Examining relationships between external linkages, absorptive capacity and gains in new product knowledge and impacts on new product innovativeness

Examining Relationships Between External Linkages, Absorptive Capacity and Gains in New Product Knowledge and Impacts on New Product Innovativeness

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Abstract

This thesis investigates relationships between external linkages and new product innovativeness focusing particularly on the perspective of a knowledge-enabled view of new product development. Building on organisational learning theory and knowledge-based theories of inter-firm collaboration, this thesis argues that the effects of external linkages on new product innovativeness vary and these are largely contingent upon a firm's absorptive capacity. The firm's level of absorptive capacity determines how effectively knowledge from external collaborators relevant to the new product project is absorbed, resulting in the creation of new knowledge that the firm can apply for its own commercial use. It considers why some firms are more effective than others at absorbing new product related knowledge from external collaborators to facilitate more innovative product development.

Based on an empirical study of 116 new product development projects in Taiwanese Information Technology (IT) firms, the thesis assesses the relative importance of external linkages in increasing new product innovativeness. The results show that the impact of horizontal links (that is, collaboration with other companies, research institutes, and universities) on gains in new product related knowledge is greater than that of vertical linkages (that is, supplier and customer involvement). Compared to links with customers, universities, and research institutes, corporate linkages play the most prominent and consistent role in enhancing the accumulation of new product related knowledge. This knowledge namely pertains to predevelopment assessment, R&D, manufacturing and marketing. The thesis confirms that the firm's absorptive capacity positively affects its gains in new product related knowledge. In addition, absorptive capacity's interactions with corporate linkages have significant, positive effects on gains in new product related knowledge. However, such interaction effects were not observed for the other external linkages, with exception of industry-based research institute linkage. Moreover, the results confirm that the positive impacts of absorptive capacity, corporation linkages, and supplier linkages on new product innovativeness are mediated by the extent of new product related knowledge gained.

This thesis bridges the gap between theories of organisational absorptive capacity and the effective generation of new products. It contributes to our understanding of the role of a firm's absorptive capacity in NPD research. It examines this issue from a knowledge-enabled view of new product development. The findings will assist managers to more effectively formulate NPD strategy by incorporating firms' internal learning capacity with the complementary knowledge and technology that external collaborators can provide.

Key words: New product development; external linkages; absorptive capacity; new product innovativeness; NPD collaboration; Taiwanese IT industry

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List of Abbreviations

AC	Absorptive capacity
ANOVA	Analysis of variance
CD-RW	Compact disk- read and write
CFA	Confirmatory factor analysis
CITC	Corrected item-to-total correlation
CPU	Central processing units
DRAM	Dynamic random assess memory
ICs	Integrated circuits
ICVs	Inter-firm cooperative ventures
IT	Information technology
LAN	Local area network
LCD	Liquid crystal display
M&A	Merge and acquisition
MNCs	Multi-national companies
MRA	Moderated regression analysis
NICs	Newly developed countries
NPD	New product development
OEM	Original equipment manufacturers
ODM	Original design manufacturers
PAK	Pre-development assessment knowledge
PC	Personal computer
R&D	Research and development
ROE	Return on earning
SMCs	Small and medium-sized companies
SRAM	Static random access memory
VCs	Venture capital companies
WAN	Wide (broad band) area network

Chapter 1

Introduction

1.1 Background

Continuously developing and launching more state-of-the-art products than one's competitors is one of the most challenging activities facing firms today. Their ability to generate product innovations increasingly relies on the effective acquisition of new product knowledge through external linkages (Bierly and Chakrabarti, 1996; Leonard-Barton, 1995; Rothwell, 1992). However, new knowledge is often tacit, un-codified, and contains 'sticky' information (Nonaka, 1994; Nonaka and Takeuchi, 1995; von Hippel, 1994; von Hippel, 1998). This thesis explores ways in which firms gain new sets of knowledge or learn from potential partners in order to improve existing technology bases and develop more innovative products.

Organisational learning literature highlights the importance of external integration and boundary learning expansion efforts in enabling firms to explore new theory-in-use (Argyris and Schon, 1978) as well as knowledge, which can then lead to radical innovation (Leonard-Barton, 1995; McKee, 1992). Along with this need for external integration, scholars of the knowledge-based view of the firm (Grant, 1996; Conner and Prahalad, 1996) advocate that the organisation's ability to innovate depends on its capacity to integrate knowledge residing both inside and outside its boundaries. However, for a given new product development (NPD) project, it is unlikely that potential links with external parties, including customers, suppliers, competitors, research institutes, and universities, will affect such knowledge-integration and learning to an equal degree. Hence, external linkages may vary in their relevance to, as well as their impacts upon, product innovativeness. Moreover, the latter may depend not only on a new set of complementary product knowledge that external links or alliances can provide, but also on the firm's learning ability or absorptive capacity (Cohen and Levinthal, 1990). This ability refers to the extent to which the firm is equipped to absorb the new knowledge that it is available. Arguably, both external linkages and internal absorptive capacity to access and gain new product knowledge are necessary to facilitate innovative NPD.

Drawing on organisational learning theory and the theory of knowledge-based views of the firm, the thesis argues that the effects of external linkages on new product innovativeness vary and are largely contingent upon a firm's absorptive capacity. The firm's level of absorptive capacity determines how effectively knowledge relevant to the new product project is absorbed from its external collaborators, resulting in the creation of new knowledge that the firm can apply for its commercial use. New product innovativeness is conceptualised as the extent of newness of the technology embraced by the new product and of the market served (Cooper, 1979). Past studies of product innovativeness have largely focused on organisational learning factors, with much interest centering on the types of linkages or internal team learning skills (Bierly and Chakrabarti, 1996; Madhavan and Grover, 1998). Although previous organisational learning literature has examined inter-unit knowledge transfer within an organisation and the role of absorptive capacity in enhancing a business unit's innovation performance (e.g., Tsai, 2001), less attention has been focused on the interaction effects between absorptive capacity and alternative external knowledge sources and impacts on new product innovativeness. Previous research on technology transfer has also highlighted the need for strong absorptive capacity when firms seek to leverage and benefit from the technical know-how acquired from external suppliers of technology (Lane et al., 2001; Mowery et al., 1996). However, inadequate attention has focused on distinguishing between the types of external sources of new knowledge and impacts on new product innovativeness. Moreover, few studies have delineated the mediating effects of new knowledge or knowledge gain in explaining the impacts of external linkages on new product innovativeness. There continues to be a need for product level research that distinguishes between alternative external sources of knowledge, absorptive capacity, and their influence on the effectiveness of learning activities in NPD.

1.2 Research Objectives and Contributions

The primary objective of this research is to explore the complex relationships among external linkages, absorptive capacity, gain in new product knowledge, and new product innovativeness. A secondary objective is to examine which types of external linkages are most important in supporting the development of more innovative products. More specifically, this thesis tests the important relationships including: (1) the direct impact of a firm's absorptive capacity on the effectiveness of gain in new product knowledge; (2) the direct impacts of firms' external linkages on the effectiveness of gain in new product knowledge; (3) the moderating impact of absorptive capacity between external linkages and gain in new product realted knowledge; and, (4) the mediating impact of gain in new product related knowledge in the relationship between external linkages and new product innovativeness.

A major contribution of this thesis to NPD literature is its integration of two research streams: the theories of organisational absorptive capacity and the effective generation of new products. It does this in order to bridge a gap in current understanding of the role of a firm's absorptive capacity in new product development. The thesis has implications for managers because it addresses a key issue for dynamic, technology-based industries: that is, how firms can absorb new knowledge effectively from external collaborators to achieve more innovative product development. The research findings will assist managers in identifying the factors that most affect a firm's effectiveness in accumulating new product knowledge and technology, enabling more effective use of existing NPD collaborators, and achieving greater new product performance.

1.3 Thesis Overview

This thesis explores two related research questions: (1) what types of external linkages most influence a NPD project's product innovativeness? and, (2) what is the role that absorptive capacity plays in the relationship between a NPD project's external linkages and new product innovativeness? A conceptual framework is proposed depicting links between external linkages, absorptive capacity, gains in new product knowledge and new product innovativeness. Effective new product development requires a spectrum of know-how covering pre-development planning, concept development and evaluation, marketing research, technical development, pre-test, market launch (Cooper and Kleinschmidt, 1987; Song and Parry, 1996 & 1997). New product knowledge gained in a NPD project mediates the relationship between external linkages and new product innovativeness. This rationale is based on the fact that the primary objectives of external linkages in NPD are to gain access to complementary technologies (Hamel, 1991; Link and Tassey, 1987; Rothwell and Dodgson, 1991; Powell et al., 1996), to assess and acquire a new set of complementary product-specific know-how, and to fill the gap between the product domain and technology domain (Grant and Baden-Fuller, 1995). These linkages lead to an increase in product knowledge stock. A novel product development requires new product know-how (both marketing and technological). If the technology gap between the new product know-how and the firm's existing product know-how can be narrowed, the firm increases the probability of developing a more innovative product. The conceptual framework regards absorptive capacity as a moderator (a quasi moderator) residing between the relationship of external linkages and gains in new product knowledge. Absorptive capacity is defined as a firm's ability to recognise the value of new knowledge, assimilate it and apply it to commercial ends (Cohen and Levinthal, 1990). Firms with a strong absorptive capacity are more able to assimilate new product knowledge from external collaborators, resulting in more innovative product development.

The researcher adapted the newness-to-the-firm approach to measure the level of new product innovativeness. The constructs representing external linkages include vertical linkages (i.e., customer linkage and supplier linkage) and horizontal linkages (i.e., corporation linkage, research institute linkage, and university linkage). The constructs of gains in new product related knowledge consist of gain in research and development (R&D) knowledge, gain in manufacturing knowledge, gain in predevelopment assessment knowledge and gain in marketing knowledge. Absorptive capacity is a multi-faceted construct comprising existing knowledge base, knowledge scanning ability, communications network, and communications climate. The conceptual framework informs the development of hypotheses concerning the relationships among the study's key constructs. Accordingly, this research is designed to collect and analyse data for testing the proposed hypotheses.

The unit of research is a NPD project. The key informant method is used to collect data through questionnaires. Because of the reflective nature of questionnaire answering, the key informants must have been closely involved in the NPD project that is being referred to in their responses. Informants include R&D managers, new product managers and vice presidents of R&D. In the questionnaire, they were asked to select a NPD project that was launched in the past two years and with which they were closely involved.

The initial questionnaire was developed from an extensive literature search and pre-pilot tested with both NPD academics and practitioners. The measurement instrument was then piloted with a sample of 72 managers who were R&D managers, product managers and NPD project managers. The piloted results were used to provide preliminary assessments on the reliability and validity of the instrument. Taiwanese information technology (IT) industry was chosen as the primary context for this research on the grounds that it is the third largest IT product producer in the world, and that it represents the major ODM (original design and manufacturing) source for international IT competitors[1]. Most NPD projects in this industry involve a certain amount of networking for new technology acquisition (Wong et al., 1998). The two most frequently used IT company index sources - the 2000 directory of Hsinchu Science-based Industrial Park and the 2000 Top 1000 Taiwanese Manufacturing Firms of the Commonweath - were selected to form a sampling frame. The sampling frame consists of firms, including four sub-industries – semiconductors, computer and peripherals, telecommunications and software. With the help of high-tech venture capital companies and investment banks, a list of 230 NPD related managers' names was compiled. Administration of the survey followed a variation of Dillman's Total Design Method (Dillman, 1978). Of the returned questionnaires, one hundred and sixteen were usable, resulting in 50.43% response rate.

Both factor analysis and the corrected item-to-total correlation analysis were used to purify the multi-item measurement scales in order to ensure these scales' validity and reliability. For research hypothesis testing, the summated scores from the purified scales were submitted for hierarchical regression analysis.

On the whole, the results of empirical investigation support the framework presented in the research model. The findings reflect the fact that the range and types

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[1] According to Asia IT report (2000), Taiwan is the third largest IT hardware producers worldwide next to the US and Japan. However, OEM/ODM orders represented more than 65% of IT exports in 1999.

of external linkages deployed in a NPD project characterise its external knowledge acquisition potential. Horizontal linkages offer more opportunities for firms to gain access to complementary knowledge that tends to lead to more innovative product development. Absorptive capacity moderates the effects of external linkages, in particular the corporation linkage and research institute linkage, on gains in new product knowledge. Moreover, the findings also confirm that the development of more innovative products is mediated by the project unit's ability to learn from external collaborators and to gain additional R&D, manufacturing, predevelopment assessment, and marketing knowledge that facilitates more innovative product development. In conclusion, this research explores the relationship between external linkages and absorptive capacity in a sample of Taiwanese IT-industry based new product development projects. It offers insights into the relative importance of external linkages and the moderating influences of absorptive capacity in the relationships between external linkages and new product innovativeness.

1.4 Organisation of the Thesis

The thesis is organised into eight chapters. Following this introduction, Chapter Two presents a review of the extant literature in new product innovation from the perspectives of organisational learning and knowledge management. The literature review informs the construction of a conceptual framework that integrates key constructs of external linkages, gain in new product knowledge, absorptive capacity and new product innovativeness.

Chapter Three proposes the research hypotheses of this study based on the conceptual framework. The rationale underlying each hypothesis is discussed. Chapter Four addresses the research methodology relating to research design, operationalisation of the constructs, and analytical techniques.

Chapter Five discusses the development of the questionnaire, its refinement, pre-testing, and piloting. A preliminary examination of reliability and validity of the measurement instrument is reported. In addition, it details the administration of the large-scale survey and the purification of the construct items, as well as the validation of the purified measures.

Chapter Six covers the main body of empirical analysis. It examines the direct effects of external linkages on new product knowledge accumulation, and the moderating role of absorptive capacity as well as the mediating role of gain in new product knowledge between external linkages and new product innovativeness.

Empirical findings of the current study are summarised in Chapter Seven, where the results are discussed in the light of relevant literature. Lastly, Chapter Eight presents the implications, contributions, and limitations of the study, as well as future research directions. Research instruments, the residual and normality plots of regression analyses, and the outline of Taiwanese IT industry are provided in the appendices.

Chapter 2

Literature Review

2.1 Introduction

Knowledge management- the way companies generate, communicate, and leverage their intelligent assets – has only recently emerged as an essential source of competitive advantage. New product development, from this viewpoint, has something to do with the continual process of creating, enlarging and retrieving the repository of NPD knowledge that eventually leads to a competitive edge for firms in the marketplace (Nonaka, 1991; Takeuchi and Nonaka, 1986). Learning theorists (McKee, 1992; Malerba, 1992; Lynn et al., 1996; Leonard-Barton, 1995) with technological innovation perspectives see NPD as a corporate-wide learning process, where multi-discipline knowledge is created, accumulated, and shared between functional departments. Moreover, as suggested by organizational learning theory that a double-loop mechanism challenges the validity of an established knowledge base (Argyris, 1977), the development of truly innovative NPD knowledge requires that firms allocate vast resources to boundary expansion and external integration (Kogut and Zander, 1992; Leonard-Barton, 1995). As such, network studies emphasize the importance of a firm's history of technological networking and cumulative stream of technological projects in innovation implementation (Pennings and Harianto, 1992a & 1992b). Networking is deemed critical for facilitating access to strands of technology that are unknown to a firm. Therefore, external partners can provide complementary technologies and may participate in NPD alliances to implement innovations covering multiple technologies (Grant and Banden-Fuller, 1995). This chapter reviews the literature relevant to this research in order to establish a theoretical foundation for the development of a conceptual model that delineates the relationships between a firm's external learning activities, NPD knowledge acquisitions and its product innovativeness. This review particularly focuses on the theory of technological learning and the knowledge-based theory of inter-firm collaboration, which are applied to explain how and why technological learning and the acquisition and assimilation of NPD knowledge affects a firm's product innovation efforts.

Section 2.2 starts with a discussion of organisational learning and its relationship to new product innovation. This section aims to investigate the concept that different learning orientations (i.e. external and internal) lead to a distinct degree of product innovativeness. More specifically, that external learning contributes more significantly to product innovativeness than internal learning. These learning activities lead the generation of organisational knowledge. Section 2.3 considers how organisational knowledge is created through learning, how external knowledge is assimilated and internalized, and what impact knowledge has on a firm's product innovativeness.

Section 2.4 discusses factors affecting product innovation from an external linkage perspective. Specifically, this section explores the reason why external linkages differ in their effects on the degree of product knowledge accumulation that accounts for a firm's product innovativeness. Section 2.5 discusses the concept of absorptive capacity and its influence on the effectiveness of external knowledge acquisition as well as product innovation. On the basis of the literature, Section 2.6 presents a conceptual framework, which delineates the relationship between external linkages, absorptive capacity, gains in new product related knowledge and new product innovativeness.

2.2 Organisational Learning and Product Innovation

Organisational learning has generated great interest among organisational theorists, management scientists, sociologists, and psychologists. Various definitions have been proposed including the organisational learning as a process for detecting and correcting errors (Argyris and Schon, 1978: 2), and as a process for improving actions through better knowledge and understanding (Fiol and Lyles, 1985: 803). Still other theories have argued that it is a process of learning by encoding inferences from historical experiences into routines that guide behaviour (Levitt and March, 1988: 319), learning through shared insights, knowledge, and mental model building on past knowledge and experience (i.e. on memory) (Stata, 1989). Yet others refers to it as the approach that organisations take in order to adapt and develop organisational efficiency by improving utilization of their workforce's skills (Dodgson, 1993a: 319). Huber (1991) argues "organisational learning occurs in an organisation if, through its processing of information, the range of the organisation's potential behaviour changes" (p.89). The extent of these potential changes provides management researchers with two fundamental conceptions, cognition and behaviour, to realise theoretical avenues into an organisational learning study.

2.2.1 Content of Organisational Learning - Cognition vs. Behaviour

Management theorists, with a cognitive view of learning, posit that learning has occurred when there has been an adjustment or change in the way organisations or individuals process information, develop shared meaning, and interpret events, with a focus on changes in knowledge and beliefs (Argyris and Schon, 1978; Crossan et al., 1999; Fiol and Lyles, 1985;& Kim, 1993). In other words, learning has occurred if there is a change in thought processes – an unobservable phenomenon. In contrast, behavioural theorists postulate that learning has occurred if there is a noticeable change in behaviour or action - observable factors, with a focus on the adaptation of systems and strategies (Daft and Weick, 1984; Daft and Huber, 1987;& Huber, 1991).

An organisation's cognitive systems are quite different from those of an individual. Hedberg (1981:19), adopting a cognitive perspective on organisational learning, states that: " Organisations do not have brains, but they have cognitive systems and memories. As individuals develop their personalities, personal habits, and beliefs over time, organisations develop world-views and ideologies. Members come and go, ... but organisations' memories preserve certain behaviours, mental maps, norms, and values over time". The cognitive systems of organisations are frequently referred to as shared mental models (Kim, 1993), belief systems, mental maps (Argyris and Schon, 1978), or cognitive frameworks (Bartunek, 1984).

Fiol and Lyles suggest that learning involves changes in cognition, while adaptation involves changes in behaviour. They state that: "it is essential to note the difference between cognition and behaviour, for not only do they present the different phenomena, but also one is not necessarily an accurate reflection of the other" (Fiol and Lyles, 1985: 806). According to Cangelesi and Dill (1965), a behavioural approach regards learning as synonymous with adaptation, which involves bringing action in line with previous new needs. The adaptation (of behaviour) perspective on learning assumes that changes in knowledge will ultimately be related to changes in actions or behaviour (Crossan et al., 1995). By contrast, the interpretation (of cognition) perspective on learning assumes that learning refers to when one assesses something and then acts on it accordingly.

Although the perspectives of "cognition" and "behaviour" are instrumental to realising a conceptualisation of a learning theory, most concepts of learning theory recognise the relevance of both approaches (Crossan et al., 1995). For example, Garvin's comments reflect this phenomenon. He states that: "Organisational learning can be traced through three overlapping stages. The first step is cognitive. Members of an organisation who are exposed to new ideas expand their knowledge, and begin to think differently. The second is behavioural. Employees begin to internalize new insights and alter their behaviour. And the third step is performance improvement, with changes in behaviour leading to measurable improvements in results: superior quality, better delivery, increased market share, or other tangible gains. Because cognitive and behavioural changes typically precede improvements in performance, a complete learning must include all three." (Garvin, 1993: 90). Kim (1993) suggests that in the context of technological learning for innovation, it is sufficient to put forward the acquisition of "know-how" (which implies the physical ability to produce some activities) as behavioural (operational) learning, and the acquisition of "know-why" (which implies the ability to articulate a conceptual understanding of an experience) as cognitive (conceptual) learning. Both cognition and behaviour approaches allow organisational learning theorists to examine learning results according to the extent of the learning object which an organisation has achieved.

2.2.2 Levels of Learning

The literature on organisational learning is for the most part divided over whether learning occurs at an individual level, or at a group level, or at the level of the organisation as a whole. However, theories of learning by individuals, groups, and organisations are crucial for understanding organisational learning. The following three sections will examine these theories in detail.

Individual-level Learning

Much of the research on individual learning comes from psychological studies of human behaviour. Behaviourists provided some of the earliest theories of learning in terms of stimulus-response models of behaviour (Skinner, 1938). Cognitive theorists then offered an interpretation of concepts like memorising, and forgetting under the model of stimulus-response generalizations (Postman, 1963, Underwood, 1964). The information processing perspective of cognitive psychology (with an emphasis on problem-solving) viewed learning as a change in states of knowledge, rather than a change in probabilities of response (Bruner et al., 1956). The research focus then shifted to investigate memory structures, processing of information, the organisation, and acquisition of and the search for information in problem solving (Klahr and Wallance, 1976, Newell and Simon, 1972).

March and Olson (1975) advanced an individually based perspective to organisational learning that focuses on information exposure, memory, retrieval, learning incentives, and belief structures of an organisation's members. They developed a conceptual model of learning based on the assumption that the individual's belief (which affects individual action and is, in turn, affected by environmental response) influences the actions of organisations (ibid, 1975). According to this view, a complete cycle of organisational learning should be a tight chain between individual action, organisational action, environmental response and individual beliefs. Likewise, Simon offers a straightforward interpretation of organisational learning that suggest: "all learning takes places inside individual human heads; an organisation learns in only two ways: (a) by the learning of its members, or (b) by ingesting new members who have knowledge the organisation didn't previously have" (Simon, 1991: 125). This interpretation holds that internal learning- that is, transmission of information/knowledge from one organisational member or group of members to another, is a fundamental part of organisational learning. However, this stream of theory omits consideration of a crucial element of organisational learning - external learning - which radical innovations rely upon.

Group-level Learning

Several organisational learning theorists have recognised that learning occurs not only at the individual level, but at the group level as well. These theorists assert that organisational learning would be incomplete if no information was disseminated (Shrivastava, 1983; Daft and Weick, 1984; Stata, 1989; Huber, 1991;& Kim, 1993). This notion of group learning emphasises the transmission of information among group members. For instance, Daft and Huber (1987) suggest that organisations would need to design two learning systems - a logistical system to handle the processing of data, and an interpretive system to enable an appropriate perception and understanding of data. Another perspective of group-based learning focuses on the change and development of organisational knowledge (Duncan and Weiss, 1979; Nonaka, 1994). Duncan and Weiss suggest that organisational learning is possible only to the extent that there is communication among individuals who engage in organisational activities and formulate action-outcome knowledge. Moreover, Nonaka (1995) proposes a middle-up-down management, emphasising the dynamic role middle managers play in communicating information upwards and downwards to facilitate knowledge creation, which is required in a learning organisation. Clearly, learning theorists with a group-based perspective tend to focus on how data, information and knowledge flow amongst organisational members to achieve effective organisational learning.

Organisation-level Learning

A widely accepted view of organisational level learning is that the systems, structures, and procedures of an organization affect learning (Fiol and Lyles, 1985). Hedberg (1981) asserts that systems, structures, and procedures of an organisation are the repositories for learning. The recognition of an organisational level component within organisational learning leads proponents of this view to suggest that unless the knowledge gained from a system is encoded and institutionalized, only individuals but not organisations learn (Argyris and Schon, 1978). That is, a transfer of knowledge from the individual to the organisation results in learning at an organisational level as distinct from learning at the individual level. Levitt and March state that organisations learn "by encoding inferences from history into routines that guide behaviour" (Levitt and March, 1988: 320). Likewise, Shrivastava (1983) explains this process as the "conversion of individual knowledge and insights into a systematic organisational knowledge base which informs decision-making" (1983: 18).

Studies of learning at the organisational level primarily focus on "organisational routines." This stream of research maintains that organisational learning involves the development of new and continually improved routines (March and Olsen, 1975; Levitt and March, 1988; Kim, 1993). These new routines may well be the outcome of trial and error that results from learning about old routines, and/or arises from incomplete socialisation of organisational members (March and Olsen, 1975). Routines, for example, that are held in the organisational memory include collective norms about appropriate behaviour, myths and technology, and may be simple or complex in their components. Routines that specify the nature of production runs may be fairly simple and those that prescribe the way that organisations view themselves in relation to other firms in the marketplace may be complex (Levitt and March, 1988). Organisational routines, such as standard operating procedures, are generally viewed as an important part of an organisation's memory, a repository of its past learning (Kim, 1993).

Theorists of the strategic renewal perspective have tended to develop a learning framework at the organisational level. For example, Kim (1993) and Crossanm et al. (1999) suggest that through shared mental models, the thoughts constructed affect how people and organisations operate in the world, and it is these results of learning that can then be institutionalised. The learning models of this stream of research tend to apply both cognitive and behavioural approaches to integrate the three learning levels (i.e. individual, group, and organisational) in order to achieve a holistic view of organisational leaning.

2.2.3 Types of Learning

Researchers in management have proposed a variety of dyadic types of learning, which can be used to distinguish the effectiveness of learning. In these dyadic types of learning, there has been much argument about the nature of incremental and radical (or transformational) learning (Argyris and Schon, 1978; Miner and Mezias, 1996). Both learning types are differentiated primarily on the basis of the degree of change to observed patterns of organisational behaviour. Simply put, incremental learning manifests itself by small changes in patterns of behaviour, whilst radical learning manifests itself in fundamental changes in behaviour patterns (Crossan et al., 1995). Similarly, this distinction often applies to new product development, as this may involve either incremental or radical innovations (McKee, 1992).

Single-loop versus Double-loop Learning

The distinction between single-loop and double-loop learning, as developed by Argyis and Scheon (1978), is a seminal learning concept, which is widely referred to and frequently discussed in strategic and innovation management literature. In single-loop learning, an organisation learns by means of its long established values (i.e. its theory-in-use) and the validity of the theory is judged by its effectiveness in enacting oganisational values (Argyris, 1977). Single-loop learning occurs when errors are detected and corrected within an existing set of governing variables. In double-loop learning, however, organisations not only detect errors but also question espoused theories (Argyris, 1977). Double-loop learning occurs when, in addition to the detection and correction of errors, an organisation is involved in changing governing variables. This suggests that double-loop learning involves fundamental changes to frames of reference or theories-in-use that have previously prevailed.

On the whole, single-loop learning is linked to incremental change, by which an organisation tries out new methods and actions and attempts to receive rapid feedback on their consequences for making continuous adjustments and adaptations (Argyris, 1977, Fiol and Lyles, 1985). This process has been referred to as "lower-level learning" by Fiol and Lyles (1985) and "adaptive learning" by Senge (1990). Double-loop learning, on the other hand, is associated with radical changes, which might involve major alternations to a firm's strategic direction (Argyris, 1977). This type of learning may be linked to the development of a new product line involving the overhaul of a firm's new product technologies. Radical changes in a firm's technology platforms, which are the results of this type of learning, require an entirely new process of strategic planning as well as cognitive changes of top management. These platform changes may lead to the development of radical innovations. Double-loop learning is referred to as labeled "higher-level learning" by Foil and Lyles (1985), and "generative learning" by Senge (1990).

According to Argyris and Scheon's definition, both types of learning involve cognitive and behavioural changes. Specifically, double-loop learning involves cognitive and behavioural changes that are outside of an existing strategic paradigm, whereas single-loop learning encompasses change but that change takes place within an existing paradigm. Double-loop learning is commonly considered to be more crucial to an organisation's long-term viability than single-loop learning (Argyris, 1996; Miner and Mezias, 1996). Argyris states that: "Single-loop learning and routines, although they dominate organisational life, are the enemy of organisations solving difficult problems, that they are embarrassing and threatening. It is variables such as these that temper human beings and limit their commitment" (1996:78). He further contends that organisations tend to create defensive routines that inhibit double-loop learning and only by continuously questioning their norms, objectives, and paradigms can they curtail these routines.

Lower-level versus Higher-level Learning

Within a cognition development perspective, Fiol and Lyles (1985) propose a dyad of learning: lower- and higher-level learning. Lower-level learning occurs within a given set of rules and leads to the development of a fundamental association between behaviour and outcome. Its impact is short-term and reaches only part of an organisation. Such a process of learning is the result of routines and repetition and involves association building (ibid. p.807). Higher-level learning, on the other hand, refers to an adjustment of fundamental rules and norms rather than an adjustment of specific activities or behaviours (ibid. p.808). It typically provides a long-term impact on the organisation as a whole.

Lower-level learning is similar to what Duncan (1974) calls "behavioural-level learning," a level of learning that is involved with adjustments to a firm as it adapts to an environment, and to what Argyris (1977) calls "single-loop learning." In contrast, higher-level learning occurs through the use of heuristics, skill development, and insight (Fiol and Lyles, 1985). Foil and Lyles argue that, some types of crisis, for example, a competence-destroying technology that has been developed, or a revolution from within, can be driving forces for higher-level learning. The consequences related to this type of learning do not lead to any particular behavioural outcome, but rather, to the development of a new frame of reference (Shrivastava and Schneider, 1984) or a new cognitive framework within which decisions are made (Bartunek, 1984). Therefore, higher-level learning is a more cognitive process than lower-level learning, the latter being simply the result of repetitive behaviour (ibid. p.808). Higher-level learning, based on the extent of change in cognition and behaviour can, at times, be linked to radical learning. In contrast, however, lower-level learning is referred to as incremental learning.

Conceptual versus Operational Learning

Building on experiential learning theory, Kim (1993) suggests a dyad of learning: conceptual and operational learning. Operational learning accumulates from and changes routines (ibid. p.40). Operational learning represents learning at a procedural level, where for example, one learns the steps necessary to complete a particular task. In this process, the know-how or the physical ability to produce some action (ibid. p.38), is captured in routines. By contrast, conceptual learning involves the cognitive thinking behind an action that sometimes challenges prevailing conditions, procedures, or conceptions, and leads to a new framework being ascribed to the mental model (ibid. p.40). Kim maintains that the new framework, in turn, can provide opportunities for discontinuous steps of improvement, whereby a problem is reframed in radically different ways. In this process, the know-why or the ability to articulate a conceptual understanding of an experience (ibid. p.38), is captured in a new framework. Simply put, operational learning produces new or revised routines to replace old ones. Conceptual learning, on the other hand, creates changes to the mental framework, which leads to new ways of perceiving the world. Operational learning can be considered relative to incremental learning, whilst conceptual learning is associated with radical learning.

Learning versus Unlearning

Building on theories of environmental adaptation, Hedberg (1981) advocates the concept of organisational unlearning. He argues that learning is the process that occurs when organisations interact with their environments, where each action adds information and strengthens or weakens linkages between stimuli and responses. Leading from this he defines "unlearning" as "a process through which learners (both individuals or organisations) discard knowledge ... which makes way for new responses and mental maps" (Hedberg 1981: 18). In his stimuli-response framework (ibid. p.10), he proposes that unlearning has three modes of operation. The first involves the disassembly of mechanisms for selecting or identifying stimuli. The second mode induces a disconfirmation of connections between stimuli and responses and the third mode involves a disconfirmation of connections between responses. In this process, when unlearning occurs, a new theory of action (i.e., theory-in-use) replaces the old one.

Unlearning poses particular problems to organisations that move from stable, benevolent environments into unstable, hostile ones (Hedberg et al., 1976) because habitually successful organizations are often unable to unlearn obsolete knowledge, in spite of strong disconfirmations. Therefore, unlearning that establishes new organisational practices becomes more difficult as firms age because new knowledge contends with a firm's existing approaches to operations, or its "dominant logic" (Bettis and Prahalad, 1995).

Organisational unlearning is normally problem-triggered (Hedberg, 1981:19). Company crises, such as falling revenues, eroding market share, diminishing popular support or public criticism, often trigger unlearning within an organisation (Nystrom and Starbuck, 1984). Also, new myths and/or substantial problems can be triggers for unlearning (Bettis and Prahalad, 1995). In a similar vein, Bettis and Prahalad (1995) maintain that organisations far away equilibrium that helps to increase adaptability is suggestive of conditions that facilitate unlearning. Unlearning ability makes room for organisations to take on more adequate interpretative frameworks. The development of a new set of dominant logic for a newly changed environment can then be held in the organisational memory, whilst learning ability generates new knowledge and updates existing knowledge. Some scholars of knowledge-based theory of the firm suggest that the generation of new organisational knowledge is maximized in close to the domain of existing knowledge, in conditions under which there are few existing organisational routines to unlearn and organisational assimilation and subsequent retrieval of the knowledge occurs in an intense and repetitive fashion (Cohen and Levinthal, 1990; Bettis and Prahalad, 1995). Hedberg (1981: 20) concludes that the balance between an organisation's ability to learn and unlearn indicates its long-term survival. This seminal concept of unlearning has directed management theorists to develop several important managerial concepts such as competence trap (Levitt and March, 1988), core capabilities and core rigidities (Leonard-Barton, 1992), and the dominant logic (Bettis and Prahalad, 1995). On a broad scale, unlearning is similar to what Argyris (1977) calls- "double-loop learning" and thus can be classified as "radical learning."

Tactical versus Strategic Learning

In the context of technological learning, Dodgson (1991) proposes that learning, on the basis of organisational aims, could be classified as strategic or tactical. Tactical learning relates to an immediate problem-solving action, such as an operational or product problem. The aim of this learning process is identifiable and the time-scale is short. In contrast, strategic learning involves an organisation developing skills and competences which provide the basis for future projects (ibid. p.140). Simply put, tactical learning is concerned with immediate problems, where as strategic learning involves the accumulation of technology/knowledge for its future potential. This theory bears some similarity to Argyris and Schon's (1979) distinction between "single-loop" and "double-loop" learning. Likewise, tactical learning can be categorized as "incremental learning" whilst, strategic learning can be associated with "radical learning."

Table 2.1 summarises the dyadic types of learning discussed above. In general, a learning process that leads towards more changes in cognition or long-term effects can be classified as radical learning. By contrast, learning that involved behavioural changes or short-term improvement can be categorized as incremental learning. Both types of learning are not mutually exclusive but overlapped. Learning leading towards cognitive changes triggers behavioural changes. In contrast, the results of behavioural changes could also evoke cognitive changes.

Table 2.1 Summary of Types of Organisational Learning and Changes

Types of Learning	Incremental vs. Radical Changes	Behavioural vs. Cognitive Changes
Single-loop Learning Double-loop Learning (Argyris, 1978)	Incremental Radical	More behavioural More cognitive
Low-level Learning Higher-level Learning (Fiol and Lyles, 1985)	Incremental Radical	More behavioural More cognitive
Operational Learning Conceptual Learning (Kim, 1993)	Incremental Radical	Behavioural Cognitive
Learning Unlearning (Hedberg, 1981)	Incremental Radical	More behavioural More cognitive
Adaptive Learning Generative Learning (Senge, 1990)	Incremental Radical	More behavioural More cognitive
Tactical Learning Strategic Learning (Dodgson, 1991)	Incremental Radical	More behavioural More cognitive

Learning scholars have claimed that both types of learning can enhance or hinder an organisation's survival and prosperity depending on certain conditions(Miner and Mezias, 1996). Incremental learning may put an organisation into a competency trap[1] (Levitt and March, 1988), whereas radical learning may engender organisational chaos if, for example, the organisation lacks funds to sustain this learning process. March (1991) suggests that firms should pay particular attention to the related trade-off between an allocation of resources to exploit existing practices (i.e. incremental learning) or to explore new alternatives (i.e. radical learning). That is,

[1] Levitt & March (1988: 322) suggest that: "a competency trap can occur when favourable performance with an inferior procedure leads an organization to accumulate more experience with it, thus keeping experience with a superior procedure inadequate to make it rewarding to use... Competency traps are likely to lead to maladaptive specialisation if newer routines are better than older ones."

focusing more on internal learning allows the firm to develop its own core competencies and appropriate more profits. Alternatively, external learning is required for the firm to guide more radical changes, develop a broader knowledge base and keep abreast of cutting-edge technologies (Grant, 1996b).

2.2.4 Technological Learning and Product Innovation

As previously discussed, no comprehensive model of organisational learning is widely accepted and conceptualisations of this topic tend to be diverse. However, by focusing on learning from the perspective of a firm's development of its technology, a better understanding of how an organisation's technological learning ability affects its product innovation has been gained.

2.2.4.1 Towards a Definition of Technological Learning

Dodgson defines "technological learning" as "the way which firms build and supplement their knowledge-base about technologies, products and processes, and develop and improve the use of broad skills present within their work forces" (1991: 135). He further states that technological learning includes two elements: invention and innovation. The former is characterized by search routines designed to bring knowledge into the firm, or to generate it internally. The latter is essentially concerned with providing a particular new product, or service for customers. Consistent with this reasoning, Bierly and Chakrabati define technological learning as " the acquisition and generation of explicit and tacit knowledge, which is used in improving either the development of new products or the production of current products" (1996a: 369). In developing a topology of technological learning, Malerba (1992) proposes six types of technological learning processes carried out by firms: learning by doing, by using, by searching, from advances in science and technology, from inter-industry spillovers and by interacting. The first three processes are internal to firms and are related to production activities, such as the use of products, machinery, inputs, and R&D functions in generating new knowledge. The latter three processes are external to firms and relate to the absorption of new product knowledge through collaboration with research institutes and strategic alliances, interacting with suppliers, users, and monitoring the movement of competitors and other firms in the industry (ibid. p.848). In brief, technological learning is a process for enhancing an organisation's technological capability. The development of such an ability is linked to different sources of knowledge that may either be internal or external to the firm. These definitions suggest that organisations take two different but complementary learning routes -internal and external - to achieve their product/process innovation.

2.2.4.2 Internal and External Learning

The results of internal learning are the generation of new knowledge within the organisation through the integration or recombination of functional know-how such as R&D, marketing, and production experiences (Bierly and Chakrabarti, 1996b). The outcome includes not only the extension of a specific knowledge area, but also the combination of existent knowledge in a new way. Learning at all three levels (i.e., individual, group, and organisational) is intrinsic to internal learning. Individuals learn from the organization and their work group as they become socialised to organisational beliefs, norms, rules, and procedures that make up organisational culture (March, 1991). However, work groups can also learn from individuals within that group, and this process is referred to as "intra-functional learning". Workgroup may also learn from other parts of the organization and this is known as "inter-functional learning" (Bierly and Chakrabarti, 1996b). Intra-functional learning creates new knowledge through the process of co-operative problem solving. Inter-functional learning is a function of the formal and informal communication systems within an organisation. It requires specialists from different areas to communicate information and develop their understanding of each other's knowledge so as to facilitate a successful integration of different specialties. When the dependence between different work groups is tightened and the difference between the cognitive frames of these groups is increased, then the need for inter-functional learning escalates (Daft and Lengel, 1986). An organisational culture that encourages communication and sharing is crucial for inter-functional learning (Mintzberg, 1991). Easterby-Smith (1986) emphasises the importance of evaluative activities in management that may contribute directly to this learning process.

External learning refers to the process of bringing knowledge from outside an organisation's boundaries into the organisation and integrating it into the organisation's internal knowledge base (Dodgson, 1991; Bierly and Chakrabarti, 1996b). It primarily occurs through boundary spanning individuals who search and link an organisation's internal network to external sources of information (Tushman, 1977). Tushman and Scanlan (1981) note that a boundary-spanning individual must have strong network links both outside an organisation and among peers so that he/she can transfer knowledge to others within an organisation. External learning may also take place through strategic alliances with other firms (Koza and Lewin, 1998), co-development with lead users and suppliers, and research collaboration with sources outside the industry such as, research institutes or universities (von Hippel, 1988, Leonard-Barton, 1995). As such, external learning enables firms to view issues from different perspectives whereas internal learning is mainly based on established organisational routines and biases. Leonard-Barton (1995) maintains that a firm without an effective external learning system could run the risk of losing its adaptability to environmental changes, obsoleting existing knowledge, thus jeopardizing its long-term survival.

2.2.4.3 The Impact of Technological Learning on Product Innovativeness

Learning theorists (Malerba, 1992; Bierly and Chakrabarti, 1996b; DiBella et al., 1996; Lynn et al., 1996; Lynn, 1997; Leonard-Barton, 1995) have greatly contributed to our understanding of how technological learning influences product innovativeness. These studies can be categorised in respect of: (1) learning skills (2) team learning strategy (3) learning process (4) learning styles and (5) learning factors.

In examining how a technological learning process affects product innovation, McKee (1992) developed a framework that integrates the learning skills required at each innovation/learning level (see Table 2.2). A firm's learning skills for incremental innovations, as illustrated, focus on inter-functional contacts within the organisation, to analyse problems in depth and to maintain current organisational structures, norms, and bases of technology. By contrast, an organisation committing itself to radical innovations requires a completely new set of learning skills (i.e. double-loop learning skills) because innovation that implies radical change is often accompanied by ambiguity, complexity, and re-orientation (Norman, 1971). Since radical innovations are inherently unpredictable and uncertain (Rice et al., 1998), learning skills linked to environmental contacts, exploratory methods and environmental adaptation capacity at individual, group and organisational levels, become critical. Thus, a focus on the development of marketing and technical capabilities enabling radical innovation is more external than internal.

Table 2.2 Learning Skills and Innovation/Learning Level

Learning Skills	**Innovation/Learning Level**	
	Incremental/Single-loop	Radical/Double-loop
Inter-personal	Inter-functional Contact -Inter-functional teams -Job rotation -Communication rewards	Environment Contact -Out-rotation -Outsider involvement -Boundary-spanning rewards
Analytic	Analytic Depth -Analytic training -Conclusion methods -Competency trap avoidance	Analytic Width -Skill acquisition -Exploratory methods -Confrontational methods
Organisational	System Maintenance -System stability -Camouflage avoidance	Organisational Adaptability -Unlearning, Error tolerance -Slack resources

Source: Adapted from McKee (1992)

Research on R&D team learning in association with new product development reveals three forms of new product team learning: within-team, cross-team (i.e., teams learn from other teams within their own firms), and cross-company learning (i.e., teams learn from other players outside their own firms) (Lynn, 1997, Lynn, 1998). Lynn (1997) proposed that within-team learning is the focal point when an organisation is involved in the development of incremental products because such products are sold to existing customers and cost reduction is of a primary concern, as observed in Figure 2.1. On the other hand, when a company tries to develop and commercialise new products which combine new technologies with new markets, both within-team and cross-company learning become critical because teams must complete thorough external technical analysis to learn about available technology and conduct comprehensive market surveys to analyse the competitors' marketing mix. This study also illustrates that innovations involving more than one dimension newness (i.e. technology and market) require cross-company learning. In other words, the learning orientation of those organisations involved in either new technology or new market development tends to be external rather than internal. Although indicating the importance of cross-company learning for radical innovation, this research contributes less to questions about how radical innovation necessitates external team learning and what key elements are generated from this learning. The latter question informs the knowledge-based view of the firm whose focus is on the development of organisational knowledge and the impact of a firm's innovation. To a great extent, findings derived from team learning strategy in truly innovative NPD projects are consistent with the importance of interpersonal learning skills proposed by McKee (1992) because the injection of both new market and technological knowledge is required.

Figure 2.1 Team Learning Patterns for Product Innovation

(Market)	Existing **(Technology)**	New
New	Evolutionary Market Innovation Cross-Company Learning	Radical Innovation Cross-Company Learning, Within-Team Learning
Existing	Incremental Innovation Within-Team Learning	Evolutionary Technological Innovation Cross-Company Learning, Cross-Team Learning

Source: Adapted from Lynn (1997)

Malerba (1992) classifies the process of technological learning according to sources of knowledge as internal learning processes (learning by doing, learning by using, and learning by research) and external learning processes (learning by interacting, learning from advances in science and technology, learning from inter-industry spillovers). External learning processes are essential to more novel innovations. For instance, learning by interacting with users can stimulate trajectories of horizontal product differentiation. Learning from advances in science and technology and inter-industry spillovers that allow new trajectories of product technologies leads firms to develop a really new product line that cannot be realised with current technologies. However, learning by searching particularly through internal R&D permits vertical product differentiation in terms of quality and performance. On the whole, external learning processes lead towards more significant changes than internal learning processes.

By focusing on the source of knowledge and the extent of change, Dibella et al. (DiBella et al., 1996) propose four learning styles as shown in Figure 2.2. When organisations need external knowledge for a transformative (i.e. radical) innovation, a certain extent of "acquisition" is recommended. "Adaptation" occurs when organisations take on incremental innovation as the basis of external knowledge. When organisations learn from their own product/process development and use that knowledge transformatively, they create "innovations" of their own. In brief, radical innovation, in addition to applying internal knowledge more transformatively, requires more external links to facilitate the acquisition of external knowledge than incremental innovation. When the development of a product/service is concerned with incremental innovation, a firm's learning focus is more internal than external. However, this matrix framework lacks a link indicating how firms are capable of converting internal knowledge into radical innovation. This link requires theories from the knowledge-based view of the firm where the development of knowledge is considered a dynamic process of internal and external learning.

Figure 2.2 Styles of Learning, Knowledge Sources and Learning Foci

(Knowledge Source)	Incremental (Learning Focus)	Transformative (i.e. Radical) (Learning Focus)
External	**Adaptation**	**Acquisition**
Internal	**Correction**	**Innovation**

Source: Dibella et al. (1996)

On the whole, radical innovations not only require more external product technologies to realize product development but also need more external market information for product marketing. As radical innovation is frequently associated with risk and uncertainty (Tushman and Anderson, 1986), Lynn et al. (1986) suggests that a learning process for marketing radical products places less emphasis on analysis and more on "probe and learning" from experiences (gained through exploring the external environment at every subsequent "probe"). Similarly, Bierly and Chakrabarti (1996b) empirically confirm that the correlation between technological learning and radical product development is higher when there is less commitment to current marketing efforts. Effective current marketing efforts may be a mobility barrier for a firm that is attempting to enter an unfamiliar market (Porter, 1980). Thus, exposure to external information is more crucial in marketing radical products than for incremental products.

A firm's ability to process market information and turn it into marketing knowledge also plays a key role in deciding the success of NPD projects. Cooper's (1979) NewProd projects identifies that effectively processing customer knowledge is a critical part in enriching new product characteristics. Li and Calantone (1998) also confirm that firms' marketing competencies in terms of market information acquisition, integration and application lead to greater product advantage. In his triple stream NPD process, Crawford (1997) further maintains that marketing ability starting from identifying target market to new product launch management is no less important in effectively handling the entire NPD process. Hence, the element of marketing knowledge informs technological knowledge acquisition.

This section briefly reviewed the impact of technological learning on product innovativeness. The empirical findings of the studies of technological learning approaches can be briefly summarized as:

(1) Learning by interaction with external actors is more critical than with internal

actors when a radically new product is involved (Malerba, 1992, McKee, 1992, Lynn, 1997, Lynn, 1998).

(2) External learning is the focal point for radical innovation, whilst internal learning is more concerned with incremental innovation (McKee, 1992, Bierly and Chakrabarti, 1996b, Lynn, 1997, Lynn, 1998).

(3) The focus for technical and market contacts to sources of information in radical innovation is more external than internal (McKee, 1992, Lynn et al., 1996).

(4) Exposure to external information is more critical for both developing and marketing radical products than incremental ones (McKee, 1992, Lynn et al., 1996).

2.3 Knowledge Management and Product Innovation

As the transition from an industrial to a knowledge-based economy takes place, the basic economic resource for a firm is no longer capital, natural resources, or labour, but is knowledge (Drucker, 1993). Knowledge affects the organisation as a whole but it is particularly important for new product development. Learning theorists taking the perspective of organisational knowledge have generated extensive explorations of product innovation, which are considered in this section particularly in relation to a firm's new product innovativeness.

2.3.1 Organisational Learning and Organisational Knowledge

Learning theorists (Duncan and Weiss, 1979; Huber, 1991; Garvin, 1993), who consider organisational learning to be about the effective processing, interpretation of and response to information and knowledge both inside and outside the organisation have noted that knowledge is the outcome of organisational learning. For instance, Garvin defines a learning organisation as "an organisation skilled at creating, acquiring, and transferring knowledge and insights" (1993, 80). Similarly, Huber argues that organisational learning occurs when: "an entity learns if, through its processing of information, the range of its potential behaviour is changed... and an organisation learns if any of its units acquire knowledge that it recognizes as potentially useful to the organisation." (1991, 89). Organisational knowledge in these contexts is viewed as information and knowledge available for decision-making and relevant to organisational activities. Learning leads to new knowledge development that in turn changes organisational behaviour.

