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**Innovation in Small and Medium-Sized Enterprises:
A Study of Businesses in New South Wales, Australia**

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1 INTRODUCTION

This paper examines the process of innovation within SMEs, focusing, in particular, on a sample of firms in New South Wales, Australia. The trend of the last several decades towards increased integration of global markets, or globalization, has meant that many firms are experiencing continuously increasing pressure to remain viable as their markets expand, and they begin competing with a larger number of firms. SMEs, in particular, are vulnerable to this pressure, since they tend to be disadvantaged relative to larger firms that generally have better access to funding and other resources. The ways in which SMEs operate to remain economically viable, and contribute to economic performance, is of especial interest to governments given the prominent roles that they play in most economies. One way of doing so is through innovation.

In this paper, we present a more complex model of the innovation process than the traditional linear model involving R&D investment, building upon recent developments in the literature. The empirical section involves a survey of NSW firms. The state of NSW is well suited for a study of firm innovation as the NSW government arguably places the highest priority on innovation as a driver of economic growth compared with any other state in Australia. This recognition of the importance of innovation makes the state of NSW an ideal region for empirical study.

The paper is structured as follows. Section 2 provides an overview of concepts of innovation, including Schumpeter's (1934) five categories and definitions used in the current literature, as well as the core measures of innovation inputs, outputs and firm performance. Section 3 then provides a review of the place of innovation in economic theory and, more specifically, the theory of the firm. We also review research on the relationship between innovation and firm size, and more recent work on the link between innovation and a firm's external linkages or networks. This sets the stage for our model of firm innovation in Section 4, where hypotheses suggested by the model are also presented and discussed. Section 5 outlines the methodology for the study and the results. Finally, in section 6, we summarize and discuss the policy implications of our findings.

2 INNOVATION

Innovation Concepts

The current understanding of innovation in the literature is that it embodies "a process that begins with an invention, proceeds with the development of the invention, and results in the introduction of a new product, process or service to the marketplace" (Acs and Audretsch, 1990). The Australian Bureau of Statistics (ABS) also uses a definition for its surveys that involves the commercialization of new or improved products and processes (Rogers, 1998). This is consistent also with the Oslo Manual (OECD, 1997), which is an attempt by the OECD to provide a generally agreed standard for innovation data collection and interpretation.

There remains, however, a degree of subjectivity in the definition of innovation, arising from the usage of such words as "new", "significant" and "improved." First, what is new to one firm is not necessarily new to another. Considering this, it is possible that the exact same behaviour in two separate firms may be labelled "innovative behaviour" in one firm but not in the other.¹ Second, the degree of improvement necessary to qualify as an innovation is discussed in the *Oslo Manual*, where changes that are minor and insignificant are not included as part of innovation. This distinction is largely subjective, as acknowledged by the *Manual*, which again introduces the problem of subjectivity; what constitutes an innovation heavily depends on the opinion of survey respondents and database creators. The exclusion of minor improvements also denies the possibility of economic growth due to gradual, incremental improvements (Rogers, 1998).

In addition, there have been attempts to categorize innovation into various types, dating back to the first recognition of innovation as an important

concept in economic systems. Joseph Schumpeter is often referred to as the first economist to assign significance to the concept of innovation in economics (see, for example, Rogers, 1998). Sundbo (1998), Rogers (1998) and Pol and Carroll (2004) outline the five categories of innovations, as defined by Schumpeter (1934):

- The introduction of a new/improved product, generally referred to as *product innovation*.
- A new/improved process to a particular industry, commonly referred to as *process innovation*.
- Changes in industrial organization, both inter-organizational and intra-organizational, such as the creation of a monopoly firm or a change in management structure. This is commonly termed *organizational innovation*.
- Opening of a new market: this includes targeting a niche market for the first time, and is very likely to involve product innovation for obvious reasons. This gives rise to the notion that these various types of innovation are often interconnected.
- New sources of supply of inputs into production: this strategic type of innovation includes inputs that may be raw materials and/or supplier products.

More commonly a two-fold distinction is made, between product innovation and process innovation, with most studies going no further than recognizing these two categories.² Table 1 presents an attempt to differentiate between them.

Rosegger (1980) clarifies process innovation further by defining two sub-categories. *Labour-saving* process innovations cause a reduction in the level of labour required for production. For example, the introduction of improved machinery on an assembly line may replace functions previously conducted by people. The use of capital may increase, decrease or remain the same as a result of labour-saving innovations. *Capital-saving* innovations, on the other hand, cause a reduction in the amount of capital used. For example, the use of mobile phones that fulfil several functions of other machinery, such as cameras, computers (for internet access and emailing). Such process innovations may result in an increase, decrease or no effect on the level of labour used.

Measuring Innovation

There are three general methods of collecting innovation data: by using existing databases and statistics (for example, intellectual property statistics), by administering surveys or questionnaires, and by using case studies. Often,

if there is insufficient data available, the survey method and/or case studies may be used in conjunction with the first method. The limitation of utilizing surveys is that a short, concise innovation definition needs to be used, and that inevitably the respondents will interpret the questions differently (Rogers, 1998). For example, questions involving ranked answers (which are popular as they lend themselves very well to data analysis) are easily distorted by the varying perceptions between respondents. The limitation of using case studies is the narrow scope of analysis they provide which raises questions regarding the accuracy and generalizability of any conclusions reached (Hoffman et al., 1998). Acs and Audretsch (1990) argue that the inherent problems in measuring innovation have been perhaps the biggest obstacle in understanding innovation's role in economic processes. If the very definition of innovation is so riddled with subjectivity, it is hardly any surprise that its measurement is also fraught with difficulty. In addition, a number of other factors also hinder the various methods and techniques of collecting and interpreting innovation data. The principal core measures of innovation are discussed in this section. Research and Development (R&D), marketing and technology are generally considered as innovation inputs, whereas new or improved products and processes are considered as outputs.

Table 1 Product v Process Innovation: impacts on economic variables

Product Innovations	Process Innovations
Most probably result in an <i>increase</i> in employment	Most likely result in a <i>decline</i> in employment within the innovating firm
Have no effect on productivity	Increased productivity growth
Involve uncertainty in technical and engineering aspects, as well as acceptability in the marketplace	Involve uncertainty in technical and engineering aspects only
Are relatively easy to imitate	Are relatively difficult to imitate due to protection by trade secrets
Are generally protected by patents and property rights	Are protected by trade secrets

Source: Hodgkinson (1998)

Research and Development

R&D expenditure has been the most commonly utilized proxy for innovation effort within firms. It is easily measurable, as it is recorded in monetary terms and is widely available, although a precise definition is yet to be agreed upon

(Rogers, 1998; Pol and Carroll, 2004). The OECD defines R&D as:

compris[ing] creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications (Hodkinson, 1998; Pol and Carroll, 2004).

The Australian Bureau of Statistics defines it as follows:

Systematic investigation or experimentation involving innovation or technical risk, the outcome of which is new knowledge, with or without a specific practical application of new or improved products, processes, materials, devices or services (ABS, 1996, cat. 8104.0).

However, R&D expenditure will not exactly track innovation activity, as it does not require any “practical application” (Rogers, 1998). In addition, several common methods of measuring R&D are used: the *absolute level of R&D investment*; the ratio of R&D expenditure to sales volume, or *R&D intensity*; and the ratio of research personnel to total employees, or *R&D effort* (Acs and Audretsch, 1990). The limitation of using any of these as a measure of innovative activity is the fact that R&D is an input and not an output in the innovation process (Acs and Audretsch, 1990). In other words, it is a representation of the resources, or inputs, used in generating some innovative output. However, there may not be a direct correlation between the level of inputs and outputs.

Another limitation of this measurement focus is spillover effects. Spillover effects, or externalities, of innovation refer to the costs and/or benefits received by firms other than the innovating firms, which are sometimes not paid for. For example, the knowledge generated by one firm’s investments in R&D activity may be learnt by other firms at a fraction of the expense and input this new knowledge into their own products, processes and organization. Therefore, measuring by R&D may distort the accuracy of innovation levels by understating the actual innovative output of a firm.

Marketing Intensity

The marketing of new products is often considered an innovative activity, especially in more recent literature. Expenditure on marketing is often used in innovation surveys as another input measure, besides R&D (OECD, 1997; Rogers, 1998; University of Aberdeen, 2001). Marketing, involving any promotional activity, is generally measured as the proportion of annual sales allocated towards marketing new or improved products, or *marketing intensity*. This input measure is often included in innovation surveys, which

follows the idea that innovation does not only involve R&D.

Technology

Data relating to the purchases and sources of outsourced technology is considered a measure of innovative input *and* outputs, as firms may purchase technology as part of their innovation strategy (Hodgkinson et al., 2003). As technology is often tied up in capital equipment, this measure also includes the costs associated with tooling up, industrial engineering and manufacturing start up. That is, in improving products and processes. However, replacement purchases are not considered as innovative behaviour, which presents slight difficulty when relying on the opinions of survey respondents as to whether investment is for the purposes of adding, improving or replacing a product or process (Rogers, 1998).

