to be generalized for the whole population. Such extrapolation of validity would only hold if the sample is an accurate reflection of the whole population.

Technology policy research has employed non-random sampling procedures in the study of technological phenomena. The point to bear in mind is that the conclusions reached are limited to that sample and cannot serve as a basis for further generalizations. However, one can suggest tentative implications by including cautionary qualifications.

Non-random sampling procedures are four types: accidental, accidental quota, purposive and systematic matching sampling. No attempt will be made here to give a detailed and comprehensive account of these procedures; only a brief overview will suffice.

Accidental sampling refers to the deliberate targeting of specific elements (e.g. an energy parastatal) for purposes of study. Such targets are "soft", proximately accessible, relatively easy to handle and require no large expenditure of preparatory efforts.

The selection of a sugar firm to fathom technological phenomena may have been prompted by a researcher's familiarity with the investment as part of his childhood's experience. The major drawback of this sampling procedure is that the research results are exclusive to the sample investigated.

Accidental quota sampling refers to the selection of samples according to a specified criteria. A researcher may wish to compare two very successful cases of technological accumulation in an environment dominated by cases of technological failure. In this regard, quota sampling could be invoked in situations where certain characteristics are rare in a population. However, like the accidental sampling method, the quota technique would select samples whose research conclusions cannot be generalized.

Purposive sampling involves the use of one's judgement to select firms which exhibit certain typical tendencies. The latter patterns are distinguished on the basis of specified criteria. Given this feature, it is possible to advance tentative, though qualified generalizations from such purposive samples.

The final procedure under the class of non-random sampling techniques is the systematic matching sampling method. This approach has been used by researchers to compare certain specified features in elements (e.g. firms) of very different sizes. The number of firms of one size must be equal to the number of firms of the different size. Again, research conclusions reached from such samples cannot be generalized, given their exclusive character.

Gathering Data for Technology Policy Research

The completion of a sampling design is followed by the establishment of appropriate means to gather data according to a set of variables identified during the research design stage. A brief look at the following data collection methods is appropriate:

- Observational methods
- Interviews and questionnaires
- Archival material (records and documents)
- Content analysis

The Technique of Observation

The legacy of the seventeenth century empirical endeavours by Galileo and Newton continues to extol the significance of observation in scientific inquiry. Those who subscribe to the inductivist tradition argue that science begins with observation. A large body of facts gathered through sensory experience is examined for evidence of existing regularities. In this respect, the mission of an inductive researcher would be to proceed from facts to generalizations in the task of building scientific knowledge.

Another methodological approach to generating scientific knowledge is deduction. Here, a researcher would have been guided by some non-trivial preliminary ideas and observations, which enable him to formulate conjectures. These are no more than intelligent guesses that form the basis of an organized investigation. Using this method, a researcher invokes the technique of observation to gather data that potentially falsifies the generalization. Deduction then, proceeds from generalizations to the search of evidence that elucidates on the operation of the generalizations.

In strict epistemological terms, the method of deduction would involve the use of logical procedures to reach conclusions from a set of axiomatic principles or premises. We shall not pursue the debate here except point out that it is the former version of the deductive methodology that we would invoke in arguing the scientific basis of technology policy research as regards firm level case studies.

Technology policy research is an empirical endeavour that relies overwhelmingly on organized and careful observation. This tends to build facts or generate data through sensory experience — we record what we see, hear and touch. The facts of experience are gathered and efforts are made to discern persistent patterns or regularities for industry or national studies. Law-like generalizations are then distilled from empirical data according to the principle of induction. The process of inductive reasoning proceeds from facts to generalizations, an approach known as the inductive method.

A naive inductivist, who places a special premium on observation, puts down facts in the form of *observation statements*. *Singular* observation statements are drawn from specific experiences. They establish the truth of a particular event occurring at a given place and specified time.

Examples:

- Liberalization has led to the underdevelopment of technological capacity of sugar firm X
- Former President Jerry Rawling's exclusion of the Science and Technology (S&T) Ministry in his inner cabinet since 1993, undermined science and technology policy development in Ghana.
- The absence of a proactive subcontracting policy in Kenya's power sector, designed to promote the utilization of domestic technological capabilities, constrained the growth and use of locally available capacities/inputs during the second phase of the geothermal programme.

Most firm level case studies tend to generate observation statements of the singular type. If this is granted, how then can such statements pass for scientific knowledge i.e. knowledge that is reliable and credible? Could a single, specific statement about an event inside a firm be a basis for advancing law-like generalizations?

As far as inductive science is concerned, only *general* statements that make claims about the behaviour of firm processes or events can account for scientific knowledge, and such statements are known as *universal* observation statements. In other words, a universal observation statement would be formulated from *many* or *all* experiences.