The growth and change of organisational knowledge is particularly associated with the organisational learning process (Duncan and Weiss, 1979; Huber, 1991; DiBella et al., 1996; Drongelen et al., 1996; Sinkula et al., 1997). Daft and Weick (1984) propose that this process consists of three sequential phases: scanning, interpretation, and action taken. Using this widely accepted model, Table 2.3 summarizes several conceptual interpretations that attempt to bridge the gap between organisational learning and the evolving process of organisational knowledge development.

Table 2.3 Organisational Learning Process and Organisational Knowledge

Sources	Acquisition (Scanning) →	Interpretation →	Learning (Action Taken)
Huber (1991)	Knowledge acquisition -Congenital learning -Experiential learning -Vicarious learning -Grafting -Search & noticing	Information interpretation -Cognitive maps & framing -Media richness -Information overload	Organisational memory -Storing & retrieving information -Computer-based organisational memory
Duncan & Weiss (1979)	Knowledge acquired by individuals	Knowledge evaluated	Knowledge integrated
Navis et al. (1995)	Knowledge acquisition (The development or creation of skills, insights, relationships)	Knowledge sharing (The dissemination of what has been learned)	Knowledge utilization (The integration of learning so that it is broadly available and can be generalized to fit new situations.)
Drongelen et al. (1996)	From new information to internalized information	-Sifted knowledge -Stored knowledge -Opened up knowledge	Conveyed knowledge
Sinkula (1997)	Market information generation (affected by learning orientation)	Market knowledge dissemination	Marketing programme dynamics (organisational actions)

In the first phase, scanning (knowledge acquisition) occurs through congenital learning, experiential learning, vicarious learning and searching and noting (Huber, 1991), or individual learning (Duncan and Weiss, 1979) which then results in the development of skills, insights, and relationships (Nevis et al., 1995). Drongelen et al. (1996) interpret this stage as a move from new information to internalised information. Sinkula et al. (1997) suggest that an organisational learning orientation such as commitment to learning, shared vision and open-mindedness affects information generation that, as a consequence, affects knowledge acquisition.

Interpretation occurs where new knowledge is interpreted via cognitive maps and framing (Huber, 1991). Knowledge is then evaluated and disseminated (Duncan and Weiss, 1979; Nevis et al., 1995). Drongelen et al. (1996) propose that knowledge at this stage is sifted, stored and opened up to become conveyed knowledge. Finally, new knowledge is assimilated and stored as "organisational memory" (Huber, 1991). The act of learning provides new knowledge and information for interpretation. Feedback from organisational actions may provide new collective insights for an organisation's members. This dynamic integration of learning encourages growth and change in organisational knowledge. At the macro level, this three-stage interpretation model highlights a link in the relationship between organisational learning and organisational knowledge development.

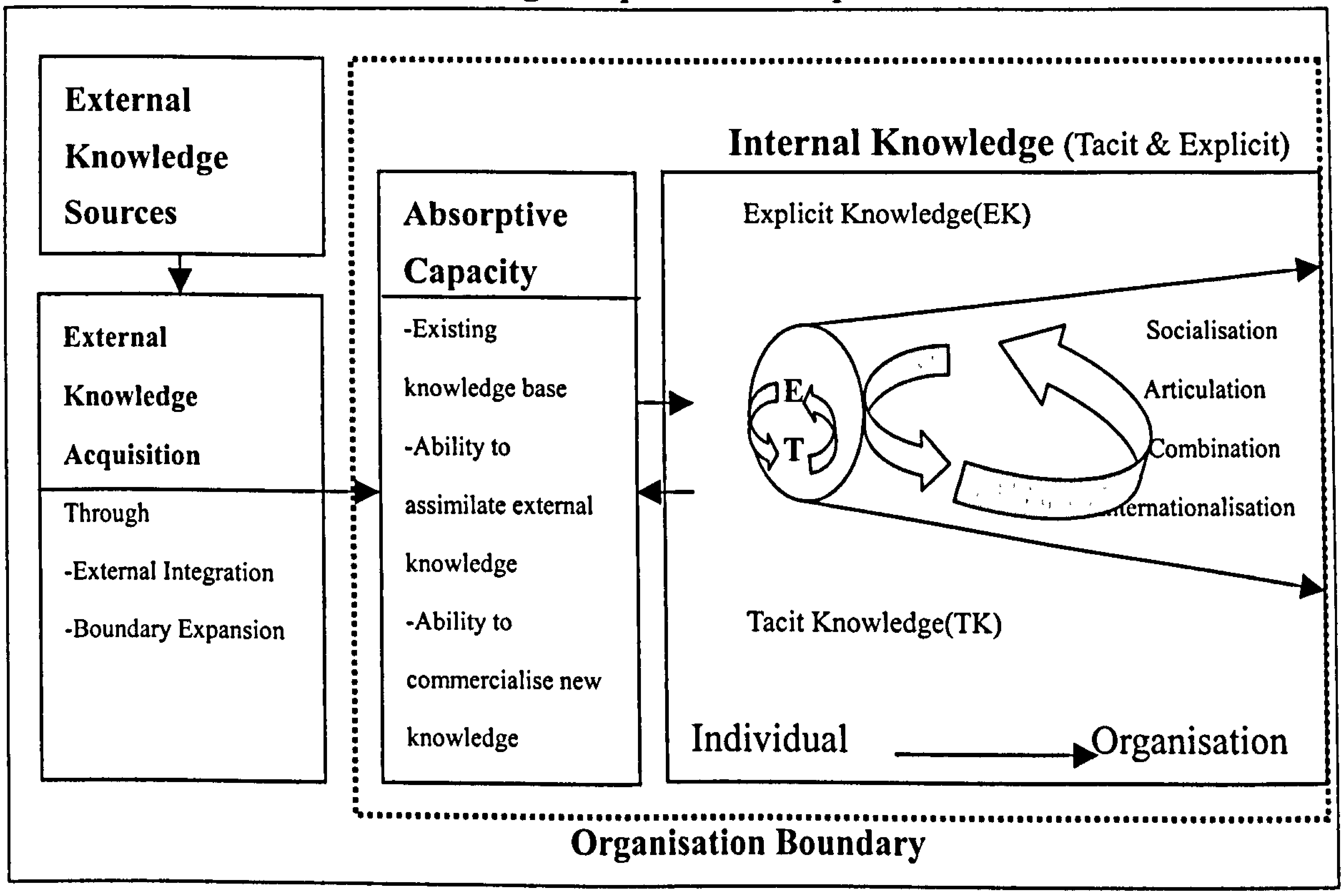
2.3.2 The Dynamics of Organisational Knowledge Creation

Traditional theories of organisational economics (e.g., Williamson's transitional cost) (Williamson, 1979) have limitations in explaining the phenomena and behaviour of inter-firm collaboration prevalent in today's highly dynamic industries. A number of scholars (e.g., Demsetz, 1991; Kogut and Zander, 1992; Nonaka, 1994;& Grant, 1996b) have suggested an alternative theory: "the knowledge-based view of the firm". This can be understood as a theory of the existence, organisation and competitive advantage of the firm based on the role of firms in creating, storing, and applying knowledge. A key issue in this stream of research has been an attempt to conceptualise how firms acquire, assimilate and accumulate their knowledge. For instance, Nonaka (1994) has suggested that knowledge creation is a process of transformation from individual tacit knowledge to firm-level explicit knowledge, and finally to everyone's tacit knowledge within the firm. Using product development cases from several Japanese large-sized companies, he proposes a model in which knowledge creation takes place through the dynamic processing of four modes of conversion (socialisation, externalisation, combination and internalisation) between tacit and explicit knowledge (ibid, p. 20). He further suggests that facilitative conditions of creative chaos, redundancy of information and requisite variety are required to enable the process to occur. This model is widely referred to in knowledge management literature as describing the processes involved in a firm's knowledge creation. However, this model does not describe how firms interact with and absorb external knowledge because it does not address how a firm can effectively scan, import and assimilate external knowledge.

In contrast, by focusing on the development of core capability, Leonard-Barton (1995) proposes four critical activities- (1) problem solving (present), (2) implementing and integrating (internal), (3) experimenting (future), and (4) importing knowledge (external)- which together make up a firm's knowledge creation process. The first three activities are internally focused. The last activity (importing and absorbing technological knowledge from outside of the firm) is externally focused and considered to be the most critical for filling a firm's technology gap. This model makes a good attempt at delineating managerial practices for the development of a firm's core capabilities through external knowledge importation, although it does not take the detailed dimensions of knowledge into account.

More recently, Grant (1996b) suggested two primary mechanisms - direction and organisational routines - to integrate the various knowledge dimensions. Direction provides the integration of knowledge through each specialist establishing rules, guidelines, and directives for members of organisations. This involves the codifying of tacit knowledge into explicit knowledge (Grant and Baden-Fuller, 1995). Organisational routines permit the integration of knowledge through patterns of interaction between different specialists. Routine is advantageous in economising the communication of tacit knowledge. However, the application of these two mechanisms in interpreting the dynamic process of organisational knowledge creation (e.g., how external knowledge is acquired through various linkages and internally assimilated and how an organisation creates its own knowledge from individuals to the organisation as a whole) is somewhat limited.

Figure 2.3 The Dynamics of Organisational Knowledge Creation – An External Knowledge Acquisition Perspective



Sources: Adapted from Levinthal & Cohen (1990), Nonaka (1994), Leonard-Barton (1995), Kim (1998) and McKee (1992)

Scholars (Loenard-Barton, 1995; Hamel, 1991) with the perspective of the knowledge-based view of firms suggest that importing knowledge beyond a firm's boundaries leads to building its core competencies. In particular, inter-firm collaborations facilitate integrating external explicit knowledge as well as bridge the gap between a firm's knowledge and product domains (Grant and Baden-Fuller, 1995). External knowledge acquisition is then becoming an increasingly critical element in a firm's knowledge-creating system.

Figure 2.3 is a simplified model that integrates external knowledge sources into knowledge creating processes. It shows that firms acquire external knowledge through external linkages (e.g., close contact with scientific communities, alliances & networks, and R&D contracts) and activities of boundary expansion (e.g., competitor/non-competitor benchmarking, hiring experts, external consultants). The extent of external knowledge absorption in both tacit and explicit dimensions depends on a firm's absorptive capacity (Cohen and Levinthal, 1990). Knowledge creation tends to occur faster and become larger in scale as firms are equipped with related prior knowledge and the abilities of assimilating and commercialising external knowledge. The outcome of knowledge conversion and creation (internalized knowledge) feeds back to absorptive capacity and in turn increases its level.

By integrating the elements of external knowledge sources and "absorptive capacity", this model further assists us in conceptualising how a firm creates knowledge. The key element of the model is the role of absorptive capacity that bridges the gap between external knowledge and internal knowledge. This conceptualisation of absorptive capacity goes beyond conventional interpretations of how firms acquire and assimilate external knowledge and convert it into internalised knowledge. Although the importance of acquiring external technology/knowledge is well known in NPD research (Cooper, 1992; Day, 1991; Li and Calantone, 1998; Kotabe and Swan, 1995; Pennings and Harrianto, 1992a; Pennings and Harrianto, 1992b), few have investigated how and to what extent absorptive capacity, together with external linkages, affect a firm's product innovation. The subject of external knowledge assimilation in association with absorptive capacity will be discussed in Section 2.5.

2.3.3 The Impact of Knowledge on Product Innovativeness

There is an enormous list of criteria concerned with factors that affect the success of new product development (e.g., Rothwell et al., 1974; Cooper, 1979a; Maidique and Zirger, 1984; Maidique and Zirger, 1985; Cooper and Kleinschimidt, 1987; and Ziger and Maidique, 1990). For instance, the SAPPHO study (Rothwell et al., 1974) proposes that product success is primarily dependent upon the following five factors:

(1) Understanding of user need

(2) Attention to marketing and publicity

(3) Efficiency of development

(4) Effective use of outside technology and external scientific communication, and

(5) Seniority and authority of responsible managers.

By way of contrast, the three general areas strongly correlated with new product success, as indicated by the results of the Project NewPro (Cooper, 1979a), are:

(1) Product uniqueness and superiority

(2) Market knowledge and marketing proficiency, and

(3) Technical and production synergy and proficiency.

In addition, the Stanford Innovation Project (Maidique and Zirger, 1984) suggests that market knowledge, proximity of new product technologies and markets to existing strengths, and planning and coordination of new product processes are key factors that affect product outcome. The findings of these early large-scale studies suggest that the following two types of product knowledge are associated with NPD success: first, marketing knowledge gained through customer interaction; and second technological knowledge (for both product and process) developed internally and externally. Based on these studies, the impact, in particular, of external knowledge on product innovation demands special attention.

Given the learning nature (i.e., a firm's knowledge creation) of NPD activities, there is increasing application of organisational knowledge development to the study of NPD. Table 2.4 summarises the findings of recent research that both conceptually and empirically examine how different knowledge (in terms of sources and dimensions) influence a firm's capacity for product innovation.

Table 2.4 Summary of Impact of Knowledge on Product Innovation

Source	Knowledge Sources	Dimensions of Knowledge	Impact of Knowledge on Product Innovation	Other Contextual Factors	Types of Products
Bierly & Chakrabati (1996)	Internal: R&D, production, marketing External: Users, Suppliers, Science & Technology Linkage	Internal Technology; External Technology	The narrower the R&D knowledge base, the higher the product innovativeness.	Manufacturing flexibility, financial flexibility, marketing flexibility	Industrial products
Li & Calantone (1998)	External: Customers, Competitors Internal: Marketing-R&D Interface	Market Knowledge Competence	Market knowledge competence has a significant influence on new product advantage (i.e., quality, reliability, newness, and uniqueness)	Customer demandingness, competition intensity, technology changes top management's perceptions of market knowledge	Software
Madhavan & Grover (1998)	NPD Team	Tacit Knowledge; Explicit Knowledge	The more innovative the product is, the more tacit knowledge there is to be converted. Thus, the greater the impact of T and A-shaped skills of team members.	Endogenous Variables: Trust in team members, information redundancy, rich personal interaction Exogenous Variables: T and A-shaped skills, shared mental models, NPD routines	Conceptual Development
Malerba (1992)	Internal: R&D, production, marketing External: users, suppliers, science & technology links	Internal Technology; External Technology	Both internal and external technologies have a positive impact on a firms' incremental product innovation.	Industrial life cycle Demand variables	Industrial products
Pennings & Karianto (1992)	External: technological alliances	External technology	Technological networking has a positive relationship with a firm's technological innovation. Firms with extensive networking are more likely to implement innovation externally.	Industrial factors Organisation size Intensity of Competition	Banking
Souder and Chakrabarti (1979)	Internal: R&D, marketing & sales, top management External: competitors, customers, suppliers, technical agents	Internal Technology External Technology	The majority of a product's origins depends upon internal knowledge sources.		Consumer and industrial products

Using the notion of tacit knowledge, Madhavan and Grover (1998) propose that NPD is the process of converting embedded knowledge into embodied knowledge (explicit knowledge). The development of more novel products entails further efforts to more effectively convert tacit knowledge. Therefore, more NPD team members equipped with T and A-shaped skills[2] are required to facilitate this conversion process. Madhavan and Grover's study may be the first that attempted to theorise tacit knowledge within the context of new product innovation.

Another strand of research centres on the impact of market knowledge competence on new product advantage (Day, 1991; Cooper, 1992; and Li and Calantone, 1998). For instance, by testing the relationship between new product advantage and market knowledge competence (as composed of customer knowledge process, competitor knowledge process, and the market-R&D interface) Li and Calentone (1998) reveal that each component of market knowledge competence is positively associated with product advantage in terms of quality, reliability, newness and uniqueness. Similarly, Day (1994) confirms the importance of customer knowledge for the success of new product development in several industrial settings.

Research on technological alliances (Bierly and Chakrabati, 1996a; Deeds and Hill, 1996; Kotabe and Swan, 1995; Li and Calantone, 1998; Pennings and Harrianto, 1992a; Pennings and Harrianto, 1992b; Rothwell and Dodgson, 1991) has particularly extended the understanding of ways that external knowledge affects a firm's new product development performance. For example, Souder and Chakrabati (1979) suggest that the correlation between a firm's capability for technological learning

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[2] Individuals with T-shaped skills are those who are not only experts in specific technical areas but those who are also intimately acquainted with the potential systemic impact of their particular task. On the one hand, they have a deep knowledge of discipline like ceramic materials engineering (for example), represented by the vertical stroke of the T. On the other hand, these ceramic specialists also know how their discipline interacts with another, such as polymer processing- this is represented by the T's horizontal top stroke (Iansiti 1993: 139). Leonard-Barton (1995: 77) describes A–shaped skills as: "some individuals embody technology fusion. Some people actually learn more than one discipline (although more than two is unlikely) and so have two different disciplinary 'legs' on which to stand."

(both internal learning and external learning) and its radical product development is higher when this correlation is compared with incremental product development. In addition, the breadth of a firm's R&D intensity moderates the relationship between technological learning and the level of product innovativeness for both incremental and radical product development. That is, given a technological learning opportunity, firms with a broad base of R&D knowledge in their product domain are more likely to develop relatively new products. Bierly and Chakrabati (1996: 377) conclude that: "it is more important for organisations to develop a dominant strength in one area of expertise so that firms have a core competence than it is for them to have a wider knowledge base for increased flexibility." In general, empirical findings from these studies demonstrate that knowledge gained through technological networking, such as licensing, joint ventures and long-term contracts greatly influence a firm's novel product development as well as its tendency for adopting new innovative technology. These findings highlight the importance of absorbing external knowledge (through inter-firm learning) and networking to respectively boost product innovativeness of the firm's technological innovations and, facilitate access to strands of technological knowledge that may be alien.

In brief, empirical studies concerned with the impact of product knowledge (both marketing and technological knowledge) on the nature of product innovation have arrived at divergent results. Most of this research centres on the level of product innovativeness or product advantage that is influenced by internal and/or external acquired knowledge. There is, however, little research addresses ways in which a firm's accumulation of its stock of new product knowledge through external linkages contributes to new product performance. The following questions remain unanswered. First, are the mechanisms of knowledge creation within internal subunits and with external parties for new product development different? Second, is it the case that extensive internal effort is crucial for effective knowledge acquisition? Although Souder and Chakrabati (1996) reveal the moderating role of a firm's R&D intensity in the relationship between its technological alliances and product innovativeness, they do not show what constitutes the outcome of the firm's technological learning effort. Neither, do they illustrate the extent to which the results of this learning effort influence product innovativeness. There is also no consideration of whether R&D intensity moderates or mediates the relationship between the extent of technological linkages and the results of this learning effort. This suggests that there is a need to revisit the dominant conceptual framework, and, more explicitly, the mechanisms whereby firms assimilate external knowledge. To this end, it is important to reassess the role of absorptive capacity. Accordingly, following on discussion on the role of external linkages in product innovation (Section 2.4), Section 2.5 is devoted to a review of the concept of absorptive capacity and its impact on a firm's acqusition of external knowledge.

2.4 Product Innovation: An External Linkage Perspective

This section considers NPD learning in relation to external linkages, such as customers, suppliers, cooperating firms, research institutes and universities. In particular, the emphasis is on how and to what extent various types of external linkages contribute to firms' gains in new product related knowledge and NPD efforts.

2.4.1 The Importance of External Linkages

Jack Welsh of General Electric argues that the traditional boundaries of hierarchy, function and geography are no longer appropriate for tasks confronting business day (Barlett and Ghoshal, 1995). He advocates a new organisational mode – "a boundaryless company." Similarly, Leonard-Barton (1995: 135-136) states that: "very few, if any, companies can build core capabilities without importing some knowledge from beyond their boundaries. Therefore, successfully absorbing technological knowledge from beyond the periphery of the firm is as important a managerial activity as integrating it across internal boundaries – and no less difficult." Empirical evidence from innovation management literature confirms that firms that do not expand into new technical sub-fields tend to perform poorly in their established businesses, and firms that expand beyond their established business survive longer and achieve a greater subsequent market share (Michell and Singh, 1993; Bierly and Chakrabarti, 1996b). Organisational learning literature also advances the importance of multi-disciplinary involvement with the learning process (Argyris, 1977; Fiol and Lyles, 1985; Senge, 1990; Garvin, 1993). For instance, Marquardt and Reynolds (1994) argue that the ultimate purpose of multidisciplinary networks is to transform firms into learning organisations, the learning disposition of which facilitates and maximises the exploitation of both internal and external knowledge. Moreover, strong linkages to external resources not only stimulate learning but also allow firms an opportunity to rethink the validity of their "theory-in-use"; justifying the relevance of their current operations. As such, these linkages provide ample opportunities for firms' double-loop learning (Argyris, 1977), or high-level learning (Fiol and Lyles, 1985).

Moreover, strategic researchers confirm that sustaining a competitive advantage under conditions of dynamic competition requires continuous integration, by extending existing capabilities to encompass new knowledge outside a firm's boundaries and reconfiguring existing knowledge with new patterns of integration (Porter, 1980; Kogut and Zander, 1992; Grant, 1996a). Grant (1996b) proposes three basic alternatives for the knowledge transfer and integration of organisational capability: (1) internalization within the firm, (2) market contract, and (3) relational contacts (which create various forms of firm networks). The latter two alternatives emphasise the need for external linkages for knowledge integration. Other researchers (Link and Tassey, 1987; Hamel, 1991; Rothwell and Dodgson, 1991; Powell et al., 1996) discuss the importance of complementary technologies from different industrial sectors and consider collaborative practices from external linkages (such as strategic alliances, R&D consortia, networks) as a powerful method for knowledge creation and transfer, in spite of the risk of knowledge erosion. For instance, Link (1987) suggests that a firm's internal R&D functions and external technology sources should be united into one focused development process as they are continuously facing more "competence-destroying" technological change (Tushman and Anderson, 1986). Internal R&D serves as the development of firm-specific technical knowledge, whereas external sources are utilised to acquire generic technological knowledge. Rothwell and Dogson (1991: 128) argue that "it is not only in-house R&D commitment that should be a focus of corporate technology strategies; also of extreme importance is having an external orientation directed towards creating a network of linkages plugging the firm into appropriate sources of complementary technological information and expertise." Similarly, Teece (1986) maintains that association with external knowledge sources facilitates the process of gaining access to and acquiring complementary knowledge.

Empirical evidence shows that external information from the marketplace (such as customers and key suppliers) is not only beneficial in defining product projects, but also pivotal in guiding the rest of the NPD process (Dougherty, 1990; Song and Parry, 1992). Scholars within this discipline, therefore, suggest that a close link between customers and market intelligence sources is required for product innovation (Gemunden et al., 1992; Peacock, 1993). Japanese firms are more adept at carrying out innovation based on their integrating NPD activities with external collaborators such as key users in the marketplace (Nonaka & Takeuchi, 1995). For instance, Matsushita Electric Co., in working with several professional pastry bakers, introduced the first fully automatic bread-making machines for home use. The advantage of Japanese system is attributed to firms' external integration skills, such as their better communication systems and more effective supplier networks between functional departments within the firm and the marketplace (Nonaka, 1994).

The creation and accumulation of knowledge cannot exist without quality information processing. Technology-related information is indeed the driving force that makes product innovation possible (Fish, 1979; Baston, 1987). Research suggests that external linkages with universities and national research institutes are vital sources of technological information (Wigand and Frankwick, 1989; Gemunden et al., 1992). In addition, joint research with firms from other industries benefits a firm in its absorption of new technology (Kodama, 1992; Gemunden et al., 1992; Samuels, 1994) and in its development of more innovative products, which may require multi-faceted technologies.

This shows there is a need for contemporary organisations to establish linkages with relevant external parties. Today's increasingly competitive environment has made this imperative for continual development of innovative products. These linkages both activate learning and provide a new perspective for firms to revalidate their current domain knowledge and technology. As a result, firms are able to generate more up-to-date knowledge (both marketing and technological knowledge) that is vital in their next run of new product development.

2.4.2 Modes of External Linkage and Sourcing Technological Knowledge

Rothwell (1992: 232) states: "Today it seems progressively less meaningful to consider solely 'firm A and innovation' or 'firm B and innovation' when it is becoming evident that innovation increasingly derives from a network of companies interacting in a variety of ways." The trend for establishing various forms of alliances is indeed quite evident in today's industries, particularly in those highly dynamic sectors such as computers, communications and biotechnology. Firms form alliances for various reasons. Proponents of knowledge-based view of the firm highlight the need for inter-firm collaboration because of a gap between the firm's product domain and knowledge domain. For instance, Grant and Baden-Fuller (1995) posit four sets of circumstances for inter-firm collaboration: (1) integrating explicit knowledge (2) incongruent product and knowledge domains (3) the role of uncertainty in knowledge-product linkage and (4) dynamic effects in knowledge-product linkages. Other innovation scholars (Tidd et al., 1997) view the need for inter-firm collaboration from the perspective of the improvement of a firm's productivity. These includes factors such as the cost of technological development, the timing of market entry, the risk of development and/or market entry, scale economies in production, and the time taken to develop and commercialise new products (ibid, p.198). In his study of 4192 strategic technology alliances, Hagedoorn (1993) notes that complementary technologies, reductions of time-span for innovation, and market access and/or influence to the market structure are firms' most frequently cited motives for inter-firm collaboration. His findings further indicate that firms in more dynamic industries such as IT consider complementary technology and a reduction of time span for innovation as their primary motives for technological partnering, whereas firms from mature industries such as the chemical, consumer electronic, and food and beverage list market access and restructuring as major determinants in entering an alliance. Along with the perspective of complementary technology/knowledge in the contexts of NPD, the primary consideration for collaboration particularly for those firms in dynamic industries lies in the accumulation of both technological and marketing knowledge, leading to the effectiveness and efficiency of product and market development.

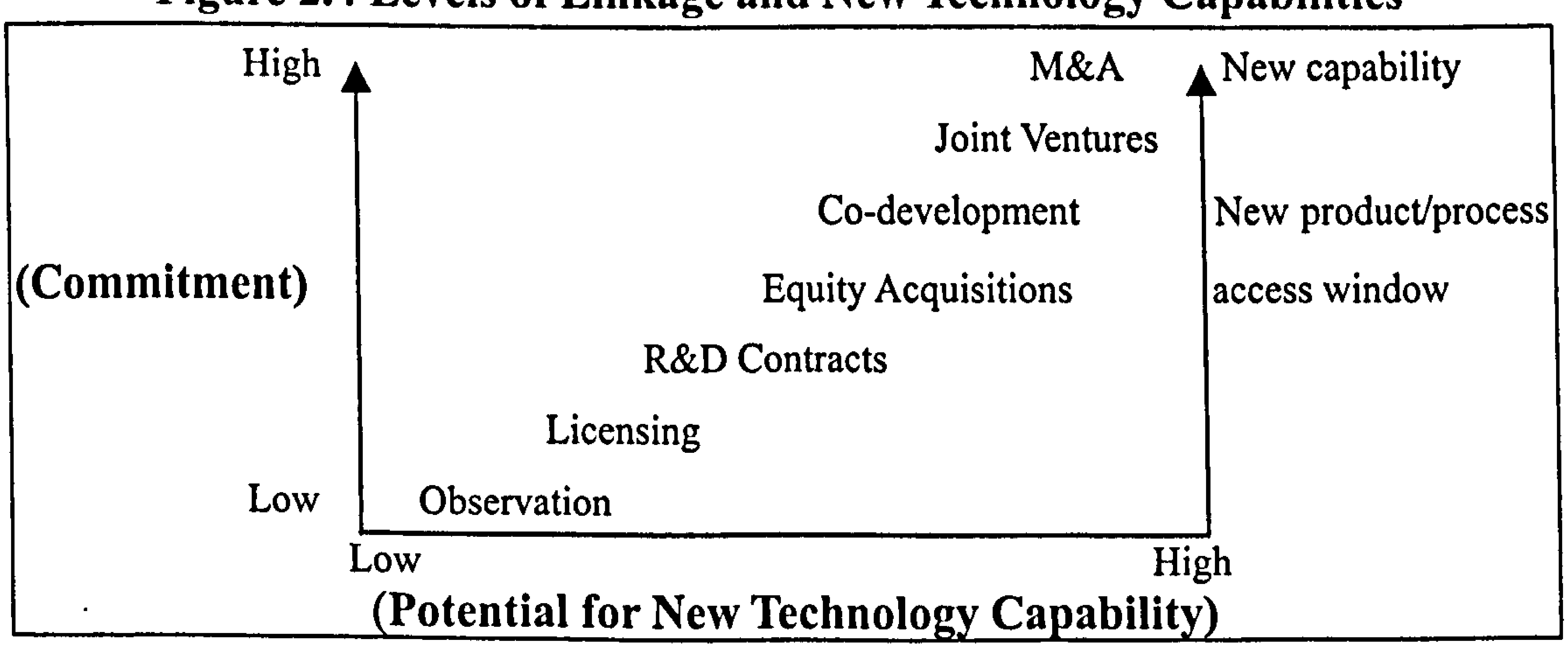
Previous literature has examined a variety of modes for inter-firm collaboration such as subcontracting, licensing, collaborative R&D, long-term contracting, strategic alliances, and joint ventures. Hagedoorn (1993), examined technological alliances in various industries and confirmed that complex inter-organisational modes of cooperation, such as joint ventures and minority investment, are motivated by long-term market and technology-mediated objectives. In contrast, contractual alliances, such as sub-contracting and licensing are primarily aimed at short-term technological achievements. Consistent with this line of research, Tidd et al. (1997) argue that in practice, most sub-contracting or outsourcing arrangements are based on potential and/or a desire to save costs. Hill's study (1992) indicates that the speed of imitation, the extent of first mover advantages, and the transaction costs of licensing play a major role in a firm's decision to license or not. Licensing may offer a firm the opportunity to exploit the intellectual property of another firm, but it tends to be restricted by the licenser. A survey using data from the chemical, engineering and pharmaceutical industries found that the primary reason behind licensing is related to speed of access, rather than cost (Atuahene-Gima and Patterson, 1993).

The benefits of collaborative R&D for firms are linked to the complexity and costliness of product development, the need for input from outside expertise, and shorter development time (Gugler, 1992, Bruce et al., 1995). Amongst those benefits, the most commonly cited is that organisations gain access to new technology and expertise to complement their product development (Dodgson, 1993b). The increasing phenomenon of technology convergence or "technology fusion" (Kodama, 1992) may partly account for R&D collaboration (Blonder and Pritzl, 1992). Rothwell (1991) maintains that firms taking part in collaborative R&D have a tendency to actively seek external ideas or technologies. Furthermore, Dodgson (1993) argues that R&D alliances may serve as means of overcoming barriers to entry into overseas markets. The rationale for joining an R&D consortium, a special form of collaborative R&D (consisting of a number of organisations working together on a relatively specific project), includes pooling scarce expertise, sharing the risk of research and conducting pre-competitive research and setting standards (Tidd and Trewhella, 1997). Tidd et al. suggest that R&D consortia tend to focus on more basic research issues, whereas strategic alliances in NPD (that typically take the form of an agreement between two or more firms to co-develop a new technology or product) involve commercialised development projects. Thus, clearly, R&D linkage activities in this type of collaboration (i.e. collaborative R&D, strategic alliances, joint ventures) are more strategic in nature.

In general, collaborative modes, such as sub-contracting and licensing, tend to result in a short-term, tactical achievement; whereas those modes that require a relative degree of integration, such as strategic alliances, collaborative R&D and joint ventures, are likely to generate long-term, strategic achievement (Tidd and Trewhella, 1997). The latter modes, which take strategic significance into account, are more appropriate mechanisms for technological learning than those simply for tactical purposes.

Leonard-Barton (1995) suggests the following framework to show the relationships that exist between the potential for new technological capabilities, modes of linkage, and a firm's commitment. As Figures 2.4 indicates, technological observation, licensing, and R&D contracts are generally less likely to achieve new technological capabilities. These linkages, primarily, provide windows of access to new technology. In contrast, equity acquisitions or co-development that offer opportunities for firms to examine technology in depth, and joint ventures or merge and acquisition (M&A) that directly transfer technology in its full context, provide firms with new technology and capabilities (Leonard-Barton, 1995: 153-154). In other words, the more integrative modes of collaboration, including joint ventures, R&D co-development and equity acquisitions, provide more effective channels for acquiring new technology than less integrative modes, such as contracting and licensing. As a result, the acquisition and accumulation of new technology, that a firm lacks, through more integrative modes is likely to lead to a more innovative product development when fused with its technological expertise.

Figure 2.4 Levels of Linkage and New Technology Capabilities



(Source: Leonard-Barton, 1995)

Tidd and Trewhella (1997) offer another perspective of firms' attitudes towards technology acquisition by identifying four dimensions of characteristics of technology: (1) competitive significance of the technology (2) complexity of the technology (3) codifiability (how easily the technology is embodied) (4) credibility (political profile of the technology). Basically, the more complex a product's technology is (i.e. a product with a high number of component technologies), the greater the tendency for a firm to acquire technology through collaborative arrangements such as R&D collaboration and joint ventures. This is due to the specialisation of know-how. By contrast, in less complex product technology situations, firms simply engage in sub-contracting or licensing to gain advantages associated with the division of labour. However, when a product's technology is of less codifiability nature (a high degree of tacitness in its nature) its transfer requires experience and face-to-face interaction. In this case, inter-firm linkage modes, such as joint ventures and/or equity acquisition, are effective in gaining tacit knowledge (ibid. 1997).

Investigation into how that corporate strategies affect a firm's tendency to acquire technology suggest that the strategy of technology diversification is a key factor that gives rise to increasing external linkages (Granstrand et al., 1992). The underlying rationale is that since the technology diversification strategy leads to a broader requirement for different component technologies, firms need to develop more linkages.

The technology life cycle also affects a firm's decision regarding its acquisition strategy. For instance, Lambe and Spekman (1997) argue that firms are more inclined to enter into technology sourcing alliances when facing new technology that has already taken hold. But, as the technology cycle moves into its later stages, firms often shift their focus from alliances to internal development because the technology and market requirements become more stable.

2.4.3 External Linkages for Knowledge Acquisition and Product Innovation

2.4.3.1 Classification of External Linkages

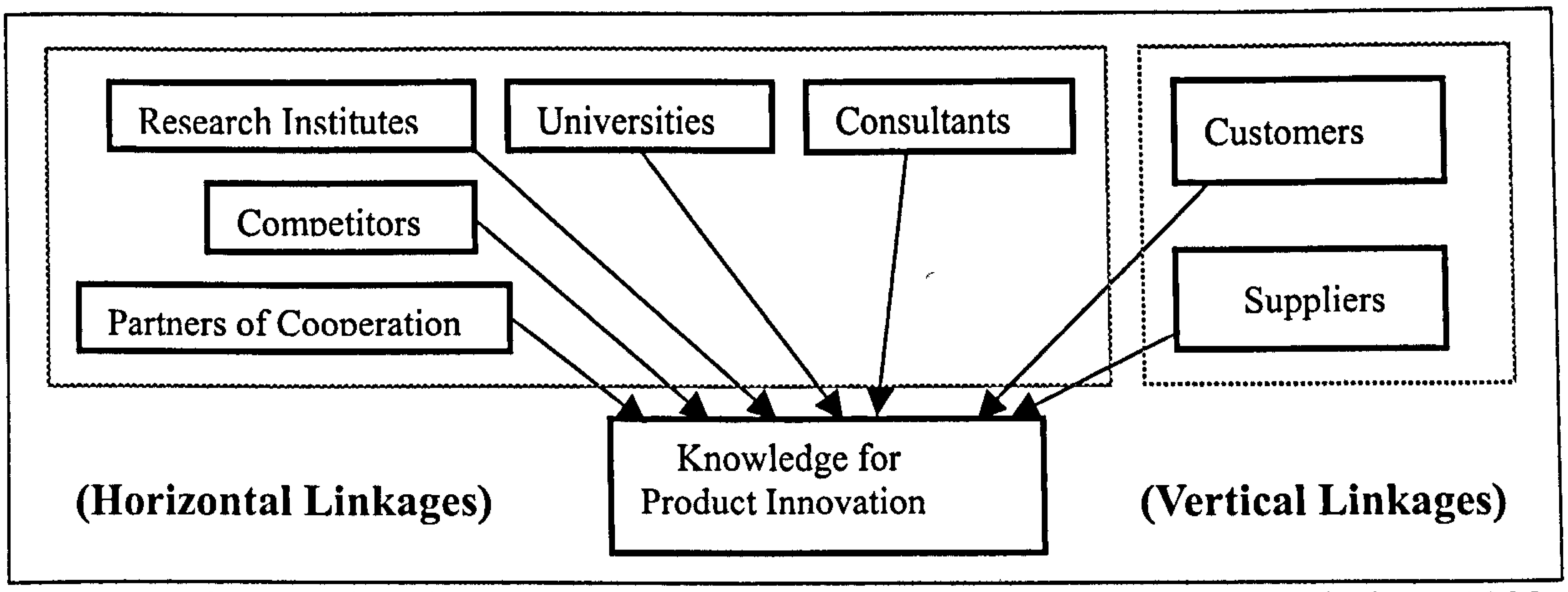
Firms' external linkages can be distinguished in different ways. For instance, on a broad industry scale Porter and Fuller classify 'X form' and 'Y form' coalitions between competitors. They state that: "...in X coalitions, firms divide the activities within an industry between themselves. In Y coalitions, the firms share the actual performance of one or more value activities" (1986: 336). Tidd et al. (1997a) suggest a traditional classification: vertical or horizontal. They propose that vertical relationships are to cooperate with and/or integrate suppliers and customers while horizontal relationships are to collaborate with potential competitors, research institutes, and universities, over cost and timeliness advantages, complementary technology or marketing know-how.

Hennart, based on the theory of transaction cost, identifies two contrasting purposes for differentiating joint ventures- scale or link types. He states: "scale joint ventures are created when two or more firms enter together a contiguous stage of production or distribution or new market... (whilst) in link joint ventures, the position of the partners is not symmetrical" (1988: 362). On this basis, Dussauge et al. (2000) further explain that scale alliances allow partners to achieve economies of scale and to reduce excess capacity. In contrast, link alliances aim at integrating complementary skills and resources in a way where each partner contributes. Similar to Hennart's classification, Sakakibaba (1997) defines alliances according to either cost-sharing or skill-sharing motives and found that firms with homogeneous capabilities tend to form cost-sharing alliances, whilst those with heterogeneous capabilities tend to form skill-sharing alliances. Moreover, Nicholls-Nixon (1993) classifies alliances in two categories: equity-based and non-equity based. Equity-based alliances refer to joint ventures, R&D partnerships, minority investment and acquisitions; whereas non-equity based alliances refer to contracts and licensing agreements. Equity-based alliances are considered to be a more effective mechanism for acquiring technology that is more complex, un-codified, and difficult to be assimilated than non-equity based ones.

The classifications reviewed above are tailored to service each research's particular purpose. There is as yet no empirical work examining the nature of vertical versus horizontal alliances and how this affects a firm's product innovativeness as well as the effectiveness of its new knowledge accumulation. Thus this research adapts Tidd et al.'s (1997a) perspective with an attempt to investigate this relationship. Figure 2.5 briefly illustrates knowledge sources of external linkage for product innovation by categorising them into horizontal and vertical linkages. In this classification, parties to vertical linkages are those involved in a product/project's value chain activities. Typically, a NPD project's upstream suppliers and downstream customers or channel members are in this category. In contrast, parties to horizontal linkages are those, which a firm has no direct business relationship but can gain access to them through contract arrangements, strategic alliances and/or equality acquisitions. This category in the context of NPD includes industrial research institutes, universities, cooperating firms and third party technical consultants.

A detailed discussion concerning the effect of each linkage on both gains in new product knowledge (both marketing and technological) and the level of product innovativeness in the context of new product development follows.

Figure 2.5 Knowledge Sources of External Linkage for Product Innovation



Sources: (von Hippel, 1988, Rothwell and Dodgson, 1991, Malerba, 1992, Leonard-Barton, 1995)

2.4.3.2 NPD Learning Through Vertical Linkages

Customers

As discussed in Section 2.3, market knowledge gained through customer interaction is crucial in deciding the outcome of new product performance. Empirical evidence from innovation literature (Rothwell et al., 1974; Cooper, 1979a; Cooper, 1981; Bonnet, 1986; Dougherty, 1990; Song and Parry, 1992) suggest that an accurate understanding of customers' needs, wants, preferences and responses to existing products is the factor which discriminates most significantly between commercially successful and unsuccessful, industrially innovative projects. Drucker (1985) notes that a firm's process of generating knowledge about customers and competitors underlies its competence in new product development.

Research on a firm's ability to process customer knowledge has attested to the impact of customer intimacy on new product performance (Cooper, 1979b; Sanchez and Elola, 1991; Li and Calantone, 1998). Li and Calantone (1998) for example, claim that a customer knowledge process consists of three sequential aspects: customer information acquisition, interpretation and integration. Following this process model, they suggest that a more intense process of customer knowledge in new product development leads to greater product advantage. Similarly, Sanchez and Elola (1991), in a study of 56 industrial organisations, argue that a firm's activities regarding the market knowledge process provide great stimuli to innovation. Cooper (1979), in his research on NewProd projects, notes that an effective process of attaining customer knowledge plays a crucial part in enhancing new product characteristics. Ottum and Moore (1997) further suggest that understanding customer wants and needs ultimately comes down to a company's capability for gathering, sharing, and using market information, which in turn plays a pivotal role in determining the success and failure of new products. Although the integration of customer knowledge into the design process has a decisive role in new product performance, there is little research devoted to investigating the extent to which this integration accounts for the level of product innovativeness in comparison with other external links.

The success of innovative products in many industrial sectors is closely associated with active user involvement in defining product specification or testing a prototype (von Hippel, 1976; von Hippel, 1978; Rothwell, 1986; von Hippel, 1986; Brown, 1991). Von Hippel (1976 and 1978) suggests that industrial users (in sectors such as scientific instruments, medical equipment and semiconductor process machinery) do not only play a dominant role in innovation, but they also play an active part in re-innovation. Therefore, instead of a traditional manufacturer-active paradigm for consumer products, von Hippel (1978) argues for a customer-active paradigm, in which the user plays the key product-initiating role for the generation of industrial product ideas. In addition, he further urges industrial firms to identify, analyse, and work closely with lead users for the source of new product concepts (von Hippel, 1986).

In his widely referred to model (coupling model/fifth model) of the innovation process, Rothwell (1986: 112) emphasises the importance of user-technology provider-producer links and states: "the overall pattern of the innovation process can be thought of as a complex net of communication paths, both intra-organisational and inter-organisational, linking together the various in-house functions and linking the firm to the broader scientific and technical community and to the marketplace. In other words, the process of innovation represents the confluence of technological capabilities and market needs within the framework of the innovating firm." This model strongly suggests that industrial firms couple their technological capabilities to user need at the earliest possible stage. Even as the project develops, the firm must remain coupled to the marketplace in order that changing market requirements can be detected and fed back to the development process to produce a modified design. However, this stream of research mainly uses cases from traditional industrial sectors such as instruments, equipments, and automobiles where speed of technology change is somewhat slow. In comparison, in today's IT industry, product technologies are evolving rapidly. IT users' knowledge is limited to currently available products and is therefore of limited use in guiding new product design.

Suppliers

Relations with suppliers are one of the five forces driving industrial competition (Porter, 1980). Porter groups suppliers with functional units into the upstream value-chain, a model that detects a firm's competitive advantage (Porter, 1985). Special supplier firms in some industries design, develop, and build specialised inputs for production, and interact closely with their (often large) technically progressive customers. In Silicon Valley, for example, computer firms and their suppliers build collaborative relationships so as to spread the costs and risk of developing new products, whilst at the same time enhancing their ability to rapidly adapt to changing markets and technologies (Saxenian, 1991). Von Hippel (1988) suggests that suppliers as well as customers are primary sources for innovation ideas. The links to suppliers, indeed, have an important role to play in product innovation.

Early comparative research on Japanese and US car manufacturers confirms the importance of supplier integration on new product development (Aoki, 1986; Blenkhorn and Noori, 1990; Kamath and Liker, 1994; Dyer, 1996). For instance, Dyer (1996) claims that differences in asset specialisation within supplier networks may explain performance gaps between Japanese and US car manufacturers. His findings suggest that human asset co-specialisation of the supplier-automaker network has a positive association with both new product quality and cycle time. He, therefore, argues that a tightly integrated supplier network, characterised by proximity and a high level of human cò-specialisation outperforms a loosely integrated supplier network (Dyer, 1996: 271). In testing the effects (as to the extent to which a new product is based on unique parts developed in-house) on new product development performance, Clark (1989) concludes that amongst Japanese car manufacturers intensive supplier involvement and a high level of unique parts (such as those used in engineering) accounts for a significant part of their advantage in lead-time and costs over their US counterparts. In particular, intensive supplier involvement allows auto firms to benefit from a supplier's know-how and to capture it more effectively in the design of the product and in the conduct of the development process. Blenkhom and Noori (1990) note that Japanese parts-suppliers participate in an early stage of NPD, often in advance of their OEM partners. This early and intensive involvement allows the supplier's NPD processes of designing, prototyping, testing and specification setting to be carried out in conjunction with their OEM customers, in much the same way as partners in a project design team would operate. As such, these lines of research commonly suggest that the degree and stage of supplier involvement in NPD is a prime contributor to differing performance between Japanese and US automakers.

However, more recently the empirical work of Takeishi (2001) indicates that the significance of the automaker's integrated problem-solving process with suppliers is related to effective internal coordination inside the automaker's organization, particularly within various engineering functions and between engineering and purchasing functions. This implies that effective external integration also needs effective internal capacity to effect the success of new key part development. In other words, a relative internal capacity and an early supplier involvement together affect an automaker's new product performance.

The integration of key suppliers in the NPD process is deemed an important resource for developing quality new products faster and at a lower cost (Clark, 1989; De Mayer and van Hooland, 1990; Ragatz et al., 1997; Droge et al., 2000). In examining supplier-involvement mechanisms, such as timing of a supplier's involvement, suppliers' design responsibility and communication frequency in assembly industries, Hartley et al. (1997) suggest that early supplier involvement increases the supplier's perceived contributions to product development, regardless of whether a standard or customer component is used. This is because the supplier perceives its own contribution as well as feels to be part of the development team, which leads to them to be more committed to the product development in the process. Dorge et al. (2000) also confirm that the extent of supplier integration (which consists of supplier development, supplier partnership and just-in-time purchasing) is significantly related to a firm's ability to reduce design cycle time. But, the level of product innovativeness can also impact on the effectiveness of early supplier involvement in NPD process. Eisenhardt and Tabrizi (1990) empirically examine time-compression strategies for accelerating the development of certain (mature) and uncertain (innovative) projects. They suggest that for less predictable projects (more innovative products), early involvement may be difficult to achieve because there is less certainty as to exactly for what purposes suppliers will be needed. In contrast, for predictable projects (less innovative products) key suppliers are more likely to be identified at an initial stage of development, and as a result, early involvement for the sake of speeding up NPD design cycle is much possible to be achieved. Not only can the involvement of key parts/components suppliers contribute to product innovation, but also R&D equipment suppliers and suppliers of manufacturing equipment may act as major contributors to a firm's technological progress, particularly for vertical product differentiation (Malerba, 1992).

Broadly speaking, research in this area has revealed that the main advantages of supplier linkages are cost reduction, timeliness, quality and risk sharing. These linkages are more effective in incremental innovations than in radical innovations. However, there have been few investigations concerning the extent to which integration of different sorts of suppliers (i.e. key parts/material, R&D equipments and manufacturing equipments) affects a firm's product innovation and the ways in which a firm can effectively utilise and integrate key suppliers' knowledge to enhance its NPD capability.

2.4.3.3 NPD Learning Through Horizontal Linkages

Partners of Cooperation

The inter-disciplinary nature of new product development is a characteristic present in all high-technology industries (e.g., biotechnology, telecommunications, and semiconductor) (Mowery and Rosenberg, 1989). This characteristic has increasingly induced such firms to form alliances with non-competing or competing organisation units to assist in their NPD projects. Empirical research on inter-firm collaboration in association with innovation has been well documented (Arora and Gambardella, 1990; Arora and Gambardella, 1994; Decarolis and Deeds, 1999; Deeds and Hill, 1996; Granstrand et al., 1992; Hagedoorn and Schalenraad, 1994; Pennings and Harrianto, 1992a; Pennings and Harrianto, 1992b; Shan et al., 1994). Primarily the motives for inter-firm collaboration include gaining access to complementary know-how, reducing time-spans and lowering costs or risks of technology development (Tidd et al., 1997; Hagedoorn, 1993; Beesley and Rothwell, 1987; Grant and Baden-Fuller, 1995, Arora and Gambardella, 1990; Arora and Gambardella, 1994). The rationale for technology alliances lie in the fact that no company has an all-embracing competence in every field of technology and therefore an evaluation of possible synergies might at some stage of a particular technological trajectory warrant collaboration with another company. The reduction of cost and minimising and sharing uncertainty is inherent to the characteristics of NPD projects. The advantage of the division of global labour accelerates particularly, the adoption of transnational collaboration projects (Subramaniam and Venkatraman, 2001). This measure allows firms to keep abreast of their competitors in launching new products and at the some time to minimise uncertainty.