Managerial and Organizational Change

Any changes in managerial methods or organizational structure are considered as innovation. However, most survey questions regarding this topic are yes/no questions, supposedly because firms either traditionally do not record such expenditures, or do not like to disclose such information (Rogers, 1998). We omit this input measure from our empirical analysis, due to the associated difficulty in measuring and obtaining the required information.

Number of New and Improved Products and Processes

A measure of innovation output is the number of new or improved products and the number of new or improved processes introduced, which may be referred to as *innovation counts*. However, owing to commercial sensitivities, the existence of new or improved products and processes is often measured in surveys by yes/no questions, which does not tend to accurately capture the quantity of innovations (Rogers, 1998).

Total Innovation Rate

An improvement on innovation counts is the total innovation rate, which accounts for the number of new or improved products and processes weighted for the number of people involved. For example, when calculating the total innovation rate of a firm its size is taken into account. Thus, small and large firms can be compared with regard to innovation activity. Acs and Audretsch (1990) advocate this measure as the best possible one available and define it as the “total number of innovations per 1,000 employees” over a given set of industries. It offers a more reliable measure, as it is weighted

according to the relative presence of large and small firms in the industry (Acs and Audretsch, 1990). However, as Tether (1998) pointed out, while it adjusts for the size of the firms, this method would still be biased toward product innovations. Also, both the total innovation rate and the innovation count measures do not give any indication of the value of the innovations.

Innovation Intensity

A related output measure is the proportion of sales accounted for by new and improved products, where high percentages indicate innovative firms. This measure is also known as *innovation intensity* (Evangelista et al., 1998). Innovation intensity is used frequently in empirical analysis, normally measured in a survey format and is highly subjective since it depends on the respondent's estimations (Evangelista et al., 1998; Rogers, 1998; University of Aberdeen's (UOA) Survey of Enterprise in Scotland 2001; Hodgkinson et al., 2003). As Padmore and Gibson (1998) note, there is a problem with reliably associating the value of an innovation with sales. Sales include wages and salaries, cost of material inputs, interest costs, taxes and profits and the question of reliability occurs when survey respondents are required to attribute an innovation's value from total sales.

Intellectual Property Statistics

The use of intellectual property (and specifically patent) statistics as a measure of innovation stems from the rationales commonly put forward for patent protection. First, patent protection is urged on the grounds that patents create a temporary monopoly, which encourages firms to innovate as they capture more of the benefits of their labour than if they had no market power. Second is the argument that patents may encourage innovation dissemination since, without patent protection, innovators rely on secrecy to capture the benefits of innovation. A third rationale is that patents may induce development or commercialization of initial inventions that have little commercial value in their raw form, but require further development and investment to become commercially viable. Patent protection can encourage firms to further develop these initial ideas. A fourth rationale emphasizes the idea that patents can encourage an orderly approach to developing cumulative innovations from initial ones, rather than following a haphazard approach (American Bar Association, 2002).

While the fact that a firm has taken out one or more patents implies the generation of new and potentially commercially valuable knowledge and innovative behaviour within the firm, using patent statistics as a measure of innovation is problematic for several reasons (Rogers, 1998). First, patents are an intermediate innovation output, that is not all lead to innovations;

second, not all innovations are patented (for example, they may be protected as trade secrets, as is the case with Coca Cola's recipe for Coke); and third, the system of applying for, and being granted, patents may vary between industries (Acs and Audretsch, 1990; Rogers, 1998; Acs et al., 2002). Besides patents, other intellectual property measures are trademarks, designs data and copyrights. The general ambiguity surrounding this output measure generally means that it is not as commonly used as some other output measures. It is not used in the empirical analysis of this chapter.

Outcomes of Innovation: Measuring Firm Performance

The main outcome of innovative activity is the firm's success, which may be proxied by such indicators as sales growth, export intensity (the proportion of annual sales accounted for by export sales), market share, market capitalization, productivity or profits. One drawback of these measures is determining the degree of impact that innovative activity actually has on these variables, as they will be influenced by other factors (Rogers, 1998).

3 ECONOMIC THEORIES OF INNOVATION³

Innovation in Economic Theory

Innovation theory is generally regarded as consisting of two main strands: the traditional Neoclassical approach and the institutionalist, or Schumpeterian, approach. The latter is named after its instigator, Joseph Schumpeter, who provided many of the insights that are foundational in this school of thought (Hodgkinson, 1998).

The Standard Neoclassical Model

A key focus of the standard Neoclassical model has been on specifying the conditions under which equilibrium will be attained. One implication of this focus, however, is the elimination of change once equilibrium has been achieved. Knowledge and information are assumed to be readily available and absorbed instantly (Legge, 1993). The model considers innovation and R&D as instances of market failure, for as an innovating firm falls short of attaining all the benefits attached to its expenditure on innovating it will rationally under-invest in R&D activities. This results in a lower level of R&D than is optimal for society as a whole (Hodgkinson, 1998). The firm is treated as a "black box", and there is no scope for the process of innovation to have any affect on production or firm performance. The assumption of diminishing returns, which is required to establish the law of supply and demand, actually ensures that growth will eventually disappear (Legge, 1993).

The result of long run zero growth has been a source of much dissatisfaction since it obviously contradicts the actual experience of most economies over time. Solow (1956) is generally credited with the initial development of the New Growth Theory, which allows for continuous growth. Solow's main concept was that the increased use of capital caused higher labour productivity as a result of "a dynamic process of investment and growth" (Grossman and Helpman, 1992). The concept of capital is treated rather narrowly so that while it applies well to tangible capital, intangible capital, such as knowledge, is not well represented. Solow's own criticism of this model was that it did not explain historic growth very well either. In the first formulation of new growth theory, growth increases but at a decreasing rate.

Arrow (1962) introduced the concept of "learning by doing" in his growth model. He proposed that as firms undertake new activities during production processes, they add to their knowledge base. Grossman and Helpman (1992) show that Arrow's model, under a conservative interpretation, also results in the cessation of growth. However, in a more recent variation of Arrow's (1962) growth theory, Romer (1986) eschewed the "black box" treatment of the firm and proposed that knowledge needs to be considered as a third factor of production. This allows growth to increase in a decelerating manner, eventually approaching some constant long-term rate (Legge, 1993). Moreover, once it is established that knowledge, unlike capital and labour, is not subject to the constant or diminishing returns rule, it is possible to see acceleration in the rate of growth over time using increasing returns to knowledge as the basis.

Schumpeterian economics signified a shift in the literature from *formal* to *appreciative* economics. While the Neoclassical approach favours the rigidity of mathematical descriptions and models attributed to the inner workings of the economy the Schumpeterian approach tends to be philosophical and descriptive, incorporating empirical evidence with the purpose of making prescriptions and providing guidance (Fagerberg and Verspagen, 2002). While Schumpeter (1934) accepted the "circular flow" concept of the standard Neoclassical model, he rejected the growth-constricting assumptions of rational expectations and perfect foresight. Rather, he proposed a circular flow with innovation, or improvement, as central to this flow (Legge, 1993). This approach considers innovation and R&D to be the result of the particular institutional structure of the knowledge base of each society (Hodgkinson, 1998). As such, the entrepreneur assumed a major role in Schumpeter's theory, as the main driver of innovation and, hence, growth in the economy. Schumpeter (1934) assumed that entrepreneurial ability is distributed randomly among the population, an assumption that was incorporated by Lucas (1978) and Oi (1983) into their models which are able to explain the existence of small firms in the economy. However, while the stochastic

distribution of entrepreneurial talent explains the distribution of intra-industry firm sizes, it also produces the result that the proportion of large firms to small firms is equal in every industry (Acs and Audretsch, 1990). This has been contradicted by empirical evidence (Acs and Audretsch, 1990).

Whilst Schumpeter (1934) saw a role for small firms, his 1942 work favoured the existence of large firms in the long run. The reason for this was that, theoretically, those firms that failed to maintain a sufficient rate of innovation would get trapped between falling market prices and fixed costs, eventually exiting the market (Legge, 1993). As a result, the remaining firms become fewer, larger and more profitable, resulting in monopolistic traits in the long run. Consequently, older markets tend to possess larger firms and younger markets consist of mainly small firms. However, progressive monopolization could be counteracted with what Schumpeter called “creative destruction”, whereby an innovative entrepreneur within a small firm could introduce a superior product (in terms of quality and price) such that it replaces the current, inferior version. Creative destruction thus provides a mechanism for overcoming the barriers to entry that arise as markets mature.