Examples:
- Market forces lead to the underdevelopment of technological capacities in SSA.
- Transnational corporations (TNCs) have perpetuated technological dependence of SSA economies through the sustained application of restrictive business practices.
- The introduction of agricultural biotechnologies by the dominant TNCs has exacerbated the food security situation in SSA.

These generalizations can be scientific if they have been legitimately derived from a finite list of singular observation statements. The fundamental guiding principle of an inductivist is the principle of induction which can be formulated in the following way:

> *If a large number of event Es have been observed under specific conditions, and if all or most of the observed Es exhibited property T, then the general tendency of Es is that they will be characterized by property T.*

If this is an accepted premise of science scholarship, would it be legitimate to generalize from a *singular observation statement* (this often occasioned by firm level case studies), for the claim to pass as scientific knowledge?

From the inductivist point of view, observation statements can be scientific if the following conditions obtain:
- The number of observation statements that underpin a law-like generalization must be large
- An independent observer could establish the truth by careful observation and that observation can be verified under a specified set of conditions.

Unfortunately, technology policy research focusing on single case study situations has not proceeded to *reproduce* or *repeat* investigations carried out by others to establish the truth or falsity of a generalization. How then can firm level evidence, in this case revealing a limited set of specific observation statements, pass as reliable knowledge?

This is certainly a methodological issue. Here we are confronted with a paradox. On the one hand, we are excited by the thought that firm level case studies, by virtue of the fact that they grapple with idiosyncratic and particularistic events, would yield observations that offer unique insights (singular observation statements). On the other hand, we are disturbed by the fact that each of these singular observation statements cannot yield generalizations that can pass firm level case studies as reliable scientific knowledge.

The grave implication of this paradox is that firm level case studies are worthless, time wasting exercises, because they are in their own right incapable of producing universal observation statements. Therefore, if such a premise is held, the inevitable conclusion will be that all technology policy research activities which focus on firms as distinct units of analysis, would amount to mere exercises in scientific futility, unless they form a part of a larger sectoral or national research effort, where the principle of induction finds operational validity.

Without a doubt, the canons of inductivism would dictate such an outcome. But to subscribe to such a methodological approach would be too simplistic as it would be naive (Richards, 1983; Chalmers, 1978). In the first place, firm level case studies can stand alone and still produce law-like generalizations from a finite but large combination of idiosyncratic singular observation statements if these observations, in their overall cumulative thrust, account for, explain or predict events, which the tentative hypothesis tend to suggest, imply or indicate. Alternatively, the study will be scientific if the particular singular observation statements are used to deduce other statements, which lend credence to a study's working hypothesis.

We have already made remarks about the technique of observation in research. The meaning of this term has been defined broadly by recording information and facts obtained through sensory experience such as seeing (watching), hearing and touching. Needless to say, the process of observation will be guided by the research problem, hypothesis and objectives. One could delineate the range of issues (or variables) by summarizing them in not more than two or three words. Such a checklist would serve two purposes: it would assist a researcher to zero-in on observations and help him systematize the recording of those observations.

Interviews and Questionnaires

Interviews are a data gathering technique that entail asking people questions. This can be achieved by meeting the respondent at his place of work or other appropriate venue. Alternatively, the researcher could ask his questions over the telephone. A questionnaire is an instrument that contains the questions to be read and answered by the respondent. It is delivered in person or by post, but can also be administered by a researcher in the presence of a respondent. In this case, the researcher records the data on the questionnaire. It is beyond the scope of this paper to discuss in detail the nuts and bolts of these techniques, but certain basics need to be borne in mind:

- the method used should not be unduly long
- the questions must be clear and should seek information directly, relevant to research objectives and hypothesis.
- the questions should be addressed to the appropriate person who would have expressed willingness to respond
- the questions should be direct, simple and to the point, to avoid emotive and offensive terms and eschew the use of complex phraseology.
- wherever possible, pretest your questionnaire by giving it to people who approximate those envisaged by your study.

Archival Material and Content Analysis

Very useful information about a firm, industry or sector could exist in abundance in records, official reports and documents held by individuals or found in libraries, government or international agencies and documentation centres. A researcher has to contend with four problems:

- The issue of *access*.
- Concerns on the *provincial nature* of the data i.e. too narrowly confined in terms of scope and/or depth.
- The problem, especially involving statistics, relates to the current applicability of the information.
- The information in archival records could have been gathered for purposes different from those presently engaging a researcher. Who collected the data in the first place, for whom and for what reasons?

These should be questions foremost in the mind of an investigator.