Shan et al.'s (1994) study examining the biotechnology industry confirms a positive relationship between the number of inter-firm alliances entered into and the innovation output (number of patents) made by the firm. Along with this line of research, Deeds and Hill suggest that an inverted U-shape relationship exists between the number of alliances that a firm has entered into and the rate of new product development. They further explain: "given bounded rationality, it is likely that management's ability to properly screen partners and monitor alliances will be inversely related to the number of alliances in which the firm is involved" (Deeds & Hill 1996: 44). This rationale implies a diminishing return result, relative to an increase in the number of alliances.

In their examination of ways in which different alliance strategies of a firm may be complementary, Arora and Gambardella (1990 and 1994) claim that large companies tend to form R&D collaborative alliances with small research firms, for product-specific projects, but sign basic research agreements with universities when more basic research issues are involved. These findings are consistent with Hagedoorn's (1993) argument that corporate basic research is of little relevance to inter-firm technology cooperation. Arora and Gambardella make two main points in their central argument. First, basic research is to provide a technological infrastructure on which universities probe further. On the other hand, basic research is an essential corporate activity, because in R&D intensive industries, it comes close to a company's corporate core and as such it is not a desirable subject for collaboration. The work of Granstrand et al. (1992) also reveals that strategies for external technology acquisition are positively correlated to development strategies that emphasise product diversification and R&D investment. In other words, the strategy of technology diversification is a fundamental causal factor that gives rise to both increasing external technological alliances and increasing R&D budgets.

Findings taken from the implementation of electronic banking illustrate that banks, having accumulated more technological networking skills (as inferred by their magnitude of strategic alliances), are likely to offer more innovative services (Pennings and Harrianto, 1992a; Pennings and Harrianto, 1992b). In studying the differences of alliances across industries, Hagedoorn and Schakenraad (1994) conclude that firms having effectively absorbed technology through R&D collaboration alliances, then generate a higher rate of profit. In addition, the intensity of these alliances tends to rise relative to an increase in the size of companies. In other words, firm size reflects the degree to which firms seek and find external opportunities in inter-firm linkages.

In the context of product innovation, one of the prime advantages of learning through R&D collaboration is to gain access to complementary technology/knowledge. These learning opportunities permit firms to acquire existing technologies from outside sources, and integrate them with their own technologies. This allows the application of newly assimilated knowledge to the successful development of new products, or to the improvement of current products and processes. Although past research provides rich empirical evidence on the relationship between inter-firm collaboration and innovative capability (Rothwell, 1992; Bierly and Chakrabarti, 1996b), there has been less investigation with respect to particular organisational characteristics, such as the capability to absorb external technology and knowledge through collaboration. Neither, has the impact of these collaborative sources on the extent of product innovativeness been explored. The investigation of these two issues will form part of the objectives of the present study. The subject of a firm's learning capacity with respect to acquiring and absorbing external technology/knowledge-absorptive capacity will be discussed in the section 2.5.

Competitors

On a broad scope, firms take two routes by which to assess and absorb competitors' technological knowledge: observation and collaboration. Observation through a firm's competitor intelligence system (which consists of various functional groups) facilitates competitive analysis. In his seminal book, Michael Porter (1980: 72) asserts the need for "competitive analysis" in the modern corporation, and hence "the need for an organisation mechanism - some sort of competitive intelligence system – to ensure that the process is efficient." Researchers have sought to investigate the components of a firm's competitive intelligence system and competitive analysis. For example, Ghoshal and Westney (1991) identify six different functions of competitor analysis in organisations: decision-making, planning, inspiration, legitimation, benchmarking and sensitisation. Amongst these functions, competitive benchmarking provides a set of specific measures by which to compare competitors against aspects of core technology, product cost/performance ratio, quality and productivity. This benchmarking always influences and challenges a firm's basic assumptions (e.g. currently employed technology, product specification, unit production costs, etc) (Leonard-Barton, 1995). Change to these basic assumptions then invites the implementation of innovation.

Firms may collaborate with competitors by means of various forms (e.g. joint ventures, out-sourcing agreements, product licensing, co-operative research). This "competitive collaboration" (Hamel et al., 1989) is considered a low-cost route for both new and current competitors to gain technology and market access when the new technology is highly complex, and time to market is crucially important. In addition, this collaboration eases alliance firms' benchmarking as a result of close proximity. Consequently, competitive collaboration results in advantages such as inter-firm learning, new capability acquisition and the creation of markets. However, the competitive element of such cooperation is likely to affect the knowledge transfer process. Khanna et al. (1998) suggest that a firm's ratio of private to common benefits would decide the competitive aspects of alliances. A high ratio leads to an acute learning relationship.

Universities, Research Institutes, and Consultants

Research collaboration between industrial firms and universities as well as industrial research institutes has been widely noted. Close proximity to the university scientific community offers firms better access to knowledge that may have great value in the marketplace and can contribute to a firm's performance (Mowery and Rosenberg, 1989; Decarolis and Deeds, 1999). Universities and industry-oriented research institutes having multi-disciplinary scientists provide important support for, particularly, cross-disciplinary research projects. Firms usually employ both university and industrial institute research to conduct either fundamental research or to develop more speculative in-house new technology, which may have a strategic significance complementary to their core technologies but cannot be justified internally because of the high risk involved or limited resources (Tidd et al., 1997).

Firms establish links with universities and industrial research institutes for a variety of reasons. These include access to specialist technical support; extension of in-house research; and the provision of a window on emerging technologies (Tidd and Trewhella, 1997). In testing the hypothesis that external linkage strategies employed by biotechnology firms with other parties are complementary to one another, Aurora and Gambardella (1990) observe that most development agreements signed with other companies tend to be product-specific, whereas the agreements with universities tend to focus on more basic research objectives. The former centres on rather downstream product-specific development activities, the latter provides the firms with access to basic scientific knowledge and opportunities to interact with university scientists for recruitment purposes. They suggest that universities are more often useful sources of scientific information and capabilities than other sources of new innovation in this industry (Arora and Gambardella, 1994). Similarly, Beesley and Rothwell (1987) note that R&D activities carried out with public sector organisations, such as universities and industry-oriented research institutes, provide high-tech small and medium-sized enterprises (SMEs) with a useful means by which to gain access to state-of-the-art research and knowledge.

Other unique knowledge sources, such as consultants and/or consulting organisations are often used to find leads, evaluate alternative technology, and provide missing pieces of technological information (Chatterji and Manuel, 1993). Professional consultation seems to be an effective and efficient method to acquire external knowledge, when a firm encounters technological barriers. However, Hauschuldt & Nesta (1999: 109) state: "the expertise of consulting experts only covers a small segment of the innovative problems. In integrative innovations the consultant is rather a seeker, not a knower of truth." This argument implies that the resolution of tacit parts of NPD projects still calls for internal expertise. Here, a firm's absorptive capacity has a fundamental role to play in effectively acquiring external knowledge and then engendering technological innovation. A detailed discussion of "absorptive capacity" follows in the next section.

2.5 Absorptive Capacity and External Knowledge Acquisition

The continual development of more innovative products requires firms to import some knowledge from beyond their boundaries through various linking mechanisms, as previously discussed. However, increased external integration or boundary expansion activity does not guarantee better accumulation and creation of knowledge for innovative product development. The ability of a firm to recognise the value of new external knowledge, assimilate it and apply it to commercial ends, which is known as "absorptive capacity", is perceived to be the most crucial element in a firm's process of knowledge absorption (Cohen and Levinthal, 1989). This capacity considerably distinguishes between firms that are capable of identifying, assessing and assimilating new knowledge from those who are not.

As Fiol (1996: 1012) states: "Organisations, like sponges, must have the capacity to absorb inputs in order to generate outputs. Researchers have developed theories of organisational absorptive capacity; researchers have also developed models of the effective generation of new products. The challenge lies in integrating the two research streams." Indeed, a firm's knowledge absorption and diffusion is like the soaking of a sponge. Firms need to continuously identify new sources of knowledge that complement existing core technologies. The absorption of this complementary technology/knowledge, which is subsequently turned into part of new NPD capability, allows firms to squeeze out new products. The concept of "absorptive capacity" has been increasingly researched and now represents one of the most crucial constructs in distinguishing a firm's ability to absorb external knowledge (Fiol, 1996; Cockburn and Henderson, 1998; Lee, 1999; Tu, 1999; Sivadas and Dwyer, 2000). As yet little attention has been placed on a NPD model, which identifies the role of absorptive capacity and assesses its impact on product innovation (Fiol, 1996). In this section, the perspective of knowledge-enabled NPD is used to investigate absorptive capacity, and its relationship with both knowledge acquisition and new product innovativeness.

2.5.1 Concept of Absorptive Capacity

The term "absorptive capacity" originally referred to the ability of an economy to utilise and absorb external information and resources (Adler, 1965). Cohen and Levinthal (1989) first adapted this concept to organisational innovation and defined a firm's "absorptive capacity" as "the firm's ability to identify, assimilate, and exploit knowledge from the environment." They later redefined the term as "the ability of a firm to recognize the value of new, external information, assimilate it and apply it to commercial ends" (Cohen and Levinthal, 1990: 128).

2.5.1.1 The ability to recognise and value new external knowledge

A firm's ability to recognise external knowledge is dependent upon two criteria: (1) a prior knowledge that is closely related to new knowledge and (2) some fraction of that knowledge that is diverse enough to allow an effective utilisation of the new knowledge (ibid. p.136). Cohen and Levinthal (1994) suggest that firms with a sufficient prior knowledge base will have the ability to pro-actively envisage future technological advances, particularly those close to the domain of existing knowledge, thus improving absorptive capacity. On the other hand, firms where prior knowledge is non-existent may be discouraged by this uncertainty from further developing their absorptive capacity for an unfamiliar domain. That is, if a firm lacks investment in an area of expertise, its future development of the technical capability in that area will be foreclosed as the development of absorptive capacity is path/history-dependent.

Empirical studies confirm that possession of complementary knowledge (i.e., diversity in knowledge domains that are complementary) is a prerequisite for a knowledge search (Cockburn and Henderson, 1998; Shenkar and Li, 1999). In their study of the US biotechnology industry, Arora and Gambardella (1990) observe that the level of a firm's internal knowledge (as measured by the number of patents) has positive impacts on its ability to evaluate and exploit knowledge that is generated outside its organisational boundaries. Likewise, Sen and Rubenstein (1989) find that the success of a firm's international technology licensing largely depends on its R&D unit's awareness of developments in external technology, as well as its corresponding technologies that play a facilitative role in the overall process of implementation. This evidence suggests, that to an extent, firms tend to stay in the same industrial sector and find it hard to shift to a new frontier.

2.5.1.2 The ability to assimilate new external technology

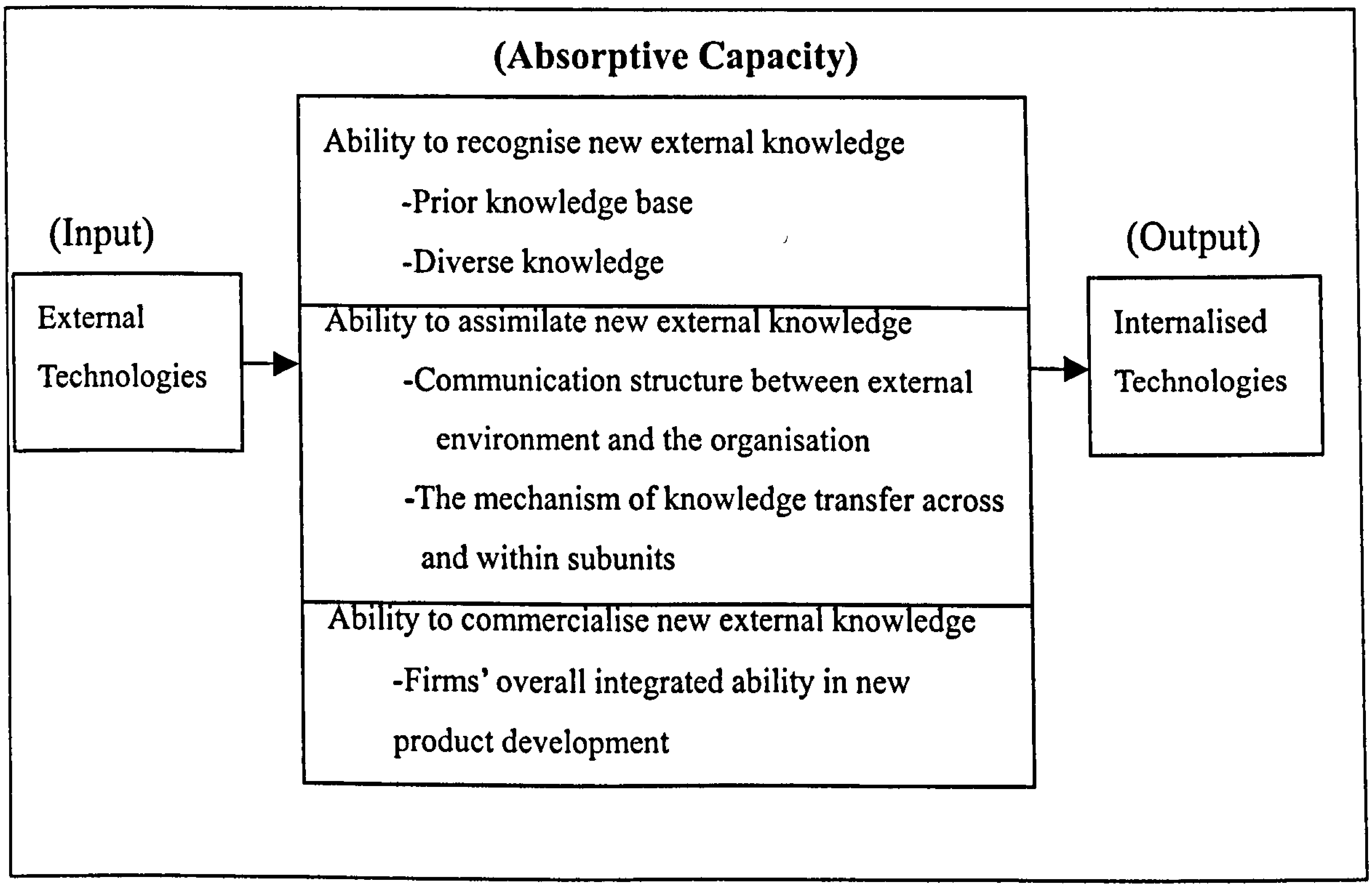
Once they recognise the value of external knowledge that is strategically important and can act as a bridge to a new frontier business, firms then need a productive process to internalise it. Cohen and Levinthal (1990: 131-132) argue that this internalisation process is largely affected by structures of communication between the external environment and the organisation, and the character and distribution of expertise within the organisation. For instance, technological gatekeepers (Tushman, 1977) and an organic structure that facilitates communications help the assimilation process. Similarly, other researchers (e.g. Leonard-Barton, 1995; Madhavan and Grover, 1998)) suggest that engineers or managers with T-shaped skills, A-shaped skills of team leaders and team members having shared mental models are some of the key elements required for the formation of an effective NPD team engaging in the development of novel innovations. This is because multi-disciplinary expertise as well as good communications in a NPD team can effectively facilitate the interpretation of diverse, external technology/information. In general, the most difficult part of knowledge assimilation lies in its tacit nature. The conversion of tacit knowledge into coded knowledge that can then be distributed within organisational units determines a firm's ultimate level of external technology/knowledge acquisition. Nonaka (1991) suggests that the conscious overlapping of a company's complementary functions for creating "redundancy" of knowledge and information is imperative because this redundancy helps create a common cognitive ground between employees and thus facilitates the transfer of tacit knowledge.

2.5.1.3 The ability to commercialise new external knowledge

The innermost phase of absorptive capacity is the ability to commercially apply the assimilated knowledge to achieve organisational objectives, such as innovative product development. To this end, firms' R&D capability plays a critical role. Cohen and Lenvinthal (1990: 140) claim: "when outside knowledge is less targeted to a firm's particular needs and concerns, a firm's own R&D becomes more important in permitting it to recognize the value of knowledge, assimilate, and exploit it." This R&D capability mainly consisting of design and development, manufacturing, marketing abilities not only enables a firm to implement and commercialise newly acquired technologies but also allows the firm to seek particular needs in its next phase of NPD projects.

In sum, a firm's absorptive capacity can be symbolised as the central processing unit of a firm's knowledge-absorbing system, like that of a computer (see Figure 2.6). This unit enables the firm to recognise and value external technologies (i.e., input), assimilate them, and convert them into internalised technologies (output). The amount of external technology/knowledge assimilated depends on the effectiveness of a firm's absorptive capacity. Once more valuable external technologies are imbued and assimilated into the system, the stock of new knowledge is increased. This increase not only allows firms to generate more innovations but also reciprocally reinforces their absorptive capacity. In other words, this knowledge-absorbing system is a feedback, self-learning knowledge generating system.

Figure 2.6 Absorptive Capacity and External Technology



(Source: the current study)

2.5.1.4 Development of Absorptive Capacity

Absorptive capacity can be developed and maintained as a by-product of routine activities, such as R&D and manufacturing in the current knowledge domain (Cohen and Levinthal, 1990). In addition, a firm can further foster its absorptive capacity by hiring technical experts, sending employees for advanced training, and encouraging employees to study technical journals. Cohen and Levinthal (1990: 132) reason that the accumulation of a firm's absorptive capacity is dependent upon three major factors. First, a firm's direct interface with the external environment initiates boundary-spanning activities. External sources include industrial research laboratories, public research institutes, universities, consulting firms, buyers, suppliers, and competitors amongst others. Second, a firm's subunits, which interact together, transfer knowledge across and within each other. Third, a firm's communication structure, between the external environment and the organisation, as well as between the subunits of the organization, also determines absorptive capacity building.

Although absorptive capacity is mainly the function of a prior knowledge base, intensification of learning efforts is also needed to foster the building of absorptive capacity (Kim, 1998). However, as the accumulation of absorptive capacity tends to be within a firm's domain, a critical question is: how far should a firm invest in its absorptive capacity of that particular domain before falling into a competency trap (Levitt and March, 1988). Leonard-Barton (1992: 118) contends that: "value, skills, managerial systems, and technical systems that served the company well in the past and may still be wholly appropriate for some projects or parts of projects, are experienced by others as core rigidities – inappropriate sets of knowledge." These may explain why established firms often encounter difficulties once dominant designs of their product lines change. The details of how the development of absorptive capacity leads to competency trap invite more empirical investigation.

2.5.2 The Impact of Absorptive Capacity on External Knowledge Acquisition

A growing body of research has provided empirical evidence as to the effect of absorptive capacity on external knowledge acquisition (Arora and Gambardella, 1990; Atuahene-Gima, 1992; Atuahene-Gima, 1993; Mowery et al., 1996; Luo, 1997; Veugelers, 1997; Cockburn and Henderson, 1998; Lane and Lubatkin, 1998; Mangematin and Nesta, 1999; Shenkar and Li, 1999). Most research investigates how various forms, such as; inter-firm cooperative ventures (ICVs), strategic alliances, networking and learning with public institutes, could effectively enhance the acquisition of external technological knowledge. For instance, Mowery et al. (1996), using data from 792 alliances, studied inter-firm knowledge transfers and concluded that absorptive capacity significantly influences the acquisition of capabilities through alliances. In particular, alliances with prior experience in related technological areas have proved to be an important determinant of absorptive capacity (i.e. path-dependent and firm-specific). That is, the basic requirement for enriching effective inter-organisational learning in an alliance lies in having learning partners equipped with the requisite absorptive capacity (Levinson and Asahi, 1995). In addition, continually enhancing the absorptive capacity of the alliance is critical if a planned change is to be successfully implemented.

Koza and Lewin (1998) suggest that absorptive capacity is particularly more important for exploratory alliances (i.e. those having an exploratory objective) than in exploitative alliances (i.e., those with objectives such as cost reduction, risk sharing and economies of scale). In a research model of differential learning within the dynamics of a strategic alliance, Kumar and Nti (1998) hypothesise that the knowledge appropriated by an alliance partner depends on its absorptive capacity and the volume of alliance generated knowledge to which it is exposed. That is, greater absorptive capacity assists a firm in appropriating more knowledge when exposed to a given volume of alliance generated knowledge. This is because with exposure to multiple sources of knowledge, an alliance firm with a higher absorptive capacity gains greater leverage. Furthermore, Kumar and Nti (ibid.) suggest that a firm's ability to appropriate knowledge from an alliance depends on the quality of its employees, its knowledge base, the resources at its disposal, and its management systems, all of which constitute major elements in a firm's overall absorptive capacity.

A stream of research focuses on how firms differ particularly in their absorption of applied and basic/generic types of knowledge. Based on the empirical results from 112 R&D cooperation projects between the National Scientific Research Institute and industrial firms in France, Mangematin and Nesta (1999) argue that a firm with high absorptive capacity facilitates the assimilation of both applied and basic knowledge. In addition, a higher absorptive capacity is more critical for absorbing basic research knowledge than applied research knowledge. Also, an increasing absorptive capacity essentially diversifies firms' absorption mechanisms. Cockburn and Henderson (1998), in a study related to the transfer of public technological knowledge, further confirm that a firm needs to conduct a similar research internally first (i.e. to foster its absorptive capacity relating to/close to the knowledge/technology to be absorbed) before taking advantage of publicly generated cutting-edge research, labeled basic knowledge.

Although absorptive capacity is the crucial factor in absorbing external knowledge/technology, it may not directly drive a firm to develop more external linkages. Atuahene-Gima (1993) investigated firms' decisions on inward technology licensing and found that, if equipped with a relatively high level of internal R&D capability (i.e. one of major elements of a firm's absorptive capacity), firms are more likely to internalise new product developments than to have co-operative R&D projects. This is because of the tendency towards "not-invented-here" syndrome (Katz and Allen, 1982) among internal R&D staff, which inhibits the consideration of external sources of technology. The development of "not-invented-here" syndrome must be confined when firms have accumulated sufficient levels of absorptive capacity in their design domains.

Absorptive capacity also determines a firm's internal knowledge transfer capability (i.e. within-organisation diffusion of knowledge). For instance, Szulanski (1996) identifies three major barriers influencing internal knowledge transfer: (1) the recipient's lack of absorptive capacity, (2) causal ambiguity, and (3) an arduous relationship between the source and the recipient. Obviously a firm's internal subunits, without having adequate absorptive capacity, could have difficulties in knowledge transfer between them even though they are organizationally closed.

Although previous research highlights the importance of absorptive capacity in both acquiring external knowledge and effecting internal knowledge transfer, few have attempted to examine the relationship between absorptive capacity and a firm's new product innovativeness. The paucity of this type of research may be because NPD researchers have not yet investigated how and to what extent external knowledge (e.g., from alliances) affects the effectiveness of new product development. More recently, Sivadas and Dwyer (2000) developed a construct –cooperative competency- derived from the concept of absorptive capacity and relational capacity and tested whether it determines the success of new product development in alliance-based processes. This research suggests that "cooperative competency" (relative absorptive capacity) is positively related to NPD success in both internally and externally conducted projects. Other influential factors include institutional support for cooperative competency, administrative mechanisms, and mutual dependence. They suggest that more research on absorptive capacity in the context of NPD needs to be conducted for both theory development and managerial application.

Absorptive capacity, therefore, plays a crucial role in a firm's acquisition of external technologies whether knowledge transfers takes place in inter-firm cooperation or organisational subunits. It enables a firm not only to envisage industrial technological trends, but also to effectively assimilate external knowledge/technology that may significantly contribute to its new product development, particularly, radically innovative projects in the long run. The development of absorptive capacity results from a prolonged process of investment and knowledge accumulation. As Cohen and Levinthal argue (1990), the ability to explore and exploit external knowledge is often a by-product of R&D investment. Firms investing more in their own R&D increase their ability to generate more innovative projects. Subsequently, this investment reciprocally helps their development of a higher capacity for absorbing external knowledge. Firms with relatively high innovative culture, such as creating a conductive knowledge-creation environment, encouraging external knowledge scanning, and open communications with external parties, are more capable of recognising and acquiring relative technology/knowledge (Tu, 1999). The accumulation of new product technology/knowledge will encourage more innovative NPD projects and thus, reciprocally increase firms' level of absorptive capacity.

2.5.3 Other Concepts of Knowledge Acquisition Capability

On a broad front, scholars with both a resource-based and a knowledge-based view of the firm have conceptualised similar constructs regarding capabilities for both external and internal knowledge acquisition. For instance, Henderson and Clark (1990) develop two types of innovation capabilities – component versus architectural[3]. Architectural capability is recognised as a key ability by which firms can integrate external knowledge effectively for architectural innovation. In their empirical examination of pharmaceutical companies, they identified two particularly important forms of architectural capabilities as sources of advantage in research productivity: the ability to access new knowledge from beyond the boundaries of the organisation and the ability to integrate knowledge flexibly across disciplinary boundaries and

[3] Henderson and Clark (1990: 10-11) argue that the development of a new product requires two types of knowledge – component knowledge and architectural knowledge. The latter concerns the way in which a set of components in the product are integrated and linked together to form a coherent whole. Henderson and Cockburn (1994: 65) define "component capability" as "local abilities and knowledge that are fundamental to day-to-day problem-solving", and "architectural capability" as "the ability to use these component capabilities – to integrate them effectively and to develop fresh component capabilities as they are required".

product ideas within an organisation (Henderson and Cockburn, 1994). Similarly, Kogut and Zander (1992) introduce the concept of "combinative capability" as a firm's ability to synthesise and apply current and acquired knowledge through both internal and external learning. Innovations, under this notion, are products of a firm's combinative capabilities to generate new applications from existing knowledge.

In contrast to the ability to recognise and exploit external technology as suggested by absorptive capacity, Garud and Nayyar (1994) propose the construct of "transformative capacity" and stress that this ability allows a firm to continually redefine its product portfolio based on the technological opportunities created within. They further contend that absorptive capacity alone is not enough to sustain firms' competitive advantage "when: (1) path-dependent, cumulative knowledge is involved; (2) entry timing is important, (3) a firm operates in a continually changing environment in which it does not just react to external changes, but instead, creates them on its own," (ibid, p.367). In these circumstances, the development of transformative capacity is required to maintain corporate vitality. Admittedly, this argument is based on a few specific observations taken from cases of giant MNCs and cannot be extended to SMEs. The latter in fact do not have the necessary resources to create diverse technologies without commercial applications over an uncertain period. Thus, "transformative capacity" may serve as an important capability for MNCs but definitely not for SMEs.

More recently, Lorenzoni and Lipparini (1999), using the concept of relational rents by Dyer and Singh (1998), coined the term "relational capability"- meaning the ability to interact effectively with other companies. They argue that a high level of relational capacity between a lead firm and networking parties helps to accelerate a lead firm's access and transfer of knowledge, as well as contributing to the growth and innovation of network parties. The development of this relational capability further helps managers of a lead firm to internalize specialised knowledge across a network of firms whilst at the same time managing the inter-organisational network.

By re-conceptualising the concept of absorptive capacity, Lane and Lubatkin (1998) coined the term "relative absorptive capacity". They suggest that one firm's ability to learn from another depends upon "the similarity of both firms' knowledge bases, organisational structures and compensation policies, and domain logics" (p. 461). This is because the tacit part of knowledge, which is unique and inimitable and is embedded in a firm's social context, cannot be easily absorbed (Beaumard, 1999). Learning or acquiring such un-codified complex knowledge requires more than just a firm's absorptive capacity. Hence, to gain better learning performance, both student and teacher firms need to have a high degree of relative absorptive capacity. This ability enables alliance firms to achieve an effective learning process for knowledge sharing from the stage of know-what, know-how through to the final stage of know-why. The concept provides useful guidance for firms in search of learning alliance partners for external knowledge acquisition. However, researchers applying the construct of "relative absorptive capacity" to the study of knowledge acquisition through collaborations with, for example, universities or industry-based research institutes could encounter difficulties. Since universities and research institutes operate in a way that differs from profit-oriented enterprises, identifying resembled relative absorptive capacity amongst them could require great research efforts.

Table 2.5 summarises different terms pertaining to absorptive capacity proposed in the existing literature. In short, except for transformative capacity, the constructs of combinative, architectural, and relational capabilities place the emphasis on how a firm's competence can be achieved by combining/integrating both internal and external knowledge, rather than on what affects the acquisition and assimilation of external technology/knowledge. The latter is more concerned with a firm's ability in generating innovative products. As such, the construct of "absorptive capacity", proposed and defined by Cohen and Liventhal, more precisely conveys and captures the essence of external knowledge acquisition, particularly in a NPD research model, than the other constructs do.

Table 2.5 Summary of Constructs Pertaining to Absorptive Capacity

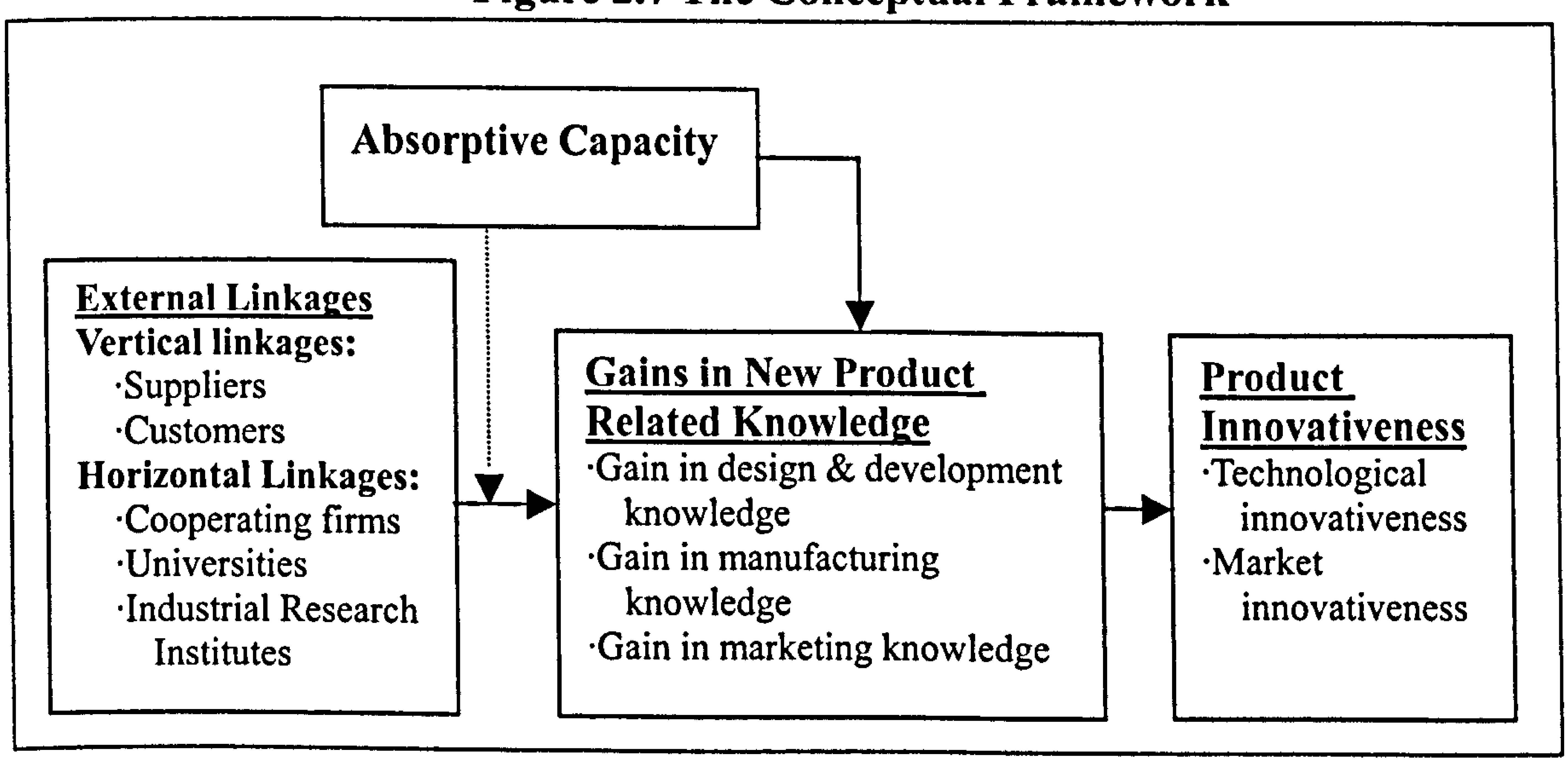
Sources	Label	Description
Cohen & Levinthal (1990)	Absorptive Capacity	The ability of a firm to recognise the value of new, external information, assimilate it, and apply it to commercial ends
Lane & Lubatkin (1998)	Relative Absorptive Capacity	The ability of a firm to learn from another firm depends on the similarity of both firms' (1) knowledge bases, (2) organisational structures and compensation polices, and (3) dominant logics[4]
Kogut & Zander (1992)	Combinative Capability	The ability of a firm to synthesize and apply current and acquired knowledge
Henderson & Clark (1990)	Architectural Capability	The ability of a firm to integrate existing competencies and to generate new knowledge
Lorenzoni & Lipparini (1999)	Relational Capability	The ability of a firm to interact and share knowledge with other companies
Garud & Nayyar (1994)	Transformative Capacity	The ability of a firm to redefine its product portfolio based on the technological opportunities created within

[4] Prahalad and Bettis (1986 & 1994) define the dominant logic as "the way in which managers in a firm conceptualise the business and make critical resource allocations decisions..." It is stored via shared schemas, cognitive maps or mind sets and was determined by the managers' pervious experiences; but was largely unrecognised by the managers themselves. Prahalad and Bettis also confirmed that it refers to belief structures, and frames of reference as being intimate aspects of a dominant logic.

2.6 Conceptual Framework

As indicated in preceding sections, there has been a wealth of research concerning the ability of organisations to absorb external knowledge. Knowledge that is acquired externally and assimilated assists a firm to further enhance its product innovation. The literature on external learning suggests that external information is crucial to radical innovation (McKee, 1992; Bierly and Chakrabarti, 1996b; Lynn et al., 1996; Lynn, 1997). Other research (Bierly and Chakrabarti, 1996b; Li and Calantone, 1998; Pennings and Harrianto, 1992a; Pennings and Harrianto, 1992b) suggests that the nature of external linkages is key to understanding a firm's technological innovation. Grant and Banden-Fuller (1995) argue that a firm's capability to develop more innovative products consists of the interaction between its existing knowledge bases and the extent to which external, new complementary knowledge can be integrated. The higher complementarities of new product technology and the firm's technology domain enable innovative product development. The importance of external linkages, particularly relating to external knowledge acquisition, is widely acknowledged in various disciplines. Importantly, this study reconceptualises the relationship between external linkages and new product innovativeness. Specifically, this thesis revisits the concept of absorptive capacity and investigates the how and to what extent linkages and absorptive capacity influence new product innovativeness. The thesis addresses the following questions. First, what types of external linkages significantly influence industrial product innovation? For example, does the horizontal linkage contribute more to a firm's accumulation of new product knowledge, and thus lead to more innovative product development than the vertical linkage does? Second, does absorptive capacity influence the relationship between a firm's external linkages and new product innovativeness? What is the role of absorptive capacity in these relations? Third, does the extent of a firm's external linkages enable us to predict its gain in new product knowledge? A review of the existing literature suggests that these questions have not been sufficiently empirically examined and thus remain, at least in part, unanswered. Therefore, the following conceptual framework (Figure 2.7) has been developed to depict the proposed relationships, which are examined in the following chapters.

Figure 2.7 The Conceptual Framework



In the framework, derived from the knowledge creation school of innovation (Nonaka, 1994; Grant and Baden-Fuller, 1995; Leonard-Barton, 1995), gains in new product knowledge mediate the link between external linkages and product innovativeness. This is because the primary motives behind external linkages are to gain access to complementary technologies (Link and Tassey, 1987: Hamel, 1991; Rothwekk and Dodgson, 1991; Powell et al., 1996) to fill the gap between the product and knowledge domains (Grant and Banden-Fuller, 1995), and to acquire complementary knowledge (Teece, 1986), thus resulting in an increase in product knowledge stock. These complementary technologies include design & development know-how, manufacturing know-how, marketing know-how and pre-development assessment knowledge know-how that transfer a new product concept into a viable, commercialized product (Crawford, 1997). The increase of new product knowledge stock in design & development, manufacturing and marketing know-how subsequently predicts the level of product innovativeness (Leonard-Barton, 1995; Nonaka, 1994). This framework reflects the assumption that a difference in the accumulation of new product knowledge (both marketing and technological) in a NPD project exists across various types/forms of external linkages (Eisenhardt and Tabrizi, 1990; Hennart, 1988; Dussauge et al., 2000; Sakakibara, 1997; Tidd and Trewhella, 1997).

Absorptive capacity is included to examine the relationship between external linkages and new product innovativeness. Absorptive capacity has been empirically examined and confirmed to be a crucial factor influencing the effectiveness of external knowledge acquisition (Arora and Gambardella, 1994; Mowery et al., 1996; Veugelers, 1997; Lane and Lubatkin, 1998; Mangematin and Nesta, 1999). Firms, as learning systems, must have the capacity to absorb inputs in order to generate outputs. Firms that possess relevant prior knowledge are likely to effectively value and acquire relevant external technologies that can help them generate new ideas resulting in more innovative product development. As a result, firms with a high level of absorptive capacity are more likely to explore and exploit technologies acquired through collaboration with external partners than those with less. Following this line of logic, absorptive capacity is constructed as a predictor/moderator variable, one that not only affects a firm's gain in new product knowledge, but which also moderates the impact of the external linkages on the level of new product knowledge accumulation.

2.7 Summary

This chapter reviews the literature related to product innovation primarily based on organisitional learning theory and the knowledge-based theory of inter-firm collaboration. The objective there is to establish a conceptual framework for analysing how and to what extent external linkages influence a firm's level of accumulation of new product knowledge, and subsequently, how this affects the level of new product innovativeness. This chapter lays the foundation for a critical response to Fiol's (1996) call for research integrating theories of absorptive capacity into NPD. The research framework outlined here forms the basis for a series of hypotheses, which are presented in the following chapter.

Chapter 3
Research Hypotheses

3.1 Introduction

Drawing on theoretical and empirical perspectives from organisational learning, knowledge management, product innovation and inter-firm alliances, chapter two proposes a conceptual framework to delineate the relationship between factors including: vertical linkages, horizontal linkages, gains in new product related knowledge (about a given NPD project), absorptive capacity and new product innovativeness. This framework proposes that the effects of external linkages on gain in new product knowledge are largely contingent upon a firm's absorptive capacity. New product knowledge gained through collaboration in a NPD project mediates the relationship between external linkages and new product innovativeness. This chapter uses this framework to develop and discuss four sets of hypotheses.

The chapter begins by considering the effect of external linkages on gains in new product knowledge that in turn contribute to new product innovativeness. Section 3.2 starts with a discussion of empirical evidence from studies of organisational learning. Following this, I discuss empirical works drawn from the fields of knowledge management and inter-firm collaboration. Hypotheses concerning the relationships between external linkages and gains in new product knowledge are then presented. Next, the rationale and hypothesis regarding the mediating role of gains in new product knowledge, as depicted in the conceptual framework, is discussed.

Section 3.3 centres on the direct and moderating effects of absorptive capacity as well as the direct effects of external linkages on gains in new product knowledge. This section elaborates on the effect of absorptive capacity on external knowledge absorption. The empirical evidence discussed here is primarily drawn from studies of inter-organisational learning, inter-firm alliances and product innovation management.

3.2 External Linkages and New Product Innovativeness

3.2.1 The Effects of Horizontal and Vertical Linkages on Gains in New Product Knowledge

Past research, from a learning perspective, has highlighted the importance of external learning for effective product innovation (McKee, 1992; DiBella et al., 1996; Lynn et al., 1996; Lynn, 1997). McKee (1992) argues that radical innovations rely more on external learning practices such as staff involvement with outside experts and external skills acquisition than those required for incremental innovations. Similarly, Lynn (1997 &1998) suggests that when a firm develops and commercialises radically new products, that encompass new technology and serve new markets, cross-company learning (i.e. inter-organisational learning) becomes more critical than in the development of incremental products. Dibella et al. (1996) posit that for "transformative innovation" (i.e. radical innovation) a certain degree of acquisition of external knowledge is required. Lynn et al. (1996) even argue that firms in technology intensive industries should put more emphasis on experiences gained from the "probe and learning" process of exploring external environments when marketing radical products. The implication of this evidence is that developing truly innovative products requires a firm to foster more external links to facilitate the influx of external knowledge, than in the development of incremental products.

Empirical studies on inter-firm collaboration also provide some evidence of this relationship regarding the effectiveness of product innovation. Pennings' (1992 & 1992a) studies of electronic banking applications show that those banks that have accumulated more technical networking skills tend to display a higher tendency of implementing new innovation. Complementing this view, Deeds and Hill (1996)

(1996) propose that the productivity of a firm's new product development efforts is positively associated with the extent of its inter-firm alliances. Furthermore, the empirical works of Deeds and Hill (1996) and Shan et al. (1994) also reveal a positive relationship between the number of strategic alliances that a firm has and the productivity (measured in terms of products on market, new products in the pipeline and patents) of new product development in the biotechnology industry. However, they suggest that this relationship might be depicted as an inverted U-shape due to the result of diminishing returns relative to an increase in the number of alliances that increases the burdens on management (Deeds and Hill, 1996). In brief, the advantages of inter-firm collaboration for new product innovation lie in two respects. First, alliances offer firms a set of complementary technologies that are needed in the development of a relatively new product. Second, alliances are an effective mechanism for enabling the integration of these complementary technologies with a firm's existing technology.

Research on knowledge management has greatly contributed to the understanding of the way in which various sources of knowledge affect product innovation. Knowledge of external sources, such as customers, suppliers, and competitors, has been shown empirically to have a significant impact on product performance (Grant and Baden-Fuller, 1995; Madhavan and Grover, 1998; Pennings and Harrianto, 1992a; Pennings and Harrianto, 1992b). For instance, Pennings (1992, 1992a) state that new knowledge gained through technological networking such as licensing, joint ventures and long-term contracts is positively associated with a firm's implementation of new technological innovation. However, the difficulty of this knowledge absorption resides in gaining the tacit part of knowledge. For example, some researchers (Grant and Baden-Fuller, 1995; Madhavan and Grover, 1998) argue that the success of R&D collaborative projects depends on converting tacit knowledge into explicit knowledge to which learning parties can interpret and apply. That is, the more innovative a new product, the more tacit knowledge there is to be converted by collaborative parties (Madhavan and Grover, 1998).

The conversion of tacit knowledge requires certain extensive and deep linkages, such as R&D collaboration and joint ventures, as these alliances offer firms an effective mechanism with which to learn about the tacit skills of other firms (Hamel et al., 1989). The rationale of this effectiveness is that R&D collaboration or joint ventures provide more opportunities for experience sharing and face-to-face discussions and these may facilitate a firm's assimilation of, in particular, tacit know-how that is often accompanied by a product with complex technology. In addition, firms engaged in collaboratively developing highly innovative products also require a high standard of learning ability to effectively convert tacit know-how into explicit know-how (Madhavan and Grover, 1998). In line with this, Badaracco (1991) also suggests that tactical alliances (i.e., sub-contracting and licensing, which are less integrative forms of collaboration) are appropriate for bringing in explicit knowledge. However, he argues that more strategic links (i.e., joint ventures and cooperative research) are necessary to acquire tacit or embedded knowledge as the latter offers more opportunities for R&D experience sharing. Furthermore, Grant (1995) posits that a more integrative mode of collaboration, as opposed to market transactions, such as contracting or licensing, is a more efficient way to transfer explicit knowledge, as well as to embody tacit knowledge. In contrast, in less complex product technology situations, firms simply take on a less integrative form of cooperation, e.g. sub-contracting or licensing. As such, it can be concluded that the more innovativeness within the new product is, and then a greater degree of external linkages (such as collaborative development and joint ventures) will be needed. This greater linkage allows more intimate knowledge sharing, experience exchanging and frequent communications, which facilitate the assimilation of tacit part of new product knowledge.

Besides the extent of an external linkage, the object of that linkage also affects the type and extent of new knowledge that a firm is to absorb. For instance, Tidd et al. (1997) argue that the primary motives for vertical linkages (i.e. collaboration with suppliers and customers) are cost reduction, sharing risks, and timeliness. The effectiveness of vertical linkages primarily lies in the fact that a new product project is relatively less innovative. Industrial goods firms, for instance, such as the automobile industry often work closely with their specialist suppliers to improve the quality and reduce the costs of sub-contracted products (Aoki, 1986; Blenkhorn and Noori, 1990; Kamath and Liker, 1994; Dyer, 1996). The work of Dyer (1996) stresses that a tightly integrated supplier network (featuring proximity and a high level of human co-specialization) outperforms a loosely integrated supplier network from the aspect of project costs and cycle time. The studies of Clark (1989) and Blenkhom and Noori (1990) also found that intensive supplier involvement and participation at an early stage of NPD is one of the primary factors that distinguish Japanese car manufacturers, who enjoy cost and quality advantages, in comparison with their American counterparts. Moreover, Eienhardt and Tabrizi's (1990) empirical work confirms that less innovative products (i.e. predictable projects) are more likely to achieve the results of reduction in cost or timeliness associated with a supplier's early involvement in NPD process, than relatively more innovative products (i.e. unpredictable projects). That is, an effective process of supplier involvement in NPD relies on the extent to which the technology of the new product employed is mature and stable. Under such conditions, firms' absorption of relatively new product knowledge/technology through these types of projects tends to be minimal. The product knowledge that a firm can further gain through supplier linkages is therefore more useful for incremental products than relatively innovative ones.

Although several studies (Rothwell et al., 1974; Cooper, 1979; Cooper, 1981; Bonnet, 1986; Dougherty, 1990; Song and Parry, 1992) suggest that an accurate understanding of customers' needs, wants, preferences and responses to existing products is the factor which discriminates most strongly between commercially successful, industrially innovative projects and those which fail. Other views have been put forward. O'Connor (1998), for example, argues that the weight of market learning through the current users seems less apparent if the NPD project involves a really new project (i.e. radical innovation). This lack of contribution is primarily due to the fact that current users are incapable of describing their requirements for a product that is entirely new to the market. Therefore, the effectiveness of user involvement in a NPD project tends to be less significant in radical types of innovations than in incremental types since the primary concerns of the latter are cost reduction, quality improvement or time to the market, where current users can, to a greater degree, make some contributions.

In contrast to vertical linkages, the primary advantage for a firm's horizontal linkages is to gain access to a wide range of complementary know-how (Tidd et al., 1997). This complementary know-how, which includes knowledge/technology in respect of technological, marketing, and manufacturing know-how, is necessary to translate an innovative R&D project into a visible product (Teece, 1986). The implementation of a novel product development increasingly involves a set of multi-disciplinary processes that require the integration of knowledge from various external sources (Mowery and Rosenberg, 1989). For instance, developing links with university research allows firms to access specialist technical support, to extend in-house research and to provide a window on emerging technology (Tidd et al., 1997). Tidd et al. (1997) contend that firms utilise university research not only to conduct a more basic types of research but also to explore a more speculative new technology, which cannot be justified internally because of limited resources or because of the high risk involved. Similarly, Beesley and Rothwell (1987) find that R&D activities carried out with industry-oriented research institutes and universities are particularly effective ways for high-tech SMEs to gain access to state-of-the-art research and knowledge. Aurora and Gamgardella (1990) also identify that most development agreements signed with universities tend to be centred on more basic research objectives, rather than ready-to-market applications in the biotechnology industry. On the whole, these studies suggest that the NPD projects that deploy horizontal links with universities and research institutes, aimed at exploiting complementary technology to fulfill firms' technology gaps, tend to be more innovative.

Entering into alliances enables a firm to learn about the skills of other firms (Hamel et al., 1989). Studies (Sinha and Cusumano, 1991; Dussauge et al., 2000) of R&D alliances, comprising a group of competing or non-competing firms, suggest that learning new skills and/or acquiring know-how would be more effective between partners if alliance firms were to contribute different capabilities. In addition, Sakakibara (1997) confirms empirically that the skill-sharing motive is likely to increase in R&D consortia displaying heterogeneous capabilities. This evidence highlights the importance of complementary technology from alliances of competing or non-competing firms, whose technologies, once integrated with internally existing technologies, permit the firm to develop a more innovative product.