Many of Schumpeter’s (1942) ideas have been adapted into recent schools of thought, even into more recent Neoclassical models (Grossman and Helpman, 1992). One prominent approach is evolutionary theory, which has been brought to bear on aspects of innovation. Nelson and Winter (1982) is commonly referred to as the starting point of evolutionary economics. Despite the fact that the two authors had published earlier explications of their ideas⁴ the (1982) work includes the refined, collective theory, which has been integral in examining the economics of innovation. There are strong parallels between Nelson and Winter’s (1982) evolutionary theory and Darwin’s Theory of Evolution, which gives Evolutionary economics its name. The marketplace is the “environment”; a business practice or procedure (referred to in the theory as a *routine*) is a “cell”; and a firm is a “gene”. In relation to the innovation process, innovative activity implies “mutation” (changed business routines). If successful, these mutations are observed and mirrored in the routines of other firms (adaptation). In a competitive environment successful innovations must be copied or bettered by other firms through adaptation and further mutation of routines, else the firm will exit the market or go bankrupt. That is, the idea of “survival of the fittest” applies here. This theory follows Schumpeter’s “creative destruction” concept closely.

In sum, the two main economic approaches to innovation are the Neoclassical and the Schumpeterian approaches. The former either fails to incorporate innovation, or does so with difficulty, although recent versions of Neoclassical theory have attempted to make innovation more integral. Schumpeterian economics places innovation and the entrepreneur as its core

focus, an approach that has been incorporated into many modern schools of thought such as Evolutionary economics.

The Relationship Between Innovation and Firm Size

Research on the relationship between innovation and firm size has been described as “the second largest body of empirical literature in the field of industrial organization” (Cohen, 1995). The earlier research tended towards the view that large firms are more innovative, a view which seemed to find empirical support through the use of R&D investment as a proxy for innovation. However, later studies, utilizing additional measures of innovation, have produced somewhat more ambiguous results.

While the nature of the firm size-innovation relationship remains a mystery, much of the literature provides general consensus on the characteristics of small and large firms (Rogers, 2002; Hoffman et al., 1998; Morck and Yeung, 2001). These characteristics are quite different. It is now generally recognized that small and large firms innovate in different ways. The fact that technological innovations tend to be generated by large firms, and that smaller firms tend to innovate in informal ways that are not readily recognized in the literature (such as external linkages), has significant implications (Hoffman et al., 1998). Consequently, recent research has begun to study the impact of other firm characteristics on innovation. One that has not received much attention, however, is the age of the firm. As larger firms tend to be older firms (according to Schumpeter, 1942), it has been suggested that the real relationship underlying firm size and innovation may actually be between firm age and innovation (Brown and Medoff, 1989).

Another firm characteristic that has received recent attention is the particular industry in which a firm operates. We refer to this as the “industry-specific argument”, by which the optimal firm size for innovation varies according to the industry. The argument is that there is *no overall* optimal firm size pertaining to innovation. Rather, there is an optimum prescription for each industry, in terms of not only firm size, but also character, age, etc., that yields the maximum facilitation of novel ideas⁵.

Hallberg (2000) examined three factors in a review of industrial organization, economies of scale, transaction costs and market structure. As she argued:

There is no “ideal” distribution of firms, but rather an “equilibrium” size distribution determined by resource endowments, technology, markets, laws and institutions.

Therefore, according to the firm’s environment, of which industry type is a

part, there is a specific distribution profile that best facilitates innovation. Dosi (1988a) argued that studies in the area of innovation and firm size must be accompanied by “an analysis of the learning and competitive process through which an industry changes”, which emphasizes the importance of the given industry for the innovation and firm size relationship and the dynamic nature of the relationship (Rogers, 2002). However, a dynamic analysis adds extreme complexity to an already complicated analysis. Hence, most literature does not incorporate the effects of time. Acs and Audretsch (1987, 1990) also found in their empirical study of US manufacturing firms that the industry conditions conducive to innovation are widely different between large and small firms, with small firms able to produce more innovations under the following conditions:

- Lower capital intensity, as they do not tend to own the resources to innovate in highly capital-intensive industries.
- Lower market concentration.
- Low levels of unionization.
- A high total innovation rate within the *entire* industry.
- A high component of skilled labour within the industry.
- Low levels of advertising across the industry.

Much of the existing empirical literature on the industry-specific argument focuses on innovation within the manufacturing industry (Acs and Audretsch, 1990; Mansfield, 1963). As a result the literature on the topic of innovation in service industries is very sparse. However, as markets are becoming increasingly global, the service industry is becoming more prominent and manufacturing industry is declining in developed countries, according to their competitive advantage⁶. There is divergence, in what literature there is, regarding the question of whether specific innovation theory needs to be developed for service firms, or whether the manufacturing-industry based theory can be applied to these firms (Channon, 1978; Gershuny, 1978; Sundbo, 1997; Gadrey and Gallouj, 2002).

In sum, the relationship between innovation and firm size is now understood to be more complex than previously believed. The industry-specific argument represents one direction of new research. Another recent direction is the examination of external assistance of innovation through networking, particularly for smaller firms. This is examined in more detail in the following sub-section.

Innovation and External Linkages

The study of innovation and external linkages is a more recent approach, reflecting the view that small firms utilizing external linkages, or networks, can access resources not otherwise available to them. The existence and

impact of ties between SMEs and external (or inter-firm) linkages is a topic that has received recent attention in the literature (Berry, 1997; Deroian, 2002; Rogers, 2002). However, some empirical work suggests that the impact of external linkages on innovation may be overstated (Hoffman et al., 1998).

It is generally recognized that small firms are frequently at a disadvantage relative to large firms due to their lack of access to various resources, including information, knowledge and expertise. One solution to these significant problems is networks, which are created through both formal and informal relationships. Like the concept of innovation, that of networks is vague and therefore used according to various definitions throughout the literature. An attempt to standardize the concept and formulate a relatively precise definition is OECD (2000b) which refers to networks as occurring when firms agree to work together on projects as a group, temporarily combining their resources into a larger and more effective tool for project success. DeBresson and Amesse (1991) loosely define a network as “an inorganic and decomposable system ... [which exhibits] synergy” (DeBresson and Amesse, 1991). The latter definition shows that the concept of networks is not merely an economic concept, and it is used in a wide variety of broad social science and information technology literature (Fritsch, 2001).

Rogers (2002) found in his Australian study that in manufacturing industry networks tended to lower innovation levels except for the smallest firm size (1-4 employees), whereas in non-manufacturing industries networks assisted innovation in the 5-19 employees group and for large firms. Rogers concluded that these findings support the idea that the process and nature of innovation varies greatly across firm size and industry (Rogers, 2002). DeBresson and Amesse (1991), however, argued that networks are necessary for innovation, particularly in high technology industries such as biotechnology. Their reasoning for this is that innovative firms in these industries require strong connections on both the demand and supply sides. Using the biotechnology example, links are necessary with research centres, hospitals and government agencies. DeBresson and Amesse (1991) thus concluded that as the rate of technological innovation increases, so too does the importance of networking. The theoretical advantages and disadvantages of networking are discussed below.

Networks in general are seen to be valuable because they provide a solution to the accepted disadvantages of small firms while, at the same time, they preserve the flexibility of production advantage inherent in smaller firms (Acs and Audretsch, 1990; Dodgson, 1990; DeBresson and Amesse, 1991). In other words it is argued that networks overcome some of the hindrances to innovation within SMEs in competing with large firms, without destroying

their key advantage. Some authors argue that networks are formed when uncertainties exist in the market and in technology. That is, when technology requires a complex system of multiple developments far beyond the scope of any one firm and when networks exhibit successful technical cooperation, the result will be greater gains than the sum of the possible individual gains (DeBresson and Amesse, 1991; Dodgson, 1990).

The advantages of small firm networking include⁷:

- *Innovation opportunities*: Improved search and evaluation mediums for different possible innovations.
- *Lower transaction costs*: The development of trust within network relationships, which requires less effort in detailing complicated legal agreements and results in compatible business goals.
- *Cost sharing*: Networks allow for spreading of the risks, learning and other costs, which aids technological convergence between firms, resulting in enhanced efficiency of production and innovation processes and communication.
- *Greater production efficiency*: Production is coordinated more effectively and efficiently, which generates increased production flexibility, as firms increasingly respond quickly and correctly to changes in the markets. They may also experience quality improvement and lower production costs and failures.
- *Economies of scale*: Small firms within networks have a greater ability to utilize economies of scale. Given their integrated production processes each firm can concentrate on a separate component of their combined final product, rather than each firm producing small quantities of every part.
- *Information access*: Networks may give rise to increased and less costly access to more reliable global information and information regarding available technology, which may enhance the generation of new ideas in addition to the early adoption of innovation and current ideas.

However, while networking has theoretical advantages, there are also costs which have been identified in the literature:

- *Sunk set-up costs*: These involve the time taken in the initial stages of forming networks, costs of coordinating production processes, making assets compatible and consequential failed attempts. Networks also experience unique, continuous costs of coordination that are not present in market transactions.
- *Rigid production processes*: The presence of rigidities within the production processes (due to the unique sunk costs) implies that networked firms may be stuck in inefficient processes or

relationships that can be a hindrance to innovative activity.