In content analysis, a researcher (guided by his objectives and hypothesis) would identify examples, issues, ideas, approaches, methods, anomalies and patterns that have a bearing on his study. Tendencies that reinforce or run counter to his arguments should be recorded.

In conclusion, it would be necessary to return to two issues that were raised earlier, namely, reliability of methods used and data collected and the validity of the conclusions reached. These questions are of profound methodological and epistemological significance. A technology policy researcher should satisfy himself and those concerned that the means he used, the data he gathered, and the conclusions he reached are reliably appropriate and legitimately defensible, respectively.

Chapter Five

In Search of Relevance: Identifying Priorities and Potential Directions for Future Technology Policy Research

One of the key challenges to technology policy researchers is how their products and investigative endeavours and programmes, can stimulate African governments to take determined strides towards a *sustained* technological effort for technological development. Thus, the process has to be *continuous* and *systematic*.

The Needs Approach

The research to be carried on subjects whose results could provide useful, practical insights on how a wide range of *needs* can be met technologically. I suspect that African governments will begin paying attention to the end-results of technology policy research, if these offer tangible options to demands stimulated by needs. Studies could select topics on the basis of the following relationships:

Needs assessment → technological assessment → technology assessment

The ability to generate feasible, technology policy solutions may be the right way to proceed. We viewed technology policy research as the mechanism which employs scientific techniques of inquiry to generate reliable knowledge with broad application. However, what policy institutions of SSA have generally lacked, is *normative commitment.* Research bodies need to devise ways of engaging policy institutions to develop a culture of *technological responsiveness*, i.e. a capacity for translating relevant knowledge into public policy and implementable programmes. Therefore, while the major preoccupation of ATPS researchers has been the pursuit of research and scientific evaluation of the works of colleagues, a comparable level of emphasis need to be made to proactively influence policy institutions in embracing generated knowledge and using the research results in solving outstanding social and economic problems.

Disseminating the results of technology policy research is one way of pursuing that engagement. It is worth remembering that policy makers and the offices they run have been incapable of reading long treatises and technical reports. The imperative of producing, say, one-page executive summaries, would be a crucial ingredient of normative commitment. Indeed, African Technology Policy Studies Network (ATPS) researchers should be requested to submit short summaries for the exclusive attention of policymaking institutions.

Research institutions should capitalize on the disseminative power of the media in the diffusion of novel results. The links need to be formalized through regular contacts and invitations to participate in seminars and workshops. These acts of “reaching out” should also form an integral part of ATPS’ public relations.

In this regard, ATPS could sharpen its mandate by not only committing itself to scholarship (research and publications), but also in policymaking (e.g. offering professional advice and directly participating in policymaking decision) and public service training.

If some SSA policy institutions have shown interest in translating research results into viable solutions with welfare-enhancing potential, how can ATPS assist? Can ATPS devise follow-up arrangements to monitor progress? How can ATPS researchers operating outside official government circles be incorporated into policymaking bodies through a new kind of ATPS-driven partnership? ATPS could seek some “special status” in the echelons of policy influence or request representation similar in orientation to what NGOs now enjoy within the United Nations system. The results of ATPS research must be seen to be invaluable and helping to solve outstanding societal problems for these considerations to bear fruit.

Part of ATPS’ quest for relevance and its desire to win the hearts and minds of policy institutions is to organize capacity-building workshops in technology analysis (and related domains), for high-level policy-making officials. Such workshops should devote a large part of their time discussing policy material that made a real difference in the lives of people.

Moreover, institutions supporting technology policy research in SSA, would be doing interested parties a lot of good by organizing short training courses (2-3 weeks). The courses can be on theoretical foundations and background material on technical change, technological change, firm behaviour and innovation and technology transfer and diffusion. They can be mounted regularly as a matter of urgency. Capacity building in this area would not only enhance the quality of technology policy research in the region, but it would also promote a more meaningful contribution (by researchers) to policymaking processes. Just as important, it would strengthen the methodological abilities of investigators and, in consequence, improve their empirical powers and scientific objectivity.

If this option would represent one of the elements in the projected path of ATPS, then a candid evaluation of its past record would be essential. ATPS should seek to know how many of its funded research projects generated results that:

- captured the imagination of Africa’s policy institutions
- influenced such institutions in the direction of policy reforms and development
- stimulated policymakers to undertake technology-based projects.

Conclusions from such an evaluation would be invaluable in redesigning ATPS’ future research expectations.