The theoretical arguments and empirical evidence discussed above indicates that horizontal links with potential competitors, non-competitors (e.g., OEM/ODM[1]

[1] OEM stands for original equipment manufacturers. This term has been used frequently in the high-tech industry and connotes the meanings of contracted manufacturing. An ODM (original design

partners), universities, and industry-intensive research institutes all tend to provide firms with complementary technology and/or novel technology that cannot be verified and developed internally. Just as complementary knowledge can boost a firm's innovative productivity (Teece, 1992), a more innovative NPD project tends to be associated with a relatively high extent of horizontal linkage that, in consequence, results in the absorption of relatively high extent of novel product knowledge. By contrast, the vertical linkages, which are less to do with gaining new product/technology knowledge, are more likely to be associated with incremental product innovations, involving more stable and mature technology. Hence, the first hypothesis is put forth as:

*Hypothesis 1: The positive effects of **horizontal linkages** on **gains in new product knowledge** will be stronger than those of **vertical linkages.***

In order to develop new products, a firm has also to develop a body of technological know-how with commercial possibilities. To transform this know-how into a viable product, the firm must integrate a set of abilities that include complementary design/development know-how, manufacturing know-how, and marketing know-how into its NPD process (Crawford, 1997; Teece, 1986). Complementary design/development know-how is crucial because, increasingly, new product development involves several specialist technologies that need to be effectively integrated. Manufacturing know-how is also crucial for two reasons. First, it allows the firms to assemble new product more efficiently in order to meet the cost/performance ratio set by the marketplace. Second, it is one of the key drivers in converting an engineering prototype into a mass production unit (Cooper, 1999).

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and manufacturing) is a firm that not only manufactures but also designs/develops new products for its international customers, which market these products under their own brands. ODM firms develop their own R&D capability and gain more competitiveness than OEM firms.

Furthermore, marketing know-how is critical since the firm needs to understand customer's needs and wants, which should be designed into new product specifications, and also the firm must be able to distribute the new product to the target customers efficiently. Hence, the three sub-hypotheses are:

*H1A: The positive effects of **horizontal linkages** on **gains in R&D knowledge** will be stronger than those of **vertical linkages**.*

*H1B: The positive effect of **horizontal linkages** on **gains in marketing knowledge** will be stronger than those of **vertical linkages**.*

*H1C: The positive effect of **horizontal linkages** on **gains in manufacturing knowledge** will be stronger than those of **vertical linkages**.*

3.2.2 The Mediating Role of Gains in New Product Knowledge

As the primary aims of external linkages are to gain access to complementary technologies (Rothwell and Dodgson, 1991; Powell et al., 1996), to assess and acquire a range of complementary product-specific know-how (Teece, 1986), and to fill the gap between the product domain and knowledge domain, these linkages, therefore, lead to an increase of product knowledge stock. Subsequently, as the technology gap between the new product know-how and the firm's existing product know-how disappears, a relatively innovative product can then be realized. That is, the larger the technology gap that exists in a NPD project, the more innovative a new product will be if the gap vanishes. The logic is that while external linkages are important, it is the extent of absorption of new, complementary product-specific knowledge that decides the new product's innovativeness. In other words, an increase in design & development, manufacturing and marketing knowledge stock as a result of external linkages leads to the development of a more innovative new product in a NPD project. Thus, the next hypothesis is proposed as:

Hypothesis 2: The positive effects of external linkages and absorptive capacity on ***new product innovativeness*** *are mediated by gains in new product related (that is, design & development, manufacturing and marketing) knowledge.*

H2A: The positive effects of external linkages and absorptive capacity on ***technological innovativeness*** *are mediated by gains in new product related knowledge.*

H2B: The positive effects of external linkages and absorptive capacity on ***market innovativeness*** *are mediated by gains in new product related knowledge.*

3.3 Absorptive Capacity and External Knowledge Absorption

3.3.1 The Direct Effect of Absorptive Capacity on Gains in New Product Knowledge

A firm engaged in more innovative product development requires not only a great deal of learning opportunities from its alliances, but also a high standard of learning ability to effectively convert, in particular, tacit know-how into explicit know-how (Madhavan and Grover, 1998). This learning ability - absorptive capacity - is considered one of the most crucial factors influencing the effectiveness of external knowledge acquisition (Arora and Gambardella, 1990; Atuahene-Gima, 1992; Atuahene-Gima, 1993; Arora and Gambardella, 1994; Mowery et al., 1996; Veugelers, 1997; Luo, 1997; Lane and Lubatkin, 1998; Mangematin and Nesta, 1999). Absorptive capacity provides firms, first, with the ability to recognize the value of new, external technology (Cohen and Levinthal, 1990). Cohen and Leventhal (1990: 136) state, "if the firm does not develop its absorptive capacity in some initial period, then its beliefs about the technological opportunities present in a given field will tend not to change over time, because the firm may not be aware of the significance of signals that would otherwise revise its expectations." Several empirical studies (Arora and Gambardella, 1990; Arora and Gambardella, 1994) indicate that the level of a firm's internal knowledge has a positive impact on its ability to evaluate emerging external technology. Sen and Rubenstein (1989) point out that a firm's R&D unit's awareness of future development concerning external technology is a crucial factor that often decides the success of international technology alliances. Cohen and Levinthal (1994) further stress that absorptive capacity also, to a certain extent, improves a firm's ability to correctly predict its future technological advances.

Secondly, in addition to recognising the value of external technology, this ability allows firms to assimilate newly recognized technologies. For instance, Mangematin and Nesta (1999) argue that a firm with higher absorptive capacity more easily assimilates fundamental or scientific/basic knowledge while they engage in R&D collaboration with research institutes. Moreover, Cockburn and Henderson (1998) suggest that a firm needs to equip itself with a relative knowledge in advance (i.e. a proper absorptive capacity) prior to taking advantage of publicly generated research (i.e. basic technology). However, the difficulty in assimilating external technology lies in the tacit part of the knowledge, the acquisition of which requires extensive experience sharing and face-to-face discussion. Therefore, a certain extent of in-depth linkages between learning parties is needed.

Finally, absorptive capacity enables a firm to apply assimilated knowledge to commercial ends as well as for the creation of firm-specific new knowledge (Cohen and Levinthal, 1990). For instance, Sivadas and Dwyer (2000) confirm that NPD success in both internally and externally conducted projects is positively associated with absorptive capacity. An extensive body of research, particularly, from the field of inter-firm collaboration has investigated the effect of absorptive capacity on a firm's performance in absorbing external technology through various forms of alliances (Levinson and Asahi, 1995; Mowery et al., 1996; Koza and Lewin, 1998; Kumar and

Nti, 1998). For instance, Levinson (1995) suggests that learning partners who are equipped with the requisite absorptive capacity are necessary in order to carry out effective inter-organizational learning through an alliance network. The empirical study of Mowery et al. (1996) illustrates that absorptive capacity significantly affects the acquisition of technology through alliances. In particular, the coincidence of alliances where there is prior experience in related technological areas is a crucial factor that determines the quality of inter-firm learning. Nicholls-Nixon (1993) also suggests a positive relationship between a firm's use of multiple types of technological sourcing linkages and its absorptive capacity. This evidence in general confirms the crucial role of absorptive capacity in external knowledge acquisition through alliances, and absorptive capacity is highly associated with the effectiveness of technology assimilation as well as knowledge acquisition between learning partners. In other words, a firm with a relatively high absorptive capacity would be more able to assimilate new product knowledge from external collaborators in a NPD project. Hence,

Hypothesis 3: A firm's level of ***absorptive capacity*** *is positively related to its* ***gains in new product related knowledge (design & development, manufacturing, and marketing)*** *in a NPD project.*

> *Hypothesis 3A: A firm's level of* ***absorptive capacity*** *is positively related to its* ***gains in R&D knowledge*** *in a NPD project.*
>
> *Hypothesis 3B: A firm's level of* ***absorptive capacity*** *is positively related to its* ***gains in marketing knowledge*** *in a NPD project*
>
> *Hypothesis 3C: A firm's level of* ***absorptive capacity*** *is positively related to its* ***gains in manufacturing knowledge*** *in a NPD project..*

3.3.2 The Moderating Role of Absorptive Capacity

Absorptive capacity is also likely to moderate the effect of external linkages on gains in new product knowledge. Although external linkages provide access to new, complementary knowledge that is required when developing new products, their impact on the amount of new knowledge absorbed and developed is dependent on the level of the firm's absorptive capacity. Firms may gain access to new knowledge though collaboration, yet be unable to absorb the knowledge if they do not have a relative, complementary set of absorptive capacity. As new product knowledge tends to be more tacit, uncodified (Nonaka, 1994; Nonaka and Takeuchi, 1995) and essentially contains "sticky" information (von Hippel, 1994; von Hippel, 1998), the level of complementary absorptive capacity decides the amount of knowledge absorption. Kumar and Nti (1998) hypothesise that knowledge appropriated by a firm through an alliance arrangement relies upon its absorptive capacity as well as the volume of exposure of alliance-generated knowledge. In other words, the greater the absorptive capacity of a firm, the more knowledge it can appropriate when exposed to a given volume of alliance-generated knowledge. When a NPD project is a radical innovation and requires an extensive association of knowledge from its R&D collaborators, absorptive capacity becomes crucial in determining the extent of such knowledge absorbed. In contrast, when a NPD project is an incremental innovation requiring less external linkage, the role of absorptive capacity becomes less significant since less knowledge of external collaborators is to be absorbed. That is, absorptive capacity moderates the relationship between external linkages and the extent of new knowledge absorbed. Hence,

Hypothesis 4: A firm's level of ***absorptive capacity*** *moderates the positive effects of* *external linkages on its* ***gains in new product related knowledge*** *in a NPD project.*

Hypothesis 4A: A firm's level of ***absorptive capacity*** *moderates the positive effects of external linkages on* ***gains in R&D knowledge.***

Hypothesis 4B: A firm's level of ***absorptive capacity*** *moderates the positive effects of external linkages on* ***gains in marketing knowledge.***

Hypothesis 4C: A firm's level of ***absorptive capacity*** *moderates the positive effects of external linkages on* ***gains in manufacturing knowledge.***

3.4 Summary

This chapter focuses on the development of the research hypotheses, which are derived from the conceptual framework presented in Section 2.6. Hypotheses 1A, 1B, 1C, 2A and 2B refer to the proposed relationship between external linkages, new product innovativeness and gains in new product related knowledge. Hypotheses 3A, 3B, 3C, 4A, 4B, and 4C consider the role of absorptive capacity that not only moderates the relationship between external linkages and gains in new product knowledge, but also positively affects the extent of gains in new product knowledge.

The next chapter presents the research methods related to the development of survey instrument, data collection, and statistical methods for hypothesis testing.

Chapter 4
Research Method

4.1 Introduction

This chapter describes the research design, procedures for collecting data and the analytical methodology for hypotheses testing. Section 4.2 explains the process of instrument development for a questionnaire survey. Section 4.3 discusses the survey design. The measures for constructs are described and illustrated in Section 4.4. Finally, Section 4.5 details the analytical methodology for hypothesis testing and focuses on the analytical techniques of both moderated and mediated regression analysis.

4.2 Instrument Development

The research process for the instrument development, guided by Churchill (1979), includes four phases: (1) Item generation, (2) Pre-pilot study, (3) Pilot study and (4) Full-scale survey and instrument validation. These four items are discussed below.

(1) Item Generation

The literature reviewed in Chapter 2 is used to identify the main content of constructs in the research framework and to generate initial items and the definition of each construct. A fundamental requirement for a good measure is content validity, which means the measurement items in an instrument should cover the major content domain of a construct (Churchill, 1979). Content validity is usually achieved through comprehensive literature review and interviews with practitioners and academic experts. An early version of questionnaire was designed and ready for the pre-pilot after this phase.

(2) Pre-pilot Study

Using a preliminary version of the questionnaire, the pre-pilot study involved semi-structured interviews with NPD practitioners and academic experts with the aim of refining contents of measurement items of each construct.

(3) Pilot Study

The third phase was to pilot the questionnaire by sending it to a sample of qualified senior project managers. These managers were greatly involved in their firms' NPD activities. Returned questionnaires were then used to examine initial reliability and validity of the measuring instruments. Based on the feedback of the pilot study, the instruments were further refined. The details concerning the pre-pilot, the pilot study and instrument development will be discussed in Chapter 5.

(4) Large-scale Data Analysis and Instrument Validation

A sampling frame was constructed for the development of a mailing list by using several public Taiwanese IT company data books. Before mailing out the questionnaires, the mailing list was further refined to remove unqualified companies, such as multiple names from the same company or companies that do not engage in new product development. The survey instrument used in the large-scale study was submitted to rigorous reliability and validity assessment using the response data. In the large-scale study, the sample size was large enough for construct level confirmatory factor analysis to examine unidimensionality, that is, convergent validity of each measuring instrument. Chapter 5 details the large-scale survey and the assessment of the measurement instrument.

4.3 Unit of Analysis and Sampling Frame

The term, a unit of analysis, is used to refer to the variables or phenomena under study and the research problem ascribed, about which data is collected and analysed

(Hussey and Hussey, 1997). The major objective of this research is to examine the impacts of various forms of learning linkages involved in a firm's NPD project, as well as its absorptive capacity on the level of new product innovativeness. In this case, the unit of research is a new product project. Because of the reflective nature of questionnaire answering, a qualified respondent must be a senior manager who has been greatly involved in the complete process of a NPD project. In addition, the new product derived from such a NPD project needs to meet conditions such as the product being launched successfully within two years and its NPD processes carried out within the firm.

In the current study, firms in the IT industry were selected as research objects for two reasons: (1) IT firms operate in a highly dynamic environment and they are involved in a multidisciplinary NPD process that naturally requires them to need access to a broad range of knowledge sources (Mowery and Rosenberg, 1989; Mowery et al., 1996); and, (2) these firm are more inclined to collaborate with external sources of technology to assist in new product development (Hagedoorn, 1993; Hagedoorn and Schalenraad, 1994; DiBella et al., 1996; Lynn et al., 1996). For instance, in his examination of 4129 strategic alliances across various industries, Hagedoon (1993) found that technological alliances in these so-called high-tech sectors (i.e. biotechnology, microelectronics, computers, telecommunications, and software) are strongly related to R&D co-operation, particularly, for the development of new products and/or new technology. This suggests there may be a prevalence of technological alliances within the IT industries.

Following on Wong et al.'s (1998) and Sher's (1998) previous surveys of Taiwanese IT firms, this study focuses on the knowledge-absorption activities of selected firms' NPD projects. The Taiwanese IT firms in the study were selected for several reasons. First, Taiwan is ranked the third largest IT producer in the world and represents the major OEM/ODM source for global IT competitors (Asia IT Report, 2000). More than sixty-five percent of its IT production is exported. Taiwan is an island without rich natural resources and is a newly developed country with an export-oriented economy. Against this background, IT firms in Taiwan are well used to establishing links with international technology sources from places such as Japan and the west coast of the United States in order to acquire either new product ideas or related product technologies. Furthermore, these IT firms operate in a severely competitive environment where a continuous, quick release of new products to the market is a way of business life and the effectiveness of new product development plays a crucial role in future viability. These firms tend to collaborate with external sources of technology for NPD projects (Wong et al., 1998). Another reason for choosing Taiwan is the researcher's own advantage. The researcher has been involved in the NPD collaboration of some of these IT firms for many years. This long experience of involvement offers both insights and connections that have proved useful throughout the research process. Finally, Taiwanese IT firms are aggregated in the northern part of island within a radius of 50 miles. This condition particularly facilitates carrying out face-to-face interviews for the pilot study.

The sampling frame of this research was comprised of IT firms listed in three sources: the 2000 Directory of the Hin-Chu Science-based Industrial Park, the 2000 Directory of the Taipei Computer Association and the Top 1000 Manufacturing Firms in 2000 compiled by the most well-known economic monthly in Taiwan, *Commonwealth*. Firms from these sources cover four IT sub-industry sectors: computers (both PC and servers) and peripherals, telecommunications, semi-conductors and software. The number of IT firms qualifying for the survey in the sampling frame was estimated at around 550. With a relatively small sample and the low response rate expected of industrial surveys (Kanuk and Berenson, 1975;

Krysan et al., 1994), a random sampling procedure might prevent the current study from collecting adequate samples needed for a significantly statistical analysis with a statistical power that is selected. Chapter 5 details how a sample list was composed to meet the requirement of a minimal sample size.

4.4 Measurement of Variables

4.4.1 Measures of Absorptive Capacity

Cohen and Levinthal (1990) define absorptive capacity as the ability to recognise the value of new, external technological knowledge and assimilate it and apply it for commercial ends (see section 2.5.1). Absorptive capacity *per se* is a complex, multifaceted construct, as the diversity of research themes in the literature suggests and these range from knowledge intensity to innovative culture. No generally accepted approach to the measurement of absorptive capacity has yet been developed. Objective indicators of absorptive capacity, such as number of patents and R&D intensity (i.e. R&D expenditure divided by sales) have problems of instability (Spender and Grant, 1996). For instance, start-up firms tend to allocate a high proportion of budget in R&D expenditures. Similarly, in a period of economy downturn R&D expenditure is often disproportionately high due to slack sales. The number of patents possessed may sometimes reflect a firm's strategic stance in R&D corporative alliance rather than its absorptive capacity. The use of subjective measures for absorptive capacity in this case is preferred to objective proxies. As Spender and Grant stated, "There is a growing realization that the variables which are most theoretically interesting are those which are least identifiable and measurable" (1996: 8). Researchers will continue to face such dilemmas when conducting knowledge-based research.

Following Tu's mass customisation study (1999), the current study defines absorptive capacity as a firm's ability to identify, communicate and assimilate relevant external and internal knowledge and technology. Under this definition, absorptive capacity is a function of the firm's existing knowledge base, knowledge scanning ability, and effectiveness and efficiency of its knowledge communication processes.

Cohen and Levinthal (1990) suggest that prior related knowledge will be a major determinant of absorptive capacity. They further suggest that firms with sufficient prior knowledge, which is closely related with new knowledge, will have the ability to proactively envisage future technological advances (Cohen and Levinthal, 1994). A firm's NPD related prior knowledge base might depend upon its engineers' and managers' prior working experience, educational level, and overall job competence in a related technology field.

A firm's NPD knowledge scanning ability is defined as a learning system that enable a firm to effectively link and exploit relevant internal and external knowledge and technology for its NPD purposes. Leonard-Barton (1995: 155-160) identifies five measures to enhance this ability: (1) encouraging knowledge scanning activities; (2) providing for continuous interaction with related technology or knowledge; (3) nurturing technological gatekeepers; (4) nurturing boundary-spannes; and (5) fighting "not-invented-here" syndrome. Cohen and Levinthal (1994) also suggest that firms who send employees for advanced technical training or encourage them to monitor and read the appropriate technical literature also benefit their development of absorptive ability. Furthermore, the establishment of close relationships with external sources (e.g. R&D collaborator, suppliers, buyers) that link information channels and expose employees to new ideas can also contribute to a firm's knowledge scanning ability (Cohen and Levinthal, 1990; Leonard-Barton, 1995).

The effectiveness of an organisation's knowledge communication processes depends upon its communications networks and culture (ibid., Levinson and Asahi, 1995; Nonaka and Takeuchi, 1995). For instance, functional integration, redundancy of information, and knowledge diversity are critical requirements to enable effective communication processes (Cohen and Levinthal, 1990; Nonaka, 1994). An open communication culture facilitates information flow leading to an effective learning organisation (Levinson and Asahi, 1995) and resulting in increased absorptive capacity.

A five-dimension model of absorptive capacity, consisting of the engineer knowledge base, management knowledge base, knowledge scanning ability, communication network, and communication climate was adapted from Tu's measurement items, as well as the work of Leonard-Barton (1995). A 29-item reflective scale was used to measure the construct of absorptive capacity. Respondents were asked to indicate the degree to which they agree with the items on seven-point Likert scales where 1 = strongly disagree and 7 = strongly agree. A conventional, objective scale, R&D intensity, was also used to cross validate this reflective scale.

Engineer Knowledge Base (Existing Knowledge Base) (Tu, 1999)

1. The general knowledge level of our engineers is high.
2. The overall technical knowledge of our engineers is high.
3. The general educational level of our engineers is high.
4. The overall job competence of our engineers is high.

Management Knowledge Base (Existing Knowledge Base) (Tu, 1999)

1. The knowledge of our managers is adequate when managing daily operations.
2. The knowledge of our managers is adequate when solving technical problems.
3. The knowledge of our managers is adequate when dealing with new technology.
4. The knowledge of our managers is adequate when making business decisions.

Knowledge Scanning Ability

1. We seek to learn from benchmarking best practices in our industry. (Tu, 1999)
2. We seek to learn from trying out new technologies. (Tu, 1999)
3. We seek to learn from our buyers, suppliers, and R&D collaborators. (Leonard-Barton, 1995)
4. We seek to learn from tracking new market trends in our industry. (Tu, 1999)
5. We seek to learn from conducting R&D activities. (Tu, 1999)
6. We seek to learn from taking new business opportunities. (Tu, 1999)
7. We seek to learn from the routine search of useful information. (Tu, 1999)
8. We seek to nurture technological gatekeepers for various new technologies. (Leonard-Barton, 1995)
9. We seek to fight the not-invented-here syndrome. (Leonard-Barton, 1995)
10. We seek to nurture boundary spanners. (Leonard-Barton, 1995)

Communications Climate (Tu, 1999)

1. Our employees tend to trust each other.
2. Our employees are willing to accept changes.
3. Our employees have no difficulty accepting new ideas.
4. Our employees share ideas freely with each other.
5. Our employees are supportive of each other.
6. Our employees have strong feelings of belonging to our organisation.

Communications Network (Tu, 1999)

1. The communications among functional areas are frequent.
2. The communications among functional areas are extensive.
3. The communications between supervisors and the subordinates are extensive.
4. The communications between supervisors and the subordinates are frequent.
5. The communication of new ideas from one department to another is extensive.

4.4.2 Measures of External Linkages

The degree of an external linkage is defined as the extent to which it is involved in the development of the NPD project. Adapted from Tidd et al.'s (1997a) classification, the external linkages studied included: two forms of vertical linkages (customers and suppliers) and three forms of horizontal linkages (cooperating firms, industry-based research institutes, and universities). The customers in the external linkages are defined as end-users, channel members, and down-stream manufacturing customers. Similarly, the suppliers in the external linkages are defined as a NPD project's upstream suppliers that may supply key components, materials, testing equipments and manufacturing facilities. The cooperating firms are defined as firms that are either competitors or non-competitors, which are involved in any development stage (from initial concept development to final product launch) of the NPD project to be studied. This includes technical consulting companies, OEM and ODM customers, and new project co-developers. The industry-based research institutes and universities in the external linkages are research institutes and universities that are involved in any development stage of the surveyed NPD project.

Although many researchers postulate that successful product development requires a chartered set of steps (Cooper and Kleinschimidt, 1986; Cooper and Kleinschimidt, 1991; Dwyer and Mellor, 1991), no author has claimed that there is only one particular set of activities required for all firms. The current study adapts Cooper and Kleinschimidt's (1986) new product process model, which forms a set of 13 activities. Therefore, a thirteen-item, formative scale was employed. The following is an example of a 13-item scale to measure the degree of external linkage from customers. Respondents were asked to indicate the degree to which they agree with the items on seven-point Likert scales where 1 = strongly disagree and 7 = strongly agree in relation to each linkage.

1. Our customers provided their expertise in helping out the project's initial go/no go decision.
2. Our customers provided their expertise in the project's preliminary market assessment.
3. Our customers provided their expertise in the project's preliminary technical assessment.
4. Our customers assisted us in conducting a detailed market study/market research.
5. Our customers provided their expertise in a financial or business analysis leading to a go/no go decision prior to product development.
6. Our customers were closely involved in the design and development of the product, resulting in, e.g., a prototype or sample product.
7. Our customers were closely involved in testing the product in-house: in the lab or under controlled conditions.
8. Our customers were closely involved in testing the product under real life conditions, e.g., with customers and/or in the field.
9. Our customers provided their expertise in the product's test market/trial sell.
10. Our customers were closely involved and provided their expertise in a trial production run to test the product facilities.
11. Our customers were closely involved in a financial analysis, following product development but prior to full-scale production.
12. Our customers were closely involved and provided their expertise in the start-up of full-scale production.
13. Our customers were closely involved and provided their expertise in the launch of the product.

4.4.3 Measures of Gains in New Product Knowledge

Some scholars have viewed product development as a process of reducing uncertainty through information processing (Clark and Fujimoto, 1991; Clark and Wheelwright, 1993). Others have increasingly envisaged product development as a process of organisational learning involving the acqusition, dissemination, and utilisation of information (Leonard-Barton, 1992; Nonaka, 1994; Moorman and Miner, 1997) that eventually leads to the reduction of the gap between the new product domain and the firm's knowledge domain. As product development includes a series of uncertain activities, resolving all these uncertainties encompasses developing a new set of know-how, including design/development know-how, manufacturing know-how, and marketing know-how (Teece, 1986; Henderson and Clark, 1990; O'Connor, 1998).

Gain in new product knowledge is defined as the extent to which a firm's familiarity of new product know-how in design/development, marketing and manufacturing in comparison with prior knowledge of the NPD project. A 20-item reflective scale was developed to capture this construct from the related literature (Song and Parry, 1996; Song and Parry, 1997; Cooper and Kleinschimidt, 1987).

The scale was primarily derived from Song and Parry's (1997) six proficiency scales (proficiency of the predevelopment planning process, proficiency of concept development and evaluation, proficiency of marketing research, pre-test proficiency, market launch proficiency, technical proficiency) and Cooper and Kleinschmidt's (1987) three proficiency scales (proficiency of pre-development activities, proficiency of technological activities, and proficiency of market-related activities). These proficiency scales, which were used to assess a firm's competence and dexterity during key stages of the product development process, cover the complete range of the development of new product know-how. These scales formed four dimensions of

NPD knowledge: predevelopment assessment knowledge, marketing knowledge, design and development knowledge, and manufacturing knowledge. A seven-point scoring format (1 = strongly disagree; 7 = strongly agree) was used for all 20 items.

Gain in Predevelopment Assessment Knowledge

1. We have gained new knowledge in preliminary market assessment of the product. (Cooper and Kleinschimidt, 1987; Song and Parry, 1996)
2. We have gained new knowledge in determining marketing characteristics and trends. (Cooper and Kleinschimidt, 1987; Song and Parry, 1996)
3. We have gained new knowledge in the preliminary business/financial analysis. (Cooper and Kleinschimidt, 1987; Song and Parry, 1996)
4. We have gained new knowledge in initial screen techniques. (Cooper and Kleinschimidt, 1987; Song and Parry, 1996)
5. We have gained new knowledge in handling the after-service programme. (Items recommended by NPD practitioners)
6. We have gained new knowledge in handling testing of the product prototype. (Song and Parry, 1996)
7. We have gained new knowledge in the preliminary engineering and technical assessments. (Song and Parry, 1996; Song and Parry, 1996)

Gain in Marketing Knowledge

8. We have gained new knowledge in detailed market study/market research of the product. (Song and Parry, 1996; Cooper and Kleinschimidt, 1987; Song and Parry, 1997)
9. We have gained new knowledge in identifying "appeal" characteristics that would differentiate and sell the product. (Song and Parry, 1996; Song and Parry, 1997)
10. We have gained new knowledge in executing test market programs in line with the

plans for commercialisation of the product. (Song and Parry, 1996; Cooper and Kleinschimidt, 1987; Song and Parry, 1997)

11. We have gained new knowledge in launching and introducing new products into the targeted marketplace – selling, promoting and distributing of the product. (Song and Parry, 1996; Song and Parry, 1997)

Gain in Design and Development Knowledge

12. We have gained new knowledge in building the product to designated or revised specifications. (Song and Parry, 1996; Song and Parry, 1997)
13. We have gained new knowledge in evaluating laboratory tests to determine basic performance against specifications of the product. (Song and Parry, 1996; Song and Parry, 1997)
14. We have gained new knowledge in executing prototype or "in-house" sample product testing of the product. (Song and Parry, 1996; Cooper and Kleinschimidt, 1987; Song and Parry, 1997)
15. We have gained new knowledge in determining the final product design and specifications of the product. (Song and Parry, 1996; Song and Parry, 1997)
16. We have gained new knowledge in working continuously for cost reduction and quality control of the product. (Song and Parry, 1996; Song and Parry, 1997)

Gain in Manufacturing Knowledge

17. We have gained new knowledge in conducting preliminary manufacturing assessments of the product. (Song and Parry, 1996)
18. We have gained new knowledge in executing trial/pilot production of the product. (Cooper and Kleinschimidt, 1987)
19. We have gained new knowledge in conducting production start-up of the product. (Cooper and Kleinschimidt, 1987)
20. We have gained new knowledge in controlling manufacturing quality of the

product. (Item recommended by NPD practitioners)

4.4.4 Measures of New Product Innovativeness

Previous research suggests that new product innovativeness be investigated from a perspective of inherent product attributes: 'newness to the market', 'newness to the firm', or a combination of both (Booz, 1982). Studies that seek to distinguish types of innovation by how drastically the product has changed, such as radical innovation versus incremental innovation or revolutionary versus evolutionary innovation (Utterback and Abernathy, 1975) have mostly adopted the schema of 'newness to the market.' This approach classifies innovations by their effects on established usage patterns. Research that focuses on the change of a firm's innovation capability from its previous products has taken on the schema of 'newness to the firm.' Although this framework cannot fully reflect a product's impact on either competitors or consumers, this measure, from a broader perspective, captures the ability of the firm to service and continue to update technology which is vital to its long-term survival and future growth. The third schema is a combination of 'newness to the market' and 'newness to the firm' frameworks developed by Booz, Allen and Hamilton (1982). The framework is divided into a six-level scale along the two dimensions to reflect a dynamic interaction between the firm and the marketplace. The six levels of product innovativeness include cost reductions to existing company product, repositionings of existing company product, improvements/revisions to existing products, additions to an existing company product, product lines new to the firm, and new-to-the-world products. Boon, Allen and Hamilton's framework is particularly useful in analysing a firm's product strategy.

This study adopted the newness-to-the-firm approach to measure the level of new product innovativeness. Newness of the product in each NPD project was measured with an eight-item multidimensional scale drawn from Cooper (1979a & 1979b) on the seven point "strongly disagree – strongly agree" Likert scales. Respondents were asked to indicate their perception of degree of product newness in comparison with other products developed within the firm in two dimensions: market and technology.

Technological Innovativeness (Cooper, 1979a & 1979b)

1. In comparison to the existing product range, the product class was new to our firm.
2. In comparison to the existing product range, the product use (need served) was new to our firm.
3. In comparison to the existing product range, the product production process was new to our firm.
4. In comparison to the existing product range, the product design/technology was new to our firm.

Market Innovativeness (Cooper, 1979a & 1979b)

5. In comparison to the existing product range, our customers for the product were new to our firm.
6. In comparison to the existing product range, distribution and sales force for the product were new to our firm.
7. In comparison to the existing product range, advertising and promotion for the product was new to our firm.
8. In comparison to the existing product range, the product's competitors were new to our firm.

4.4.5 Control Variables

Control variables including firm size, sub-industry sector and type of new product are taken into consideration in the survey. Firm size may affect the project unit's resources and capability to gain leverage over external knowledge sources which enhance the unit's propensity to generate more innovative products (Damanpour, 1996). Ettlie and Rubenstien (1987) confirm that larger firms are more likely to adopt ambitious new technologies to introduce new products. In this study, the number of employees is used as the indicator for firm size. Types of new products comprise system products, sub-assemblies, components/parts and software. Since a system product is developed by combining a set of sub-assemblies or parts from a variety of key suppliers, its NPD project tends to involve more technological collaboration activities. The study then sought to control the effect of product types in the later statistical analyses.

4.5 Analytical Methodology

Hierarchical multiple regression analysis was utilised to analyse four hypotheses. This is instrumental in testing complex relationships involving moderating and mediating effects while analysing a set of dependent variables and predictor variables. Although a structural equation modeling analysis is considered to be more effective in examining a series of dependence relationships simultaneously (Hair et al., 1998), both sample size requirements and the limitation of the measuring scale deters the choice of this technique. Since the foci of this research are to examine the moderating effect of absorptive capacity as well as the mediating effect of gains in product knowledge between external linkages and new product innovativeness, both moderated regression and mediated regression analyses adequately serve these purposes and are therefore employed.

4.5.1 Hierarchical Regression Analysis

The following two regression models are used to test the direct effect of external linkages on gains in new product knowledge.

1. $PK_k = B_0 + B_1 CV_i + e$

2. $PK_k = B_0 + B_1 CV_i + B_2 EL_j + e$

Where PK = a measure of gains in new product knowledge,

CV = control variables, and

EL = a measure of external linkage.

The employment of the two equations is to confirm that EL (predictor variable) further predicts gains in new product knowledge (PK, dependent variable) after CV explains the variance when there exists high correlations between PK and CV. The direct effects of EL on gains in new product knowledge are certain when an increase of F-value from Equation 1 (reduced model) to Equation 2 (full model) is statistically significant and the coefficients (B_2) of EL are significant.

4.5.2 Moderated Regression Analysis and Sub-Group Analysis

The hypotheses propose that external linkages have a positive impact on gains in new product knowledge, and this relationship is moderated by absorptive capacity. Both moderated regression analysis (MRA) and sub-group analysis are utilised to test the moderating effects of absorptive capacity. Each of these techniques provides different insights into the relationship being studied as well as the explanation of different theoretical supports. Also, each technique possesses certain limitations that must be taken into account.

The main distinction between the two techniques is the ability to test between the "*degree*" of relationship between two variables X and Y and the "*form*" of the relationship between the same variables. The regression coefficient B_{yx} is the index of the form of relationship, while the correlation coefficient r_{xy} is the index of the degree of the relationship (Zedeck, 1971, Sharma et al.; 1981, Arnold, 1982). Specifically, the moderated regression analysis (MRA) is used to determine existence of a moderating effect, and subgroup analysis is utilised to test the degree/strength of moderation (Baron and Kenny, 1986; Venkatraman, 1989).

MRA requires the following three regression models to test moderating effects (Zedeck, 1971; Sharma et al., 1981; Cohen and Cohen, 1983):

1. $DV = \beta_0 + \beta_1 CV + \beta_2 IV$
2. $DV = \beta_0 + \beta_1 CV + \beta_2 IV + \beta_3 MV$
3. $DV = \beta_0 + \beta_1 CV + \beta_2 IV + \beta_3 MV + \beta_4 (IV \times MV)$

Where MV = Moderating Variables,

DV = Dependable Variables,

IV = Independent Variables, and

CV = Control Variables.

Here IV×MV reflects the joint effect of IV and MV. The moderation hypothesis (the form of relationship) is supported if Equations 2 and 3 are significantly different from each other and the coefficient of the cross-product term (i.e. IV × MV) differs significantly from zero (i.e., $\beta_4 \neq 0$). If Equations 2 and 3 are significantly different from Equation 1, but not from each other (i.e., $\beta_3 \neq 0$; $\beta_4 = 0$), then the MV is an independent predictor, not a moderating variable. Sharma et al. (1981) further point out that for MV to be a pure moderator variable Equations 1 and 2 should not be different from each other, but should be different from Equation 3 (i.e., $\beta_3 = 0$; $\beta_4 \neq 0$). For MV to be identified as a quasi moderator, Equations 1, 2, 3 should be different from one another (i.e., $\beta_3 \neq 0$; $\beta_4 \neq 0$).

The procedures of subgroup analysis are, first, to split the sample into groups based on hypothesised moderators and then, following this, to compare correlation coefficients between subgroups. The degree/strength of moderation is supported when statistically significant differences exist in the value of correlation coefficients. One appropriate statistic that can be employed to test significant difference in r_{xy} for two subgroups is (Arnold, 1982):

$$Z = (r_1 - r_2) \;/\; (1/n_1 - 1 + 1/n_2 - 1)^{1/2} ,$$

Where

r_1 = r_{xy} in Group 1;

r_2 = r_{xy} in Group 2;

n_1 = sample size of Group 1;

n_2 = sample size of Group 2;

Z = distributed by $N(0,1)$.

In testing the equality of correlation coefficients across more than two subgroups, the following chi-squared statistic can be applied:

$$\chi^2 = \Sigma(n_i - 1)\, r_i^2 \; - \; \{\Sigma(n_i - 1)(r_i)\} \;/\; \Sigma(n_i - 1)$$

Where

n_i = sample size for subgroup *i*,

$r_i = r_{xy}$ for Subgroup *i*.

However, subgroup analysis has its limitations. First, it presumes that the variables have equal variance at each level of the moderator. Second, the amount of measurement error in the dependent variable can cause the correlations between the independent variables and dependent variables to differ spuriously if it varies as a function of the moderating variable (Baron and Kenny, 1986). Zedeck (1971) argues that the differences in errors of estimate for different subgroups, in addition to correlation coefficients, should be examined. Third, the problem of subgroup sample sizes affects the performance of significance tests. The number of different subgroups should be carefully formed. As a solution, Zedeck (1971) proposes that we consider several moderators simultaneously as the basis for subgroups or to use a single multiple moderated regression equation, which maintains the total sample size in the analyses.

Venkatraman (1989: 426) suggests that four analytical issues are to be addressed when an empirical researcher takes the moderation perspective: (1) the distinction between form and strength of moderation, (2) the impact of multi-collinearity, (3) the comparison of main versus interaction effects, and (4) the requirement of partialling out quadratic effects for testing the moderating effects.

The form and degree/strength of moderation implies different meanings of the hypothesis. If a researcher specifies that the predicting outcome is jointly affected by the interaction of the predictor variables and the moderator, then the hypothesis reflects the form of moderation. In contrast, if the hypothesis indicates that the outcome differs across different subgroups according to the effect of moderator, then the one that adopts the degree/strength perspective can apply the subgroup analysis.

The problems of multicollinearity in the presence of cross-product terms, such as (MV×IV) which is likely to be strongly correlated with IV and MV, are longstanding issues in regression analysis. When the predictors' means (relative to their standard deviation) are far from zero, a regression analysis is likely to encounter substantial multicollinearity. Therefore, mean-centred scores of predictors are recommended to replace raw scores to reduce the level of correlation between the cross-product term and the predictor variables while testing a moderating effect (Cronbach, 1987; Venkatraman, 1989). But if the variables are measured using ratio scales, such a transformation changes the meanings of the measures and cannot be so applied (Southwood, 1978). Researchers now tend to mean-centre data of both dependent and independent variables while applying moderated regression analysis (e.g., Mohr et al., 1996; Ottum and Moore, 1997).

The simultaneous assessment of main and interaction effects (moderation effects) while using MRA cannot be accomplished at an interval-level of measurement. This is because of the arbitrary scale of origin for interval measurement as well as incapability in comparing the relative weights of the standardized coefficients (Venkatraman, 1989). Therefore, MRA can test only for the existence of interaction effects but cannot compare the relative influence of main and interaction effects.

The fourth issue relates to partialling out the quadratic effects of IV and MV in order to confirm the presence of multiplicative effects (i.e. MV × IV). Southwood (1978) suggests that the following regression model should be employed which simultaneously uses the terms IV, MV, IV^2, MV^2 and IV × MV.

$$\text{Full model: } DV = IV + MV + IV^2 + MV^2 + IV \times MV$$

A test of the partial correlation coefficient between DV and IV × MV, after partialling out the effects of IV, MV, IV^2, and MV^2, provides support for multiplicative effects. Similarly, to test whether a relationship of curvilinearity exists, both the test of the partial correlation coefficients (a) between DV and IV^2, after partialling out the effects of IV, MV, MV^2 and IV × MV, and the test of partial correlation coefficients between (b) DV and MV^2, after partialling out the effects of IV, MV, IV^2 and IV × MV, should be applied.

4.5.3 Mediated Regression Analysis

A hypothesised variable is classified as functioning as a mediator to the extent that it accounts for the relation between the predictor and the dependent variables. In general, the following three regression models (a path-analytic framework) are used to test whether a variable functions as a mediator (Alwin and Hauser, 1975; James and Brett, 1984; Baron and Kenny, 1986):

1. $DV = \beta_0 + \beta_1 CV + \beta_2 IV$
2. $Me = \beta_0 + \beta_1 CV + \beta_2 IV$

3. $DV = \beta_0 + \beta_1 CV + \beta_2 IV + \beta_3 Me$

Where Me = Mediating Variable,

DV = Dependent Variable,

IV = Independent Variable, and

CV = Control Variable.

A mediating effect is supported when the following conditions are held: (a) the coefficients of IV in the first model must be significant (i.e., $\beta_2 \neq 0$); (b) the coefficients of IV in the second model must be confirmed to be significant (i.e., $\beta_2 \neq 0$); (c) the coefficients of Me in the third model must be significant (i.e., $\beta_3 \neq 0$); and (d) the effect of IV on DV must be less in the third model than in the second. If coefficient of IV in Model 3 is not statistically different from zero (i.e., $\beta_2 = 0$), the strongest support for the mediating effects of Me is obtained and this is termed the *complete mediational model.* This indicates that most effects of IV are transferred to the mediator. Alternatively, if the coefficient of IV is different from zero and the aforementioned conditions are all held, a relationship of partial mediation exists, implying *a partial mediational model.*

In Model 3 both IV and Me should be correlated and can produce the problem of multicollinearity because Me is assumed to regress on IV in Model 1. The result of multicollinearity can reduce power in the test of coefficients in Model 3. Baron and Kenny (1986) suggest that not only the significance of the coefficients, but also absolute size should be examined simultaneously.

The use of mediated regression to examine the hypothesized mediator must address the two assumptions: (a) there was no measurement error in the mediator and (b) the criterion variable did not cause the mediator (Baron and Kenny, 1986).

In examining a mediation model that combines moderation (e.g., the conceptual framework illustrated in Figure 2.7), the aforementioned regression models are to be reconstructed as follows (James and Brett, 1984, Baron and Kenny, 1986):

4. DV= $\beta_0 + \beta_1 CV + \beta_2 IV + \beta_4 Mo + \beta_5 Mo \times IV$

5. Me= $\beta_0 + \beta_1 CV + \beta_2 IV ++ \beta_4 Mo + \beta_5 Mo \times IV$

6. DV= $\beta_0 + \beta_1 CV + \beta_2 IV + \beta_3 Me + \beta_4 Mo + \beta_5 Mo \times IV$

7. DV= $\beta_0 + \beta_1 CV + \beta_2 IV + \beta_3 Me + \beta_4 Mo + \beta_5 Mo \times IV$

   $+ \beta_6 Me \times IV$

Where Mo = Moderating variable,

Mo × IV = Cross-product of Mo and IV

Me × IV = Cross-product of Me and IV

The function of Equations 4, 5 and 6 is similar to the function of Equations 1, 2 and 3 when trying to examine a mediation model. For instance, if β_5 in both model 4 and 5 are significant but are insignificant or less significant in Model 6, then it can be confirmed that Me mediates the Mo × IV effect on DV. James and Brett (1984) termed it *mediated moderation*. Similarly, Me can also mediate the effect of IV on DV. The additional Equation 7 is identical to Equation 6 but the interaction term (i.e., Me × IV) is added. It is utilised to assess the moderating effect between the mediator (i.e., Me) and the predictor variables (i.e., IV) that might occur. If Mo × IV has less of an effect on DV in Equation 7 than at Equation 6 and β_6 is significant, then it can be explained that the Mo × IV effect on DV can be funneled through the Me × IV.

4.6 Summary

This chapter has detailed the research design and analytical methodology undertaken by this study. The questionnaire survey method was employed to collect data from Taiwanese IT industry. Chapter 5 discusses the process of questionnaire development, the pre-pilot test, the pilot study and the results of the large-scale survey.

Chapter 5

Pilot Study, Large-scale Survey and Assessment of Measurement Instrument

5.1 Introduction

A research instrument will be useful only if the instrument is carefully developed to serve its purpose. This chapter discusses the development of the questionnaire, its refinement, pre-testing, piloting, and the administration of the large-scale survey. The instrument development process consists of the initial development of the questionnaire, refinement after considering expert opinions, translation, and piloting. The pre-testing and piloting processes aim to ensure both validity and reliability of the measuring instrument prior to conducting a large-scale survey. Section 5.4 details the process of item purification for the instrument through both the calculation of the corrected item-to-total correlation and factor analysis using piloted data. Sections 5.5 to 5.7 address the administration of the large-scale survey, the examination of the profile of respondents, and tests for non-response bias. Section 5.8 details the purification of the original set of construct items as well as the validation of the purified measures. The importance of this validation is to generate scores that reflect actual differences in the characteristics of the NPD projects to be measured prior to testing the hypothesis (Churchill, 1979).

5.2 Questionnaire Development and Pre-Pilot Testing

A pre-piloted questionnaire was developed based on an extensive literature search and interviews with NPD researchers. In order to minimise biases from the respondents, particular attention was focused on the wording, scale and general appearance of the questionnaire. Dillman's Total Design Method for the construction of an effective questionnaire has been followed (Dillman, 1978). The pre-piloted questionnaire has five sections. It begins with a short description of the qualifications of the targeted unit of the research. In brief, it asked about the most recent NPD project with which respondents were closely involved and if that product was launched within the previous two years. Section A of the questionnaire comprises of items relating to the company and project background information. Section B is formatted as items-in-a-series questions. It is constructed to measure a firm's level of absorptive capacity. Section C has five sub-sections. Each sub-section is designed to probe the extent to which a particular type of linkage is involved with the project along thirteen ordered-step NPD processes. The first two sub-sections deal with horizontal linkages including customers and suppliers. The other three sub-sections, comprising of cooperative companies, universities and industrial research institutes are constructed to measure horizontal linkages. Sections D and E consist of questions in the same format as Section B. Section D is designed to measure a firm's gain in new product knowledge during the new product development project. Section E aims to measure the level of innovativeness of the new product in comparison with other product lines within the firm.

After developing an initial measurement instrument, pre-testing was carried out to ensure each construct's relevance by conducting informal interview with five academic researchers and industrial practitioners as suggested by Churchill (1979). It was suggested that: (1) the research unit for measuring "Absorptive Capacity" focus on a NPD project basis instead of the whole company; (2) the number of measurement items for the absorptive capacity construct needs to be increased because it covers a wide range of dimensions. This construct was then modified to include more measures through a series of iterations. It finally consisted of 30 measurement items.

The pre-piloted questionnaire was initially developed in English since most existing measures were written in English. Due to cultural differences, literal word-by-word translation was not effective. In addressing this problem, Taiwanese literature using the same measurements was searched. Some measures relating to the constructs of both product innovativeness and product knowledge familiarity that have been translated and tested in Taiwanese manufacturing industries by Chung (1999) and Wu (2000) were then used. The questionnaire was then translated from English into Chinese by a team of professional translators using the parallel double-back translation procedure (Craig and Douglas, 2000).

Twelve experienced senior NPD managers from public listed IT firms in Taiwan pre-tested the Chinese language questionnaires. Each interviewee completed the pre-piloted questionnaire in the presence of the researcher. While completing the questionnaire, he/she was invited to comment on questions regarding wording of measurement items, the overall organisation of the instrument, and their feeling about the research itself. Three measurement items that involved the use of academic terms, particularly in the construct of "Absorptive Capacity", were identified as unclear to the respondents. These items went through another process of double-back translation, and the final translations were then agreed. The managers in the pre-piloting phase confirmed that the questionnaire was clear and presented no completion difficulties.

5.3 Pilot Study

The key informant method outlined by Phillips (1981) suggests that researchers interview one or more respondents identified as appropriate for collecting information on a social system about which these respondents have special qualifications. This data collection technique, according to Phillips, can be utilised in survey contexts to obtain quantifiable responses. The qualifications of the key informants are assessed in terms of (1) their formal role in the company, (2) the time they have worked for the company, (3) their knowledge about the phenomena of interest, and (4) their degree of involvement in the company's decision making with respect to the surveyed topic (ibid.).

The current study follows past research (Song and Parry, 1996; Song and Parry, 1997; Song et al., 1997) that identifies managers, such as R&D managers, NPD project managers and/or vice presidents of R&D, as key informants for NPD project research. Because they are involved in the daily operation of core confidential business, these managers tend to be highly cautious in answering questions asked by outsiders regarding their internal NPD projects. Drawing from the 2000 Directory of the Hin-Chu Science-based Industrial Park (the high-tech centre in Taiwan), the researcher contacted R&D managers, NPD project managers and/or vice presidents of R&D of each firm through investment banks as well as venture capital firms and government officers in the Ministry of Economics. A total of 72 sample respondents agreed to participate in the pilot questionnaire survey. The researcher visited each firm's site and delivered the questionnaires. Prior to respondents filling in the questionnaires, he explained how it is constructed and explained about the qualifications required for a NPD project.

There were 70 responses to the survey, of which 62 were complete and usable. The following issues were raised as the result of the pilot study:

(1) A significant number of NDP projects did not involve external linkages, such as universities or research institutes, and therefore respondents left those measurement items unanswered. This prompted the inclusion of an extra question to ask if each type of external linkage is applicable to the NPD project.