- *Risk of dissolution:* Network-specific risk exists in the sense that if the relationships are dissolved, investments between the previously networked firms may be nullified or experience lower returns to the amount invested.
- *Opposing goals:* There may exist divergent goals, strategies and influence, opportunistic behaviour and risk of exploitation by other members. The level of these costs depends on the degree of trust within the networked firms.
- *Free riders:* Some network participants may not contribute to information sharing, perhaps for fear of not realizing expected returns. This leads to inefficiency of the information network.
- *Anti-competitive behaviour:* The afore-mentioned costs of networking are experienced by the firm. However, a cost to society may exist in the form of anti-competitive behaviour, whereby strategic alliances create barriers to entry. As this particular disadvantage extends beyond the networked firms it poses a policy dilemma in terms of whether the government should facilitate the formation of networks to encourage innovative behaviour and eventually benefit society through economic growth, or to restrict collaboration due to the risk of monopolistic behaviour that imposes a cost on society.

The notion of networks supporting smaller firms in innovation is broadly supported in theory. The OECD (2000a) *Workshop 1: Enhancing the Competitiveness of SMEs Through Innovation* report asserts in its “network strategy” that smaller firms can utilize networks to assist them in enhancing firm performance. However, not much empirical attention has been devoted to the issue, while the studies to date have tended to produce inconclusive results (Hoffman et al., 1998; Rogers, 2002; Hodgkinson et al., 2003). There remains a need for the development of better measures and some standardization of the existing ones.

4 THE MODEL⁸

The model constructed for our study, which we denote the “Ripple-Effect Model”, incorporates aspects from Nonaka and Takeuchi’s (1995) ideas on knowledge, Schmookler’s (1966) schema, Kline and Rosenberg’s (1986) chain link model and Kemp et al.’s (2003) relationships between innovation inputs, outputs and firm performance. A diagram of the model follows, Figure 1, with a description of each component and its theoretical relationships. The 14 hypotheses generated were developed from various strands of theory on the innovation process and are represented by the ripple-effect model of

innovation. They are presented in Table 2.

Firm Profile

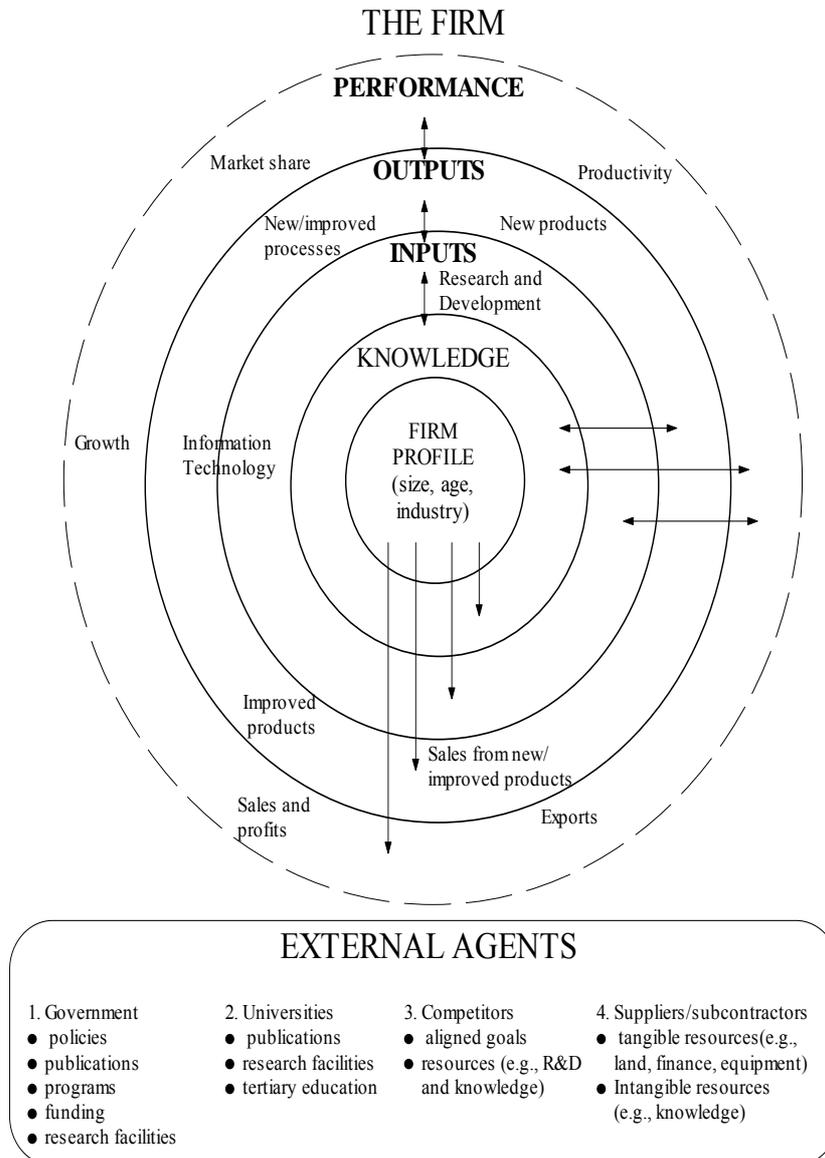
This includes the basic characteristics of the agent of the innovation process (i.e., the firm). These are the firm's size, age, and industry.

The relationship between innovation and firm size has been studied extensively. However, due to generally inconclusive results from these studies, it appears that other firm characteristics need to be considered in the innovation process. This represents the first primary objective of our study. As larger firms are generally older firms, studies that conclude any relationship between innovation and firm size should consider whether the true relationship is between innovation and firm age. The industry component reflects the industry-specific argument outlined above, whereby it is postulated that innovation levels depend on the industry in which a firm operates.

Hypothesis 1

Due to the influence of the linear model of innovation, R&D was thought to be the best indicator of innovative activity throughout much of the earlier literature (Schuetze, 1998). As a result the earlier empirical research on innovation tended to use R&D investment as a measure of innovation. Firms investing more in R&D were deemed "more innovative", and as such performed better (Mansfield, 1963; Cohen and Klepper, 1996; Evangelista et al., 1998). However, more recently (about the time that the firm was beginning to be considered as more than a "black box") the inputs to innovation were generally given larger scope than simply R&D, such as technology use and marketing activities (Padmore and Gibson, 1998). Cohen and Levin (1989), Acs and Audretsch (1990) and Evangelista et al. (1998) did not find any significant correlations between firm size and innovation outputs or firm performance in their respective empirical studies. Our model does not

Figure 1 The Ripple-Effect Model of Innovation



Source: Derived by the authors

Table 2 Hypotheses to be Tested

H1	R&D investment increases as the size of the firm increases
H2	Innovation activity and firm performance increase as the firm's age increases
H3	The level of innovation activity depends on the industry in which the firm operates
H4	Firms with greater R&D, marketing and information technology involvement are more innovative
H5	Firms with greater R&D, marketing and technology involvement perform better
H6	More innovative firms perform better
H7	Firms with a greater emphasis on networking are more involved in R&D, marketing and the use of technology
H8	Firms with a greater emphasis on networking are more innovative
H9	Firms with a greater emphasis on networking perform better
H10	A firm's education level is dependent on its size
H11	Firms with a greater emphasis on inputs to innovation have a bigger knowledge base
H12	More innovative firms have a greater knowledge base
H13	Firms with a greater firm performance have a larger knowledge base
H14	Firms with a greater emphasis on networking have a greater knowledge base

postulate any particular relationship between firm size and innovation, except that it would be expected that larger firms be able to invest more in R&D, which is to be expected from the indications of many studies on this topic.

Hypothesis 2

It is well known that larger firms are generally older firms (Brown and Medoff, 1989). As a firm ages it may be expected to become more innovative, especially in its production processes, as it becomes more efficient over time. The relationship between the age of a firm and innovation is not a popular empirical topic. However, similar to the industry-specific argument, it is an important area of analysing the true nature of the innovation process. The level of innovation output may in truth depend on the age of a firm, rather than its size.

Hypothesis 3

The industry-specific argument, as outlined earlier, is an alternative to the traditional firm size-innovation relationship expressed in Hypothesis 1. The

theory is that innovation levels vary according to the given industry in which a firm operates (Jewkes, Sawers and Stillerman, 1958; Nelson, Peck and Kalachek, 1967; Scherer, 1980; Dorfman, 1987; Acs and Audretsch, 1990; Cohen and Klepper, 1996; and Rogers, 2002). Evangelista et al. (1998) found that innovation outputs varied according to industry classification. As such, in some industries, larger firms may be more innovative, whereas in other industries small firms may have higher levels of innovation. In adopting the industry-specific argument we propose that there is no simple dependency between firm size and innovation *outputs* (and, as a result, firm performance), as smaller firms can make up for lower R&D investment in other areas and methods (e.g., through networking). Instead, the other profile characteristics, age and industry classification, determine the innovativeness (and, as a result, performance) of a firm.

Innovation Inputs

The inputs to innovation included in this model are R&D activities, marketing activities and information technology use. All inputs to innovation are assumed to generate feedback into the firm's knowledge base⁹, as well as positively affecting the innovation outputs and firm performance. The effect of R&D and technology on innovation outputs is in line with Schmookler's (1966) "science-push" hypothesis. These effects are denoted in Figure 1 by arrows. The three components are now discussed.