Before discussing some of the potentially fruitful and priority areas for technology policy research, it would be instructive to mention a few common biases, errors and weaknesses afflicting some research efforts as follows:

- Lack of focus of research objectives
- Long and windy titles
- Too many objectives
- Poor conceptualization of the research effort
- Weak technology policy emphasis
- Inclusion of irrelevant material
- Mismatch between literature review and topic under investigation
- Lack of correspondence between objectives, conceptional framework and methodological framework
- Limited exposure to technology literature
- Deficient literature review in terms of currency
- Absence of simplicity in research analysis
- Misapplication of analytical toolsLimited correspondence between objectives and results
- Differentiating between researching and reporting formats

Priority Research Areas

- Recycling technologies and activities
- Renewable energy technologies and
- Cleaner production practices
- Environmentally-friendly technologies
- Food biotechnologies
- Health technology policy studies
- Information technology policy studies
- Water harvesting and conservation technology policy studies
- Transport technology policy studies

There is a widespread tendency among professionals and laymen alike to regard technology as an inherently positive force that promotes economic growth and accelerates progress. Until the 1950s and 1960s when seminal publications began to question this positive image of innovations, technology had been extolled in no uncertain terms.

However, despite the growing mass of evidence showing that technologies have generated harmful effects and continue to do so, they still remain fantasized. The reason for this fantasization, and indeed, the potential masking of the adverse consequences that this idolization has entailed, seems to stem from the various attributes associated with technology.

Little wonder, then, that most research endeavors have focussed mainly on technology matters that harp on this favourable image. As technology policy researchers, it behooves us to grapple with technology issues whose research results could assist policymakers reshape technology policies to achieve sustainable development. We need to recognize that technology can be a double-edged sword with consequences that undermine welfare. Clearly, appreciating this duality and taking it on board in our research endeavours, is both a responsibility and a challenge. In the main, technology policy research should succeed in producing knowledge that can be applied to promote welfare-enhancing, sustainable development.

Since the concept of sustainable development has, in policy terms, assumed worldwide currency only in the last decade and a half, it is not surprising that the research interests and foci of technology policy researchers have been very limited in this regard. As such, the few studies produced so far suggest that a huge research gap exists, which in a very important policy sense, provides us with an opportunity to pursue investigations.

In our methodological pursuits, *what* type of data would we need to gather, and *where* should we direct our research energies? To a large extent, this will depend on the objectives of the study and the nature of the topic.

From a cursory glance of these studies, it is apparent that the incorporation of the environmental dimension in our research efforts would yield information with technology policy relevance. Undoubtedly, a potentially promising and fruitful area of technology policy research would entail the integration of environmental policy concerns with technology policy. Research domains amenable to such integration include the food energy, health and housing sectors. Leather textile and recycling industries are also critical in this regard. Investigators would find a large body of inspiring research material by accessing literature on cleaner production technologies, and environmentally-friendly innovations.

Methodologically, the question that again arises is what data would be appropriate and where our kind of researcher would cast his or her eyes.

Conclusions

The evolution of technology policy research and the methodological devices that accompanied the investigative endevours, have been heavily conditioned by particular conceptual categories that informed the description, interpretation and prediction of technological phenomena. Apart from the studies of economic historians, most early investigations on technology policy were conceived within the neoclassical worldview. This conceptual orientation not only imposed severe methodological limitations on research efforts but also circumscribed the potential for appreciating the wider meaning and processes of technological change.

Some of the most illuminating studies on technology policy, emerged in the wake of significant strides made in the conceptual field. The leaps in conceptualization, posed fresh methodological challenges as demands for new sets of data grew in both scope and depth. At a broad level, technology policy research shifted emphasis from country, sectoral, industrial, and finally to firm level units of analysis. This evolutionary experience was marked by new methodological paths driven by new conceptual apparatus.

These cosmological shifts, while deeply enriching our understanding of technological change, precipitated new epistemological concerns, namely, the challenges of validating, in the scientific sense, the results of firm level research. The sampling designs that would conform to the rules of scientific methodology have since emerged as a critical concern in technology policy research.

The imperative of sustainable development has raised new policy and methodological challenges to technology policy research as a whole. Explorations that seek to fathom growth-promoting technical changes in the context of sustainable principles may offer policy insights on the instrumentality of institutional and organizational innovations. The area of cleaner production technologies is particularly relevant in this regard. Tackling such fields, including the search for technological solutions in the food, energy, health and recycling domains, would go a long way towards making SSA technology policy research relevant to concerned parties. The generation of reliable and credible knowledge, invariably results from designing and using robust methodological procedures, rooted in sound epistemological foundations.

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Table of Contents

Acronyms and Abbreviations

ATPS	African Technology Policy Studies Network
K – L	Capital – Labour
MNCs	Multinational Corporations
R&D	Research and Development
SSA	Sub-Saharan Africa
S – T	Science – Technology
S&T	Science and Technology
TNCs	Transnational Corporations
UNCTAD	United Nations Conference on Trade and Development

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