(2) Respondents tended to bias their selection towards more interesting, significant and hence more relatively innovative NPD projects. To solve this type of bias, more instructions were given on the front page of the questionnaire instructing respondents that they should not be concerned about whether the project selected is

innovative. It is suggested that they discuss a project that has recently been completed.

(3) Respondents were confused about whether OEM/ODM (Original Equipment Manufacturer/ Original Design & Manufacturing) partners are categorised as customers or cooperative companies. Judging from business characteristics of OEM/ODM types of NPD projects and referring to previous research (Sher, 1998), the researcher then decided to define them within the category of cooperative companies.

(4) Meanings of terms such as "not-invented-here", "boundary spanners" and "technology gatekeepers" were not clear to technology-oriented R&D managers and/or vice presidents of R&D after translation. The measurement item associated with 'not-invented-here' syndrome was then abandoned because this measure item conveys more the connotation of a firm learning intention than its knowledge scanning ability. It addition, it was not grouped in the construct of knowledge scanning ability of absorptive capacity in the factor analysis. The measurement items related with "technology gatekeepers" were for instance revised to "R&D specialists who screen the ins and outs of new, key technologies".

(5) The last section (measuring the level of product innovativeness) of the questionnaire was found to be inadequately laid out. All measurement items in this section were relocated and grouped on the same page.

The returned questionnaires were then coded and keyed in SPSS. This sample was used to provide preliminary assessments on the reliability and validity of the pilot study instrument, as well as offering indications on how to further refine the instrument items.

5.4 Pilot Study Results and Item Modification

The key task when analysing data collected from a pilot study is item purification to ensure scale reliability and unidimensionality[1]. In the current study, item purification was achieved through the calculation of the Corrected Item-to-Total Correlation (CITC) for the items of the respective scale (Kerlinger, 1986). A commonly used threshold value for CITC is 0.5 while the inter-item correlations (the correlation among items) exceeds 0.3 (Hair et al., 1998). A slightly lower CITC may be acceptable if that item is considered to be important to the construct. For a multi-dimensional construct, item-to-total correlation needs to be calculated for individual dimensions separately. Therefore, measurement items against constructs of Absorptive Capacity and New Product Innovativeness, both of whose dimensions were pre-defined, were put forth for CITC analyses. After the CITC analysis, a dimension-level factor analysis was applied to assess the unidimensionality of each measurement scale for the purpose of further purifying measurement items. Dimensional-level factor analysis also indicates possible merging or splitting of existing construct dimensions. Since the pilot sample size meets the minimal requirement of the five-to-one ratio against variables that are concerned (Hair et al., 1998: 98-99), construct-level factor analysis was then employed to assess discriminant validity of new product innovativeness.

Reliability refers to the internal consistency of the measurement instrument that demonstrates the extent to which measuring scales are free from random errors and convey repeatedly consistent measuring results (Peter, 1979). Among various approaches to reliability, Cronbach's alpha is an often-recommended measure (Churchill, 1979; Peter, 1979). Rules of thumb suggest that the lower limit for Cronbach's alpha exceeds 0.7 while it may decrease to 0.60 in exploratory research (Hair et al., 1998). As Cronbach's alpha increases along with the number of items, researchers should be vigilant when using these scales with large number of items (Hair

[1] Unidimensionality refers to the existence of a single trait or construct underlying a set of measures (Hattie, 1985).

et al., 1998). Nevertheless, a slightly lower value for a scale consisting of a smaller number of items may be acceptable during the pilot study.

The data collected from the 62 pilot responses were coded and entered into an SPSS database for item purification following the methodology described above. Sections 5.4.1 to 5.4.4 discuss the pilot study results for the following constructs: 'Absorptive Capacity', 'Gains in New Product Knowledge' and 'Product Innovativeness.' For each construct, since its dimensions are pre-defined, the following three tables represent the analysis results of: (1) initial questionnaire items; (2) dimension-level CICT scores, and dimension-level Cronbach's alpha scores; and, (3) dimension-level or construct-level factor loading scores.

5.4.1 Absorptive Capacity

Adapted from both Tu's (1999) measures and Leonard-Barton's (1995: 155-160) empirical findings, the construct of Absorptive Capacity initially included five dimensions (see Section 4.4.1) consisting of 29 items. These are: (1) Engineer Knowledge Base (4 items) (2) Management Knowledge Base (4 items) (3) Knowledge Scanning Ability (10 items) (4) Communications Climate (6 items) and (5) Communications Network (5 items). The dimensions and items are listed in Table 5.4.1.1.

Table 5.4.1.1 Absorptive Capacity – Initial Questionnaire Items

Code	Questionnaire Items
	Engineer Knowledge Base
AC1	The overall technical knowledge of our engineers was high
AC2	The general knowledge level of our engineers was high
AC3	The general educational level of our engineers was high
AC4	The overall job competence of our engineers was high
	Management Knowledge Base
AC5	The knowledge of our managers regarding managing the daily operations was high
AC6	The knowledge of our managers for solving technical problems was high
AC7	The knowledge of our managers for dealing with new technology was high
AC8	The knowledge of our managers when making business decisions was high
	Knowledge Scanning Ability
AC9	The project team concerned sought to learn from benchmarking best practices in the

	industry
AC10	The project team concerned sought to learn from trying out new technologies
AC11	The project team concerned sought to learn from our customers and suppliers
AC12	The project team concerned sought to learn from tracking new market trends in our industry
AC13	The project team concerned sought to learn from conducting R&D activities
AC14	The project team concerned sought to learn from taking new business opportunities
AC15	The project team concerned sought to learn from the routine search of useful information
AC16	The project team concerned sought to nurture technological gatekeepers for various technologies
AC17	The project team concerned sought to fight the not-invented-here syndrome
AC18	The project team concerned sought to nurture boundary spanners
Communications Climate	
AC19	All members involved in the project tended to trust each other
AC20	All members involved in the project were willing to accept changes
AC21	All members involved in the project had no difficulty accepting new ideas
AC22	All members involved in the project were supportive each other
AC23	All members involved in the project shared ideas freely each other
AC24	All members involved had a strong feeling of belonging to our organisation
Communications Network	
AC25	The communications among functional areas was frequent
AC26	The communications among functional areas were extensive
AC27	The communications between supervisors and subordinates were extensive
AC28	The communications between supervisors and subordinates were frequent
AC29	The communication of new ideas from one department to another for the project concerned were extensive

5.4.1.1 Item Purification

Examination of CITC scores for the five dimensions in the Absorptive Capacity construct revealed that one Engineer Knowledge Base item (AC3), one Management Knowledge Base item (AC5), three Knowledge Scanning Ability items (AC13, AC14, AC17), and one Communications Climate item (AC21) were deleted due to their relatively low CITC scores. The CITC scores for all remaining items in the Engineer Knowledge Base, Management Knowledge Base and Communications Network dimensions were all above 0.5. The CITC score (0.48) of AC20 in the Communications Climate dimension was slightly below 0.5. It was however retained. On the Knowledge Scanning Ability dimension, the CITC scores for most items (five of seven) were below 0.5 even after item purification. These CITC scores could not be improved by simply removing items. It indicates that there is a need for some item revisions and rewording in this dimension. The final alphas were 0.82 for Engineer Knowledge Base, 0.77 for

Management Knowledge Base, 0.72 for External Knowledge Scanning, 0.87 for Communications Climate and 0.90 for Communications Network. Table 5.4.1.2 shows the item purification results.

Table 5.4.1.2 Absorptive Capacity – Item Purification Results

Items	Initial CITC	Final CITC	Cronbach's Alpha Scores
Engineer Knowledge Base			
AC1	0.67	0.75	α=0.82
AC2	0.70	0.75	
AC3	0.39	Deleted	
AC4	0.58	0.53	
Management Knowledge Base			
AC5	0.27	Deleted	α=0.77
AC6	0.66	0.64	
AC7	0.60	0.65	
AC8	0.53	0.55	
External Knowledge Scanning			
AC9	0.48	0.46	α=0.72
AC10	0.46	0.45	
AC11	0.41	0.39	
AC12	0.56	0.55	
AC13	0.34	Deleted	
AC14	0.44	Deleted	
AC15	0.47	0.45	
AC16	0.45	0.45	
AC17	0.36	Deleted	
AC18	0.48	0.47	
Communications Climate			
AC19	0.61	0.63	α=0.84
AC20	0.48	0.50	
AC21	0.39	Deleted	
AC22	0.75	0.73	
AC23	0.78	0.76	
AC24	0.69	0.71	
Communications Network			
AC25	0.73	0.73	α=0.90
AC26	0.86	0.86	
AC27	0.68	0.68	
AC28	0.75	0.75	
AC29	0.71	0.71	

5.4.1.2 Factor Analysis

A dimension-level factor analysis was applied to each of the five dimensions in Absorptive Capacity in order to further ensure the unidimensionality of each dimension. All five dimensions displayed a single factor respectively with most factor loadings above 0.7. As expected, the factor loadings for the dimension of Knowledge Scanning Ability are lower than those of the other dimensions and its first component is only able to explain the 42% of variance. Table 5.4.1.3 presents the factor analysis results.

Table 5.4.1.3 Absorptive Capacity – Dimension-Level Factor Analysis

Items	Factor Loadings[a]	% Variance Extracted by First Component
	Engineer Knowledge Base	
AC1	0.91	74%
AC2	0.91	
AC4	0.75	
	Management Knowledge Base	
AC6	0.73	70%
AC7	0.74	
AC8	0.61	
	Knowledge Scanning Ability	
AC9	0.64	42%
AC10	0.65	
AC11	0.57	
AC12	0.72	
AC15	0.65	
AC18	0.65	
AC16	0.66	
	Communications Climate	
AC19	0.77	64%
AC20	0.64	
AC22	0.86	
AC23	0.87	
AC24	0.84	
	Communications Network	
AC25	0.83	71%
AC26	0.92	
AC27	0.80	
AC28	0.85	
AC29	0.81	

[a] Extraction Method: Principal Component Analysis, one component extracted

5.4.1.3 Item Revision

Although both the Engineer Knowledge Base and Management Knowledge Base measures demonstrated good reliability and unidimensionality, each scale consists of only three items. More items for these two dimensions were required. A closer examination of deleted items (AC3, AC5) revealed that the wording of AC5 was unclear and the conceptualisation of AC3 needs to be redesigned from a different spectrum of the Engineer Knowledge Base. The Knowledge Scanning Ability dimension gained low scores in both CITC scores and factor loadings after deleting 3 items. It was then determined that a major revision on the wording of all items in this dimension was required. A closer examination of items AC20 and AC21 revealed that the conceptualisation of these two items is in the same domain of organization's innovative climate. However, the wording of the AC21 was obscure. After deleting AC21, the Communications Climate dimension showed fair internal consistency. Among the five dimensions, the Communications Network measure has the most internal consistency and requires no further revision.

5.4.2 Gain in New Product Knowledge

Initially, four dimensions consisting of 20 items represented the construct of Gain in New Product Knowledge: Pre-development Assessment Knowledge (7 items), R&D Knowledge (5 items), Marketing Knowledge (4 items), and Manufacturing Knowledge (4 items). The initial 20 items and their corresponding code names are presented in Table 5.4.2.1.

Table 5.4.2.1 Gains in New Product Knowledge– Initial Questionnaire Items

Code	Questionnaire Items
	Pre-development Assessment Knowledge
PK1	The preliminary market assessment of the product
PK2	Determining market characteristics and trends
PK3	The preliminary business/financial analysis
PK4	Initial screen techniques
PK5	Handling after-service programme
PK7	Handling customer testing of the product prototype
PK11	The preliminary engineering and technical assessments
	Marketing Knowledge
PK6	The detailed market study/market research
PK8	Executing test market programs in line with the plans for product commercialisation
PK9	Launching and introducing new products into our targeted marketplace- selling, promoting, and distributing the product
PK10	Identifying "appeal" characteristics that would differentiate and sell the product
	R&D Knowledge
PK12	Building of the product to designated or revised specifications
PK13	Evaluating laboratory tests to determine basic performance against the product's specifications
PK14	Executing prototype or "in-house" sample product testing
PK15	Determining the final product design and specifications
PK16	Working continuously for cost reduction and quality improvement
	Manufacturing Knowledge
PK17	Conducting preliminary manufacturing assessments of the product
PK18	Executing product trial/pilot production
PK19	Conducting production start-up which is now better than before
PK20	Executing the product quality assurance program which is now better than before

5.4.2.1 Item Purification & Dimension-level Factor Analysis

The analysis of CITC scores for the four dimensions in this construct suggested that no items were to be deleted. The CITC scores for all items in the four dimensions were all above 0.5. The final alphas were 0.88 for Pre-development Assessment Knowledge, 0.88 for Marketing Knowledge, 0.90 for R&D Knowledge and 0.92 for Manufacturing Knowledge. These indicate good internal consistency for the construct. The CITC scores of the four dimensions are listed in Table 5.4.2.2.

Table 5.4.2.2 Gain in New Product Related Knowledge – Item Purification Results

Items	Initial CITC	Final CITC	Cronbach's Alpha Scores
Pre-development Assessment Knowledge			
PK1	0.74	0.74	α=0.88
PK2	0.71	0.71	
PK3	0.84	0.84	
PK4	0.70	0.70	
PK5	0.60	0.60	
PK7	0.55	0.55	
PK11	0.58	0.58	
Marketing Knowledge			
PK6	0.65	0.65	α=0.88
PK8	0.81	0.81	
PK9	0.81	0.81	
PK10	0.71	0.71	
R&D Knowledge			
PK12	0.77	0.77	α=0.90
PK13	0.73	0.73	
PK14	0.72	0.72	
PK15	0.85	0.85	
PK16	0.69	0.69	
Manufacturing Knowledge			
PK17	0.84	0.84	α=0.92
PK18	0.83	0.83	
PK19	0.88	0.88	
PK20	0.73	0.73	

To further ensure the unidimensionality of each dimension in the Gain in New Product Knowledge construct, a dimension-level factor analysis was performed. A single factor extracted for all dimensions with factor loadings above 0.60 was confirmed. Except for Pre-development Assessment Knowledge (PAK), the first factors of all other dimensions account for more than 70 per cent variance. The PK7 item in PAK dimension was identified as having the least extraction in its factor analysis. Table 5.4.2.3 presents the factor loadings as well as percentage of variance extracted by the first component.

Table 5.4.2.3 Gains in New Product Knowledge– Dimension-Level Factor Analysis[a]

Items	Factor Loadings	% Variance Extracted by First Component
	Pre-development Assessment Knowledge	
PK1	0.83	60%
PK2	0.79	
PK3	0.92	
PK4	0.81	
PK5	0.70	
PK7	0.65	
PK11	0.79	
	Marketing Knowledge	
PK8	0.90	74%
PK9	0.90	
PK10	0.83	
PK6	0.79	
	R&D Knowledge	
PK15	0.91	72%
PK12	0.86	
PK13	0.84	
PK14	0.83	
PK16	0.80	
	Manufacturing Knowledge	
PK19	0.94	81%
PK17	0.92	
PK18	0.91	
PK20	0.83	

[a] Extraction Method: Principal Component Analysis, one component extracted

5.4.2.2 Item Revision

Although no further purification was carried out based on CITC analysis, the dimension-level factor analysis indicated that some items (namely PK5, PK7) in the PAK dimension could be improved. A closer examination of both items suggested that PK5, as conceptualised, tend to relate to Marketing Knowledge and PK7 is identified with R&D Knowledge. It was decided, therefore, that PK7 could be reasonably deleted from the construct of Gain in New Product Knowledge and the wording of PK5 item could be revised to convey a more fully explicated conceptualisation. The design of new items based on further literature searches was needed.

5.4.3 New Product Innovativeness

The New Product Innovativeness construct was represented by two dimensions: Technological Innovativeness (4 items) and Market Innovativeness (4 items). The 8 items and their corresponding codes are presented in Table 5.4.3.1.

Table 5.4.3.1 New Product Innovativeness – Initial Questionnaire Items

Code	Questionnaire Items
	Technological Innovativeness
PI2	Product class was new to our firm
PI3	Product use (need served) was new to our firm
PI4	Product production process was new to our firm
PI5	Product design/development technology was new to our firm
	Market Innovativeness
PI1	Customers for the product were new to our firm
PI6	Distribution and sales force for product was new to our firm
PI7	Advertising and promotion for product was new to our firm
PI8	Product competitors were new to our firm

5.4.3.1 Item Purification and Exploratory Factor Analysis

The CITC scores for both Technological Innovativeness and Market Innovativeness dimensions were all above 0.5 except PI3 item. The final Cronbach alphas are 0.82 for Market Innovativeness and 0.78 for Technological Innovativeness. The CITC scores for all items in this construct are listed in Table 5.4.3.2. As the ratio of the sample size to the number of variables is larger than 5 (Hair et al., 1998: 98-99), an exploratory factor analysis was applied to check if two factors could be clearly extracted. There were exactly two factors extracted with no significant cross loading (i.e. the difference of factor loadings between any two measurement item is larger than 0.3). Factor loadings for all items are above 0.6 indicating a sound unidimensionality for the New Product Innovativeness construct. Table 5.4.3.3 represents the results of factor analysis.

Table 5.4.3.2 New Product Innovativeness – Item Purification Results

Items	Initial CITC	Final CITC	Cronbach's Alpha Scores
Technological Innovativeness			
PI2	0.69	0.69	α=0.78
PI3	0.47	0.47	
PI4	0.52	0.52	
PI5	0.66	0.66	
Market Innovativeness			
PI1	0.58	0.58	α=0.82
PI6	0.76	0.76	
PI7	0.68	0.68	
PI8	0.55	0.55	

Table 5.4.3.3 New Product Innovativeness – Construct-level Factor Analysis

Items	Factor Loadings[a]		% Variance Extracted by Two Components
	Factor 1	Factor 2	
Technological Innovativeness			
PI5	**0.85**	0.01	65%
PI2	**0.84**	0.18	
PI4	**0.66**	0.35	
PI3	**0.62**	0.25	
Market Innovativeness			
PI7	0.23	**0.81**	
PI8	0.01	**0.81**	
PI6	0.43	**0.77**	
PI1	0.37	**0.64**	

[a] Extraction Method: Principal Component Analysis; Rotation Method: Varimax with Kaiser Normalization

5.4.3.2 Item Revision

The New Product Innovativeness items demonstrated good unidimensionality. However, due to a marginally low CITC score the PI3 item could be further improved in term of its wordings. A revision of the PI3 item was then undertaken to further articulate its conceptualisation for respondents.

5.4.4 A Summary of The Pilot Study

The pilot study results in the elimination of six items (AC3, AC5, AC13, AC14, AC17 and AC21) from the construct of Absorptive Capacity and minor revision of P13 item from New Product Innovativeness. In particular, three items (AC13, AC14 and

AC17) in the dimension of knowledge-scanning ability of AC were deleted. Items AC13 and AC14 were shown to be more related to NPD learning than NPD knowledge scanning ability. AC17's wording (e.g. to fight the not-invented-here syndrome) needs to be further revised subsequent to its translation, as it was not clear to questionnaire respondents. After item purification, the Cronbach's alpha scores of the two constructs are at least above 0.72, demonstrating sound scale reliability. Dimensional-level factor loading scores for the construct of Absorptive Capacity ranging between 0.57 and 0.91 indicate sound unidimensionality, while construct-level factor loading scores for New Product Innovativeness are also all above 0.62.

Results of the pilot study were then discussed with three academic researchers and five NPD related project/product managers, who offered to assist with the pre-pilot and pilot study by commenting on the revised items. The revision process went on until the feedback comments were integrated into the final survey questionnaire. This final questionnaire was then used for the large-scale survey, which is discussed in the following sections.

5.5 Large-scale Survey Administration

5.5.1 Development of the Survey Mail List

The large-scale survey carried out following the Total Design Method (Dillman, 1978) was conducted between May and August 2001. Considering the low response rate anticipated of industrial surveys (Kanuk and Berenson, 1975, Krysan et al., 1994) and in order to collect questionnaires more effectively, the researcher invited seven IT-based venture capital companies (VCs) and two investment banks to provide contact persons within IT firms that fitted the sampling frame and were involved with new product development. The venture capital firms and investment banks are shareholders in the surveyed IT firms and some are regularly involved in the IT firms' board meetings. Working with the VCs and banks enabled the researcher to correspond directly with a firm's NPD-related key person. A list of 168 IT firms was collected. Ten firms that were doubly selected were deleted. The final mailing list comprised of 230 firms, including the companies that participated in the pilot.

5.5.2 Questionnaire Packet

The mail pack comprised the questionnaire, an accompanying cover letter (see Appendix A), and a self-address, freepost, first-class return envelope. The main sections of the questionnaire are: Section 1 General Information, Section 2 Level of External Linkages, Section 3 New Product Knowledge Accumulated, Section 4 Product Newness, Section 5 Level of Absorptive Capacity (see Appendix A). The questionnaire begins with instructions that respondents should base their replies on (1) a particular, individual new product project that has been launched within the last two years, and (2), that this should be a project with which they have been closely involved. It also stated that the survey is an international research project conducted jointly by Loughborough University and National Kaohsiung First University (the university that the researcher was employed by in Taiwan), thus stressing its unique position. The last section of the questionnaire asked for respondents' contact details so that a summary of the research findings could be sent to them. The covering letter indicated that the survey was sponsored by two universities, and supported by the venture capital firm or investment bank associated with the IT firm. Next, it also spelt out the purpose of the research. A social utility appeal, emphasising the worthiness and benefit of the research, was outlined to inspire cooperation. The importance of the co-operation of respondents and their replies was emphasised, and assurances of anonymity and confidentiality were given. Finally, the researcher's contact details were listed should any questions arise from the questionnaire. An express mail was used to send the questionnaire pack, indicating its importance.

5.5.3 Follow-up Procedures

To encourage a good response rate, the survey was administered in three stages. First, the researcher telephoned each contact person about the current study and asked her or him to participate the survey. Then, the questionnaire pack, as stated in Section 5.5.2, was mailed out. Second, a week later, a follow-up letter was mailed to each of the target respondents to remind them to complete the survey. Those with e-mail addresses also received the follow-up letter electronically. Those who responded were then removed from the original mailing list. Third, after another two weeks, a second follow-up letter with a copy of the questionnaire was sent to those who still had not responded. Again, the researcher telephoned and asked for the questionnaires to be completed as soon as possible. In addition, a third follow-up letter, together with an e-mail letter (if applicable), was sent out again to remind them to complete the questionnaire.

A total of 139 questionnaires were returned. Of these, six were incomplete. Eight were answered by administrative managers or assistants and were considered invalid. Three NPD projects were not at market launch stage. They were invalid for the survey and abandoned. After checking the pattern of the industrial sector responding to the survey, it was identified that only four responses were based in software sector. They were deleted from the data analysis because they were too few to form a legitimate sample. Therefore, the final number of complete and usable responses was 118, representing an overall response rate of 51.3 percent. The remainder of this chapter discusses only these 118 usable responses.

5.6 Profile of Respondents

Responses indicated that 74.14 percent of respondents are currently R&D or NPD project managers; 14.65 percent are vice president or presidents; and, 11.21 percent are product marketing or product application managers. On average, respondents had been involved in new product management for 5.6 years. A profile of the respondents is shown in Table 5.6.1. Most of respondents in the sample, according to their job title, are directly involved with the project that they discussed in the questionnaire. A small percentage of respondents were company presidents, but where their firm was identified as an SME with less than 50 employees, they were eligible to be respondents. This is because R&D management and/or involvement with NPD projects is one of their major job functions particularly in high-tech SMEs. The profile, which is consistent with that of previous research (Sher, 1998), shows that the potential for problems with key informant bias is not severe in this study.

Table 5.6.1 The Profile of Respondents

Job Title	Frequency	Percentage of respondents
R&D or NPD project manager	86	71.49
Vice president-R&D	12	10.83
President	5	4.31
Product marketing or product manager	13	11.21

Length of NPD experience	Frequency	Percentage of respondents
Less than 3 year	8	6.90
3 – 5 years	63	54.31
6 – 10 years	30	25.86
More than 10 years	15	12.93

5.7 Tests for Non-response Bias

The existence of non-response bias can greatly reduce the generalisation of the results from the respondent sample to the entire population (Filion, 1976, Armstrong and Overton, 1977, Wallace and Mellor, 1988). In order to test for non-response bias, the present study has adopted the extrapolation method proposed by Armstrong and

Overton (1977)[2]. The first quartile of usable questionnaires (30 cases), defined as earlier respondents, was compared to the last quartile ones. The two-tailed t-tests on five demographic variables and all relationship variables were performed. Results showed that the equality of all variable means across the two groups is insignificant at the 0.01 level (see Table 5.7.1). These results confirm that non-response bias is unlikely to be an issue in the current study.

Table 5.7.1 t-Test for Non-Response Bias

Relationship Variables	t-value	p	Demographic Variables	t-value	p
Customer linkage	.211	.834	Number of R&D engineers	.842	.403
Supplier linkage	-1.191	.238	Annual revenue	.891	.377
Corporation linkage	1.441	.156	% of R&D expenditure	1.547	.128
Research institute linkage	.539	.592	Industry sectors	-.802	.426
University linkage	1.272	.209	Number of employees	.806	.423
Absorptive capacity	.178	.859	Product types	.815	.370
R&D knowledge	-1.064	.292			
Manufacturing knowledge	.116	.908			
Pre-development assessment knowledge	-.064	.524			
Marketing knowledge	.211	.834			
Technological innovativeness	.022	.983			
Market innovativeness	-1.139	.260			

[2] Armstrong and Overton (1977) reviewed the literature on non-response bias in mail surveys and summarised three methods for estimating non-response bias: (1) comparing with known values for the population, (2) subjective estimates, and (3) extrapolation methods. Because the difficulty of gaining independent records of the population or the sample frame which can provide a more definitive picture of the characteristics of the non-respondents, the method of extrapolation, which is to construct a measure of non-response bias based on the pre-assumption that "late" responses are reasonable "surrogates" of non-respondents, are more popularly employed.

5.8 Assessment of the Measurement Instrument

Measurements are inevitably associated with a certain amount of error, and these may be either random or systematic errors (Churchill, 1979). Measures including sizeable errors constitute threats to the validity of research findings. The survey instrument used in the large-scale survey was rigorously screened for reliability and validity assessment using 118 responses. The reliability assessment process was similar to that of the pilot study. The major difference lies in the instrument validation process. In the large-sale study, the sample size was sufficient for construct level factor analysis to assess the unidimensionality, convergent validity and discriminant validity of each measurement instrument that was developed.

The purification of the instrument items first examined the corrected item-to-total correlation (CITC) scores of each item with respect to the specific dimension of a construct. As a general rule, items with a CITC score of lower than 0.50 should be removed. After the CITC analysis, the remaining items of each construct dimension were submitted as a group to dimension-level exploration factor analysis to ensure the unidimensionality and convergent validity of measurement instrument. Factor analysis allows the examination of interrelationships among a number of variables and then explains these variables in terms of their common underlying dimensions. The widely accepted Principal Component analysis method was selected to extract factors and the correlation matrix was used as input. The number of factors to be extracted was decided by including only those factors with eigenvalues greater than 1 (Hair et al., 1998). The orthogonal rotation method- VARIMAX- was employed for interpreting the extracted factors. Items of the same scale that failed to exhibit significant loading on the focal factor or that cross-loaded highly on other factors were eliminated. A cutoff value of above 0.5 was adopted as a criterion for examining significant factor loading. The determination of the value was based on a 0.05 significance level, a power level of 0.80, and the sample size of 120 (Hair et al., 1998).

The following subsections present the large-scale instrument validation results. For each construct three types of tables were provided to present the results: (1) the initial large-scale measurement items for the construct; (2) the dimension-level CITC scores and Cronbach's alpha; and, (3) the construct level of exploratory factor analysis results. After exploratory analyses, the validity of the constructs was further tested through a series of confirmatory factor analyses (CFA) because adequate measurements are a premise for the assessment of valid structural relationship (Churchill and Peter 1984). Schumacker and Lomax (1996) stated that confirmatory factor analysis reflects the entire measurement models, in which observed variables define constructs. Thus, the CFA provides useful and relevant information about the actual number of latent constructs and factorial complication, particularly, the overall model fit. In the current study, the confirmatory factor analysis was conducted using the maximum likelihood estimation method in AMOS 4.0. The different fit indices reported are: Chi-Square (χ^2); Comparative Fit Index (CFI); Goodness-of-Fit Index (GFI); Adjusted Goodness-of-Fit Index (AGFI); Normed Fit Index (NFI); and Root Mean Square Residual (RMR).

5.8.1 Instrument Validation of Absorptive Capacity

The construct of Absorptive Capacity initially included five dimensions consisting of 23 items. The five dimensions are (1) Engineer Knowledge Base (4 items), (2) Management Knowledge Base (4 items), (3) Knowledge Scanning Ability (10 items), (4) Communications Climate (6 items) and (5) Communications Network (5 items) as listed in the following Table 5.8.1.1.

Initial reliability analysis for each of the five dimensions showed that the CITC scores for all items were above 0.50 (see Table 5.8.1.2). Examining the "Alpha if item deleted" scores indicated that removing AC7 would largely improve the reliability of the management knowledge base scale. However, considering the importance of this item to this dimension as well as the relatively few measurment items, AC7 was retained at this stage. The final Cronbach's Alpha scores were 0.89 for engineering knowledge base, 0.80 for management knowledge base, 0.87 for knowledge scanning ability, 0.80 for communication climate, and 0.85 for communication network.

Table 5.8.1.1 Absorptive Capacity (AC) – Questionnaire Items

Code	Questionnaire Items
	Engineer Knowledge Base
AC1	The overall technical knowledge of our engineers was high
AC2	The general knowledge level of our engineers was high
AC5	The general educational level of our engineers was high
AC6	The overall job competence of our engineers was high
	Management Knowledge Base
AC3	The knowledge of our managers for solving technical problems was high
AC4	The knowledge of our managers for dealing new technology was high
AC7	The knowledge of our managers when making business decisions was high
	Knowledge Scanning Ability
AC8	The project team concerned sought to learn from benchmarking best practices in the industry
AC12	The project team concerned sought to learn from trying out new technologies
AC13	The project team concerned sought to learn from our customers and suppliers
AC18	The project team concerned sought to learn from tracking new market trends in our industry
AC19	The project team concerned sought to learn from the routine search of useful information
AC20	The project team concerned sought to nurture technological gatekeepers for various technologies
AC9	The project team concerned sought to nurture boundary spanners
	Communications Climate
AC10	All members involved in the project tended to trust each other
AC11	All members involved in the project were supportive each other
AC14	All members involved in the project shared ideas freely each other
AC16	All members involved had a strong feeling of belonging to our organisation
	Communications Network
AC15	Communications among functional areas were frequent
AC21	Communications among functional areas were extensive
AC17	Communications between supervisors and subordinates were extensive
AC22	Communications between supervisors and subordinates were frequent
AC23	The communication of new ideas from one department to another about the project concerned was extensive

Table 5.8.1.2 Absorptive Capacity – Reliability Analysis Results

Items	Initial CITC (Corrected Item to Total Correlation)	Final CITC	Alpha if Item Deleted	Cronbach's Alpha Scores
Engineer Knowledge Base				
AC1	0.78	0.78	0.86	α=0.89
AC2	0.81	0.81	0.85	
AC5	0.75	0.75	0.88	
AC6	0.76	0.76	0.87	
Management Knowledge Base				
AC3	0.72	0.72	0.68	α=0.80
AC4	0.71	0.71	0.68	
AC7	0.56	0.56	0.84	
Knowledge Scanning Ability				
AC8	0.54	0.54	0.86	α=0.87
AC12	0.70	0.70	0.84	
AC13	0.62	0.62	0.85	
AC18	0.66	0.66	0.85	
AC19	0.68	0.68	0.84	
AC20	0.73	0.73	0.84	
AC9	0.57	0.57	0.86	
Communications Climate				
AC10	0.61	0.61	0.75	α=0.80
AC11	0.73	0.73	0.69	
AC14	0.57	0.57	0.77	
AC16	0.55	0.55	0.78	
Communications Network				
AC15	0.68	0.68	0.83	α=0.85
AC21	0.67	0.67	0.81	
AC17	0.72	0.72	0.80	
AC22	0.61	0.61	0.83	
AC23	0.71	0.71	0.70	

5.8.1.1 Exploratory Factor Analysis

The first exploratory factor analysis was performed on all 23 items of absorptive capacity. The initial results showed a five-factor structure. Cross-loadings were identified on items AC8, AC 17, AC22, AC16, and AC3, all of which, except AC 22, were removed (see Table 5.8.1.3) and a new exploratory factor analysis was performed. Four factors emerged from the second factor analysis with most factor loadings above 0.60 (see Table 5.8.1.4). It appeared that the measurement items of both the engineer knowledge base and the management knowledge base were merged. This new factor was titled as "existing knowledge base." However, the AC4 and AC7 in the new factor were observed from Table 5.8.1.4 to have several high loadings. Thus, the two items were removed. The final exploratory factor analysis results are presented in Table 5.8.1.5. All factor loadings were above 0.57. The Kaiser-Meyer-Olkin[2] (KMO) measure of sampling adequacy was 0.83. The extracted four factors explain 68.77 percent of total variance. The four dimensions- knowledge scanning ability, existing knowledge base, communication network, and communication climate- consisting of 17 items, constitute the measure of the absorptive capacity construct which is presented to subsequently confirmatory factor analyses.

[2] The Kaiser-Meyer-Olkin (KMO) measure of sample adequacy is used to ensure that the effective sample size is adequate for the current factor analysis. Generally, a KMO score in the 0.90's is considered outstanding, the 0.80 or above as meritorious, the 0.70 or above as middling, 0.60 and above as mediocre, 0.50 or above as miserable, and below 0.5 as unacceptable (Hair et al., 1998).

Table 5.8.1.3 Absorptive Capacity – Factor Analysis Results (1)

Items	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Knowledge Scanning Ability					
AC20	**.779**	.713	.188	.203	-.016
AC19	**.738**	.138	.260	.153	-.028
AC13	**.699**	.113	.105	.223	.093
AC18	**.679**	.183	.276	.150	.092
AC12	**.674**	.139	.131	.260	.313
AC9	**.665**	.070	-.041	.095	.306
AC8	**.603**	-.057	.255	-.223	**.393**
Engineer Knowledge Base					
AC2	.085	**.863**	.073	.052	.229
AC1	.064	**.861**	.044	.056	.177
AC5	.167	**.882**	.086	.119	.114
AC6	.196	**.820**	.196	.124	.055
Communications Network					
AC23	.199	.168	**.809**	.042	.140
AC21	.234	197	**.761**	.158	.115
AC15	.099	.007	**.676**	.391	.003
AC17	.158	.099	**.606**	**.503**	.130
AC22	**.418**	-.027	**.571**	.272	.055
Communications Climate					
AC11	.187	.049	.185	**.813**	.229
AC14	.315	.071	.217	**.693**	-.056
AC10	.195	.201	.181	**.648**	.216
AC16	.071	.182	**.467**	**.560**	.086
Management Knowledge Base					
AC4	.214	.296	.004	.253	**.763**
AC7	.222	.237	.323	.068	**.668**
AC3	.164	**.501**	.092	.262	**.630**
Eigen value	8.645	2.705	1.936	1.234	1.058
% of Variance Explained	37.586	11.762	8.418	5.367	4.600
Cumulative % of Variance	37.586	49.348	57.766	63.133	67.733

Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy = 0.859.

Bartlett's Test of Sphericity = 1564.37, Significance = 0.000

Table 5.8.1.4 Absorptive Capacity – Factor Analysis Results (2)

Items	Factor 1	Factor 2	Factor 3	Factor 4
Knowledge Scanning Ability				
AC20	**.769**	.123	.258	.049
AC12	**.739**	.201	.106	.248
AC9	**.725**	.141	-.080	.144
AC13	**.701**	.105	.188	.165
AC19	**.695**	.102	.327	.084
AC18	**.652**	.200	.290	.178
Existing Knowledge Base				
AC2	.091	**.893**	.049	.086
AC1	.083	**.873**	.035	.042
AC5	.148	**.818**	.116	.112
AC6	.184	**.799**	.207	.067
AC4	**.349**	**.468**	-.057	**.439**
AC7	**.346**	**.431**	.193	.237
Communications Network				
AC23	.208	.216	**.809**	.018
AC21	.208	.244	**.761**	.201
AC15	.078	-.072	**.735**	.331
AC22	.442	-.010	**.508**	.238
Communications Climate				
AC11	.207	.080	.237	**.858**
AC10	.146	.245	.213	**.786**
AC14	.332	.016	.341	**.530**
Eigen value	7.277	2.452	1.551	1.169
% of Variance Explained	38.300	12.907	8.164	6.155
Cumulative % of Variance	38.300	51.207	59.371	65.525

Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy = 0.845

Bartlett's Test of Sphericity = 1201.563, Significance = 0.000

Table 5.8.1.5 Absorptive Capacity – Factor Analysis Results (3)

Items	Factor 1	Factor 2	Factor 3	Factor 4
Knowledge Scanning Ability				
AC20	**.808**	.127	.229	.078
AC12	**.741**	.180	.106	.228
AC9	**.725**	.122	-.060	.101
AC13	**.705**	.091	.179	.163
AC19	**.707**	.105	.300	.115
A18	**.661**	.192	.264	.200
Existing Knowledge Base				
AC2	.111	**.898**	.047	.089
AC1	.101	**.875**	.029	.050
AC5	.168	**.825**	.115	.116
AC6	.209	**.814**	.179	.106
Communications Network				
AC23	.206	.188	**.850**	.002
AC21	.215	.229	**.756**	.224
AC15	.085	-.012	**.727**	.354
AC22	.428	-.019	**.562**	.264
Communications Climate				
AC11	.221	.084	.200	**.866**
AC10	.168	.259	.164	**.812**
AC14	.346	.024	.289	**.572**
Eigen value	3.732	3.198	2.596	2.164
% of Variance Explained	39.052	14.050	9.086	6.576
Cumulative % of Variance	39.052	53.102	62.189	68.765

Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy = 0.831

Bartlett's Test of Sphericity = 1081.094, Significance = 0.000

5.8.1.2 Confirmatory Factor Analysis

Different from the exploratory factor analyses, the confirmatory approach began with a second-order confirmatory analysis of the absorptive capacity indicators. This confirmatory model was applied to test the theoretical validity of a two-level construct structure of absorptive capacity. This framework of a higher-level factor, absorptive capacity, comprises of four lower level traits: knowledge scanning ability, existing knowledge base, communications clime, and communications network (Tu, 1999).

An initial second-order factor analysis with the maximum likelihood estimation method was performed using all 17 indicators from the four subscales of absorptive capacity generated through exploratory factor analyses. The fit indices (see Table 5.8.1.6) did not show a good fit of the model. The value of GFI (0.86), AGFI (0.80), and NFI (0.83) was below 0.90 (Kelloway, 1998: 23-33). The chi-square value of the specified model was significant (χ^2= 194.26, df= 115, p<0.001). It could be improved by deleting the AC15 that cross-loaded with several indicators. The model was therefore re-specified, indicating an adequate fit result with χ^2 (100) = 128.355 (p = .03), CFI = 0.97, GFI = 0.89, AFGI = 0.84, NFI = 0.88, and RMR = 0.05. The fit statistics confirmed the second-order structure of absorptive capacity (see Figure 5.1) as proposed by Tu (1999). As such, scores of the four subscales were averaged to represent absorptive capacity in ensuing regression analyses.

Table 5.8.1.6 Summary of Goodness-of-Fit Statistics for Absorptive Capacity (Second-Order CFA, 17 items)

Fit Indices	χ^2	df	p value	CFI	GFI	AGFI	NFI	RMR
(Model)								
Initial	194.26	115	0.000	0.92	0.86	0.81	0.83	0.06
Alternative (AC15 deleted)	128.36	100	0.03	0.97	0.89	0.84	0.88	0.05

Note: χ^2 = Chi-Square; df = Degree of Freedom; CFI = Comparative Fix Index; AGFI = Goodness-of-Fit Index; AGFI = Adjusted Goodness-of-Fit Index; NFI = Normed Fit Index; RMR = Root Mean Square Residual.

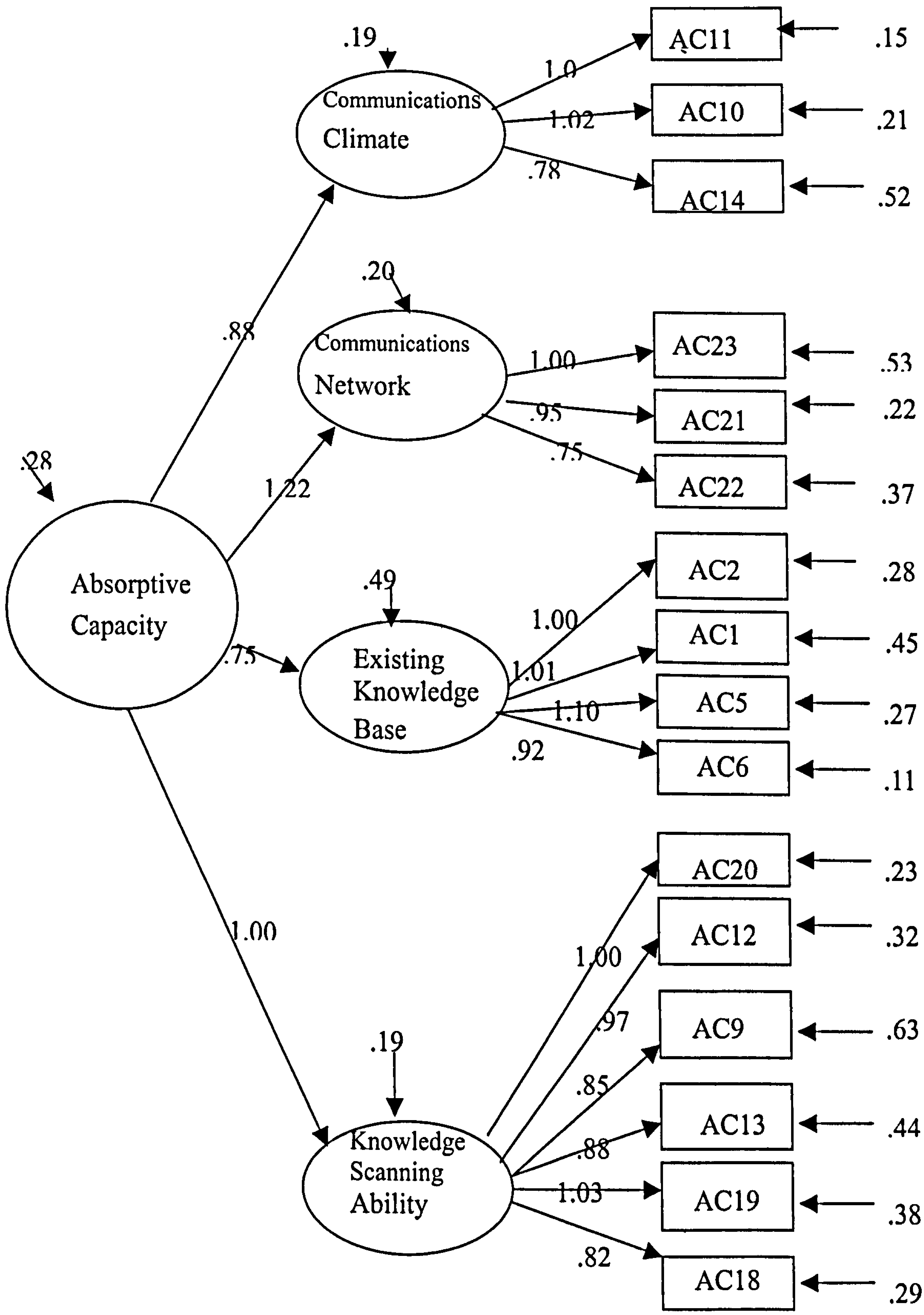


Figure 5.1 The Second-Order Diagram of the Absorptive Capacity Model

5.8.2 Instrument Validation of Gains in New Product Knowledge

Four dimensions - predevelopment assessment knowledge, marketing knowledge, R&D knowledge, and manufacturing knowledge - comprising 20 items in the large-scale survey initially represented the Gains in New Product Knowledge (PK) construct. The original 20 items and their corresponding code names are listed in Table 5.8.2.1.

Table 5.8.2.1 Gains in New Product Knowledge (PK)– Questionnaire Items

Code	Questionnaire Items
PK1	Preliminary market assessment of the product
PK2	Determining market characteristics and trends
PK3	Preliminary business/financial analysis
PK4	Initial screen techniques
PK5	Handling after-service programme
PK9	Preliminary engineering and technical assessments
PK6	Detailed market study/market research
PK7	Executing test market programmes in line with plans for product commercialisation
PK8	Launching and introducing new products into targeted marketplace- selling, promoting, and distributing the product
PK10	Identifying "appeal" characteristics that differentiate and sell the product
PK11	Conducting detailed design and development
PK12	Building of the product to designated or revised specifications
PK13	Evaluating lab tests to determine basic performance against the product's specifications
PK14	Executing prototype or "in-house" sample product testing
PK15	Determining the final product design and specifications
PK16	Working continuously for cost reduction and quality improvement
PK17	Conducting preliminary manufacturing assessments of the product
PK18	Executing product trial/pilot production
PK19	Conducting production start-up which is now better than before
PK20	Executing the product quality assurance programme which is now better than before

5.8.2.1 Exploratory Factor Analysis

These 20 items of the gain in new product knowledge construct were submitted to exploratory factor analysis. A four-factor structure emerged with all factor loadings above the threshold of 0.50 except for PK9, which cross-loaded on factor 3 (see Table

5.8.2.2). PK9 was then deleted and a new factor analysis was carried out using the remainder. According to the factor loadings, the four factors were labeled: factor 1, R&D knowledge; factor 2, manufacturing knowledge; factor 3, marketing knowledge; and factor 4, pre-development assessment knowledge. The results of the second exploratory factor analysis are shown in Table 5.8.2.3. All factor loadings were above 0.54. The KMO score of 0.86 indicated very good sampling adequacy. The four factors explain 67.24 percent variance.

Table 5.8.2.2 Gains in New Product Knowledge – Factor Analysis Results (1)

Items	Factor 1	Factor 2	Factor 3	Factor 4
PK13	**.833**	.163	.095	.159
PK14	**.817**	.104	.144	.154
PK15	**.762**	.189	.178	.106
PK12	**.735**	.239	.286	.026
PK11	**.664**	.218	.306	.039
PK16	**.589**	.286	.074	.241
PK9	**.538**	.187	**.491**	.160
PK20	.258	**.832**	.095	.127
PK18	.227	**.815**	.222	.126
PK17	.156	**.808**	.197	.082
PK19	.277	**.788**	.132	.072
PK2	.244	.131	**.789**	.151
PK3	.144	.219	**.779**	.253
PK4	.241	.087	**.717**	.288
PK1	.144	.214	**.663**	.298
PK7	.164	.069	.215	**.811**
PK6	.046	.093	.105	**.804**
PK8	.216	-.023	.279	**.713**
PK5	.049	.183	.155	**.706**
PK10	.242	.129	.320	**.523**
Eigen value	8.133	2.327	1.657	1.196
% of Variance Explained	40.667	11.635	8.287	5.980
Cumulative % of Variance	40.667	52.302	60.589	66.568

Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy = 0.854

Bartlett's Test of Sphericity = 1377.386, Significance = 0.000

Table 5.8.2.3 Gains in New Product Knowledge – Factor Analysis Results (2)

Items	Factor 1	Factor 2	Factor 3	Factor 4
R&D Knowledge				
PK13	**.829**	.167	.165	.130
PK14	**.821**	.103	.154	.172
PK15	**.765**	.188	.104	.052
PK12	**.745**	.236	.023	-.007
PK11	**.658**	.225	.050	.051
PK16	**.592**	.284	.239	.196
Manufacturing Knowledge				
PK20	.257	**.831**	.126	.071
PK17	.145	**.816**	.093	.065
PK18	.231	**.813**	.123	.109
PK19	.278	**.787**	.075	.027
Marketing Knowledge				
PK6	.034	.101	**.814**	.083
PK7	.167	.067	**.807**	.220
PK8	.214	-.021	**.714**	.277
PK5	..048	.157	**.699**	.167
PK10	.236	.137	**.535**	.373
Pre-development Assessment Knowledge				
PK2	.245	.134	.154	**.790**
PK3	.187	.220	.254	**.783**
PK4	.244	.088	.289	**.720**
PK1	.151	.213	.295	**.673**
Eigen value	7.642	2.325	1.675	1.247
% of Variance Explained	40.220	12.239	8.569	6.210
Cumulative % of Variance	40.220	52.459	61.028	67.239

Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy = 0.857

Bartlett's Test of Sphericity = 1276.513, Significance = 0.000

5.8.2.2 Confirmatory Factor Analysis

The 19 indicators of R&D knowledge, manufacturing knowledge, marketing knowledge, and pre-development assessment knowledge were subjected, as a group, to first-order factor confirmatory factor analyses. The specified four-factor structure did not fit very well (χ^2 (146) = 228.09 (p = .000), CFI = 0.92, GFI = 0.84, AFGI = 0.79, NFI = 0.81, and RMR = 0.06). The modification indices suggested room for improvement in model fit. PK2 (determining market characteristics and trends) was cross-loaded with PK7 (executing test market programmes in line with plans for product commercialisation), PK8 (launching and introducing new products into targeted marketplace – selling, promoting and distributing the product), PK15 (determining the final product design and specifications) and PK16 (working continuously for cost reduction and quality improvement). PK13 (evaluating lab tests to determine basic performance against the product's specifications) was cross-loaded with PK14 (executing prototype or in-house sample product testing) and PK8 (launching and introducing new products into targeted marketplace – selling, promoting and distributing the product) while PK9 (preliminary engineering and technical assessments) was also cross-loaded with PK1 (preliminary market assessment of the product), PK13 (evaluating lab tests to determine basic performance against the product's specifications), PK16 (working continuously for cost reduction and quality improvement) and PK18 (launching and introducing new products into targeted marketplace – selling, promoting and distributing the product). The original model was re-specified after deleting PK2, PK13 and PK9. The resulting model (Figure 5.2) adequately fits the data, with the model fit indices as follows: χ^2 (98) = 119.04 (p = .07), CFI = 0.97, GFI = 0.89, AFGI = 0.85, NFI = 0.87, and RMR = 0.05 (see Table 5.8.2.4).