Research and Development

In keeping with the tradition of other innovation process models, R&D investment is considered as one of the important inputs into innovation. However, like the later models, it is not seen as the only crucial element. The knowledge base influences the process of R&D indicating what direction the research should initially take, as does the finance component, which enables the necessary goods and services, human capital and intellectual property to be acquired. As R&D takes place the knowledge base is developed resulting in a cyclical effect, given by the double-ended arrow between the knowledge stock and the R&D component. R&D investment is also theorised to have a positive effect on the outputs of innovation and firm performance, which are discussed later.

Marketing

The marketing component in our model refers to the innovative marketing activities invested in by a firm. This may include preliminary market research, launch advertising, web pages, or any promotional activity (OECD, 1997). The idea is that investment in marketing new and improved products, like

R&D, would lead to innovation outputs and greater firm performance. As a firm invests in marketing activities, it experiences feedback into its knowledge base. This occurs as a result of experiential knowledge.

Information Technology

This component basically refers to a firm's use of information technology in the innovation process. This may include using the Internet, computers, email, a website or an online purchasing and procurement system. The use of technology is usually considered a measure of innovative input *and* output, as firms may purchase technology as part of their innovation strategy (Hodgkinson et al., 2003). Quite obviously, the use of information technology will feed back into a firm's knowledge base, particularly in enhancing the efficiency processes within a firm. It assists in the production of new products and can directly affect firm performance.

Hypothesis 4

As the linear model of innovation was replaced over time by a more complex, non-linear process with constant feedback, R&D ceased to be the only recognized factor of innovative behaviour.¹⁰ Small firms were identified as using other inputs for innovation, such as attaining external knowledge from various sources and converting it into new knowledge and applications, marketing of new or improved products and process and managerial change (Rogers, 1998; Schuetze, 1998). The conversion of innovation inputs to outputs is a crucial stage in the innovation process. If a firm is unable to convert inputs to outputs, then a large investment in inputs is meaningless. The reason for this is that the firm will not be able to generate the new and improved products and processes that are then potentially turned into profits, and other positive firm performance measures. An outcome like this indicates that the firm is wasting its resources, rather than being innovative. Hence, according to this theory it is not enough to conclude that larger firms are more innovative simply because they invest in more R&D than smaller firms. This relates back to Hypothesis 1. For example, Mansfield (1963) found insufficient evidence to correlate R&D intensity with both new and improved products.

Hypothesis 5

This relationship is theoretically thought to be one way, a spillover effect from firm performance back into innovation inputs. The performance of a firm as a result of previous innovations dictates how much, and in what direction, that firm will invest into innovation inputs (Kemp et al., 2003). For example, if a firm invests a large amount into marketing research, develops a

new product from their findings, but their profits are negligible, they would most likely reconsider the direction of their market research for future innovations or even lower their expenditure. Contrary to the theory, Hoffman et al. (1998) reported recurring evidence in their review of UK studies on SMEs that firm performance is affected by marketing effort. As this causality is supported empirically, it is incorporated into the model as a two-way relationship. However, with regard to R&D and firm performance, Mansfield (1983) found no significant evidence to support the relationship between R&D intensity and sales in his empirical study of US firms. Likewise, Hoffman et al. (1998) reported no significant evidence from the UK studies to suggest any R&D and firm performance relationship.

Innovation Outputs

New or improved products and processes are the actual tangible innovation outputs resulting from the inputs. Sales from new or improved products simply give an indication of how much focus a firm places on innovations. A high proportion of sales accounted for by innovations labels such a firm as “innovative.”

Hypothesis 6

Schumpeter (1934) introduced into economic theory the concept that innovative behaviour contributes to economic development. This belief has been incorporated by theorists and policy-makers alike. Hypothesis 6 tests the final link put forward by Kemp et al. (2003). Basically, new and improved products and processes generate greater firm performance, e.g., higher profits, market share, productivity, overall sales and export sales. In addition, the outcome of the firm’s performance can cause a firm to analyse their products and processes and make further adjustments. In one sense the firm’s performance becomes something like a “first-hand” research experience, almost like an innovation input would. This updated market knowledge then feeds back into the innovation outputs. An example of this is seen in the Microsoft Corporation which experienced rapidly increasing market share as a result of the development of an improved visual operating system, as opposed to the text-based versions. Continuous improvements to this product have been established through the release of more recent versions.

This association between outputs and firm performance is shown in Figure 1. Outputs also feed back into the firm’s knowledge base¹¹ and input investments¹², as a result of the experience of producing different products and using different processes. However, Nelson and Winter (1978) and Mansfield (1983) found no significant evidence to suggest any association

between new and improved products and sales growth. Nelson and Winter (1978) argued that this is due to “innovation by invasion” in some circumstances, whereby the entrance of new firms in the market may cause other firms to innovate for competitive purposes but, due to the market share per firm declining, sales may remain the same or even decline as well.

External Linkages

The model depicted in Figure 1 represents the innovation process for a given firm, emphasizing the importance of external linkages in the process. A certain degree of generalization has been applied, to keep the model tractable. Given the complexity of the other models that do not accommodate external linkages, it is reasonable to expect that a model that incorporates a firm’s external linkages has the potential to be extremely over-complicated and difficult to understand. For simplicity’s sake the conceptual model only refers to external linkages affecting the firm being analysed, and not how the firm affects the external agents. The main emphasis of this model is that a firm’s innovation process is influenced by other factors besides R&D (as maintained by the linear model) and the capabilities of the individual firm (as shown in the chain link model). These factors refer to external linkages, which include the networking and clustering of a firm with other firms and the use of resources from universities and government departments. There are several agents identified in this model with which a firm can collaborate. Government departments are often seen as a facilitator of learning and innovation, by providing various research documents and facilities, programs, grants and subsidies (Mytelka and Smith, 2002). Policy instruments include industrial policy (by creating demand for technology and other products), science and technology policies (which increase the capabilities of the innovating firms) and R&D grants, among others (Kim, 1997). Universities, like government departments, provide research documents and facilities. They are also a source of knowledge for a firm via tertiary education and consultancy services. The primary role for competitors in a network would be their resources. For smaller firms this would be particularly useful at the input stage of the model. This relates to the theory that smaller firms are disadvantaged relative to larger ones, due to their general inability to afford as much R&D. Finally, suppliers and subcontractors would tend to share tangible and intangible resources with a networked firm, such as market knowledge. Competitors would not share this intangible resource, for obvious reasons.

The stages of the innovation process whereby networking may be in effect are shown on the ripple-effect model by two asterisks. In theory, these collaborations can occur at all levels, the knowledge base, inputs, outputs and firm performance. However, it is expected that there be no evidence of

networking at the innovation output level, as found in the recent study by Tether (2002) of UK manufacturing and service firms. This is most likely due to the fact that this is the level where return on innovation becomes realizable, affecting firm performance, so most firms would probably rather part ways at this stage. However, the corresponding hypothesis will be tested.

Hypothesis 7

As a part of opening up the “black box” of the firm more recent theory has established innovation as a more complex, non-linear process than expressed in earlier literature by the linear model. Although not initially included in these non-linear models the concept of external linkages has arisen in more recent innovation theory as an assistant to the innovation process, particularly in smaller firms (Padmore and Gibson, 1998, p.50). This hypothesis refers closely to Schmookler’s (1966) “demand-pull” hypothesis, where interaction with other entities can assist a firm in knowing which direction to follow with regard to new products and improvements.

Hypothesis 8

In theory the presence of networking provides firms with combined resources, such as knowledge, that assist them in producing new and improved output. However, the empirical evidence would suggest otherwise. Tether (2002) found in his study of UK manufacturing and service firms that new and improved products and processes were still largely done independently of the level of “co-operative arrangements” (Tether, 2002). There are several reasons why this may occur. First, there exists an incentive for a given firm to capture the full financial benefits of their innovations, realizable at the output level. As such, network involvement would most likely require sharing the benefits among all parties. This idea does not detract from Hypothesis 7, as innovation inputs do not directly yield financial benefits. Second, producing innovation outputs co-operatively may be impractical if the particular product is firm specific. Finally, the issue of trust in networking is central to its success, therefore a lack of trust inherent in firms would detract from their collaborative involvement especially as the output stage is where potential profits are realized (Nooteboom, 1999). Rogers (2002) also found little significant evidence to suggest that the presence of networks impacts the level of innovation output of a firm, in his empirical study of Australian manufacturing and non-manufacturing firms.

Hypothesis 9

Similar to the previous hypothesis the presence of networking in firms produces several benefits that would otherwise not be present. These are the

sharing of information and tangible resources, which lowers costs of production and distribution, ultimately resulting in improved firm performance. In support of this Nguyen (2000) found, in his study of Illawarra exporting SMEs, that the presence of networks positively affected the level of sales accounted for by exports. However, Hoffman et al. (1998) argued that the value and depth of networks is not supported empirically as much as it is theoretically. It is difficult to locate empirical work that does include strong evidence that the presence of networks assists small firms in their performance.