Table 5.8.2.4 Summary of Goodness-of-Fit Statistics for Gains in New Product Knowledge (First-Order CFA, 19 items)

Fit Indices (Model)	χ^2	df	p value	CFI	GFI	AGFI	NFI	RMR
Initial	228.09	146	0.000	0.92	0.84	0.79	0.81	0.06
Alternative (PK2, PK13 and PK9 deleted)	119.04	98	0.07	0.97	0.89	0.85	0.87	0.05

Note: χ^2 = Chi-Square; df = Degree of Freedom; CFI = Comparative Fix Index; AGFI = Goodness-of-Fit Index; AGFI = Adjusted Goodness-of-Fit Index; NFI = Normed Fit Index; RMR = Root Mean Square Residual.

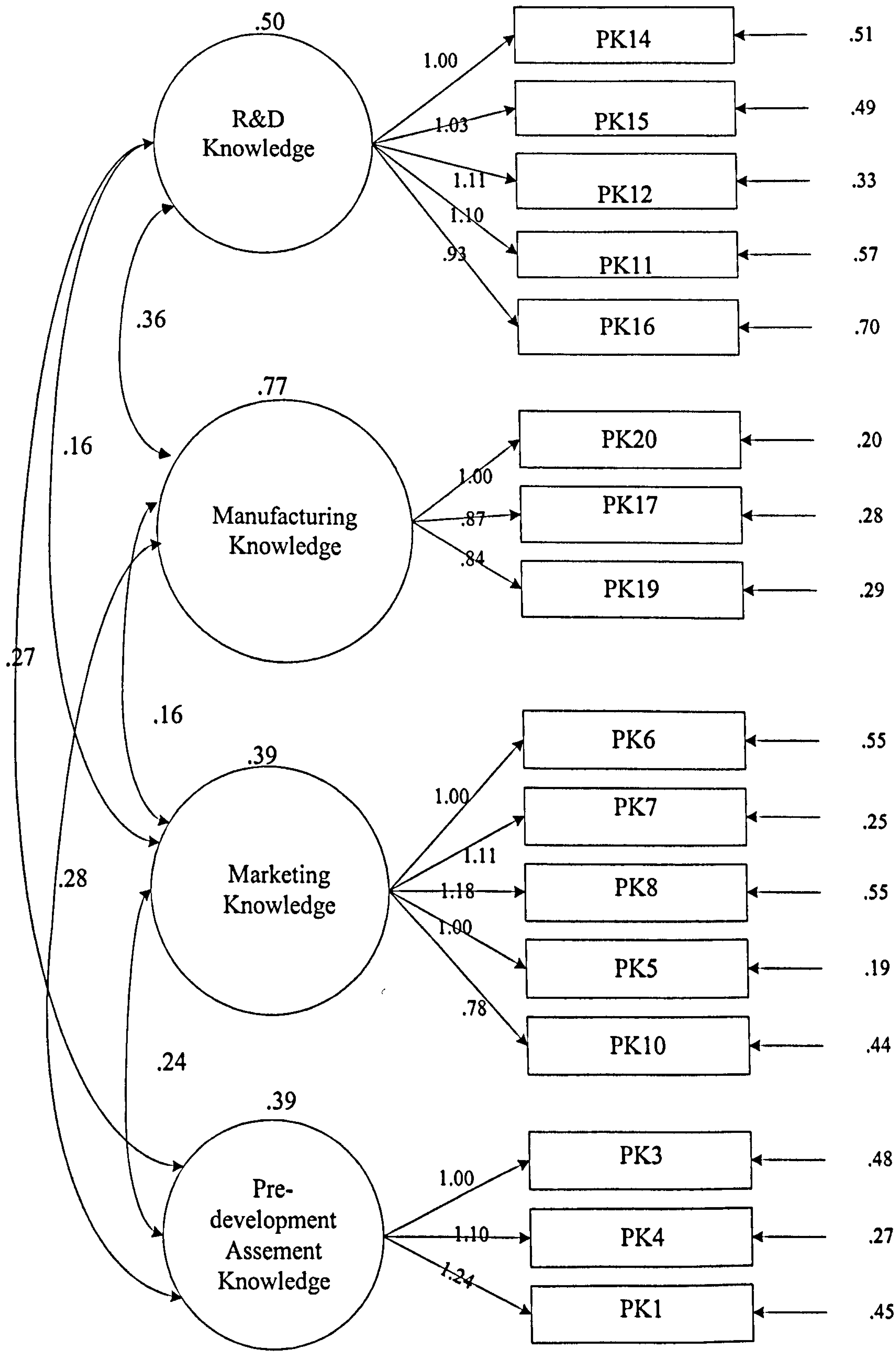


Figure 5.2 The First-Order Diagram of the Gains in New Product Knowledge Model

5.8.3 Instrument Validation of New Product Innovativeness

The construct of new product innovativeness, consisting of 8 items, included two dimensions. These are: (1) technological innovativeness (4 items) and (2) market innovativeness (4 items) as listed in Table 5.8.3.1.

Table 5.8.3.1 New Product Innovativeness (PI) – Questionnaire Items

Code	Questionnaire Items
Technological Innovativeness	
PI1	Product class was new to our firm
PI2	Product use (need served) was new to our firm
PI5	Product production process was new to our firm
PI6	Product design/development technology was new to our firm
Market Innovativeness	
PI4	Customers for the product were new to our firm
PI7	Distribution and sales force for the product was new to our firm
PI8	Advertising and promotion for the product was new to our firm
PI3	Product competitors were new to our firm

Initial reliability analysis was carried out on each of the two new product innovativeness dimensions. The CITC scores for all items were above 0.52 (see Table 5.8.3.2). The Cronbach's alpha scores were 0.86 for technological innovativeness and 0.88 for market innovativeness, indicating sound reliability.

Table 5.8.3.2 New Product Innovativeness – Reliability Analysis Results

Items	Initial CITC	Final CITC	Alpha if Item Deleted	Cronbach's Alpha Scores
Technological Innovativeness				
PI2	0.79	0.79	0.79	α=0.86
PI3	0.73	0.73	0.82	
PI5	0.52	0.52	0.86	
PI6	0.66	0.66	0.83	
Market Innovativeness				
PI4	0.74	0.74	0.88	α=0.88
PI7	0.80	0.80	0.85	
PI8	0.74	0.74	0.82	
PI3	0.64	0.64	0.83	

5.8.3.1 Exploratory Factor Analysis

The eight measurement items were submitted to an exploratory factor analysis. As expected, two factors emerged from the analysis with factor loadings above 0.72, indicating good discriminant and convergent validity. No cross loading was observed. The results of the factor analysis are showed in Table 5.8.3.3. The KMO score was 0.81, indicating very good sampling adequacy. The two factors account for 73 percent of variance. Thus, the two dimensions – technological innovativeness, market innovativeness – consisting of 8 items constitute the measure of the new product innovativeness construct.

Table 5.8.3.3 New Product Innovativeness– Factor Analysis Results

Items	Factor 1	Factor 2
Market Innovativeness		
PI7	**.885**	.193
PI8	**.849**	.281
PI4	**.832**	.223
PI3	**.735**	.255
Technological Innovativeness		
PI1	.286	**.846**
PI2	.235	**.834**
PI6	.154	**.834**
PI5	.280	**.729**
Eigen value	4.475	1.368
% of Variance Explained	55.933	17.105
Cumulative % of Variance	55.933	73.038

Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy = 0.817
Bartlett's Test of Sphericity = 562.082, Significance = 0.000

5.8.3.2 Confirmatory Factor Analysis

The CFA results demonstrate that the two-factor structure is adequately supported ((χ^2 (19)= 52.18 (p = .000), CFI = 0.94, GFI = 0.90, AFGI = 0.81, NFI = 0.91, and RMR = 0.06). Modification indices indicated that the removal of PI2 (product use was new to our firm) can further improve the fit of the model. The resulting goodness-of-fit statistics in the alternative model (presented in Table 5.8.3.4) are: χ^2 (13)= 22.41 (p = .05), CFI = 0.98, GFI = 0.95, AFGI = 0.90, NFI = 0.95, and RMR = 0.10.

Figure 5.3 illustrates the structural model of new product innovativeness. The construct of technological innovativeness therefore comprises of 3 items, PI1 (product class was new to our firm), PI6 (product design/development technology was new to our firm) and PI5 (product production process was new to out firm). The indicators for market innovativeness remain as PI3 (product competitors were new to out firm), PI4 (customers for the product were new to our firm), PI7 (distribution and sales force for the product was new to our firm) and PI8 (advertising and promotion for the product was new to our firm). These seven items constitute the final measure of the new product innovativeness construct.

Table 5.8.3.4 Summary of Goodness-of-Fit Statistics for New Product Innovativeness (First-Order CFA, 8 items)

Fit Indices (Model)	χ^2	df	p value	CFI	GFI	AGFI	NFI	RMR
Initial	52.81	19	0.000	0.94	0.90	0.81	0.91	0.14
Alternative (PI2 deleted)	22.42	13	0.05	0.98	0.95	0.90	0.95	0.10

Note: χ^2 = Chi-Square; df = Degree of Freedom; CFI = Comparative Fix Index; AGFI = Goodness-of-Fit Index; AGFI = Adjusted Goodness-of-Fit Index; NFI = Normed Fit Index; RMR = Root Mean Square Residual.

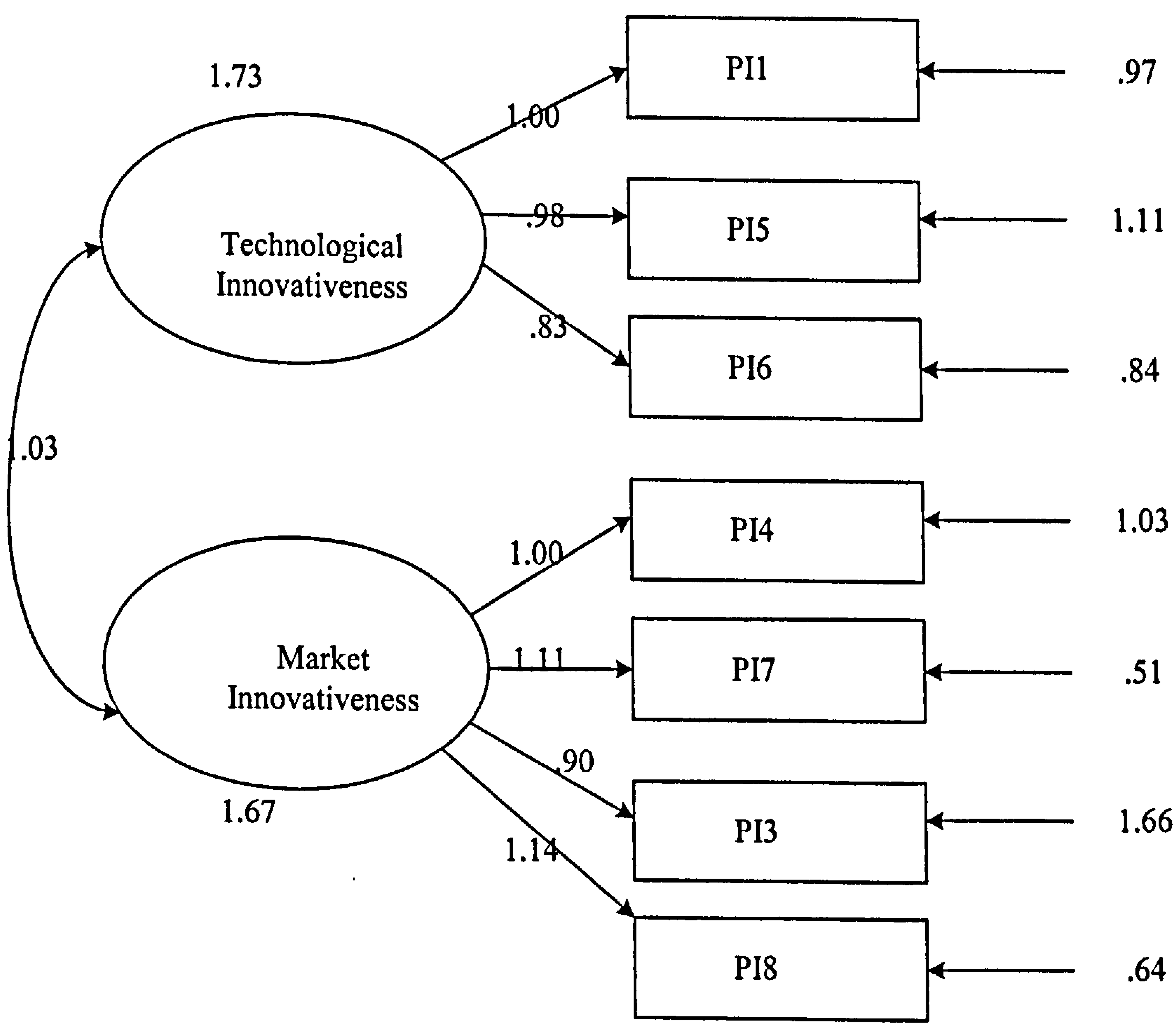


Figure 5.3 The First-Order Diagram of New Product Innovativeness Model

5.9 Conclusion: The Final Measurement Scales

This chapter discussed the results and processes of pilot study, large-scale survey and the validation of measurement instrument. The discussion of the sample characteristics included profile of respondent, response rates, and tests for non-response bias.

After the construct validation, there are seven multi-item measurement scales that were refined. The final Cronbach's alpha scores for all construct dimensions range from 0.77 to 0.89, demonstrating internal reliability (see Table 5.9.1).

The measure for both the customer linkage and the supplier linkage used a formative scale. The measure focused on the extent to which each linkage was involved in each step of NPD activities (see Section 4.4.2). A total of 13 formative indicators (i.e., 13 different, sequential NPD activities) formed the measure of each linkage. The score of each linkage was computed by averaging scores on the 13 items.

The surveyed data showed that not all NPD projects had associations with each type of horizontal linkage. Therefore, the three horizontal linkages could not be measured with a formative scale similar to that of the vertical linkages. The measuring scores of these three linkages were then converted into binary data (YES= with such a linkage, NO= without such a linkage); that is, a binary nominal scale was adopted.

The construct Table 5.9.1 presents a summary of the large-scale instrument validation results and the final scales. The final measurement scales were subsequently used in the regression analysis for testing hypotheses. Summated scales were used for all variables in the regression models except corporation linkage, research institute linkage, and university linkage. Chapter 6 discusses in detail the results of the tests applied.

Table 5.9.1 Summary of the Final Scales

Construct	Dimension Name	# of Items	Cronbach's α
Absorptive Capacity	Knowledge scanning ability	6	0.86
	Existing knowledge base	4	0.89
	Communications network	3	0.79
	Communications climate	3	0.78
Gains in New Product Knowledge	Predevelopment assessment knowledge	4	0.77
	Marketing knowledge	5	0.78
	R&D knowledge	5	0.83
	Manufacturing knowledge	3	0.84
New Product Innovativeness	Technological innovativeness	3	0.82
	Market innovativeness	4	0.88
Vertical Linkages	Customer linkage	Formative scale	N.A.
	Supplier linkage	Formative scale	N.A.
Horizontal Linkages	Corporation linkage	Binary (Yes, No)	N.A.
	Research institute linkage	Binary (Yes, No)	N.A.
	University linkage	Binary (Yes, No)	N.A.

N.A.= Not Applicable

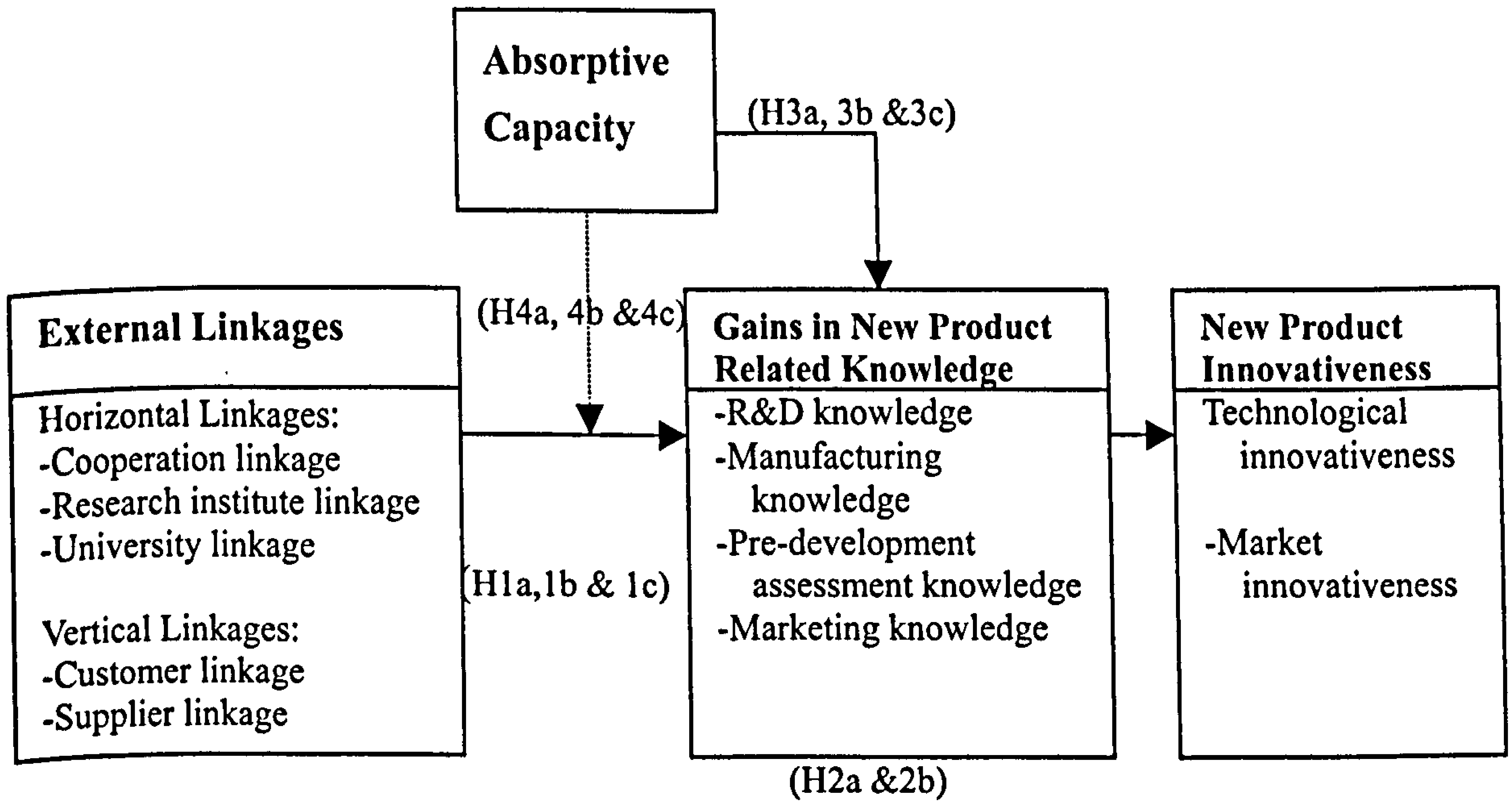
Chapter 6

Descriptive Findings and Hypothesis Testing

6.1 Introduction

Following Chapter 5, this chapter focuses on descriptive findings of the sample and the testing of the proposed hypotheses. Section 6.2 describes the sample profile. Section 6.3 discusses data examination for the application of regression analysis. Section 6.4 details testing the direct effects of external linkages on the accumulation of new product knowledge. Section 6.5 presents the results of testing both the moderating and the direct effects of absorptive capacity on new product knowledge accumulation. Finally, Section 6.6 reports the testing of the mediating effects of gains in new product related knowledge on the relationship between external linkages and new product innovativeness. Figure 6.1 summarises the relationships among this study's variables and proposed hypotheses.

Figure 6.1 An Illustration of Hypothesis Testing



6.2 Sample Profiles and Descriptive Statistics

6.2.1 Company profiles

In this research, the majority of data were collected from small- and medium-sized enterprises (SMEs) (See Table 6.2.1.1). Only 16.1 percent of firms in the surveyed sample have annual revenues exceeding one billion new Taiwan dollars (around 20 million Sterling Pounds; exchange rate: NT$ 50 = £ 1). In addition, more than 66 percent of the surveyed firms employ less than 500 people. The majority of SMEs in the sample have similarities consistent with previous research (Sher, 1998), reflecting certain inherent characteristics of Taiwanese IT industries. For instance, small firms are more likely to seek technological convergence with dominant designs[1] (Suarez and Utterback, 1995) instead of developing their own technologies. Due to limited resources, they tend to acquire new product know-how/technology externally. Therefore, the development of external linkages with major multi-national companies (MNCs) and/or industrial research institutes has become one of their major tactics in seeking and acquiring new technologies for upgrading their innovation and, most importantly, for their survival in a dramatically competitive IT environment. This also explains the reason why the majority of IT firms in Taiwan are OEM/ODM manufacturers, who concentrate their limited, valuable resources on product design and manufacturing activities and, in doing so, allocate less resources to brand marketing and/or channel development. As a result, these firms tend to predominantly acquire and absorb R&D-related knowledge instead of product marketing knowledge.

Firms with less than three percent of their revenue in R&D represent 22.9 percent of the sample. On the whole, up to 43 percent of firms invest less than five

[1] A dominant design is a specific path along an industry's design hierarchy, which establishes dominance among competing design paths (Suarez and Utterback, 1995). A dominant design has the effect of enforcing standardisation so that production economies can be sought. Effective competition then takes place on the basis of cost as well as product performance. The innovation of new products in the presence of dominant designs is more incremental than radical.

percent of their revenue in R&D (see Table 6.2.1.1). These figures reveal that the R&D budget of Taiwanese IT firms is relatively less than that of their counterparts in industrialised countries (Cooper, 1999: 16-17). Taiwanese firms' R&D investment is concentrated on product design engineering in order to meet the requirement of speedy rollouts instead of being focused on applied and/or basic research. This tendency guides the NPD activities of these firms towards incremental innovation projects as opposed to radical innovations. Firms investing more than 20 percent of their revenue in R&D represent only 6.8 percent of the sample. The majority of the sample firms (42.4%) invest five to ten percent of their revenue in R&D. Overall, firms in both the PC/peripherals and the semiconductors sectors employ more R&D engineers than those of the telecommunications sector (See Table 6.2.1.3). This may be due to the different sizes of the firms in Taiwanese IT industry, rather than the extent of R&D intensity.

Table 6.2.1.1 Profile of the Firms

Attributes	Category	Percentage	Cumulative %
Firm size (by revenue)	Less than NT $100 million	6.8	(6.8%)
	NT $100-500 million	27.1	(33.9%)
	NT $501-750 million	35.6	(69.5%)
	NT $751-1000 million	14.4	(83.9%)
	More than NT $1000 million	16.1	(100%)
Number of employees	Less than 100	16.1	(16.1%)
	100 – 500	50.0	(66.1%)
	501 – 1000	13.6	(79.7%)
	1000 – 5000	20.3	(100%)
Number of R&D engineers	Less than 10	5.9	(5.9%)
	11 – 50	46.6	(52.5%)
	51 – 100	23.7	(76.2%)
	101 – 200	13.6	(89.8%)
	More than 200	10.2	(100%)
R&D intensity	Less than 3%	22.9	(22.9%)
	3.01 – 5%	19.5	(42.4%)
	5.01 – 10%	42.4	(84.8%)
	10.01 – 20%	8.5	(93.3%)
	More than 20%	6.8	(100%)

The industry sectors of the firms are tabulated in Table 6.2.1.2. Among the four different industrial sectors, the PC and Peripherals sector, at nearly 64% of the sample firms, is ranked as the dominant group. Twenty-six firms (21.3% of the sample firms) belong to the semiconductors sector where firms are DRAM (dynamic random access memory), SRAM (static random access memory), flashing memories manufacturers, IC design houses (firms specialising at designing semiconductors) and IC foundries (firms owning silicon-wafer-fabrication plants and speicalising in IC manufacturing services). Fourteen firms (11.5% of the total) are in the communications sector where they design and produce IT products such as LAN/WAN (local/wide area network) cards, communication hubs, modems, optic fibers, wireless communication modules, mobile phones and communication managers. Only four firms are in the software industry sector. As there was a relatively small sample of the software group, the NPD projects from this group were abandoned in the later statistical analyses.

Table 6.2.1.2 Industry Sectors of the Sample

Industry Sector	Frequency	Percentage
PC & Peripherals	78	63.9
Semiconductors	26	21.3
Communications	14	11.5
Software	4	3.3
Total	122	100.0

Firms in the semiconductors and PC and peripherals sectors employ more people and have higher revenues than those in the telecommunications sector (see Table 6.2.1.3). However, semiconductors firms invest significantly more revenue in R&D than those in PC and peripherals and telecommunications sectors. On average, semiconductors firms invest more than 12% of revenue in R&D, highlighting the knowledge-intensive characteristics of competition in this sector. Based on whether or not firms own silicon-wafer-fabrication plants, semiconductors firms are normally categorised as one of two types - the fabrication chip companies and the fabless chip companies. The latter do not own their plants. Instead, they contract the manufacturing out to foundries, companies that own IC plants. That means that they can focus their investment on IC chip design and development, rather than on expensive equipment. In the surveyed sample, some of these chip design companies invest more than 20 percent of revenue on R&D, which may account for the higher percentage of R&D investment in this sector.

Table 6.2.1.3 Results of ANOVA: Industrial Sectors and Firms' Characteristics

Firms' Characteristics	Industry Sectors (1) PC and Peripherals (n=78)	(2) Semiconductors (n=25)	(3) Telecom-munications (n=13)	F[b]	Duncan Results[a]
Number of Employees (log)	6.05 (1.22)	6.04 (1.31)	4.09 (.99)	5.07***	(1), (2) > (3)
Revenue (log) (in NT$100 million)	3.02 (.69)	3.45 (.79)	1.99 (.83)	3.31**	(1), (2)> (3)
R&D Intensity (log)	1.78 (.82)	2.27 (.71)	1.82 (.66)	3.83**	(2)> (3), (1)
Number of R&D Engineers (log)	4.40 (.94)	4.22 (1.32)	3.05 (.85)	6.22***	(1), (2) > (3)

Cells are means with standard deviations in parentheses.

[a] (1), (2) > (3) denotes that the means of group (1) and group (2) are significantly larger than the mean of group (3), based on $p < 0.05$ level.

[b] * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

As indicated in Table 6.2.1.3, the mean differences of firms' characteristics across the three industry sectors are significant. It is important to observe the differences in the variable means of interest across the three industry sectors.

One-way ANOVA shows that the only significant variable is that of market innovativeness (see Table 6.2.1.4). Duncan's range test indicates that the level of market innovativeness of the NPD projects in both telecommunications and PCs and peripherals tends to be higher than that of those in semiconductors.

Table 6.2.1.4 Results of ANOVA: Industrial Sectors and Variables

Variables	Industry Sectors (1) PC and Peripherals (n=78)	(2) Semiconductors (n=25)	(3) Telecom-munications (n=13)	F[b]	Duncan Results[a]
Gain in Manufacturing Knowledge	2.31 (.82)	2.32 (.79)	2.15 (.87)	0.22	N.S.
Gain in R&D Knowledge	2.47 (.79)	2.47 (1.03)	2.25 (.63)	0.43	N.S.
Gain in Pre-development Assessment Knowledge	2.23 (.76)	2.04 (.84)	2.19 (.58)	0.59	N.S.
Gain in Marketing Knowledge	2.07 (.71)	2.01 (.73)	2.38 (.74)	1.29	N.S.
Market Innovativeness	4.03 (1.42)	3.22 (1.49)	4.02 (1.15)	3.22**	(1), (3) > (2)
Technological Innovativeness	4.81 (1.29)	4.23 (1.51)	4.69 (1.24)	1.79	N.S.
Absorptive Capacity	5.54 (.52)	5.61 (.61)	5.57 (.58)	0.13	N.S.

Cells are means with standard deviations in parentheses.

[a] (1), (3) > (2) denotes that the means of group (1) and group (3) are significantly larger than the mean of group (2), based on $p < 0.1$ level. N.S.: Not Significant

[b] $*p < 0.05$, $** p < 0.01$, $*** p < 0.001$

6.2.2 Project profiles

NPD projects were broken down into four categories: parts/components, sub-assemblies, system products, and software. Basically, developing system products requires various types of product technologies that are integrated. For instance, image scanner manufacturers normally need to possess technologies such as electronic design, scanning mechanism, optic design, firmware control and software driver programming to be capable of designing a scanner product. By contrast, part/component, such as ICs (integrated circuits) and connectors, producers focus on relatively few types of product technologies, but may put more emphasis on the automation of manufacturing process. Therefore, the scope of multi-disciplined technologies may influence a firm's tendency to use external sources for product innovation. Of the 122 NPD projects studied, forty-one (33.6%) belong to the personal computers and peripherals (see Table 6.2.2.1). These firms develop and manufacture products ranging from active components such as IC chips, chip sets (printed circuit devices that include several special functions on the boards) to passive components such as capacitors, resistors, and connectors. Fifteen projects (12.3%) belong to the sub-assemblies. The main products in this group include: printed circuit boards, LAN cards, communications hubs, hard disk modules, switching power suppliers, PC cabinets, CD-RW drives, LCD (liquid crystal display) modules and laser printer. The system products represent more than 50% (62 projects) of the sample. The firms in this group design and manufacturer IT products covering notebooks, PCs, industrial PCs, servers, image scanners, digital cameras, MVD/DVD players, LCD monitors, mouse, track balls, communication managers and so on. Four NPD projects are involved in designing application software products. These are primarily image processing/animation and anti-virus software.

Table 6.2.2.1 Product types of the Sample

Product type	Frequency	Percentage
Parts/Components	41	33.6
Sub-assemblies	15	12.3
System products	62	50.8
Software	4	3.3
Total	122	100.0

The results of ANOVA show that there is no significant difference between the surveyed firms' number of employees, revenue and R&D intensity and the three product types except for the number of R&D engineers employed (see Table 6.2.2.2). None of the F values were found to be significant at the $p<0.05$ level. The results in general indicate that the type of NPD projects is not associated with firms' characteristics in the current study. Further testing of the differences in variable means of interest across the three product types shows that market innovativeness is significant at $p<0.05$ level (see Table 6.2.2.3). Duncan's range test suggests that the level of market innovativeness of the NPD projects of both system products and subassemblies tends to be higher than that of those of parts/components.

Table 6.2.2.2 Results of ANOVA: Product Types and Firms' Characteristics

Firms' Characteristics	Product Types (1) Parts/ Components (n=40)	(2) Subassemblies (n=14)	(3) System products (n=62)	F[a]	Duncan Results[b]
Number of Employees (ln)	5.97 (1.25)	5.67 (1.18)	5.95 (1.29)	0.31	N.S.
Revenue (ln) (in NT$ 100million)	3.02 (.69)	2.48 (1.37)	3.11 (1.75)	0.79	N.S.
R&D Intensity (ln)	1.88 (.82)	1.73 (.74)	1.93 (.81)	0.38	N.S.
Number of R&D Engineers (ln)	3.74 (1.19)	3.66 (.96)	4.18 (.97)	2.92*	N.S.

Cells are means with standard deviations in parentheses.

[a] *p<0.1,

[b] NS: Not Significant. Duncan results are based on p<0.05 comparisons.

Table 6.2.2.3 Results of ANOVA: Industrial Sectors and Variables

Firms' Characteristics	Industry Sectors (1) Parts/ Components (n=40)	(2) Subassemblies (n=14)	(3) System products (n=62)	F[b]	Duncan Results[a]
Gain in Manufacturing Knowledge	2.36 (.80)	2.21 (.84)	2.27 (.82)	0.20	N.S.
Gain in R&D Knowledge	2.36 (.77)	2.61 (.99)	2.47 (.83)	0.55	N.S.
Gain in Pre-development Assessment Knowledge	2.01 (.74)	2.45 (.66)	2.24 (.78)	2.04	N.S.
Gain in Marketing Knowledge	2.03 (.69)	2.14 (.80)	2.12 (.73)	0.21	N.S.
Market Innovativeness	3.22 (1.34)	4.21 (1.10)	4.18 (1.44)	6.55***	(3), (2) > (1)
Technological Innovativeness	4.37 (1.39)	4.52 (1.13)	4.90 (1.34)	2.06	N.S.
Absorptive Capacity	5.52 (.52)	5.66 (.49)	5.56 (.57)	0.35	N.S.

Cells are means with standard deviations in parentheses.

[a] (3), (2) > (1) denotes that the means of group (3) and group (2) are significantly larger than the mean of group (1), based on p < 0.05 level. N.S.: Not Significant.

[b] **p < 0.05, *** p < 0.01

6.3 Data Examination

6.3.1 Assumptions in Multiple Regression Analysis .

Most statistical tests are founded on several assumptions about the sample data to which they are applied. The application of regression analysis to test hypotheses requires a set of assumptions to be satisfied including (Hair et al., 1998: 172-176): (1) normality of the error term distribution, (2) linearity of the phenomenon measured, (3) independence of the error terms, and (4) constant variance of the error terms. Any violations of assumptions can result in inappropriate tests of the significance of coefficients and inaccurate predictions of the dependent variables.

By testing the appropriateness of each regression model, a scatter-plot of studentized residuals (i.e., the difference between the predicted and the observed values for the dependent variable) was placed against predicted variables and or/independent variables to evaluate assumptions regarding the linearity, independence and constant variance of error terms (ibid.). The residual plots of the regression models in this study (see Appendix C) did not display any specific patterns and appeared to be randomly scattered around a horizontal line through zero, indicating the existence of meeting these assumptions.

Both a histogram of residuals and a normal probability plot of residuals were utilised for examining normality. If the data are a sample from a normal distribution, the residuals are expected to fall on or close to a straight diagonal line (ibid., pp.175-176). In this study, the histogram and normal probability plots (see Appendix C) did not provide a basis for rejecting the normality assumption for all regression models constructed.

6.3.2 Assessing Multicollinearity and Identifying Influential Observations

Multicollinearity (or collinearity) refers to the correlations among independent variables. The presence of high collinearity in the data can lead to large standard error of the estimated regression coefficients so that predictions may become unstable and/or incorrect (ibid., pp.188-189). The tolerance value and its inverse - the variance inflation factor (VIF) - are two widely accepted statistics for examining multicollinearity. Tolerance value indicates the degree to which the variance of each independent variable is not explained by the other independent variables. A variable with a small tolerance (i.e. high VIF) indicates high collinearity. A common cut-off threshold indicating existence of collinearity, suggested by Hair et al. (ibid., p.193), is a tolerance value below 0.1, which corresponds to VIF values above 10.

The examination of the condition index (which represents the collinearity of combinations of variables in the data set) and the decomposition of regression coefficient variance (i.e. the proportion of variance for each regression coefficient attributable to each condition index) is another instrumental method to diagnose variables exhibiting high multicollinearity. Collinearity is indicated when the identified condition index is above 30, accounting for a sizable proposition of variance (0.9 or above) for two or more coefficients (ibid., p.220). Then the proportion of the coefficient variance matrix is used to identify the exact variables demonstrating substantial collinearity.

As discussed in Section 4.5.2, if interaction terms are significant, the regression model is likely to encounter the problem of multicollinearity because of high correlations among predictors (i.e. independent, moderator and interaction terms). In this study in order to avoid multicollinearity, both independent variables including moderators and dependent variables are all mean-centered before entering the regression run. All regression models performed were examined for their VIF and tolerance values. VIF values of all predictor variables ranged from 3.362 to 1.051 with corresponding tolerance values ranging from 0.297 to 0.951 in the regression models. These values indicate that multicollinearity was not a significant problem as all are far above the cutoff thresholds.

Outliers can have a disproportionate influence on the estimated parameters in a regression equation. In this study, three methods of checking outliers and influential observations were utilised. First, residual plots were used to spot outliers quickly. In general, studentized residuals exceeding an absolute value of three are considered outliers. Second, hat values (the diagonal elements of the least-square project matrix) were used to identify leveraging points, which were observations with unusual combinations of values of the independent variables. It is suggested that when a hat value is greater than 2p/n, where p is the number of independent variables plus one and n is the sample size, the observation is considered to be a potential leverage point in the sample size exceeding 50 [ibid., p.224]. The third method involves using the DFBETA (in SPSS) to single out an observation demonstrating substantial change on each regression coefficient. The guidance (ibid., p.225) for identifying particularly high values of DFBETA suggest that a threshold of $| 2\sqrt{n} |$ be applied to medium or large data sets .

Applying the above three methods revealed that six cases generated potential influentials in the regression models. To detect the impact of these variables, a series of regression analyses was carried out without these cases, and the best fit in terms of R^2 was found when two cases were deleted. The subsequent results for regression analyses for hypothesis testing are based on 116 cases of projects.

6.4 Testing the Direct Effects of External Linkages on Gains in New Product Related Knowledge

H1a: The positive effects of horizontal linkages on gains in R&D knowledge will be stronger than those of vertical linkages.

H1b: The positive effect of horizontal linkages on gains in marketing knowledge will be stronger than those of vertical linkages.

H1c: The positive effect of horizontal linkages on gains in manufacturing knowledge will be stronger than those of vertical linkages.

The following three hierarchical regression models were developed to test hypotheses 1a, 1b and 1c. Table 6.4.1 reports the means and standard deviations of the variables and their Pearson correlations. The Pearson coefficients between absorptive capacity and gains in manufacturing, R&D and pre-development assessment knowledge variables are significant at $p < 0.01$ level. Therefore, absorptive capacity and company size together with the control variables of both industrial sectors and product types, which were dummy-coded, were first entred into regression equations to partial out their effects on dependent variables (i.e., gains in new product related knowledge) (see Model 1). Next, two vertical linkage variables were entered into regression equations to examine their effects on the increase in R^2 to determine the unique amount of variance explained (see Model 2). As variables of external linkage relative to corporation, industrial research institute and university are dichotomised, three dummy variables were last introduced into the regression equations (see Model 3). Model 3 is used to examine the effects of horizontal linkages on the increase in R^2 to determine the unique amount of variance explained for predicting gains in new product knowledge variables. A comparison of the increase in R^2 between the effects of vertical linkages and horizontal linkages determines which has greater impact on gains in new product related knowledge.

Model (1):

Gain in New Product Knowledge = **Company size**

+ Industrial sectors (PC & Peripherals, Semiconductors)

+ Product types (Components, Sub-assemblies)

+ Absorptive capacity

Where in industrial sector,

Variable: PC & Peripherals	= 1 if a firm operates in this category 0 if a firm operates in telecommunications or semiconductors
Variable: Semiconductors	= 1 if a firm operates in this category 0 if a firm operates in telecommunications or PC & Peripherals

Where in product type,

Variable: Components	= 1 if a new product belongs to this category = 0 if a new product belongs to sub-assemblies or system products
Variable: Sub-assemblies	= 1 if a new product belongs to this category = 0 if a new product belongs to components or system products

(Two dummy variables are utilised in the regression equations since there are three different categories in both product type and industrial sector.)

Model (2):

Gain in New Product Knowledge = Company size

+ Industrial sectors (PC & Peripherals, Semiconductors)

+ Product types (Components, Sub-assemblies)

+ Absorptive Capacity

+ Vertical linkages (Customer linkage and Supplier linkage)

Model (3):

Gain in New Product Knowledge = Company size

+ Industrial sectors (PC & Peripherals, Semiconductors)

+ Product types (Components, Sub-assemblies)

+Absorptive Capacity

+Vertical linkages

+Horizontal linkages (Corporation linkage, Research institute linkage and University linkage)

Where,

Variable: Corporation linkage	= 1 if any cooperating firm involved in the project 0 if no cooperating firms involved
Variable: Research institute linkage	= 1 if any research institute involved 0 if no research institute involved
Variable: University linkage	= 1 if any university involved 0 if university involved

(Since corporation, industrial research institute and university are dichotomous variables, one dummy variable for each variable was assigned in the regression equations.)

Hypotheses 1a, 1b and 1c posit that the magnitude of the positive effects of horizontal linkages on gains in R&D, manufacturing and marketing knowledge will be stronger than those of vertical linkages. When predicting the gain in R&D knowledge, the amount of variance explained by the horizontal linkages ($\Delta R^2 = .16$, $p < 0.01$) was larger than that of the vertical linkages ($\Delta R^2 = .01$) (see Table 6.4.2). Similarly, the increase in R^2 due to the horizontal linkages ($\Delta R^2 = .06$, $p<0.05$) was higher than the increase due to the vertical linkages ($\Delta R^2 = .03$, $p>0.1$) when predicting gain in manufacturing knowledge (see Table 6.4.2). The results confirm that the effects of the horizontal linkages on gains in new technical related knowledge (R&D and manufacturing) are higher than those observed for vertical linkages. Thus, Hypotheses 1a and 1c are strongly supported.

By a similar analysis, when predicting gain in pre-development assessment knowledge, the unique amount of variance explained by the horizontal linkages ($\Delta R^2 = .15$, $p<0.01$) was also larger than that of the vertical linkages ($\Delta R^2 = .01$, $p>0.05$) (see Table 6.4.3). Although examining the R square ($R^2 = 0.13$, $p>0.1$) for the complete model is not significant when predicting gain in marketing knowledge (see Table 6.4.3), the increase in R^2 due to the horizontal linkages ($\Delta R^2 = .08$, $p<0.05$) was higher than the increase due to the vertical linkages ($\Delta R^2 = .01$, $p>0.1$). The results lend support to Hypothesis 1b.

Table 6.4.1 Correlation Matrix

Variable[a]	Mean	S.D.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. Size (Log)	2.58	0.55	1.00																
2. PC & Peripherals	0.68	0.47	.15	1.00															
3. Semiconductors	0.21	0.41	.05	-.75**	1.00														
4. Components	0.32	0.47	.02	-.50**	.55**	1.00													
5. Sub-assemblies	0.13	0.34	-.07	.09	-.07	-.27**	1.00												
6. Absorptive capacity	5.54	0.57	.02	-.05	.05	-.03	.04	1.00											
7. Customer linkage	3.88	1.09	-.02	.01	.10	.17	.09	.05	1.00										
8. Supplier linkage	3.41	0.93	.02	.21*	-.22**	-.12	.11	-.00	.24**	1.00									
9. Corporation linkage	0.77	0.42	.05	.11	-.04	-.08	.03	.05	.12	.07	1.00								
10.Industrial research institute linkage	0.32	0.47	.17	-.05	.07	.09	-.04	.04	.09	.04	.24**	1.00							
11.University linkage	0.23	0.83	.01	-.14	.06	.16	-.02	-.08	.07	.02	.13	.60**	1.00						
12.Gain in manufacturing knowledge	2.32	0.83	-.03	.02	.01	.05	-.01	.31**	.07	.16	.25**	.10	-.01	1.00					
13.Gain in R&D knowledge	2.48	0.80	-.03	.02	-.01	-.08	.08	.29**	.02	.11	.37**	.25**	.17	.50**	1.00				
14.Gain in pre-development assessment knowledge	2.22	0.78	-.05	.09	-.11	-.18*	.13	.23**	.03	-.05	.37**	.24**	.12	.42**	.51**	1.00			
15. Gain in marketing knowledge	2.12	0.71	-.11	-.04	-.06	-.09	.05	.11*	-.08	-.03	.24*	.10	-.01	.25**	.32**	.53**	1.00		
16.Market innovativeness	3.83	1.44	-.01	.18*	-.23**	-.32	.09	.17	-.01	.13	.20*	.14	.11	.22*	.31**	.42**	.32**	1.00	
17.Technological innovativeness	4.65	1.36	-.04	.17	-.19*	-.16	-.04	.15	.08	.26**	.21*	.11	.12	.51**	.52**	.40**	.34**	.53**	1.00

* p < .05, ** p < .01, two-tailed test

[a] The scales of corporation linkage, industrial research institute linkage, and university linkage: Dummy variables 1 = 'the NPD project having such an association', 0= 'the NPD project without such an association.'

Table 6.4.2 Results of Hierarchical Regression Analysis: Effects of External Linkages on Gains in New Product Knowledge (1)

Independent Variable	Gain in R&D Knowledge			Gain in Manufacturing Knowledge		
	Model 1-1	Model 1-2	Model 1-3	Model 2-1	Model 2-2	Model 2-3
Log firm size	-.05	-.05	-.08	.01	.01	-.01
PC & Peripherals	.08	.07	.06	.10	.09	.04
Semiconductors	.11	.13	.12	.01	.05	.01
Components	-.08	-.08	-.07	.10	.10	.13
Subassemblies	.04	.03	.03	-.01	-.03	-.02
Absorptive capacity (AC)	.28**	.29**	.29**	.32**	.33**	.32**
Vertical Linkages:						
Customer linkage		-.02	-.08		-.01	-.04
Supplier linkage		.13	.10		.19†	.18†
Horizontal Linkages:						
Corporation linkage			.33**			.25**
Research institute linkage			.11			.04
University linkage			.10			-.06
R^2	.10	.11	.27**	.11	.14	.20**
ΔR^2		.01	.16**		.03	.06*
df	6, 109	8, 107	11,104	6, 109	8, 107	11, 104
F ratio	1.90†	1.64	3.55**	2.20*	2.19*	2.40**

Cells are standardized regression coefficients.

† $p < .1$, * $p < .05$, ** $p < .01$, all two-tailed test

Table 6.4.3 Results of Hierarchical Regression Analysis: Effects of External Linkages on Gains in New Product Knowledge (2)

	Gain in Pre-development Assessment Knowledge			Gain in Marketing Knowledge		
Independent Variable	Model 3-1	Model 3-2	Model 3-3	Model 4-1	Model 4-2	Model 4-3
Log firm size (Control)	-.05	-.05	-.09	-.08	-.08	-.11
PC & Peripherals	.21	.01	-.01	-.18	-.16	-.21
Semiconductors	-.03	-.06	-.08	-.15	-.14	-.19
Components	-.12	-.13	-.11	-.08	-.17	.04
Subassemblies	.08	.09	.09	.03	-.04	.05
Absorptive capacity (AC)	.23*	.22*	.22*	.11	.11	.10
Vertical Linkages:						
Customer linkage		.06	.00		-.06	-.10
Supplier linkage		-.09	-.10		-.02	-.03
Horizontal Linkages:						
Corporation linkage			.32**			.25*
Research institute linkage			.18†			.14
University linkage			.01			-.11
R^2	.10	.11	.26**	.04	.05	.13
ΔR^2		.01	.15**		.01	.08*
df	6, 109	8, 107	11,104	6, 109	8, 107	11, 104
F ratio	1.91†	1.55	3.35	0.88	0.71	1.39

Cells are standardized regression coefficients.

† p < .1, * p < .05, ** p < .01, all two-tailed test

6.5 Testing the Direct and Moderating Effects of Absorptive Capacity

6.5.1 Moderator- Absorptive Capacity

As discussed in the Section 5.8.1, the construct of absorptive capacity is composed of, namely, existing knowledge base, knowledge scanning ability, communications climate and communications networking. Absorptive capacity, on the whole, in the surveyed sample was above the moderate level, i.e. above 5 on a 7-point scale (see Table 6.5.1.1). This result indicates that the majority of IT firms maintain a receptive communication climate to support new product/idea development. The results of ANOVA (through the procedure of repeated measures of general linear model in SPSS 10.0) showed a significant difference among four dimensions (see Table 6.5.1.2). Duncan's range tests (see Table 6.5.1.1) showed that the mean value of "communications climate" was significantly higher than in the other three dimensions. Differences were also found between "communications climate" and "existing knowledge base" as well as "knowledge scanning ability". Communications network, representing the extent to which a firm establishes an effective conduit for absorbing external knowledge/technology, was ranked as the lowest among the four dimensions. These differences suggest that further improvement of a firm's communications network along the interface between internal and external environments can effectively augment its absorptive capacity.

Table 6.5.1.1 Summary of Pairwise Comparisons: Four Dimensions of Absorptive Capacity

Absorptive Capacity	Mean	SD	F-ratio[b]	Duncan Results[a]
(1) Existing Knowledge Base	5.56	.86		
(2) Knowledge Scanning Ability	5.59	.69	19.49***	(3)> (2), (1) > (4)
(3) Communication Climate	5.74	.66		
(4) Communication Network	5.21	.79		

[a] (3) > (2), (1) > (4) denotes that the mean of group (3) is significant larger than the means of groups (2), (1) and (4); and the means of groups (3), (2) and (1) are all significantly larger than that of group (4), based on $p < 0.05$ level. And, no significant difference in the means of group (2) and group (1) is identified.

[b] *** $p < 0.01$.

Table 6.5.1.2 Summary of ANOVA: Four Dimensions of Absorptive Capacity

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F-ratio
Observed cases	153.52	115	1.34	
Dimension (Predictor)	18.27	3	6.09	19.49***
Residual Error	107.81	345	.31	

*** $p < 0.01$

In order to further revalidate the construct of absorptive capacity, a traditional measure of absorptive capacity - R&D intensity - was also included in the surveyed questionnaire to examine whether any significant correlation exists between R&D intensity and aggregate absorptive capacity. A logarithm transformation of R&D intensity was performed to reduce the skewness in distribution (kurtosis: 19.75and skewness: 4.04). None of Pearson's correlation coefficients between R&D intensity and other variables were significant at $p < 0.05$ level. Nevertheless, positive correlations are displayed (see the bottom row of Table 6.5.1.3). This observation is not surprising since it is consistent with the work of Spender and Grant (1996) who illustrated the instability of using R&D intensity as a proxy for a knowledge-based construct.

The mean value of overall absorptive capacity is 5.54 (see Table 6.5.1.3). It is highly correlated with each of the four dimensions of absorptive capacity, with all correlation coefficients above or close to 0.70. The correlation coefficients among the four dimensions of absorptive capacity are greater than 0.50 except for the relationship between the existing knowledge base and the other three dimensions of absorptive capacity. Given the multi-faceted nature of overall absorptive capacity and the validation of the four-factor structure as indicated by second-order confirmatory factor analyses (see Section 5.8.1.2), aggregate absorptive capacity was then employed as the moderator variable for testing the related hypotheses in the following sections.

Table 6.5.1.3 Correlations for Absorptive Capacity

	Mean	Standard Deviation	(1)	(2)	(3)	(4)	(5)	(6)
(1) Existing Knowledge Base	5.56	.86	1.00					
(2) Knowledge Scanning Ability	5.59	.68	.37**	1.00				
(3) Communication Climate	5.74	.66	.32**	.52**	1.00			
(4) Communication Network	5.21	.79	.32**	.54**	.51**	1.00		
(5) Aggregate Absorptive Capacity	5.54	.57	.70**	.85**	.71**	.74**	1.00	
(6) Log R&D[a]	1.88	.80	.05	.05	.05	.01	.05	1.00

** $p < .001$ (two-tailed).

[a] Log R&D denotes R&D expenditures in logarithmic terms.

6.5.2 Results of Hierarchical Moderated Regression Analysis

Table 6.4.1 illustrates that absorptive capacity is significantly correlated with both the four product knowledge gain variables (R&D knowledge, manufacturing, predevelopment assessment, and marketing) and with the two product innovativeness variables (technological and market innovativeness) at $p<0.05$ level (Pearson coefficients > 0.23). The Pearson correlation coefficients between corporation linkage and gain in R&D, pre-development assessment, and marketing knowledge lie between 0.19 ($p<0.05$) and 0.35 ($p<0.01$). These may provide support for the positive effects of both absorptive capacity and corporation linkage on gains in new product knowledge. Corporation linkage is also significantly correlated with the two product innovativeness variables ($p< 0.05$). In addition, the strong correlation (Pearson coefficients ranging from 0.24 to 0.54) between the four product knowledge gain variables and the two product innovativeness variables supports that the four product knowledge variables may possibly mediate the relationship between external linkages and the two product innovativeness variables.

The following three hierarchical regression models were developed to test hypotheses 3a, 3b, 3c, 4a, 4b and 4c (derived in Chapter 3). Model 1 (below) is developed to examine and partial out the effects of control variables on dependent variables. Model 2 (below) is employed to detect the direct effects of both external linkages and absorptive capacity. Model 3, with the inclusion of interaction terms between absorptive capacity and each type of external linkages, is used to examine the moderating effect of absorptive capacity. Because of the high collinearity across the interaction terms, an equation with all of the interaction terms entered simultaneously yields no significant coefficients. Thus, all metric independent and dependent variables were mean-centred (Venkatraman, 1989) and the interaction terms were entered one at a time.

Model (1):

Gains in New Product Knowledge (R&D, manufacturing, marketing and predevelopment assessment)

= Company size

+ Industrial sectors (PC & Peripherals, Semiconductors)

+ Product types (Components, Sub-assemblies)

Model (2):

Gains in New Product Knowledge = Control Variables

(Company size +Industrial sector +Product type)

+ Absorptive Capacity

+ 5 External Linkage Variables (Customer, Supplier, Corporation, Industrial research institute, University)

Model (3):

Gains in New Product Knowledge = Control Variables

(Company size +Industrial sector +Product type)

+Absorptive Capacity

+5 External Linkage Variables

+Interaction Terms

(Absorptive Capacity × Customer Linkage, Absorptive Capacity × Supplier linkage, Absorptive Capacity × Corporation Linkage, Absorptive Capacity × Research Institute Linkage, Absorptive Capacity × University Linkage)

6.5.2.1 Test for Hypothesis 3a, 3b and 3c- the Direct Effects of Absorptive Capacity

H3a A firm's level of absorptive capacity is positively related to its gains in R&D knowledge in a NPD project.

H3b A firm's level of absorptive capacity is positively related to its gains in marketing knowledge in a NPD project.

H3c A firm's level of absorptive capacity is positively related to its gains in manufacturing knowledge in a NPD project.

Hypotheses 3a, 3b and 3c predict that a firm's absorptive capacity is positively related to its gains in new product related knowledge. The Pearson correlations (see Table 6.4.1) between absorptive capacity and the four product knowledge gain variables (R&D knowledge, manufacturing knowledge, pre-development assessment knowledge, marketing knowledge) are all significant, ranging from 0.31 to 0.11 ($p < 0.05$). Control variables were then entered into the regression equations to examine their effects on the criterion variables (i.e. the four product knowledge gain variables). In each regression model, R^2 was not significant at $p < 0.05$ (see Table 6.5.2.1), indicating that the control variables do not significantly affect gain in new product knowledge. Next, absorptive capacity and five predictors – external linkage variables – were subjected to regression analysis.

A multiple regression analysis using gain in R&D knowledge as the criterion variable showed associations between the gain in R&D knowledge with that of absorptive capacity and corporation linkage ($F_{5,110} = 6.36$, $p < 0.01$, $R^2 = 0.26$) (see Model 1 shown in Table 6.5.2.2). The standardised regression coefficients were 0.29 ($t=3.57$, $p< 0.01$) and 0.34 ($t=3.93$, $p< 0.01$) respectively. These results demonstrated that absorptive capacity is positively correlated with gain in R&D knowledge. In addition, the NPD projects that involved collaboration with corporations shows stronger effects for gain in R&D knowledge than those without such linkages.

Table 6.5.2.1 Results of Regression Analysis: Effect of Control Variables

(Gains in New Product Related Knowledge)

	R&D knowledge	Manufacturing knowledge	Pre-development assessment knowledge	Marketing knowledge
Control Variables:				
Employee (Log)	-.04	.02	-.04	-.07
	(-.37)	(.17)	(-.45)	(-.75)
PC & Peripherals	.06	.08	-.01	-.18
	(.41)	(.52)	(-.04)	(-1.23)
Semiconductors	.12	.05	-.02	-.15
	(.78)	(.03)	(-.15)	(-.95)
Components	-.10	.08	-.14	-.09
	(-.89)	(.64)	(-1.19)	(-.78)
Sub-assemblies	.05	.01	.09	.03
	(.49)	(.03)	(.93)	(.30)
R^2	.02	.01	.04	.03
F (5,110)	.37 (N.S.)	.15 (N.S.)	.99 (N.S.)	.78 (N.S.)

Cells are standardised regression coefficients with t-values in parentheses.

N.S.: Not Significant, two-tailed test.

Table 6.5.2.2 Results of Moderated Regression Analysis: Predicting Gain in R&D Knowledge

Model	1	2	3	4	5	6
Main Effects:						
(1) Customer Linkage	-.07 (-.86)	-.06 (-.73)	-.08 (-.87)	-.08 (-.95)	-.08 (-.92)	-.08 (-.97)
(2) Supplier Linkage	.11 (1.28)	.11 (.12)	.11 (1.28)	.12 (1.42)	.06 (.74)	.10 (1.11)
(3) Corporation Linkage	.34*** (3.93)	.34*** (3.93)	.33*** (3.88)	.34** (4.09)	.34*** (4.19)	.34*** (3.97)
(4) Industrial Research Institute Linkage	.09 (.86)	.08 (.81)	.09 (.89)	.08 (.75)	.04 (.39)	.10 (.94)
(5) University Linkage	.10 (.96)	.12 (1.01)	.10 (.98)	.12 (1.21)	.17 (1.65)	.11 (1.01)
(6) Absorptive Capacity	.29*** (3.57)	.29*** (3.46)	.30*** (3.56)	-.09 (-.58)	.13 (1.32)	.25** (2.68)
Interaction Terms						
Absorptive Capacity × (1)		-.11 (-.13)				
Absorptive Capacity × (2)			-.03 (-.37)			
Absorptive Capacity × (3)				.46*** (3.06)		
Absorptive Capacity × (4)					.32*** (3.28)	
Absorptive Capacity × (5)						.10 (1.00)
R^2	.26	.27	.26	.32	.33	.27
ΔR^2		.01	.00	.06***	.07***	.01
F ratio	6.36***	5.72***	5.43***	7.20***	7.48***	5.59***

Cells are standardized regression coefficients with t-values in parentheses.
* p < .10, ** p < .05, *** p < .01, two-tailed test
ΔR^2 is the difference in R^2 value between model 1 and the model with the interaction term.

Similar regression procedures were applied by using gain in manufacturing knowledge, gain in pre-development assessment knowledge and gain in marketing knowledge separately as criterion variables. A significant correlation between gain in manufacturing knowledge and absorptive capacity, corporation linkage as well as supplier linkage ($F_{5,110}$ = 4.25, p<0.01, R^2 = 0.19) was identified in Table 6.5.2.3 (see Model 1 in the table). The beta coefficients of absorptive capacity, corporation linkage and supplier linkage are positive. The effect of absorptive capacity (β = 0.32, t=3.60, p< 0.01) on gain in manufacturing knowledge was stronger than that of supplier linkage (β = 0.16, t=1.82, p< 0.10).

Additionally, a correlation between gain in pre-development assessment knowledge and the predictors ($F_{5,110}$= 4.91, p<0.01, R^2= 0.21) was also recognised (see Model 1 shown in Table 6.5.2.4). The coefficient of absorptive capacity is significant and positive (β = 0.23, t=2.61, p<0.01), confirming its positive relationship with the criterion variable – gain in predevelopment assessment knowledge. However, a correlation between gain in marketing knowledge and the predictors was not confirmed ($F_{5,110}$ = 1.72, R^2= 0.09, p> 0.05), although the association between absorptive capacity and gain in marketing knowledge was positive (β=0.11, t=1.18) as shown in Table 6.5.2.5 (see Model 1 in the table).

In sum, absorptive capacity has a positive and significant effect on the extent of gain in R&D, manufacturing and pre-development assessment knowledge, with the exception of gain in marketing knowledge. Therefore, hypotheses 3a and 3c were supported and hypothesis 3b was not supported.

Table 6.5.2.3 Results of Moderated Regression Analysis: Predicting Gain in Manufacturing Knowledge

Model	1	2	3	4	5	6
Main Effects:						
(1) Customer Linkage	-.01	-.01	-.01	-.01	-.01	-.03
	(-.13)	(-.04)	(-.10)	(-.14)	(-.14)	(-.32)
(2) Supplier Linkage	.16*	.16*	.16*	.17*	.14	.14
	(1.82)	(1.9)	(1.78)	(1.84)	(1.56)	(1.55)
(3) Corporation Linkage	.24***	.24***	.25***	.24**	.24***	.25***
	(2.67)	(2.66)	(2.77)	(2.67)	(2.70)	(2.77)
(4) Industrial Research	.05	.04	.03	.04	.02	.06
Institute Linkage	(.41)	(.33)	(.27)	(.37)	(.19)	(.55)
(5) University Linkage	-.05	-.04	-.06	-.04	-.02	-.04
	(-.45)	(-.35)	(-.57)	(-.39)	(-.15)	(-.37)
(6) Absorptive Capacity	.32***	.31***	.31***	.20	.24**	.24**
	(3.60)	(3.52)	(3.57)	(1.23)	(1.87)	(2.43)
Interaction Terms						
Absorptive Capacity × (1)		-.08				
		(-.87)				
Absorptive Capacity × (2)			.12			
			(1.37)			
Absorptive Capacity × (3)				.14		
				(.87)		
Absorptive Capacity × (4)					.15	
					(1.41)	
Absorptive Capacity × (5)						.16*
						(1.67)
R^2	.19	.20	.20	.20	.20	.21
ΔR^2		.01	.01	.01	.01	.02
F ratio	4.25***	3.74**	3.97**	3.73***	3.96***	4.10***

Cells are standardized regression coefficients with t-values in parentheses.

* $p < .10$, ** $p < .05$, *** $p < .01$, two-tailed test

ΔR^2 is the difference in R^2 value between model 1 and the model with the interaction term.

Table 6.5.2.4 Results of Moderated Regression Analysis: Predicting Gain in Pre-development Assessment Knowledge

Model	1	2	3	4	5	6
Main Effects:						
(1) Customer Linkage	-.02	-.03	-.03	-.03	-.03	-.03
	(-.27)	(-.32)	(-.09)	(-.33)	(-.28)	(-.32)
(2) Supplier Linkage	-.06	-.06	-.06	-.05	-.07	-.06
	(-.66)	(-.64)	(-.64)	(-.59)	(-.78)	(-.71)
(3) Corporation Linkage	.34***	.34***	.33***	.34**	.34***	.34***
	(3.82)	(3.81)	(3.76)	(3.95)	(3.83)	(3.82)
(4) Industrial Research	.14	.15	.15	.13	.13	.15
Institute Linkage	(1.32)	(1.33)	(1.36)	(1.23)	(1.18)	(1.34)
(5) University Linkage	.01	.00	.01	.03	.02	.01
	(.06)	(.01)	(.11)	(.25)	(.22)	(.09)
(6) Absorptive Capacity	.23***	.23***	.23***	-.11	.18*	.21**
	(2.61)	(2.63)	(2.62)	(-.72)	(1.76)	(2.09)
Interaction Terms						
Absorptive Capacity × (1)		-.04				
		(-.47)				
Absorptive Capacity × (2)			-.04			
			(-.51)			
Absorptive Capacity × (3)				.40**		
				(2.57)		
Absorptive Capacity × (4)					.08	
					(.76)	
Absorptive Capacity × (5)						.04
						(.43)
R^2	.21	.21	.22	.26	.22	.21
ΔR^2		.00	.01	.05**	.01	.00
F ratio	4.91***	4.21***	4.22***	5.37***	4.27***	4.20***

Cells are standardized regression coefficients with t-values in parentheses.

* p < .10, ** p < .05, *** p < .01, two-tailed test

ΔR^2 is the difference in R^2 value between model 1 and the model with the interaction term.

Table 6.5.2.5 Results of Moderated Regression Analysis: Predicting Gain in Marketing Knowledge

Model	1	2	3	4	5	6
Main Effects:						
(1) Customer Linkage	-.11	-.10	-.12	-.12	-.11	-.12
	(-1.19)	(-1.06)	(-1.21)	(-1.23)	(-1.20)	(-1.29)
(2) Supplier Linkage	-.01	-.02	-.01	-.01	-.03	-.03
	(-.15)	(-.18)	(-.12)	(-.07)	(-.34)	(-.29)
(3) Corporation Linkage	.24**	.24**	.23**	.24**	.24**	.24**
	(2.50)	(2.49)	(2.43)	(2.57)	(2.53)	(2.54)
(4) Industrial Research	.09	.08	.10	.08	.07	.10
Institute Linkage	(.75)	(.70)	(.83)	(.65)	(.57)	(.82)
(5) University Linkage	-.07	-.05	-.06	-.05	-.04	-.06
	(-.58)	(-.45)	(-.51)	(-.41)	(-.34)	(-.54)
(6) Absorptive Capacity	.11	.10	.12	-.26	.04	.06
	(1.18)	(1.08)	(1.21)	(-1.52)	(.38)	(.60)
Interaction Terms						
Absorptive Capacity × (1)		-.11				
		(-1.18)				
Absorptive Capacity × (2)			-.08			
			(-.82)			
Absorptive Capacity × (3)				.43**		
				(2.58)		
Absorptive Capacity × (4)					.13	
					(1.10)	
Absorptive Capacity × (5)						.10
						(.95)
R^2	.09	.10	.09	.14	.10	.09
ΔR^2		.01	.00	.05**	.01	.00
F ratio	1.72(N.S.)	1.68(N.S.)	1.57(N.S.)	2.50**	1.65(N.S.)	1.63(N.S.)

Cells are standardized regression coefficients with t-values in parentheses.

* p < .10, ** p < .05, *** p < .01; N.S.: Not Significant (two-tailed test)

ΔR^2 is the difference in R^2 value between model 1 and the model with the interaction term.

6.5.2.2 Test for Hypothesis 4a, 4b and 4c - the Moderating Effects of Absorptive Capacity

H4a A firm's level of absorptive capacity moderates the positive effects of external linkages on gains in R&D knowledge.

H4b A firm's level of absorptive capacity moderates the positive effects of external linkages on gains in marketing knowledge.

H4c A firm's level of absorptive capacity moderates the positive effects of external linkages on gains in manufacturing knowledge.

Hypotheses 4a, 4b and 4c posit that a firm's level of absorptive capacity moderates the relationship between external linkages and gains in R&D knowledge, marketing, and manufacturing knowledge. Moderated regression analysis was conducted for all of the possible combinations between absorptive capacity and each of the five external linkage variables; that is, five interaction variables (see models 2-6 in Tables 6.5.2.2 – 6.5.2.5) were generated for each of the four criterion variables (gain in R&D, manufacturing, pre-development assessment, and marketing knowledge). Each interaction variable was entered into the regression equation individually. A significant partial correlation on the interaction variable together with a significant change in R^2 confirms the existence of moderation (Cohen and Cohen, 1983, Venkatraman, 1989, Arnold, 1982).

Inspection of Table 6.5.2.2 (criterion variable = gain in R&D knowledge) indicates that two of the five interaction variables are significant at the $p< 0.01$. Specifically, the interaction terms, 'absorptive capacity $\times$ corporation linkage' (β =0.46, t=3.06, $p<0.01$) and 'absorptive capacity $\times$ research institute linkage' (β =0.32, t=3.28, $p<0.01$) were statistically significant. R^2 changes (0.06 and 0.07) in both regression equations were also significant at $p<0.01$. Positive standardized regression coefficients confirm that absorptive capacity positively moderates the effects of corporate linkage and research institute linkage on gain in R&D knowledge.

Examination of Table 6.5.2.3 (criterion variable = gain in manufacturing knowledge) revealed that only one of the five interaction variables is significant at $p<0.10$. Specifically, the interaction term, 'absorptive capacity $\times$ university linkage' ($\beta=0.16$, $t=1.67$, $p<0.10$) was statistically significant. However, R^2 change (0.02) in this regression equation was not significant at $p<0.05$. This indicates weak evidence to support the moderating effect of absorptive capacity in the relationship between university linkages and gain in manufacturing knowledge.

Inspection of Table 6.5.2.4 (criterion variable = gain in pre-development assessment knowledge) indicated that the interaction term, 'absorptive capacity $\times$ corporation linkage' ($\beta=0.40$, $t=2.57$, $p<0.05$) was statistically significant. R^2 change (0.03) in this regression equation was significant at $p<0.05$.

Inspection of Table 6.5.2.5 (criterion variable = gain in marketing knowledge) revealed that the interaction term, 'absorptive capacity $\times$ corporation linkage' ($\beta=0.43$, $t=2.58$, $p<0.05$) was statistically significant. R^2 change in this regression equation was significant at $p<0.05$. The positive regression coefficient confirms that absorptive capacity positively moderates the effects of the corporate linkage on gain in marketing knowledge.

In sum, absorptive capacity moderates the relationship between the corporation linkage and gains in R&D, predevelopment assessment, and marketing knowledge, with the exception of gain in manufacturing knowledge. The effect of the research institute linkage on gain in R&D knowledge is also moderated by absorptive capacity. It is worth noting that absorptive capacity did not appear to moderate the relationship between the vertical linkages (i.e., customer linkage and supplier linkage) and gains in all four categories of new product knowledge. Thus, hypotheses 4a, 4b and 4c were partially supported.

6.6 Testing the Mediating Effects of Gains in New Product Related Knowledge

H2a The positive effects of external linkages and absorptive capacity on technological innovativeness are mediated by gains in new product related knowledge

H2b The positive effects of external linkages and absorptive capacity on market innovativeness are mediated by gains in new product related knowledge

The previous section has identified that absorptive capacity moderated the relationship between horizontal linkages and gains in R&D, manufacturing and pre-development assessment knowledge. To test the mediating effect of gains in new product related knowledge between external linkages and product innovativeness while considering the moderating role of absorptive capacity, the following three regression models were constructed (James and Brett, 1984, Baron and Kenny, 1986):

Model 1: Gain in New Product Related Knowledge

(R&D, Manufacturing, Pre-development Assessment, and Marketing)

$= \beta_0 + \beta_{1i}$ External linkages $+ \beta_{2i}$ Absorptive Capacity $\times$ External linkages

Model 2: Product Innovativeness (Technological Innovativeness, Market Innovativeness)

$= \beta_0 + \beta_{1i}$ External linkages $+ \beta_{2i}$ Absorptive Capacity $\times$ External linkages

Model 3: Product Innovativeness (Technological Innovativeness, Market Innovativeness)

$= \beta_0 + \beta_{1i}$ External linkages $+ \beta_{2i}$ Absorptive Capacity $\times$ External linkages

$+ \beta_{3i}$ Gain in New Product Knowledge

In this analysis, the mediator variable (e.g., gain in R&D knowledge) must be a significant predictor of product innovativeness in the third model in order to demonstrate the existence of mediation. Thus, the coefficient β_{3i} must differ significantly from zero. In addition, regression coefficients of both external linkages (β_{1i}) and interaction variables (β_{2i}) in Models 1 and 2 must be significant and their effects on product innovativeness should be lower in the third model than in the second.

In Table 6.6.1, technological innovativeness (before inclusion of mediators) was first regressed on each of the external linkage variables and the interaction variables which were found to be significant predictors of the dependable variables - gain in R&D, manufacturing, predevelopment assessment, and marketing knowledge - in previous moderated regression analyses. Then, each mediator was added to the regression equation accordingly (after the inclusion of the moderators). This procedure generated eight regression equations.

Hypothesis 2a predicts that the extent of gain in new product related knowledge mediates the relationship between external linkages and technological innovativeness. Table 6.6.1 shows that gain in R&D knowledge was significantly associated with technological innovativeness (β=0.47, t=4.72, p<0.01). The significance of the effects of both the corporation linkage (from β=0.20, t=2.19, p< 0.05 to β=0.04, t=0.48, p>0.1) and the interaction of absorptive capacity and corporation linkage (from β =0.32, t=1.79, p<0.05 to β =0.18, t=1.06, p<0.10) on technological innovativeness was substantially reduced, whereas R^2 increased from 0.13, p<0.01 to 0.28, p<0.01. The results show that the extent of gain in R&D knowledge in a NPD project mediates the relationship between the corporation linkage, the interaction of absorptive capacity and corporation linkage and technological innovativeness. That is, the greater the corporation linkage developed in a NPD project and the greater the absorptive capacity possessed by a firm, the more likely it is that accumulation of new R&D knowledge contributes to the level of technological innovativeness of the new product developed.

Similarly, when technological innovativeness was regressed on supplier linkage, corporation linkage, absorptive capacity, the interaction of university linkage and absorptive capacity, and the mediator - gain in manufacturing knowledge - the significant effects of the supplier linkage and the corporation linkage were reduced (from β=0.24, t=2.78, p<0.01 to β=0.18, t=2.24, p<0.05; from β=0.20, t=2.23, p<0.05 to β=0.09, t=1.01, p>0.10). However, the R^2 increased from 0.14, p<0.01 (before the inclusion of the mediator) to 0.30, p<0.01 (after the inclusion of the mediator). In particular, the effect of corporation linkage on technological innovativeness was extensively mediated by the gain in manufacturing knowledge. Significant relations were also observed between gain in manufacturing knowledge and technological innovativeness (β=0.45, t=4.99, p<0.01). This indicates that the extent of gain in manufacturing knowledge mediates the relationship between supplier linkage, corporation linkage and technological innovativeness.

By similar regression analyses (see columns PDA and MK before and after the inclusion of the mediators, in Table 6.6.1), the coefficients of both gain in pre-development assessment knowledge (β=0.31, t=3.20, p< 0.01) and gain in marketing knowledge (β=0.25, t=2.71, p<0.05) were found to be significant when they were entered into each of the regression equations. Consequently, the significant effects of the corporation linkage and the interaction of absorptive capacity and corporation linkage on gain in pre-development assessment knowledge were largely reduced (from β=0.21, t=2.38, p<0.05 to β=0.10, t=1.05, p>0.10; from β=0.41, t=2.47, p<0.05 to β=0.29, t=1.74, p<0.10), whereas R^2 increased from 0.11, p<0.01 to 0.19, p<0.01. The significant effects of the corporation linkage and the interaction of absorptive capacity and corporation linkage on gain in marketing knowledge were also reduced (from β=0.21, t=2.38, p<0.05 to β=0.15, t=1.71, p< 0.05; from β =0.41, t=2.47, p<0.05 to β=0.30, t=1.81, p<0.01), whereas R^2 increased slightly from 0.11, p<0.01 to 0.17, p<0.01. The results confirm that both gains in predevelopment assessment and marketing knowledge during a NPD project mediate the relationship between corporation linkage and the technological innovativeness as well as that between the interaction term (absorptive capacity X corporate linkage) and technological innovativeness.

Table 6.6.1 Results of Mediated Regression Analysis: Predicting Technological Innovativeness

	Before Mediators				After Mediators			
Variables	RD	MF	PDA	MK	RD	MF	PDA	MK
Supplier Linkage		.24*** (2.78)				.18** (2.24)		
Corporation Linkage	.20** (2.19)	.20** (2.23)	.21** (2.38)	.21** (2.38)	.04 (.48)	.09 (1.01)	.10 (1.05)	.15** (1.71)
Research Institute Linkage	.05 (.52)				-.02 (.23)			
Absorptive Capacity (AC)	-.22 (-1.29)	.12 (1.23)	-.20 (-1.22)	-.20 (-1.28)	-1.17 (-1.08)	.12 (.13)	-.17 (-1.06)	-.14 (-.85)
AC X Corporation Linkage	.32** (1.79)		.41** (2.47)	.41** (2.47)	.18 (1.06)		.29* (1.74)	.30*** (1.81)
AC X Research Institute Linkage	.16 (1.40)				.05 (.50)			
AC X University Linkage		.08 (.79)				.01 (.09)		
Mediator Variables:								
Gain in R&D Knowledge (RD)					.47*** (4.72)			
Gain in Manufacturing Knowledge (MF)						.45*** (4.99)		
Gain in Pre-development Assessment Knowledge (PDA)							.31*** (3.20)	
Gain in Marketing Knowledge (MK)								.25** (2.71)
R2	.13	.14	.11	.11	.28	.30	.19	.17
ΔR^2					.15***	.17***	.08***	.06**
F ratio	3.36***	4.42***	4.82***	4.82***	7.04***	9.28***	6.48***	5.66***

Cells are standardized regression coefficients with t-values in parentheses.
* p < .10, ** p < .05, *** p < .01, two-tailed test.
ΔR^2 is the difference in R^2 value between the model with the mediator and the model without the mediator.

Table 6.6.2 Results of Mediated Regression Analysis: Predicting Market Innovativeness

	Before Mediators				After Mediators			
Variables	RD	MF	PDA	MK	RD	MF	PDA	MK
Supplier Linkage		.12				.10		
		(1.28)				(1.11)		
Corporation Linkage	.18*	.20**	.20**	.20**	.12	.17*	.07	.15
	(1.96)	(2.15)	(2.24)	(2.24)	(1.21)	(1.78)	(.75)	(1.61)
Research Institute Linkage	.08				.06			
	(.89)				(.60)			
Absorptive Capacity (AC)	-.04	.15	-.03	-.03	-.02	.12	.01	.04
	(-.23)	(1.44)	(-.15)	(-.15)	(-.11)	(.15)	(.08)	(.21)
AC X Corporation Linkage	.15		.23	.25	.09		.08	.13
	(.89)		(1.34)	(1.34)	(.49)		(.50)	(.73)
AC X Research Institute Linkage	.14*				.10			
	(1.20)				(.82)			
AC X University Linkage		.06				.04		
		(.54)				(.36)		
Mediator Variables:								
Gain in R&D Knowledge (RD)					.19*			
					(1.69)			
Gain in Manufacturing Knowledge (MF)						.11		
						(1.08)		
Gain in Pre-development Assessment Knowledge (PDA)							.36***	
							(3.69)	
Gain in Marketing Knowledge (MK)								.24**
								(2.50)
R2	.10	.09	.08	.08	.13	.10	.18	.13
ΔR^2					.03*	.01	.10***	.05**
F ratio	2.25**	2.66**	3.41**	3.41**	2.61**	2.37**	6.24***	4.24***

Cells are standardized regression coefficients with t-values in parentheses.
* p < .10, ** p < .05, *** p < .01, two-tailed test.
ΔR^2 is the difference in R^2 value between the model with the mediator and the model without the mediator.

Table 6.6.2 shows that while market innovativeness was regressed as the dependable variable, the test of the mediating effect of gain in manufacturing knowledge failed since the mediator's regression coefficients (β=0.11, t=1.08, p> 0.10) were insignificant. The finding indicates that the extent of gain in manufacturing knowledge did not mediate the relationship between corporate linkage, absorptive capacity and market innovativeness as well as that between the interaction term (absorptive capacity X corporate linkage) and market innovativeness.

The regression coefficient of gain in R&D knowledge was only significant (Table 6.6.2, after mediator) at the p< 0.10 level (β=0.19, t=1.69, p< 0.10; ΔR^2 =0.03, p< 0.10) . This indicates that gain in R&D knowledge to a lesser extent mediates the relationship between market innovativeness and corporation linkage and the interaction of absorptive capacity and research institute linkage.

When market innovativeness was regressed on corporation linkage, absorptive capacity and the interaction of absorptive capacity and corporation linkage together with either gain in pre-development assessment knowledge or gain marketing knowledge, both the coefficients of gain in pre-development assessment knowledge (β=0.36, t=3.69, p<0.01) and gain in marketing knowledge (β=0.24, t=2.50, p<0.05) were significant. As a result, the significant effect of corporation linkage on gain in pre-development assessment knowledge was reduced (from β=0.20, t=2.24, p<0.05 to β=0.07, t=0.75, p>0.10), whereas R^2 increased from 0.08, p<0.05 to 0.18, p<0.01. Similarly, the significant effect of corporation linkage on gain in marketing knowledge was reduced (from β=0.20, t=2.24, p<0.05 to β=0.15, t=1.61, p>0.10), whereas R^2 increased from 0.08, p<0.05 to 0.13, p<0.01. The results demonstrate that both gain in pre-development assessment knowledge and gain in marketing knowledge mainly mediate the relationship between corporation linkage and market innovativeness of the new product. That is, NPD projects with corporate linkages are more likely to accumulate new pre-development knowledge and marketing knowledge than those without corporate linkages. This knowledge gain through the corporate linkages leads to more market innovativeness of the new product developed.

In sum, the mediating roles of gains in new product related knowledge (i.e., R&D knowledge, manufacturing knowledge, pre-development assessment knowledge and marketing knowledge) are more consistently displayed only between corporation linkage, the interaction of absorptive capacity and corporation linkage, and technological innovativeness. Gain in manufacturing knowledge also significantly mediates the relationship between supplier linkage and technological innovativeness. Thus, hypothesis 2a was partially supported.

The effect of the interaction terms (corporation linkage × absorptive capacity, research institute linkage × absorptive capacity) on market innovativeness were not significantly mediated by gains in R&D, manufacturing, pre-development assessment and marketing knowledge. By contrast, while the effects of the mediators on the criterion variable, marketing innovativeness, were examined, gains in pre-development assessment knowledge and marketing knowledge were identified as more relevant mediators of the relationship only between corporation linkage and market innovativeness. Therefore, hypothesis 2b was also partially supported.

6.7 Summary

This chapter discussed the data analysis and presented descriptive findings and the results of hypothesis testing. The latter results are summarised in Table 6.7. In summary, certain of the theoretically drawn hypotheses received some empirical support, but not all hypothesised relationships received strong support. The discussion and implications of the results of the hypothesis testing are presented in Chapter 7 and Chapter 8 respectively.

Table 6.7 Summary of the Results of Hypothesis Testing

H1a	Horizontal linkages lead to more gain in R&D knowledge than vertical linkages	Supported
H1b	Horizontal linkages lead to more gain in marketing knowledge than vertical linkages	Supported
H1c	Horizontal linkages lead to more gain in manufacturing knowledge than vertical linkages	Supported
H2a	The positive effects of external linkage and absorptive capacity on technological innovativeness are mediated by gains in new product related knowledge	Partially Supported
H2b	The positive effects of external linkage and absorptive capacity on marketing innovativeness are mediated by gains in new product related knowledge	Partially Supported
H3a	A firm's absorptive capacity is positively associated with the extent of gain in R&D knowledge	Supported
H3b	A firm's absorptive capacity is positively associated with the extent of gain in marketing knowledge	Not Supported
H3c	A firm's absorptive capacity is positively associated with the extent of gain in manufacturing knowledge	Supported
H4a	Absorptive capacity moderates the relationship between external linkages and the extent of gain in R&D knowledge	Partially Supported
H4b	Absorptive capacity moderates the relationship between external linkages and the extent of gain in marketing knowledge	Partially Supported
H4c	Absorptive capacity moderates the relationship between external linkages and the extent of gain in manufacturing knowledge	Partially Supported

Chapter 7

Discussion of the Results

7.1 Introduction

This study responds to Fiol's (1996) call for research to integrate the theories of organisational absorptive capacity and new product innovation. Building on the theories of organisational learning and the knowledge-based view of the firm, this study develops a model in which the external linkages that a firm develops to facilitate new knowledge development lead to a high level of new product innovativeness. Absorptive capacity is integrated into the model as a predictor variable that not only moderates the relationship between a firm's accumulation of new product knowledge and the extent of external linkages, but also positively relates to new product knowledge accumulation. This study emphasises that in IT firms using complex product and/or process technologies, no single firm is likely to master all the relevant technologies for its new product projects. The ability to tap into the complementary knowledge and expertise of external learning parties, for design/development, manufacturing or marketing, is likely to lead to better product capabilities and, ultimately, better products.

The empirical findings in Chapter 6 provide insights into this intricate relationship. On the whole, the results of the empirical investigation support the framework presented in the research model (see Table 6.7). The following sections discuss the empirical findings as they relate to the hypotheses of interest. The discussions are structured to review the rationale for the supported hypotheses and provide with some explanations for the unsupported hypotheses.

7.2 Effects of External Linkages on Gains in New Product Knowledge

In this research, the horizontal linkage is defined as a NPD project that has associations with horizontal collaborators, such as third-party companies, industry-based research institutes, and universities. The vertical linkage is construed as a NPD project's processes having association with suppliers and customers. A NPD project's extent and type of external linkages characterizes its external knowledge assess. Horizontal linkages offer more opportunities for firms to gain access to the complementary knowledge that tends to lead to more innovative product development. The empirical results particularly support the claims of past research (Deeds and Hill, 1996; Dodgson, 1993; Kotabe and Swan, 1995; Pennings and Harrianto, 1992; Shan et al., 1994) that horizontal linkages are primary sources for providing both technical (i.e., R&D and manufacturing) and marketing know-how for the development of more innovative products. Of the three types of horizontal linkages, the corporation linkage was found to be the most significant contributor to both the technical and marketing knowledge. That is, this particular form of linkage provided the firms involved in this survey with product knowledge that can soon be used for commercial ends.

This result specifically reflects the fact that the unique business characteristics of Taiwanese IT firms, where OEM/ODM projects play the most important role in the NPD activities, drive the direction of their external technology acquisition. For instance, the following Taiwanese IT hardware products have garnered a greater than sixty percent share of their respective products' global production volume in 1999: notebook PCs (60%), PC motherboards (64%), hubs (66%), keyboards (68%), power suppler units (70%), PC cabinets (75%), and scanners (91%)[1]. However, up to sixty-five percent of the production was contributed by OEM/ODM orders (see

[1] The Marketing Research Center (MRC) of the Institute for Information Industry, the largest IT market research organisition in Taiwan, provides figure on revenue of global IT hardware products. These show that, in 1999, with 21 billion US dollars in sales, Taiwan ranked third, behind the US and Japan.

Appendix B: An outline of Taiwanese IT industry). Most of these IT firms play key roles in the business-to-business supply chain and vertical marketplace of the IT industry. These firms are not skilled at brand and distribution management so they have been unable to develop their own brands in the now mature PC market. Few internationally well known IT brands originated in Taiwan. Instead, Taiwanese firms concentrate more resources on the R&D and manufacturing side of technologies than on marketing. Specifically, their R&D activities are more design/development-oriented than research-oriented. NPD projects in collaboration with international IT partners become one of the primary sources for the acquisition of new complementary technology/knowledge. For example, United Microelectronics Corporation (UMC), the world's second largest independent semiconductor foundry company based in Taiwan, is dedicated to providing manufacturing services for advanced ICs[2]. UMC's only product is its IC manufacturing services. It teams up with Advanced Micro Devices (AMD), the world's second largest CPU Company, to develop the 90-nenometer CMOS process technology for semiconductor logic products. This alliance allows UMC to gain access to AMD's know-how in developing new manufacturing processes for high-speed logic ICs. In return, AMD secures a manufacturing capacity for its own brand IC production.

From the perspective of the value chain, the process of OEM/ODM-oriented new product development can be divided into five major functions: product definition, detailed development, product manufacturing, logistics and distribution, and product marketing. Taiwanese IT firms particularly specialise in middle-process functions: detailed development, product manufacturing and logistics and distribution. OEM/ODM customers excel at product definition and product marketing. The

[2] The world's largest IC foundry firm is Taiwan Semiconductors Corporation (TSMC). According to Market Research Center, both TSMC and UMC together had more than 75% of global market share in this type of manufacturing services in 2000.

specialist capabilities of both Taiwanese IT firms and OEM/ODM customers are highly complementary. They form a sort of loose strategic alliances and compete with other similar alliances in the global market. Co-developing new products with these OEM/ODM cooperating firms, which excel at product definition and product marketing, may offer Taiwanese firms tremendous opportunities to gain access to a new set of product knowledge. For instance, Taiwanese applied this model to establish business relationships with global IT competitors such as IBM, Dell and HP. Under this business model, Taiwanese IT firms receive product specifications from customers and concentrate on the design, manufacturing and delivery of finished products. These OEM/ODM customers market the products under their own brand names. According to MIC statistics (see Appendix B), OEM/ODM orders represented more than sixty-five percent of Taiwanese IT exports in 1999. The largest Taiwanese notebook PC maker- Quanta Computer- does not own its product brand, but designs and manufactures products for nine of the top ten international PC brands. It produced more than 4 million units of notebook PCs in 2001. This might explain why the corporation linkage is the most significant of the linkages that contributes to the accumulation of NPD knowledge. To a certain extent, these OEM/ODM customers can be viewed as some sort of industrial users or lead users (von Hippel, 1976&1978) that typically play an active part in OEM/OEM manufacturers' new product innovation since they act not only as the gate keeper but the evaluator in each phase of the NPD processes. New product features or concepts are automatically considered and designed in the next OEM/ODM project.

NPD projects in association with industry-based research institutes significantly differ only in gain in pre-development assessment knowledge when compared with projects that do not involve such an association. Linkages involving universities show no significant difference in gains in all four categories of new product related knowledge. The relatively insignificant impacts of these two linkages on the accumulation of new product knowledge confirm the argument that IT firms employ university and industrial institute research to conduct either fundamental research or more speculative in-house new technology, which is less product-specific and results in less effect on the development of near market products (Tidd et al., 1997). These findings are also consistent with Arora and Gambardella's (1994) argument that the university linkage appears to be more important as a source of scientific information and capabilities, rather than as a source of new innovations. The nature of the product-specific project lies in producing a successful new product that requires various technologies covering a complete set of product commercialization knowledge, such as pre-development assessment, design and development, manufacturing and marketing.

However, the two linkages play a somewhat different role in the innovation process. The advantage of university and industry-oriented research institute linkages is more specific in developing a new set of R&D capabilities in order to build up a new technology platform or to have better ability to evaluate future technologies. This rationale may account for results which show that NPD projects involving association with industry-based research institutes lead to gains in pre-development assessment and design/development knowledge, but not the knowledge that is important in commercialising a new technology, such as marketing and manufacturing. The other factor that may account for the relative insignificance of both linkages may derive from the fact that the majority of firms in the sample are SMEs (more than sixty percent). Rothwell and Dodgson (1991) suggest that one area in which SMEs can suffer a marked disadvantage is when establishing a network of appropriate contacts with external sources of scientific and technological expertise and advice. This disadvantage results from SMEs' inability to identify and evaluate complementary technologies, difficulties in funding long-term R&D, and a lack of qualified scientists and engineers in collaborating with scientific or basic research sources. As such, both university and research institute linkages in this study are less associated with these IT firms' accumulation of new product-specific knowledge.

This study indicates that supplier linkage has a significant impact on gain in manufacturing knowledge. This finding, to a certain extent, is in consonance with conventional evidence that computer firms and their suppliers build collaborative relationships in order to spread the costs and risks of developing new products (Saxenian, 1991). This relationship enhances their ability to adapt rapidly to changing technologies. Key component and equipment suppliers need to collaborate closely with manufacturing customers to ensure that their services will be continued in the next generation of NPD projects. This collaboration helps firms to enhance the technological aspect of a new product development, such as manufacturing, but not the marketing aspects.

The effect of customer linkage does not show a significant impact on gains in new product knowledge in the current study. The insignificance may confirm the argument that current users (such as channel members or end-users) are less informative in providing their requirements for innovative IT products (O'Connor, 1998). In a highly dynamic industry such as IT, the involvement of customers in the NPD process would be useful only when users have used the product extensively. Customers' knowledge can mainly contribute to current product-related features (i.e., for an extension of the product line). Therefore, the impact of this linkage is relatively negligible on a firm's gains in both new technical and marketing knowledge.

7.3 The Direct Effect and Moderating Effect of Absorptive Capacity

A firm's internal learning capacity- its absorptive capacity- determines the extent to which it can absorb new product knowledge from external collaborative parties. The results demonstrate that absorptive capacity significantly affects gains in new product knowledge in terms of R&D, manufacturing and pre-development assessment knowledge. These findings, to a greater extent, concur with the latest empirical works (Sivadas and Dwyer, 2000; Tsai, 2001) that show that absorptive capacity is a prerequisite for the success of collaborative NPD projects as well as for the release of more innovative products that require the infusion of new technologies. For example, Microtek, one of the surveyed sample and the most innovative optic-electronic companies in Taiwan, has developed a mini-handheld scanning accessory to the I-Zone instant camera for Polaroid. The NPD manager in charge of the project stated:

> "The success of developing this unique and innovative product is twofold. First, we are able to interpret Polaroid's product requirements technologically. Second, both team members contribute required technologies to implement the product specifications set by Polaroid's marketing group."

Microtek has the ability to technologically interpret the cooperating firm's product specifications because it has adequate absorptive capacity relevant to the project. A firm's internal learning capacity- absorptive capacity, determines not only the extent to which it can absorb new knowledge from external linkages (Cohen and Levinthal, 1990), but also the degree to which it integrates existing knowledge with newly acquired knowledge and converts these into the firm's context-specific knowledge (Kogut and Zander, 1992). Therefore, investing in absorptive capacity allows a firm to effectively assimilate and apply external knowledge for its own use, resulting in more innovative product development.

However, the statistical findings do not indicate a significant correlation between absorptive capacity and gain in marketing knowledge. The insignificance of this effect may be due to the contextual factor. As IT firms generally need to be equipped with not only R&D and manufacturing, but also marketing know-how in order to commercialise a new industrial product, this requirement particularly applies to firms that are engaged in branded product marketing. However, IT firms in Taiwan (see Appendix B), whose main business is in non-brand or OEM/ODM types of business, focus more of their resources on R&D and manufacturing. The acquisition of product marketing knowledge through external NPD collaborators constitutes a relatively low priority. On the other hand, the acquisition of marketing knowledge may be more contextual than that of technical knowledge. Particularly, the former requires firms to be equipped with sufficient marketing resources, such as own brand channels, years of marketing implementations and marketing culture so that they are then able to acquire marketing knowledge from external collaborators. This may explain the insignificant impact of absorptive capacity on gain in marketing knowledge. In general, the results suggest that high absorptive capacity is associated with a better opportunity to effectively acquire and assimilate R&D, manufacturing and pre-development assessment knowledge from external linkages.

Absorptive capacity not only directly affects new product knowledge accumulation, but also moderates the effects of external linkages on gains in new product knowledge. Specifically, the empirical results demonstrate that absorptive capacity moderates the effect of the corporation linkage on gains in R&D, pre-development assessment, and marketing knowledge. Moreover, absorptive capacity also moderates the effect of the university linkage on gain in manufacturing knowledge. No effect from vertical linkages (i.e., customer linkage and supplier linkage) on gains in new product knowledge is identified at different levels of absorptive capacity. Figure 7.1 illustrates a general relationship of the interactive impacts of external linkages and absorptive capacity on gains in new product knowledge. The positive impacts of absorptive capacity on gains in new product knowledge through horizontal linkages will be stronger in firms that have a stronger level of absorptive capacity than those with a lower level of absorptive capacity. Comparing with horizontal linkages, these positive impacts on gains in new product knowledge through vertical linkages will be less significant even for firms that contain a relatively high level of absorptive capacity. In firms with a relatively low level of absorptive capacity, these interactive impacts on new product gains through horizontal linkages will not be as weak as through vertical linkages.

Figure 7.1 The Impacts of External Linkages and Absorptive Capacity on Gains in New Product Knowledge

		(Vertical Linkages)	(Horizontal Linkages)
Absorptive Capacity	(High)	Weaker or No Impact	Stronger
	(Low)	No Impact	Weaker

The implications of the current findings are twofold. First, the moderating effect of absorptive capacity will be significant only when the impact of a linkage is crucial to the provision of a set of complementary knowledge. For instance, the moderating impact of absorptive capacity on the effect of corporation linkage on gains in all four categories of product related knowledge existed in the current study only when such linkages could offer a new and critical set of knowledge to which collaborating firms were exposed. Absorptive capacity, however, did not demonstrate its moderating effect on the relationship between research institute linkage and gains in marketing, pre-development assessment and manufacturing knowledge since the linkage was not able to offer such a set of strategically complementary knowledge. Second, absorptive capacity must reach a certain threshold level for it to significantly display its moderating effects. This suggests that a firm may have access to complementary knowledge through external NPD collaborators but may not have enough ability to absorb such knowledge. It also implies that firms with higher absorptive capacity are more able to codify collaborators' product knowledge that can then be assimilated and distributed within (Madhavan and Grover, 1998; Tunisini and Zanfei, 1998). These findings are consistent with the latest empirical work that demonstrates that a firm's absorptive capacity is crucial when it is exposed to an opportunity to assimilate innovative technology/knowledge from outside sources (Cockburn and Henderson, 1998; Koza and Lewin, 1998; Kumar and Nti, 1998; Mangematin and Nesta, 1999).