Knowledge

The model incorporates the resource-based approach to the innovation process, where learning is central to the innovation process (Schuetze, 1998). Thus, there is a strong emphasis on the importance of the firm's knowledge base in this process. The inputs, outputs and performance indicators feed back into the firm's knowledge stock, which is updated for future innovative activities (Cohen and Levinthal, 1990). This theory follows Arrow's (1962) concept of "learning by doing" and is reflected in Hypotheses 11 to 14. Corresponding outward and inward arrows on the conceptual model show this. The firm may use as much or as little of its knowledge stock in the innovation process. Those that use none are non-innovative firms. The firm's knowledge base affects innovation inputs, outputs and firm performance, and *vice versa*. The double-ended arrows show this effect from the knowledge component to the inputs, outputs and firm performance components.

Hypothesis 10

This hypothesis examines the effect that firm size will have on a firm's education level. It is generally theorized that larger firms will have a greater knowledge base, as such firms have more finance to afford goods, services and intellectual property and more employees to represent human capital.

Hypothesis 11

Cohen and Levinthal (1990) found, using data from the American manufacturing sector¹³, that a firm's investment in R&D contributes to their relevant knowledge base. Cohen and Levinthal argue that this feedback, or spillover, effect is an incentive for R&D investment. Much of the literature on R&D investment argues that firms under-invest because the spillovers fall into the hands of other parties. This spillover, however, affects the original firm, and is incorporated into our model.

Hypothesis 12

Arrow (1962) introduced the concept of “learning by doing” in his variation of a new growth model. The theory states that new business activity will cause feedback into the firm’s knowledge base. As such, it would be expected that innovative activity will result in an accumulation of knowledge.

Hypothesis 13

This hypothesis represents a similar concept to Kemp et al.’s (2003) theory on the feedback of firm performance into innovation inputs and outputs. The idea here is that the outcomes of firm performance measures generate new knowledge for a firm, which then affects the innovation process all over again.

Hypothesis 14

From the outline of network theory above the benefits of networking involve the sharing of information. As such, it is expected that a higher level of network involvement results in a greater knowledge base, developed from the mutual information that the network parties obtain. Empirically, however, there is little evidence to suggest that there is a relationship here.

5 METHODOLOGY AND RESULTS

Data for the purpose of testing our model was collected by way of a survey. The sample selected was stratified across industries, regions and firm size to ensure that associations discovered could be suggested for all firms in general, rather than using results from one industry or one region and projecting those results across all industries and regions. Firms in regions across the state of New South Wales in Australia and in various industries were sampled, with an initial version being first piloted on four firms. Of 196 firms approached, 105 usable responses were obtained.

The hypotheses were tested with cross tabulations and a regression model. Cross tabulations were used for examining the dependence of innovation and firm profile (size, age and industry), of firm performance and innovation inputs and outputs. Pearson’s chi-square test was used to ascertain whether the chosen variables are dependent or independent of one another, and Pearson’s R was used to ascertain a positive or negative association¹⁴ (Norušis, 1993). Significance is taken at the 95 per cent confidence level. This refers to Hypotheses 1-9. For Hypotheses 10-14 a regression model was used to test the relationship between a firm’s knowledge base and innovation inputs, outputs, firm performance, network involvement and firm size. For

each hypothesis, any significant evidence found is indicated, along with the results of previous studies testing the same relationships, for comparative purposes.

Firm Profile Cross Tabulations

H1: R&D investment increases as the size of the firm increases

From Table 3 there is significant evidence to support the link between R&D effort and firm size. However, there is insufficient evidence to suggest any association for other innovation inputs (marketing or technology use), nor is there sufficient evidence for a relationship between firm size and innovation outputs and firm performance.

Evangelista et al. (1998) found exactly the same findings in their study of 40817 European manufacturing firms. The R&D association supports the idea that larger firms can better afford R&D than smaller firms. The R&D and firm size association is supported in much of the literature (Mansfield, 1963; Cohen and Klepper, 1996; Evangelista et al., 1998). The lack of evidence to suggest any association between innovation outputs and firm performance to firm size is generally consistent with the findings of Cohen and Levin (1989), Acs and Audretsch (1990) and Evangelista et al. (1998). This fails to support the theory that large firms are better innovators, but does support the idea that smaller firms are not less innovative than larger firms.

H2: Innovation activity and firm performance increase as the firm's age increases

The cross-tabulations for firm size and firm age resulted in a very significant linear-by-linear association¹⁵, suggesting that these variables follow a similar pattern. There is insufficient evidence at the 95 per cent confidence level to suggest an association between the age of the firm and any innovation input involvement or firm performance. However, there is some significant evidence to suggest an association between firm age and improved processes. This may be because older firms become more efficient over time and discover ways to improve their production processes, whereas younger firms have not had much opportunity to improve on processes. Also, at the 90 per cent confidence level, there is some evidence to suggest a relationship between firm age and sales growth. As such it may be ideal for current researchers of the relationship between innovation and firm size to consider the idea that perhaps the *true* relationship exists between innovation and firm *age*. There is extremely little research available on the nature of this relationship, particularly in contrast to the attention that is placed on the association between firm size and innovation.

Table 3 Chi-Square Significance Statistics for Hypotheses 1-3

		Firm Size (H1)	Age of Firm (H2)	Industry (H3)
INNOVATION INPUT MEASURES	R&D Effort	0.014* R ² =0.228	0.294	0.112
	R&D Intensity	0.614	0.921	0.001* R=N/A
	Marketing Intensity	0.634	0.513	0.242
	Technology	0.956	0.862	0.086
INNOVATION OUTPUT MEASURES	Improved Products		0.855	0.016* R=N/A
	Improved Processes		0.048* R=0.205	0.033* R=N/A
	New Products		0.482	0.374
	Innovation Intensity		0.495	0.463
FIRM PERFORMANCE MEASURES	Export Intensity		0.171	
	Export Growth		0.664	
	Sales Growth		0.098	

* Significance is at the 95 per cent confidence level
+ R represents Pearson's R

H3: The level of innovation activity depends on the industry in which the firm operates.

There is quite strong evidence to support this hypothesis, suggesting associations between R&D intensity, improved products and processes to the industry in which a firm operates. These findings are consistent with Evangelista et al. (1998), who found that innovation outputs varied according to industry classification. We found the highest level of both improved products and processes in the IT industry. This is an expected result, considering the rapid development of technology and the competitive nature

of the overall market. Continuous improvements would be crucial for survival. Also, there is evidence at the 90 per cent level of a relationship between industry classification and the number of technologies, where higher levels of technology use would be found in such industries as the IT industry.

Innovation Inputs, Outputs and Firm Performance Cross Tabulations

H4: Firms with greater R&D, marketing and information technology involvement are more innovative.

Kemp et al. (2003) suggest that outputs of the innovation process should be correlated with the inputs to determine how well firms convert inputs to outputs. In other words, having a higher investment in R&D does not necessarily imply that the firm is more innovative or will perform better. From Table 4, there is evidence that R&D, marketing and technology involvement do get converted into innovation outputs. Also, the fact that there is significant evidence for all three input measures used supports the idea that R&D is not the only input in the innovation process. The insignificant evidence for R&D measures being associated with both new and improved products is consistent with Mansfield's (1983) study, using R&D intensity and product innovation counts. He did not, however, propose reasons for his results.

H5: Firms with greater R&D, marketing and technology involvement perform better.

Table 4 reports a strong association between marketing intensity and exports (using both export measures). However, the test used does not indicate the causality of the relationship. Assuming the causality postulated by the theory, Hypothesis 5 is partially supported, that is, the export performance of a firm dictates to some degree its expenditure on marketing activities. Contrary to this Hoffman et al. (1998) reported recurring evidence that firm performance is affected by marketing effort. This implies the opposite causality, that increased expenditure on marketing activities leads to better firm performance. Our model assumes a two-way relationship.

Table 4 Chi-Square Significance Statistics for Hypotheses 4-6

	R&D Effort	R&D Intensity	Marketing Intensity	Technology	Improved products	Improved processes	New Products	Innovation Intensity
Improved products	0.240	0.085	0.241	0.298				
Improved processes	0.770	0.512	0.667	0.505				
New products	0.132	0.238	0.050* R=0.270	0.031* R=0.278				
Innovation Intensity	0.193	0.011* R ⁺ =0.275	0.784	0.501				
Export Intensity	0.369	0.188	0.042* R=0.246	0.135	0.939	0.017* R=0.272	0.362	0.940
Export Growth	0.109	0.639	0.003* R=Insignificant	0.055	0.020* R=0.228	0.124	0.014* R=0.240	0.531
Sales Growth	0.181	0.619	0.198	0.061	0.115	0.903	0.335	0.359

* Significance is at the 95 per cent confidence level

+ R represents Pearson's R

 Hypothesis 4

 Hypothesis 5

 Hypothesis 6

The cross tabulations between R&D measures and sales growth are similar to those of Mansfield's (1983) empirical study of US firms, where he found no significant evidence to support the relationship between R&D intensity and sales. Likewise, Hoffman et al. (1998) reported a similar lack of significant evidence to suggest any relationship.

H6: More innovative firms perform better.

This hypothesis tests the basic premise of Schumpeter's (1934) work *The Theory of Economic Development*, the final link put forth by Kemp et al. (2003) and our model. From Table 4 it can be seen that there are dependencies between exports and improved products, processes and new products. However, for sales growth, there was no evidence to suggest an association with any innovation output measures. This is consistent with the findings of Nelson and Winter (1978) and Mansfield (1983).

Network Involvement Cross Tabulations

H7: Firms with a greater emphasis on networking are more involved in R&D, marketing and the use of technology

From Table 5 there is evidence to suggest a relationship between R&D intensity and the number of agents with which a firm networks. While causation cannot be confirmed, it does partially support Hypothesis 7 in that firms with higher network involvement are more involved in R&D. This supports the theory that smaller firms can use networks as means of enabling them to invest in more R&D.

H8: Firms with a greater emphasis on networking are more innovative

Rogers (2002) found some evidence of a positive linear relationship between network involvement and innovation, in his study of Australian manufacturing and non-manufacturing firms. A similar result is found in Tether's (2002) UK study of manufacturing and service firms, which concluded that new and improved products and processes tended to be developed cooperatively with other firms. From Table 5 our results do not support these *a priori* expectations of a relationship or association between network involvement and innovation outputs.

H9: Firms with a greater emphasis on networking perform better

From Table 5, there is some evidence to suggest a relationship between the ranked importance of networking and export intensity, similar to Nguyen's (2000) empirical findings. The insignificant Pearson's R indicates that the

association is non-linear. Closer examination of the results suggests that the relationship is more of a U-shaped curve. This may indicate the necessity for small firms to operate collaboratively in order to remain competitive in overseas markets. This does support the idea that smaller firms can use networking to assist firm performance.

Table 5 Chi-Square Significance Statistics for Hypotheses 7-9

		NETWORK MEASURES		
		Sum of Agents	Ranked Importance	Network Frequency
INNOVATION INPUT MEASURES	R&D Effort	0.810	0.186	0.773
	R&D Intensity	0.015* R=0.227	0.953	0.551
	Marketing Intensity	0.601	0.370	0.593
	Technology	0.484	0.833	0.101
INNOVATION OUTPUT MEASURES	Improved Products	0.635	0.574	0.368
	Improved Processes	0.795	0.335	0.827
	New Products	0.426	0.335	0.083
	Innovation Intensity	0.696	0.061	0.402
FIRM PERFORMANCE MEASURES	Export Intensity	0.172	0.006* R=Insignificant	0.069
	Export Growth	0.282	0.956	0.485
	Sales Growth	0.610	0.148	0.493

* Significance is at the 95 per cent confidence level

+ R represents Pearson's R

 Hypothesis 7

 Hypothesis 8

 Hypothesis 9

The lack of evidence supporting Hypothesis 8 and minimal evidence for Hypotheses 7 and 9 is consistent with the results reported in Rogers' (2002) study of Australian firms and in the study of NSW regional firms by Hodgkinson et al. (2003). These results also support the finding by Hoffman et al. (1998) of a lack of empirical support for the value and depth of networks in SMEs, despite the positive theoretical support. The reason for this may be that smaller firms tend to be younger firms, and have perhaps not had time to observe opportunities or to develop the necessary trust for collaborating.

Whilst there was insufficient evidence to support the existence of a link between innovation outputs and collaboration efforts at the 95 per cent confidence level, there is some evidence at the 90 per cent level of relationships between network frequency and technology use, new products and export intensity. At the same confidence level there is also evidence to suggest a relationship between ranked importance and innovation intensity. This indicates that the presence of networks is not entirely unrelated to the innovation process of SMEs. In addition, this relationship is a relatively new area of study that still requires much clarification and standardization of concepts. As such the theory that smaller firms can use networks to assist them in their innovation process cannot be discounted.

The Regression Model

The regression model was used to test how firm size, innovation inputs, outputs, firm performance and networks feed back into the knowledge base of a firm, which we identified as the core component of the innovation process. This is shown by the feedback components on the Ripple-Effect Model outlined above. The regression equation is:

$$\text{EDUC(Log)} = \beta_0 + \beta_1\text{EMP(Log)} + \beta_2\text{RNDINT(Log)} + \beta_3\text{IMPPROD} + \beta_4\text{EXPINT} + \beta_5\text{NETWK} + \beta_6\text{NETFRQ} + \mu$$

where:

EDUC(Log) = The natural log of the proportion of employees with a relevant tertiary education. This proxy for the firm's knowledge base is the dependent variable.

EMP(Log) = The log of the number of full time employees. This measures firm size.

RNDINT(Log) = The log of R&D intensity. This is a proxy for innovation inputs.

IMPPROD = A binary variable for improved products. This was used to measure innovation outputs.

EXPINT = The export intensity of the firm, to measure firm performance. The natural log was not taken for this variable as it was already reasonably normally distributed.

NETWK = A binary variable to ascertain whether or not the firm uses networks.

NETFRQ = The frequency of use of networks as a proxy for the degree of networking.

Natural log values were taken to transform non-linear relationships into linear relationships for the purposes of regression (Norušis, 1993). Hence, the linear equation presented here does not indicate that feedback effects of the innovation process are linear in nature, but, rather, the opposite. The data was entered into an SPSS database and regressed with the previous equation. The output is shown in Table 6 and Table 7.

Table 6 gives an indication of the expected signs of the coefficients of the independent variables in the regression model.

Table 7 shows the coefficients of the betas from the regression equation, with the corresponding t-tests to give an indication of the statistical significance of these coefficients. The R square figure of 0.288 is consistent with Cohen and Levinthal's (1990) empirical study on the influence of R&D and technology on a firm's knowledge base¹⁶. With 6 and 75 degrees of freedom, the 95 per cent confidence level F statistic needs to be at least 2.22¹⁷. For this model the statistic is 5.053, leading to the conclusion that this regression model is significant.

H10: A firm's education level is dependent on its size

According to much of the empirical literature, larger firms tend to have a larger knowledge base (Mansfield, 1963; Acs and Audretsch, 1990; Cohen and Klepper, 1996; Berry, 1997; Nooteboom, 1999; Rogers, 2002). However, we found that the *proportion* of educated employees decreases as firm size increases. At the 99 per cent confidence level, a one per cent increase in firm size results in a decline of 0.155 per cent of the proportion of educated employees. As a measure of a firm's knowledge base, however, the proportion of educated employees in a firm is an imperfect indicator, and the result may be because larger firms tend to have more production-level employees who do not require high levels of education.

Table 6 Correlations

VARIABLE		EDUC (Log)	EMP (Log)	R&DINT (Log)	IMPPROD	EXPINT	NETWK	NETFRQ
EDUC(Log)	Pearson Correlation	1.000						
	Sig. (1-tailed)	.						
	N	82						
EMP(Log)	Pearson Correlation	-0.272**	1.000					
	Sig. (1-tailed)	0.007	.					
	N	82	82					
RNDINT(Log)	Pearson Correlation	0.297**	-0.029	1.000				
	Sig. (1-tailed)	0.003	0.397	.				
	N	82	82	82				
IMPPROD	Pearson Correlation	0.302**	0.075	0.052	1.000			
	Sig. (1-tailed)	0.003	0.251	0.322	.			
	N	82	82	82	82			
EXPINT	Pearson Correlation	-0.245*	0.029	-0.206*	-0.063	1.000		
	Sig. (1-tailed)	0.013	0.399	0.032	0.288	.		
	N	82	82	82	82	82		
NETWK	Pearson Correlation	-0.071	0.064	-0.227	0.065	-0.096	1.000	
	Sig. (1-tailed)	0.263	0.284	0.020	0.280	0.196	.	
	N	82	82	82	82	82	82	
NETFRQ	Pearson Correlation	0.113	-0.139	-0.018	0.045	-0.073	0.485**	1.000
	Sig. (1-tailed)	0.155	0.107	0.437	0.345	0.257	0.000	.
	N	82	82	82	82	82	82	82

** Correlation is significant at the 99 per cent confidence level.

* Correlation is significant at the 95 per cent confidence level.

Table 7 Regression Results

Variable	Unstandardized Coefficients		Standard-ized Coefficients	t statistic	Sig.
	B	Std. Error	Beta		
(Constant)	-0.632	0.440		-1.436	0.155
EMP (Log)	-0.155***	0.059	-0.264	-2.641	0.010
RNDINT (Log)	0.124**	0.058	0.220	2.125	0.037
IMPPROD	0.842***	0.275	0.301	3.063	0.003
EXPINT	-0.484*	0.280	-0.174	-1.727	0.088
NETWK	-0.279	0.375	-0.087	-0.744	0.459
NETFRQ	0.064	0.075	0.097	0.848	0.399

Dependent Variable: EDUC (Log)

*** Significant at the 99 per cent confidence interval

** Significant at the 95 per cent confidence interval

* Significant at the 90 per cent confidence interval

$R^2 = 0.288$ $SEE = 0.73$ $F = 5.053$

H11: Firms with a greater emphasis on inputs to innovation have a bigger knowledge base

According to our regression model, it can be said with 95 per cent confidence that a one per cent increase in R&D expenditure results in a 0.124 per cent increase of the firm's knowledge level. As such the null hypothesis (that R&D intensity and the education level of a firm are independent) can be rejected in favour of Hypothesis 11. Similarly, Cohen and Levinthal (1990) also found that a firm's investment in R&D contributes to its relevant knowledge base.

H12: More innovative firms have a greater knowledge base

From Arrow's (1962) concept of "learning by doing" it would be expected that innovation activity would cause feedback into the firm's knowledge base, causing an accumulation of knowledge. From this regression model it can be said, with 99 per cent confidence, that a unit increase in the improved products results in a 0.842 per cent increase in the proportion of educated employees. This result is in line with the *a priori* expectations.

H13: Firms with a greater firm performance have a larger knowledge base

This reflects a similar concept to Kemp et al.'s (2003) notion on the feedback of firm performance into innovation inputs and outputs. The idea is that good firm performance generates new knowledge for a firm, which then affects the innovation process all over again. Using this regression model, no statements can be made at the 99 per cent or 95 per cent confidence levels. The null hypothesis (that firm performance and knowledge level are independent) cannot be rejected using this data. However, a cross tabulation using Pearson's chi-square test does indicate that education level and sales growth are dependent. The sales growth variable was included in the regression model, but it yielded insignificant results, even when logged. This suggests that the relationship between the two variables is complex and non-linear.

H14: Firms with a greater emphasis on networking have a greater knowledge base

The sparse research to date on the topic of networking has come up with inconclusive or non-linear results (Rogers, 2002; Hodgkinson et al., 2003). This suggests that the relationship between networking and any innovation process component is much more complex than linear regression allows for. Using this regression model there is insufficient evidence at the 99 per cent and 95 per cent confidence levels to suggest a relationship between network involvement and knowledge level.

In sum, several associated hypotheses suggested by the Ripple-Effect Model developed in this study are supported. The results are summarized in Table 8. The weakest support is for the impact of networking on the innovation process. This is not a surprising result as other empirical studies have also failed to find sufficient evidence to support these associations. As mentioned previously this area of research is still relatively new. As such the common measures used are simple and crude, since network activity is difficult to conceptualize and measure. From the preceding empirical discussion of the hypotheses there is ample evidence to indicate that the innovation process is, in reality, quite complex. The measures used in this analysis are few in number, yet the complexity of their relationships is obvious.

10.6 SUMMARY AND POLICY IMPLICATIONS

In this chapter we have accomplished 3 objectives: to examine other firm characteristics, in addition to firm size, in the innovation process; to formulate a more sophisticated model of the innovation process, which recognizes it as being more complex than the traditional linear process

involving R&D investment; and to examine the nature of this process in Australian SMEs, using a sample of firms in New South Wales.

Table 8 Results Summarized

Hypothesis		Result
H1	R&D investment increases as the size of the firm increases	√
H2	Innovation activity and firm performance increase as the firm's age increases	√
H3	The level of innovation activity depends on the industry in which the firm operates	√√
H4	Firms with greater R&D, marketing and information technology involvement are more innovative	√√
H5	Firms with greater R&D, marketing and technology involvement perform better	√
H6	More innovative firms perform better	√
H7	Firms with a greater emphasis on networking are more involved in R&D, marketing and the use of technology	√
H8	Firms with a greater emphasis on networking are more innovative	X
H9	Firms with a greater emphasis on networking perform better	X
H10	A firm's education level is dependent on its size	?
H11	Firms with a greater emphasis on inputs to innovation have a bigger knowledge base	√
H12	More innovative firms have a greater knowledge base	√√
H13	Firms with a greater firm performance have a larger knowledge base	X
H14	Firms with a greater emphasis on networking have a greater knowledge base	X

Key:

- √ Some support
- √√ Strong support
- X Not supported
- ? Significant but with wrong sign

The Ripple-Effect Model of innovation presented appears to be substantially supported. The data collected for this study indicates that there exists numerous relationships between a firm's knowledge level, innovation inputs, output, firm performance and the degree of networking. The model also successfully demonstrates the inherent complexity of the innovation process.

Policies written with the purpose of encouraging innovative activity need to take account of the fact that small firms behave differently to large firms in this regard, and therefore are most likely to respond to differing incentives (Acs and Audretsch, 1990; our survey data). Theoretically, larger firms would be expected to favour R&D as an innovative activity; this has empirical support in the literature, and is also supported by our data. In our sample, which primarily consisted of SMEs, marketing expenditure is strongly associated with the introduction of new products (output) and exports (firm performance), whereas R&D expenditure had no significant impact on any of these measures. In addition, this data supported a correlation between new and improved products and export sales. For assisting small exporting firms in their performance the government may need to focus on policies providing assistance in the marketing of that business' new products to overseas markets, as well as assistance in product development. This reflects the importance of developing the roles played by Innovation Advisory Centres (IACs) and Industrial Development Officers (IDOs) throughout NSW, perhaps with an export focus. However, the causality of the association between marketing new products, producing new products and export sales should be examined in more detail in empirical research before strong assertions are made as to which direction policy should take. This study highlights the interesting fact that smaller firms tend to innovate in different ways to larger firms, and provides a particular avenue for further research.

As the data suggests, innovation inputs and outputs are associated with the industry within which a firm operates. Because of the complexity of the innovation process and the different characteristics across industries, innovation policies should be aimed at specific industries. As a note to researchers the industry-specific argument needs to be developed into a more detailed theory, or into more in-depth empirical analysis. A larger-scale study on the innovation process in various industry classifications would be useful in encouraging the formulation of industry-specific innovation policies, rather than blanket policies. Local and state government should provide much of the assistance, particularly to SMEs, since they can allocate a more appropriate amount of time dealing with individual cases.

With respect to the level of education and literacy skills it seems appropriate to focus on investment in training and education institutions to promote entrepreneurial skills and knowledge, which appears to encourage innovative activity (Berry, 1997; Hallberg, 2000; our survey data). With respect to the innovation process as a whole the government may need to recognize that innovative activity can also feed back into a firm's knowledge base. This highlights the evidence that the innovation process is more than a simple linear process whereby a given innovation contributes a certain amount to economic performance. Rather, the presence of feedback from that output to

knowledge obviously results in an additional contribution to economic performance. In other words a complex innovation process (such as illustrated in the model we have presented) suggests that innovative activity is a somewhat larger contributor to economic growth than commonly believed, thus emphasizing even more the importance of formulating appropriate policies.

The weakest empirical support from our analysis was the networking component of the conceptual framework. This is common in much of the empirical literature, while, in the theoretical literature, networks are commonly asserted as a method for smaller firms to overcome barriers to innovating (Hoffman et al., 1998; Rogers, 2002; Hodgkinson et al., 2003). From this analysis, there are grounds to suggest policies that encourage networking by small firms. However, since there is little empirical support for the impact of networking on the innovation process, policymakers should be cautious in formulating network policies primarily based on theory. As mentioned previously this area of research is still relatively new and common measures used are simple and crude. As a note to researchers this indicates the need for some detailed, standard measures to be developed, perhaps in an *Oslo Manual* style. It would be desirable for the OECD to propose some common guidelines for measuring network activity in firms. Much empirical work needs to be done as a precursor to policy formulation.

NOTES

1. Holbrook and Hughes (1998), however, are more stringent in their definition of innovation, requiring that the development be new to the “competitive market” in order to identify those firms who were truly innovative and those who were simply keeping up with competitors.
2. See, for example, Acs and Audretsch (1990), Freeman and Soete (1997), and the *Oslo Manual* (OECD, 1997).
3. A more extensive literature review can be found in Olsen (2004).
4. For example, see Nelson and Winter (1974, 1977).
5. See Jewkes, Sawers and Stillerman (1958), Nelson, Peck and Kalachek (1967), Scherer (1980), Dorfman (1987), Acs and Audretsch (1990), Cohen and Klepper (1996) and Rogers (2002).
6. For a more detailed discussion on the effects of globalization on the service and manufacturing industry, see Wooden (1998).
7. See, for example, Dodgson (1990, pp.158-159); DeBresson and Amesse (1991, p.368); Berry (1997, p.7); Nooteboom (1999, pp.793-794); Nguyen (2000, p.25-26); Fritsch (2001, pp.28-32).
8. A more extensive literature review is found in Olsen (2004).
9. Shown by Hypothesis 11.

10. See, for example, the literature review by Kemp et al. (2003).
11. Shown by Hypothesis 12.
12. Shown by Hypothesis 4.
13. Data collected by the Federal Trade Commission.
14. Only Pearson's R values that are significant at the 95 per cent confidence level are considered.
15. The linear-by-linear association significance test statistic is 0.003.
16. Cohen and Levinthal (1990) reported an R square of 0.287.
17. Taken from F table provided in Appendix B of Kellar and Warrack (2000).

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