Although the supplier linkage demonstrates a significant, direct effect on manufacturing knowledge, the interactive effect of this linkage with absorptive capacity was found to be insignificant on manufacturing knowledge. The insignificance may be due to the relatively less direct effect of supplier linkage ($t = 0.16$; $p < 0.10$). That is, the impact of supplier linkage is not sufficiently significant to demonstrate that absorptive capacity can moderate its effect on manufacturing knowledge. The less direct effect further confirms Eisenhardt and Tabrizi's (1990) assertion that the involvement of supplier linkage is more effective in less innovative projects as the specifications and the technologies employed are relatively certain and stable. This linkage contributes more to a new product's reduction of cost or timeliness but less to new complementary knowledge.

The effect of industrial research institute linkage on gain in R&D knowledge was significantly moderated by absorptive capacity. This finding indicates that NPD projects with research institute linkages are more likely to accumulate new R&D related knowledge if firms have a relatively high level of absorptive capacity. On the other hand, this finding also suggests a limited role of this linkage to acquire marketing and manufacturing related knowledge.

Absorptive capacity was found to only moderate the effect of university linkage on gain in manufacturing knowledge to a lesser extent. This result further suggests a limited role for university linkage in acquiring product-specific technologies (e.g., marketing and pre-development assessment technologies) since such linkages tend to provide scientific knowledge that is less readily exploited for commercial purposes (Arora and Gambardella, 1990). As one respondent stated:

> "We mainly collaborate with universities to train our engineers in order to gain a set of fundamental knowledge that will be crucial to our development or understanding of a new technology platform. Those technologies possessed by universities are too distant to be converted into immediate product development."

7.4 The Mediating Effect of Gains in New Product Knowledge

The results of this study indicate that the four mediating variables (gain in R&D knowledge, manufacturing knowledge, pre-development assessment knowledge, and marketing knowledge) significantly mediate the relationship between absorptive capacity, the corporation linkage and technological innovativeness. That is, the effects of absorptive capacity, the corporation linkage and their interactive effect indirectly affect the level of technological innovativeness via gains in both new technical and marketing knowledge. These findings, to some extent, support empirical evidence (Deeds and Hill, 1996; Shan et al., 1994) that found a positive relationship between the intensity of a firm's NPD alliance and the research productivity because alliance firms provide access to complementary knowledge for immediate projects. It is this increase in a firm's level of new product knowledge that determines how technologically innovative a new product will be. Additionally, the results confirm that horizontal linkages lead to a higher level of product innovativeness than vertical linkages as the former is more likely to be strategically motivated to improve long-term product technology (Kotabe and Swan, 1995). These findings also imply that, once new product related knowledge is accumulated through collaborative NPD projects with partnering firms, the development of more innovative products becomes likely, as the infusion of new knowledge enhances the generation of new product ideas and helps to overcome barriers to design or development (Tunisini and Zanfei, 1998).

The significance of the indirect interaction effect of the corporation linkage and absorptive capacity on technological innovativeness, on the one hand, indicates that a firm's absorptive capacity shapes the extent to which it acquires and assimilates new product knowledge through the corporation linkage. That is to say that, a higher level of absorptive capacity will intensify a firm's gain in both new technical and marketing knowledge through NPD collaboration with other cooperating firms. The increase in both technical and marketing knowledge in turn contributes to the level of the new product's technological innovativeness. On the other hand, the significance implies that when both the NPD project firm and the cooperating firm possess higher level of absorptive capacity, the complementary technologies they provide for the NPD project will help to enhance each firm's new product knowledge accumulation, further resulting in a more technologically innovative product development (Ingham and Mothe, 1998).

Gain in new manufacturing knowledge significantly mediates the relationship between the supplier linkage and technological innovativeness. This result implies that increasing the extent of the supplier linkage in NPD projects builds up the accumulation of new manufacturing knowledge, which, in turn, positively impacts on the level of new products' technological innovativeness. Manufacturing knowledge, including pilot-run production, mass production set-up and quality control of the new product, enhances the technological aspect of innovativeness as a result of ensuring new product quality. The accumulation of manufacturing knowledge from cooperating suppliers may be due to the supply of more reliable parts or equipment that facilitates the setting up of mass production. This facilitation further enhances the quality level of new product innovativeness. This rationale finds support in Malerba's (1992) empirical work, which found that the involvement of both key components' suppliers and R&D equipment suppliers contributes to a firm's technological progress. This progress in turn leads to more innovative product development in terms of technological innovativeness.

Of the three horizontal linkages in this study, only the relationship between the corporation linkage and market innovativeness is significantly mediated by gains in R&D knowledge, pre-development assessment knowledge and marketing knowledge. Consistent with the proposed hypothesis, increasing the extent of corporation linkages strengthens the acquisition of new R&D, marketing and pre-development assessment knowledge from cooperating firms in a NPD project. This, in turn, positively affects levels of market innovativeness. However, in testing the indirect interaction effect of corporation linkage and absorptive capacity on market innovativeness, this effect was not associated with any gains in R&D, manufacturing, pre-development assessment, and marketing knowledge. In other words, a firm's absorptive capacity does not shape the effect of corporation linkage on the extent of a NPD project's market innovativeness via new product related knowledge. The knowledge of R&D, pre-development assessment and marketing that is gained through corporation linkages does, however, lead to a high level of market innovativeness in the new product project.

There are two potential reasons for these contrasting findings. One possible explanation is that the construct composition of absorptive capacity used in the current study is less able to capture a firm's ability to acquire marketing knowledge than technical knowledge. The scale for absorptive capacity included items measuring engineering knowledge, management knowledge, communication climate, knowledge scanning ability, and communication network. It did not however, include items clearly measuring prior knowledge concerning marketing-related abilities and this may have affected the relationship, which was discovered between the indirect interaction effect of absorptive capacity and external linkages on market innovativeness. An alternative explanation for the relative insignificance of the indirect interaction effect may be due to the unique characteristics of the Taiwanese IT industry where absorbing marketing knowledge is not a primary concern. This may have impacts on measuring marketing related abilities of the construct of absorptive capacity. The issue of more precisely measuring the absorptive capacity construct in the context of NPD requires future research attention.

7.5 Summary

By emphasizing the importance of complementary knowledge from outside sources, the empirical results demonstrate that of the five external linkages, the corporation linkage is the most significant in distinguishing gains in new product knowledge (both in term of technical and marketing), which, in turn, affect the level of both technological and market innovativeness. The interaction effects of absorptive capacity and the corporation linkage have a significant, positive impact on gains in both technical and marketing knowledge, leading to technological innovativeness but not market innovativeness. This finding also demonstrates that the supplier linkage has a significant effect on gain in manufacturing knowledge, resulting in a higher level of technological innovativeness. In contrast, the customer linkage, university linkage, and industry-oriented research institute linkage have no direct impact on the level of new product innovativeness.

This chapter has discussed the empirical findings in relation to the proposed hypotheses. It has recapitulated the underlying rationale for both the supported and unsupported hypotheses. Based on this discussion, Chapter 8 explores the implications of this study for practice and theory, highlights the limitations of the research and suggests directions for future research.

Chapter 8

Conclusion and Implications

8.1 Introduction

This research was designed to explore two related research questions: first, the extent to which a NPD project's different external linkages affects its product innovativeness and second, which factors relative to knowledge acquisition influence the relationship between these linkages and product innovativeness. These two questions are crucial from a managerial perspective in that the answers should guide managers towards effectively improving the performance of collaborative NPD projects. The answers to these questions also provide an empirical base for NPD researchers to further investigate these relationships in order to develop a knowledge-enabled research model. The findings of this present research offer some insightful answers to these research questions.

This chapter begins with discussion on key research findings and then discusses both theoretical contributions and managerial implications of the research model. This is followed by a discussion on the limitations of the study; finally, some suggestions are advanced regarding the direction of future research.

8.2 Summary of Key Research Findings

The research provided empirical findings that supplement anecdotal and case evidence on the role of external linkages on product innovativeness. The survey results particularly, supported the claims of past research on horizontal linkages (Deeds and Hill, 1996; Dodgson, 1993; Pennings and Harrianto, 1992a; Pennings and Harrianto, 1992b; Shan et al., 1994; Shan, 1990). These earlier researches showed that NPD project's association with corporation, industry-based research institutes, and universities is a primary source in providing technical and marketing know-how, that is essential for the development of more innovative products. Of the three types of horizontal linkages identified here, corporation linkage was found to be the most significant contributor to both technological and market innovativeness of NPD projects. University linkage did not lead to an increase in new product knowledge, but its interaction with absorptive capacity showed a positive effect on gain in manufacturing knowledge.

Past studies (Clark, 1989; Blenkhorn and Noori, 1990) demonstrate the positive impact of vertical linkages (i.e., NPD project associations with suppliers and customers) on a firm's product innovation. This research found that within the IT industry, supplier linkage positively affected a firm's gain in new manufacturing knowledge while customer linkage showed no effect on new product knowledge accumulation. However, the effect of supplier linkage on the accumulation of new manufacturing knowledge was not associated with the market innovativeness of NPD projects, indicating a weak correlation between a NPD's supplier linkage and its degree of market innovativeness in the IT industry.

In this study, the construct of absorptive capacity, which is defined as " the ability of a firm to recognise the value of new external knowledge, assimilate it and apply it to commercial ends" (Cohen and Levinthal, 1990), was integrated into the research model as both an explanatory variable and a moderator that predicts the level of gain in new product knowledge. The findings indicate that absorptive capacity positively affects a firm's gains in R&D, pre-development assessment, and manufacturing knowledge. In other words, greater absorptive capacity probes a greater capability to acquire and exploit external technology and knowledge. Furthermore, a firm's absorptive capacity shapes the relationship between gains in new product knowledge and external linkages in particular when a linkage is strategically important, i.e. when its impact on the integration of complementary knowledge for a NPD project is substantial. The more novel the new product knowledge from collaborative arrangements is, the more critical the firm's absorptive capacity will be. However, this interaction effect between absorptive capacity and the corporation linkage is primarily associated with the technological innovativeness of a NPD project rather than its market innovativeness.

8.3 Key Contributions and Theoretical Implications

Studies in NPD can be classified as "generalist" studies that identify a set of critical success factors or "specialist" studies that examine in depth one or more variables identified by the generalist studies (Craig and Hart, 1992). This research follows the specialist style in that it has tested a narrow set of variables that contribute to the level of innovativeness of new product projects carried out in collaboration. This research extends the literature by exploring and addressing the differential relationship between external linkages, gains in new product knowledge in a NPD project, absorptive capacity and new product innovativeness. These issues have been discussed in the literature but have not been documented empirically. In particular, the research attempts to bridge the gap in theories between organisational absorptive capacity and product innovation (Fiol, 1996) by developing a model that advances our understanding of these relationships. This model emphasises the importance of the moderating role of absorptive capacity as well as the mediating role of gains in new product knowledge in a firm's NPD project. It implies that a firm's new product innovativeness is decided not only by the extent of its various types of external linkages, but also by the firm's ability to absorb new knowledge from collaborative partners, to integrate it with existing knowledge, and to apply this newly generated product knowledge to the NPD project. This model therefore highlights the important role of absorptive capacity when the impact of external linkages on new product innovation is to be examined in NPD research. In addition, although the importance of absorptive capacity has been underlined, most of these NPD research investigated the success of new product development in alliance-based processes (e.g., Atuahene-Gima, 1993; Sivadas and Dwyer, 2000) without considering what types of new product knowledge absorption would be mostly affected by a firm's level of absorptive capacity. This study explored this issue by further probing the impact of absorptive capacity on the absorption of four different categories of new product knowledge. This research has tested causality in doing mediational/moderational analyses.

Previous studies on organisational learning have emphasised the role of external learning in developing radical innovations (McKee, 1992; Malerba, 1992; Bierly and Chakrabarti, 1996b; Lynn, 1997; Lynn, 1998). This research further bisected external learning sources into vertical and horizontal linkages and empirically examined the impact of these two types of linkages on product innovativeness. The results of this research are largely consistent with previous views on how external linkage supports product innovation (Rothwell and Dodgson, 1991; Rothwell, 1992). However, the findings also suggest some different conclusions from the conventional view of external linkages. First, these findings contrast with the findings of previous research, which emphasised the importance of customers and suppliers as sources of new technology (von Hippel, 1976; von Hippel, 1978; von Hippel, 1986; von Hippel, 1988). Vertical linkages in the current study are less relevant to the development of complementary knowledge in NPD projects. This may be due to the sector-specific focus of much of the previous work. The role of vertical linkages in IT industries is quite distinct from that of traditional industries, such as the automobile industry, where key suppliers are deeply involved in the design of parts of an integrative system

(Dyer, 1996; Kamath and Liker, 1994; Takeishi, 2001). The contribution made during this early involvement is therefore important to the success of new product development in terms of the benefits, such as, reducing design cycle time and cost advantage. Second, in the current study it is the horizontal linkages - particularly corporation linkage - that significantly influence a firm's accumulation of new product knowledge on which a relatively new product is developed. A NPD project's association with industry-based research institutes and universities is not correlated with the level of the new product's innovativeness. This result is not in line with the claims of the previous literature (Arora and Gambardella, 1994; Arora and Gambardella, 1990; Hartley et al., 1997) that tend to focus on how western firms behaved in certain industries (e.g. pharmaceutics). An IT industry such as the one in Taiwan, where in order to compete in a hyper-competitive IT market, most IT firms focus their resources on certain specific activities of the value chain and tend to form special types of co-development projects with international OEM/ODM partners, demonstrated a different pattern of external knowledge acquisition. For theory to be advanced, future research should extend the analysis to include industries and country contexts.

Another contribution of this research is highlighting the moderating role of absorptive capacity as a source of influence on new product innovation. Even though the role of absorptive capacity in acquiring external knowledge and creating internal new knowledge has recently been the subject of interest in the literature (George et al., 2001 & Stock et al., 2001), its interactive effects with different linkages on new product innovativeness has not been carefully documented in empirical research. The empirical results relating to the effect of absorptive capacity on the acquisition and accumulation of external knowledge in this study is consistent with other studies that have demonstrated the importance of absorptive capacity on strategic alliance and external technology transfer (Levinson and Asahi, 1995; Mowery et al., 1996; Koza and Lewin, 1998; Mangematin and Nesta, 1999). However, these results further indicate that the impact of absorptive capacity is more significant on acquiring new product knowledge in respect of R&D and manufacturing than on marketing knowledge. Although this result could be industry-specific and/or country bounded, an in-depth investigation on these disparities might pave the way for a better understanding of the effect of absorptive capacity on marketing knowledge acquisition. The moderating effect findings are, to a certain extent, also in consonance with studies that have demonstrated that a certain level of absorptive capacity is a prerequisite for external linkages to take effect in absorbing external knowledge/technology (Bierly and Chakrabarti, 1996b; Koza and Lewin, 1998). This research further contributes to our understanding of how absorptive capacity affects external product knowledge accumulation in two respects. First, absorptive capacity was empirically tested as a moderator variable between various types of external linkages and gains in new product related knowledge (i.e., R&D, manufacturing, pre-development assessment and marketing knowledge). The findings suggest that the moderating role of absorptive capacity is more significant on the relationship between gains in new product knowledge and horizontal linkages, as observed from a comparison with vertical linkages. The role of the moderating variable confirms a contingency perspective for absorptive capacity in future NPD studies when the constructs of external linkages or knowledge absorption-related variables are to be included in a research model. Second, the results suggest that absorptive capacity not only has a moderating effect, but also has a direct effect on the accumulation of new product knowledge and the level of new product innovativeness. That is, absorptive capacity is a quasi moderator variable rather than a pure moderator variable (Sharma et al., 1981). Therefore, when constructing a research model involving a knowledge absorption-related variable, this study's findings suggest that researchers simultaneously consider both the direct and moderating effects of this variable on a target dependent variable.

Previous studies in NPD and strategic alliances primarily examined how various types of external linkages affect new product performances. In addition to analyzing the moderating role of absorptive capacity, this study introduced the construct of gains in new product related knowledge that act as variables that mediate the impact of external linkages on new product innovativeness. The mediating effects of gains in new product knowledge corresponds with the requirement to absorb new, external knowledge in order to foster more innovations. The research findings suggest that both the interaction effect of horizontal linkages (i.e., particularly corporation linkage) and absorptive capacity and the main effect of horizontal linkages directly and indirectly affect technological innovativeness. The indirect effect is primarily transferred through the extent to which new product knowledge has been gained in a NPD project. Absorptive capacity becomes crucially important when a firm requires acquiring and assimilating a relatively new set of external knowledge or technology. The testing of the mediating role of gains in new product knowledge in the relationship of product innovativeness and the interaction of external linkages and absorptive capacity further examines this relationship.

These contributions should be viewed in the context of inadequate empirical testing in prior studies of the role of absorptive capacity within research on NPD. As Fiol (1996: 1012) states: "researchers have developed theories of organizational absorptive capacity; researchers have also developed models of the effective generation of new product. The challenge lies in integrating the two research streams." This study adds to address this gap in the literature by examining 116 NPD projects of IT firms.

8.4 Managerial Implications

This research investigated the impact of external linkages, absorptive capacity and gains in new product knowledge on the level of product innovativeness of a NPD project. The research findings provide several guidelines for managers, particularly in the IT industry, for the effective planning and execution of their NPD activities. First, managers need to be aware that various forms of external linkages or alliances provide firms with opportunities to expose themselves to different types of technologies. Each of these linkages has its impacts on new product innovativeness. This impact primarily depends on the extent of the involvement of the external linkage, type of unique knowledge/technologies that the linkage furnishes, and the firm's ability to absorb external product-related technologies. Although the results of this research demonstrated that horizontal linkages more significantly affect a firm's product innovativeness than vertical linkages, managers should explicitly consider whether innovativeness, timeliness or cost reduction is the primary objective of a NPD project before allocating resources to a particular type of linkage, because each form of linkage has its particular advantages.

Second, managers should assess the extent of NPD project innovation in accordance with the required amount of external new technologies, such as, product design/development, manufacturing, or marketing. This must take place prior to applying more effective managerial practices, for instance, differentiating mechanisms (i.e., job specification, hierarchy) or socio-integrative mechanisms (i.e., cross-functional team and co-location, etc.) (Olsen et al., 1995; Liker et al., 1999). This assessment enables the utilisation of an effective organisational mechanism that is in alignment with the specific objectives of a NPD project. For instance, more innovative projects, which may establish some close links with OEM/ODM parties or industrial research institutes in order to acquire and/or develop some complementary technologies, may be executed more effectively using socio-integrative mechanisms. On the other hand, an incremental project whose external linkages tend to be with existing suppliers or customers (i.e. vertical linkages) for the sake of cost reduction, timeliness or quality improvement can be executed more efficiently by a hierarchy team.

Third, this research explored the role of absorptive capacity relative to a firm's ability to assess and assimilate external knowledge that subsequently contributes to its new product innovativeness. The research findings indicate that absorptive capacity conditions the extent to which the firm acquires and assimilates new product knowledge when a critical knowledge source is available. The effects of external linkages on the knowledge-absorbing process are realized only when the firm has been equipped with a certain amount of absorptive capacity. In other words, when the linkage is strategically important and the impact of its knowledge/technology on new product development is substantial, absorptive capacity plays a decisive role in ensuring the success of this novel innovation. This result suggests that before allocating extensive resources to pursue strategically important collaborative projects, a firm should carefully evaluate if its absorptive capacity is relevant and complementary to the source knowledge and if it is capable of both providing its complementary technologies and absorbing new know-how from the alliances. In this respect, the ability of in-house R&D in evaluating and utilising both technological and scientific knowledge is extremely important.

Furthermore, firms should construct appropriate alliance strategies, based on achieving synergy between in-house technological accumulation and external inputs which enables existing products to be updated and new product arenas to be exploited. This means that it is not only in-house development of absorptive capacity that should be a focus of corporate technology strategies; also of crucial importance is having an external orientation directed towards creating a network of technology linkages. These linkages let the firm gain access to complementary technological know-how and expertise.

Fourth, the results of this research suggest that IT firms particularly in newly industrialised countries (NICs) such as Taiwan, where most of these firms are SMEs, must assign greater efforts not only to pursue horizontal linkages but also to foster absorptive capacity in order to learn effectively. This applies particularly to the absorption of specialty knowledge from alliance partners when developing and launching more innovative products becomes crucial. Managers must therefore continuously probe their organisational boundaries to determine how absorbent they are to admitting the influx of external knowledge. Company culture and organisational structures that facilitate the diffusion of technological capability as well as the absorption of external knowledge are essential to technological learning. Therefore, in order to facilitate the elevation of absorptive capacity, these firms should endeavour to create a conducive knowledge-creating environment by encouraging more external knowledge scanning activities, nurturing technological gatekeepers or boundary spanners (Leonard-Barton, 1995), and establishing a more effective communication network (Tu, 1999; Sher, 1998). These mechanisms cover both internal and external management and may often involve long-term efforts, conflict with existing corporate values, and face trade-offs with other objectives. Despite this, the use of such mechanisms should endow firms with a set of unique strategic assets that are difficult for competitors to imitate. A study of external linkages and innovation based on high-tech SMEs in the UK (Rothwell and Dodgson, 1991) pointed out that the most important factors determining these SMEs' propensities and ability to access external sources of technology are the employment of qualified scientists and engineers and the proactive characteristics of management. Qualified scientists and engineers may enable a SME to build up its ability to successfully access external know-how for external technology acquisition. Therefore, information and technology SMEs particularly in NICs should consider employing in-house qualified scientists and engineers so that they are capable of scanning up-to-date technologies and are receptive to external sources of knowledge. Moreover, to effectively utilize these scientists, top management must be proactive in accepting external ideas.

Fifth, NPD managers must also realize that the involvement of external parties in more innovative project developments helps to reinforce the NDP team's absorptive capacity. NPD managers are encouraged to pursue co-development opportunities, in particular, with industrial research institutes or international OEM/ODM partners. Such a strategy will become increasingly relevant as these firms seek to strengthen their global competitiveness by engaging in more radical or truly innovative product development. However, it must be understood that the management of external technological linkages is a challenging undertaking. This includes the identification of areas for collaborative development, the selection of compatible learning partners, the productive management of the collaboration, and ensuring benefits accrue from the joint activities. All of these factors will entail considerable management of resources and expertise. A crucial requirement for managers is to have the ability to motivate and effectively organise creative collaborative activities.

IT firms in newly developed countries have gradually developed their specialty in global business systems to become a part of the multi-national companies' (MNCs) international division of technical labour. Taiwanese IT firms under such systems are observed to be more capable of absorbing the technical dimension of product knowledge than the marketing knowledge. Finally, but not last, these firms should consider developing their own marketing ability not only to further strengthen their absorptive capacity relative to marketing capabilities, but also to put in place strategically interesting assets (generally a variety of competencies) to attract MNCs in a collaboration project involving both technical and marketing development.

The lack of any significant effect on new product technological knowledge observed in this research suggests that industrial research institutes and universities are not playing an important role in producing product-specific knowledge/technology. This result has implications for Taiwanese government's public policy making. Iansiti and West (1997: 79) point out: "an R&D organisation resides in a given geographic environment, and its effectiveness is linked to its ability to leverage local expertise, customer, and traditions." Therefore, a policy that encourages the development of more IT incubators inside public research institutes or universities and of more collaborative R&D projects between public research institutes and private firms should be useful for facilitating the transfer of up-to-date technologies to private IT firms. In addition, some public funds could be allocated to direct more applied research that is product-specific and can be financially realized in a shorter period than basic, fundamental research.

8.5 Limitations of the Study

The generalisability of this study's results is limited by industry and country. The positive impact, as well as the moderation effects, of absorptive capacity on product knowledge accumulation and external linkages is more likely to exist in industries experiencing rapid innovation (such as IT and biochemical industries) (Mangematin and Nesta, 1999; Shenkar and Li, 1999) because in such industries a continual updating of a firm's knowledge and the technology that it currently employs is required to meet competitors' offerings. In stable manufacturing industries (such as the car and steel industries), an increase in absorptive capacity beyond a certain level may not be effective. This is because demands in these industries are relatively unchanging and product specifications are well defined. The additional costs of developing knowledge-based activities may put a firm in a situation of cost or economy of scale disadvantage relative to competitors.

In newly developed countries where IT firms depend largely on collaborative new development projects with MNCs of developed countries for the source of innovative technologies, the importance of absorptive capacity and development links with international corporations is more likely to be manifest in product innovativeness. The pattern of significant interaction between absorptive capacity and external linkages may very according to data which is collected from, for example, pharmaceutical firms in a developed country or IT firms in a country where the OEM/ODM business model is not dominantly adopted. This analysis needs to be repeated in other industries or nations, preferably ones with, for example, different industry characteristics and industry structures so that contextual factors could be further analysed.

The findings should be interpreted cautiously as the explanatory power (R^2) of the models is relatively weak. Strictly from a statistical point of view, the use of categorical variables reduces the model's explanatory power, but generates more conservative results than the use of quantitative variables. Thus, these findings should be considered conservative.

The limitations of this research are partially inherent in the design and subject context. The first limitation concerns the use of a single key informant per unit of analysis. The single-source issue is less of a concern when measured variables are objective and/or factual in nature. On the other hand, it becomes a more serious concern when most variables have the nature of perceptual judgments (Summers, 2001). Measurement items for several variables used in this study are perceptual in nature. Although qualified respondents such as NPD managers, vice presidents of R&D, and product managers, who are closely involved in their respective new product projects, were selected, the use of information from a single source to generate information about an entire new product project might produce biased findings. In addition, these respondents could bias the extraction of more R&D-oriented information than new product marketing knowledge. However, the quality of the survey method applied in this study and the use of highly knowledgeable participants in the project are mostly consistent with other methodologies typically found in literature.

Second, the research used subjective measures of absorptive capacity in preference to objective proxies (such as R&D spending or number of patents) because the latter has been criticized on the grounds of its imprecision (Spender and Grant, 1996). Considering the multi-faceted characteristics of the absorptive capacity construct, this study chose the subjective, multiple measurement items for the construct. Nevertheless, the choice of the subjective measures did show construct validity and internal reliability. As knowledge or learning-based approaches to research progress, researchers will continue to face such dilemmas. Subjective measures were also applied to the items in the product knowledge accumulation construct. This application may also involve the disadvantages of self-reporting and/or key-informant reports from a single source (Summers, 2001).

Third, the focus of this study was to investigate the moderating and direct effect of absorptive capacity on product innovativeness. Because of the limitation of the sample size as well as its cross-sectional nature, this study did not attempt to examine either the possibility of feedback effect of product knowledge accumulation on absorptive capacity or the correlative effects among variables by applying techniques of structural equation modeling. Future research should expand the dataset across different new product development cycles (i.e. time cycles) in a firm so as to explore the feedback effect.

8.6 Suggestions for Future Research

Based on this exploratory study, several avenues for future work can be identified. One direct extension of this framework is to further examine the relationship between absorptive capacity and the accumulation of new product knowledge found in this study. As the development of absorptive capacity is a by-product of routine activities (Cohen and Levinthal, 1990; Kim, 1998), an intensification of current efforts to develop new product knowledge would reciprocally elevate the level of absorptive capacity. Although this study reflects the role of absorptive capacity as both a direct predictor and a moderator, there may exist a reciprocal causation between absorptive capacity and product knowledge accumulation. Specifically, effective gain in new product knowledge reinforces absorptive capacity and elevates absorptive capacity. A longitudinal research with a time-series analysis should be able to reveal this relationship.

In this research, the focus has been on ways in which the interaction between external linkages and absorptive capacity affects product knowledge accumulation and, in turn, how this affects product innovativeness. Previous empirical evidence (Ottum and Moore, 1997) found that product newness is a significant factor that moderates the relationship between NPD performance and the amount of market information gathered, shared and used. This implies that the level of product newness may moderate the effects of absorptive capacity on the external knowledge that is assimilated. By extending the current research model to include new product newness as a moderating variable (recursive design), future studies could further explore this issue.

Boundary-spanning activities initiate a firm's accumulation of its absorptive capacity (Cohen and Levinthal, 1990). This research may be extended to investigate whether firms with a higher absorptive capacity have a tendency towards more external linkages in their NPD activities. In other words, absorptive capacity may be hypothesized as a direct predictor of external linkages, the effect of which subsequently contributes to gain in new product knowledge. This accumulation of new product knowledge reinforces absorptive capacity. Under this relationship, a study of cyclical recursive designs involving feedback loops would be necessary for such a research framework. For instance, a possible relationship can be mathematically expressed as: absorptive capacity = f (gain in new product knowledge); gain in new product knowledge = f (external linkages); and external linkages = f (absorptive capacity), the relations of which establish a cyclical feedback loop.

Other empirical works (Atuahene-Gima, 1992; Atuahene-Gima, 1993; Atuahene-Gima and Patterson, 1993) suggest that absorptive capacity might not directly drive a firm to develop more external linkages. This is because a "not-invented-here" (Katz and Allen, 1982) syndrome, inhibiting the consideration of external sources of technology, may have developed among internal R&D staff. The growth of "not-invented-here" syndrome in a firm or in its R&D department may indicate that the engineers are complacent about the capabilities relevant to the design/technology domain that has been developed. An interesting research question emerges as to what managerial measures a firm can take without falling into a competency trap (Levitt and March, 1988). Organisational learning theory suggests that unlearning ability makes room for more adequate interpretative frameworks to be held in the organisational memory, whilst learning ability generates new knowledge and updates existing knowledge (Hedberg, 1981). Researchers may explore the issues of developing "not-invented-here" syndrome and the difficulties in unlearning ability in dealing with such a managerial dilemma – i.e. the need to strike a balance between maintaining core technology and investing in a newly emerging and relevant technology.

Another research direction is to examine the impact of absorptive capacity on the various types of knowledge acquisition. Several empirical studies confirm that absorptive capacity is more critical for collaboration with basic and scientific research as well as for exploitative alliances (Koza and Lewin, 1998; Mangematin and Nesta, 1999). But, whether the impact of absorptive capacity is more significant on tacit types of knowledge than on explicit types of knowledge remains empirically unconfirmed. The insights of knowledge management should encourage investigation of this issue.

One of the key abilities of absorptive capacity lies in granting firms the ability to effectively recognise and value new technologies (Cohen and Levinthal, 1990). Empirical evidence confirms that possession of complementary knowledge, i.e. diversity in knowledge domains that are complementary, affects a firm's search for new knowledge (Cockburn and Henderson, 1998; Shenkar and Li, 1999). The advantages of productively recognising valuable new technologies may enable and drive firms to develop a broad spectrum of product families. The implication of these findings may direct researchers to postulate that absorptive capacity could affect product diversification strategies. In other words, firms with relatively higher absorptive capacity may tend to develop a variety of product families for market competition.

It would be useful to attempt to cross-validate the model advocated in the current research by using data from different industries or different countries. For example, case studies from the biochemical industry highlight the importance of research collaboration between industrial firms and universities as well as industrial research institutes (Decarolis and Deeds, 1999; Mowery et al., 1996; Bierly and Chakrabarti, 1996a). In addition, several empirical studies in the car industry suggest the significant role of supplier integration in product innovation (Aoki, 1986; Blenkhorn and Noori, 1990; Kamath and Liker, 1994; Dyer, 1996). However, the current study predominantly identified the significant impact of corporation linkages on product innovativeness in an IT context. A cross-country comparative study, particularly between OEM/ODM-dominated and non-OEM/ODM-dominated IT industries, may provide researchers with more precise and unique suggestions for managerial practices.

In a similar vein, the concept of absorptive capacity can be extended to investigate service innovation. For instance, it would be interesting to consider the effects of absorptive capacity on the performance of a retailing chain's service technology transfer both within and from outside its units, the level of its service innovation, and the amount of customer feedback being processed to reduce customer complaints. But, this would require a different conceptualisation of absorptive capacity because learning behaviour in service contexts is less R&D-oriented.

The most challenging part of this research was in determining appropriate measures of the multi-faceted concept of absorptive capacity, and further studies with different types of measures are needed to better define this construct. Past studies (Tsai, 2001; Mowery et al., 1996; Koza and Lewin, 1998) utilised an objective indicator such as R&D spending as the proxy for absorptive capacity, but they have been shown to have problems of accuracy (Spender and Grant, 1996). The moderating effects of the absorptive capacity variable have been partially supported in this study because only a few of the more simplistic elements of the construct were measured.

The most important elements of absorptive capacity, particularly in the context of new product development, may be more intricate than the factors that were actually measured in this study. These elements may include the more complex and difficult-to-measure elements, such as relative learning capacity, innovative culture, prior knowledge base of the organisation, and the nature of communication within the organisation. Each of these elements is in essence a multi-faceted construct. Qualitative research, such as case studies of individual organisations, would be useful in determining if a better measure of absorptive capacity can be developed for NPD research.

To conclude, this research explores the complex relationship between external linkages and absorptive capacity from a knowledge-enabled view of new product development. It offers new perspectives on how and why absorptive capacity and product knowledge accumulation are critical to new product innovativeness. The researcher advocates the need to empirically investigate different knowledge-absorption mechanisms (e.g., firm's IT-support-for knowledge-management system and unlearning practices) to further untie the secrets of knowledge/technology creation in respect of product innovation. The theoretical development and empirical results from this thesis provide a ready springboard for future research.

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Appendix A

Survey Questionnaires and Cover Letters

External Linkages, Absorptive Capacity and Product Innovativeness

(Questionnaire for R&D Executives or Project Team Leaders)

General Instructions

The unit of this research is a new product development project. External linkage refers to the joint activities and relationships created together with external partners such as customers, suppliers or universities during the period of project development. <u>Please answer questions based on (1) the situations of a particular, individual new product project that has been lunched within last three years, and (2) one such project that you have been closely involved with.</u>

This questionnaire is divided into five sections. Each question ask you to choose the alternative that best fits your views on the topic. We estimate that it will take about 30 minutes to complete the questionnaire. No additional file search is needed to answer the questions. The information provided will be treated in the **strictest confidence.** Your responses will entere in a coded format and only be used to aggregated statistical analyses.

Section 1 General Information

For the following set of questions please tick that category which best describes your firm's situation. Where a blank is left, please complete the answer.

1. Your job title:______________________________
2. How many years have you been involved in a company's new product project management ?
   ______________ Years
3. Please indicate what year the new product of this project (which you refer to fill in the following questions) was launched. □□□□
4. Please indicate the category that best describes your product type:
   □ Components/parts, □ Sub-assemblies, □ Software, □ System Products
5. Size of your company:
   (a) Approximate number of total employees: ____________________
   - in R&D department: ____________________
   (b) Annual Sales in 1999: ____________________million NT$
6. What is R&D expenditure as a percentage of total sales in your company? ___________%
7. For which quality standards is your company certificated (tick all that apply)?
   □ ISO9001 □ ISO9002 □ ISO14000
   □ Others (Please specify) ______________________________

8. Please indicate the category of industry that best fits your firm.

☐ PC/Peripherals, ☐ Semi-conductors, ☐ Telecommunications, ☐ Software

Section 2 Level of External Linkage

The following statements describe various external linkages that your firm may be involved with in order to source new knowledge or technologies for completion of the project. Those linkages contribute to the effectiveness of the project's new product development, manufacturing and marketing. Please circle the appropriate number to indicate the extent to which you agree or disagree with each statement in relation to the project. For example, if you strongly disagree with the first statement then please circle (1).

1	2	3	4	5	6	7
Strongly Disagree			Neither			Strongly Agree

If you wish to change an answer, please put a line through the old answer.

A. **Customers** (defined as end-users, channel members, your down-stream manufacturers/customers, but not including OEM/ODM customers)

	Strongly Disagree						Strongly Agree
1. Our customers provided their expertise in helping out with the project's initial go/no go decision ---------------	1	2	3	4	5	6	7
2. Our customers provided their expertise in the project's preliminary market assessment -------------	1	2	3	4	5	6	7
3. Our customers provided their expertise in the project's preliminary technical assessment ----------	1	2	3	4	5	6	7
4. Our customers assisted us in conducting a detailed market study- market research -----------------------------	1	2	3	4	5	6	7
5. Our customers provided their expertise in financial or business analysis leading to a go/no go decision prior to product development -----------------------------	1	2	3	4	5	6	7
6. Our customers were closely involved in testing the design and development of the product, resulting in, e.g., a prototype or sample product ------------------------	1	2	3	4	5	6	7
7. Our customers were closely involved in testing the product in-house: in the lab or under controlled							

conditions	1	2	3	4	5	6	7
8. Our customers were closely involved in testing the product under real life conditions, e.g., with customers and/or in the field	1	2	3	4	5	6	7
9. Our customers provided their expertise in the product's test market/trial sell	1	2	3	4	5	6	7
10. Our customers were closely involved and provided their expertise in a trial production run to test the product facilities	1	2	3	4	5	6	7
11. Our customers were closely involved in financial analysis, following product development but prior to full-scale production	1	2	3	4	5	6	7
12. Our customers were closely involved and provided their expertise in the start-up of full-scale production	1	2	3	4	5	6	7
13. Our customers were closely involved and provided their expertise in the launch of the product	1	2	3	4	5	6	7

B. Suppliers

	Strongly Disagree						Strongly Agree
1. Our suppliers provided their expertise in helping out with the project's initial go/no go decision	1	2	3	4	5	6	7
2. Our suppliers provided their expertise in the project's preliminary market assessment	1	2	3	4	5	6	7
3. Our suppliers provided their expertise in the project's preliminary technical assessment	1	2	3	4	5	6	7
4. Our suppliers assisted us in conducting a detailed market study- market research	1	2	3	4	5	6	7
5. Our suppliers provided their expertise in financial or business analysis leading to a go/no go decision prior to product development	1	2	3	4	5	6	7
6. Our suppliers were closely involved in testing the design and development of the product, resulting in, e.g., a prototype or sample product	1	2	3	4	5	6	7
7. Our suppliers were closely involved in testing the product in-house: in the lab or under controlled conditions	1	2	3	4	5	6	7
8. Our suppliers were closely involved in testing the							

product under real life conditions, e.g., with customers and/or in the field---1 2 3 4 5 6 7

9. Our suppliers provided their expertise in the product's test market/trial sell-- 1 2 3 4 5 6 7

10. Our suppliers were closely involved and provided their expertise in a trial production run to test the product facilities--1 2 3 4 5 6 7

11. Our suppliers were closely involved in financial analysis, following product development but prior to full-scale production---------------------------------------1 2 3 4 5 6 7

12. Our suppliers were closely involved and provided their expertise in the start-up of full-scale production --1 2 3 4 5 6 7

13. Our suppliers were closely involved and provided their expertise in the launch of the product ------------ 1 2 3 4 5 6 7

C. Third-party Companies

(Third-party companies here are defined as firms that are either non-competitors of your firm, which have had some sort of contracted or non-contracted relationship with the project, such as OEM/ODM customers, and have contributed their expertise to the development of the project.) If the situation not applicable, please tick the left box □.

	Strongly Disagree						Strongly Agree
1. Our cooperating companies provided their expertise in helping out with the project's initial go/no go decision	1	2	3	4	5	6	7
2. Our cooperating companies provided their expertise in the project's preliminary market assessment	1	2	3	4	5	6	7
3. Our cooperating companies provided their expertise in the project's preliminary technical assessment	1	2	3	4	5	6	7
4. Our cooperating companies assisted us in conducting a detailed market study- market research	1	2	3	4	5	6	7
5. Our cooperating companies provided their expertise in financial or business analysis leading to a go/no go decision prior to product development	1	2	3	4	5	6	7
6. Our cooperating companies were closely involved in testing the design and development of the product, resulting in,e.g., a prototype or sample product	1	2	3	4	5	6	7

7. Our cooperating companies were closely involved in testing the product in-house: in the lab or under controlled conditions---------------------------------------1 2 3 4 5 6 7

8. Our cooperating companies were closely involved in testing the product under real life conditions, e.g., with customers and/or in the field-------------------------1 2 3 4 5 6 7

9. Our cooperating companies provided their expertise in the product's test market/trial sell-------------------- 1 2 3 4 5 6 7

10. Our cooperating companies were closely involved and provided their expertise in a trial production run to test the product facilities-------------------------------- 1 2 3 4 5 6 7

11. Our cooperating companies were closely involved in financial analysis, following product development but prior to full-scale production--------------------------1 2 3 4 5 6 7

12. Our cooperating companies were closely involved and provided their expertise in the start-up of full-scale production ------------------------------------- 1 2 3 4 5 6 7

13. Our cooperating companies were closely involved and provided their expertise in the launch of the product --- 1 2 3 4 5 6 7

D. Universities (If not applicable, please tick the left box ☐.)

	Strongly Disagree						Strongly Agree
1. The university with which we cooperated on the project provided their expertise in helping out with the project's initial go/no go decision	1	2	3	4	5	6	7
2. The university with which we cooperated on the project provided their expertise in the project's preliminary market assessment	1	2	3	4	5	6	7
3. The university with which we cooperated on the project provided their expertise in the project's preliminary technical assessment	1	2	3	4	5	6	7
4. The university with which we cooperated on the project assisted us in conducting a detailed market study - market research	1	2	3	4	5	6	7
5. The university with which we cooperated on the project provided their expertise in financial or business analysis leading to a go-no go decision							

prior to product development ------------------------------	1	2	3	4	5	6	7
6. The university with which we cooperate on the project was closely involved in testing the design and development of the product, resulting in, e.g., a prototype or sample product -----------------------------	1	2	3	4	5	6	7
7. The university with which we cooperated on the project was closely involved in testing the product in-house: in the lab or under controlled conditions------------------	1	2	3	4	5	6	7
8. The university with which we cooperated on the project was closely involved in testing the product under real life conditions, e.g., with customers and/or in the field------	1	2	3	4	5	6	7
9. The university with which we cooperated on the project provided their expertise in the product's test market/trial sell---	1	2	3	4	5	6	7
10. The university with which we cooperated on the project was closely involved and provided their expertise in a trial production run to test the product facilities-----	1	2	3	4	5	6	7
11. The university with which we cooperated on the project was closely involved in financial analysis, following product development but prior to full-scale production-	1	2	3	4	5	6	7
12. The university with which we cooperated on the project was closely involved and provided their expertise in the start-up of full-scale production --------------------	1	2	3	4	5	6	7
13. The university with which we cooperated on the project was closely involved provided their expertise in the launch of the product --------------------------------	1	2	3	4	5	6	7

E. Research Institutes (If not applicable, please tick the left box ☐.)

	Strongly Disagree						Strongly Agree
1. The research institute with which we cooperated on the project provided their expertise in helping out with the project's initial go/no go decision ---------------	1	2	3	4	5	6	7
2. The research institute with which we cooperated on the project provided their expertise in the project's preliminary market assessment -------------	1	2	3	4	5	6	7
3. The research institute with which we cooperated on the project provided their expertise in the project's							

preliminary technical assessment -------------------------1 2 3 4 5 6 7

4. The research institute with which we cooperated on the project assisted us in conducting a detailed market study- market research ----------------------------1 2 3 4 5 6 7

5. The research institute with which we cooperated on the project provided their expertise in financial or business analysis leading to a go/no go decision prior to product development ---------------------------- 1 2 3 4 5 6 7

6. The research institute with which we cooperated on the project was closely involved in testing the design and development of the product, resulting in, e.g., a prototype or sample product ---------------------------- 1 2 3 4 5 6 7

7. The research institute with which we cooperated on the project were closely involved in testing the product in-house: in the lab or under controlled conditions------1 2 3 4 5 6 7

8. The research institute with which we cooperate on the project were closely involved in testing the product under real life conditions, e.g., with customers and/or in the field---1 2 3 4 5 6 7

9. The research institute with which we cooperated on the project provided their expertise in the product's test market/trial sell--- 1 2 3 4 5 6 7

10. The research institute with which we cooperated on the project was closely involved and provided their expertise in a trial production run to test the product facilities--1 2 3 4 5 6 7

11. The research institute with which we cooperate on the project was closely involved in financial analysis, following product development but prior to full-scale production--1 2 3 4 5 6 7

12. The research institute with which we cooperated on the project was closely involved and provided their expertise in the start-up of full-scale production --1 2 3 4 5 6 7

13. The research institute with which we cooperated on the project was closely involved and provided their expertise in the launch of the product -------------- 1 2 3 4 5 6 7

Section 3 Gains in New Product-related Knowledge

This section presents a set of NPD activities. Please circle the appropriate number to indicate the extent of your project team's familiarity with each activity prior to and after the project.

	(Before the project) Very low — Very high							(After the project) Very low — Very high						
1. Preliminary market assessment	1	2	3	4	5	6	7	1	2	3	4	5	6	7
2. Market trend study or market research	1	2	3	4	5	6	7	1	2	3	4	5	6	7
3. Handling the customer test of prototype	1	2	3	4	5	6	7	1	2	3	4	5	6	7
4. New product screening techniques	1	2	3	4	5	6	7	1	2	3	4	5	6	7
5. After-service analysis for the new product	1	2	3	4	5	6	7	1	2	3	4	5	6	7
6. Detailed market study/market research	1	2	3	4	5	6	7	1	2	3	4	5	6	7
7. Executing test market prior to mass launch	1	2	3	4	5	6	7	1	2	3	4	5	6	7
8. Introducing the new product into the target marketplace – selling, promoting and distributing the products	1	2	3	4	5	6	7	1	2	3	4	5	6	7
9. Preliminary assessment of R&D technologies	1	2	3	4	5	6	7	1	2	3	4	5	6	7
10. Defining and analysing the new product's differential features	1	2	3	4	5	6	7	1	2	3	4	5	6	7
11. Detailed product design and development	1	2	3	4	5	6	7	1	2	3	4	5	6	7
12. Building the engineering control file for the new product's detailed specifications and its revision	1	2	3	4	5	6	7	1	2	3	4	5	6	7
13. Evaluating lab tests to determine basic performance against specifications of the product	1	2	3	4	5	6	7	1	2	3	4	5	6	7
14. Executing prototype or 'in-house' sample product testing of the product	1	2	3	4	5	6	7	1	2	3	4	5	6	7
15. Determining the final product design and specifications of the product	1	2	3	4	5	6	7	1	2	3	4	5	6	7
16. Working continuously on cost reduction and better quality and features	1	2	3	4	5	6	7	1	2	3	4	5	6	7
17. Conducting preliminary manufacturing assessment of the product	1	2	3	4	5	6	7	1	2	3	4	5	6	7
18. Executing trial/pilot production of the product	1	2	3	4	5	6	7	1	2	3	4	5	6	7

19. Conducting production start-up of the product --1 2 3 4 5 6 7 1 2 3 4 5 6 7

20. Controlling and manufacturing quality of the product --1 2 3 4 5 6 7 1 2 3 4 5 6 7

21. Our overall familiarity with the new product's technologies ------------------------------------1 2 3 4 5 6 7 1 2 3 4 5 6 7

Section 4 Product Newness

The following statements describe the level of your firm's familiarity with the product of this project in comparison with the existing product range. Please circle the appropriate number to indicate the extent to which you agree or disagree with each statement as applicable to the product.

	Strongly Disagree						Strongly Agree
1. In comparison with other existing product ranges, product class of the project is new to our firm-----------	1	2	3	4	5	6	7
2. In comparison with other existing product ranges, product use (need served) of the project is new to our firm --	1	2	3	4	5	6	7
3. In comparison with other existing product ranges, the product's competitors are new to our firms---------	1	2	3	4	5	6	7
4. In comparison with other existing product ranges, the product's potential customers are new to our firm --	1	2	3	4	5	6	7
5. In comparison with other existing product ranges, the product's production process is new to our firm----	1	2	3	4	5	6	7
6. In comparison with other existing product ranges, the product's technology is new to our firm-------------	1	2	3	4	5	6	7
7. In comparison with other existing product ranges, the product's channel and sales forces are new to our firm--	1	2	3	4	5	6	7
8. In comparison with other existing product ranges, the product's advertising and promotion are new to our firm--	1	2	3	4	5	6	7
9. Overall, product newness of the project is very high----	1	2	3	4	5	6	7

Section 5 Level of Absorptive Capacity

The following statements describe typical characteristics of a firm's capacity to absorb new knowledge and technology. Please circle the appropriate number to indicate the extent to which you agree or disagree with each statement as applicable to your organization.

	Strongly Disagree						Strongly Agree
1. The overall technical knowledge of our first-line engineers is high	1	2	3	4	5	6	7
2. The general knowledge level of our first-line engineers is high	1	2	3	4	5	6	7
3. The knowledge of our managers is adequate when solving technical problems	1	2	3	4	5	6	7
4. The knowledge of our managers is adequate when dealing with new technology	1	2	3	4	5	6	7
5. The general educational or technical level of our first-line engineers is high	1	2	3	4	5	6	7
6. The overall job competence of our first-line engineers is high	1	2	3	4	5	6	7
7. The knowledge of our managers is adequate when making business decisions	1	2	3	4	5	6	7
8. We seek to learn from benchmarking best practices in our industry	1	2	3	4	5	6	7
9. We seek to nurture boundary spanners for various new technologies	1	2	3	4	5	6	7
10. Our project members tend to trust each other	1	2	3	4	5	6	7
11. Our project members are supportive of each other	1	2	3	4	5	6	7
12. We seek to learn from trying out new technologies	1	2	3	4	5	6	7
13. We seek to learn from our customers and suppliers	1	2	3	4	5	6	7
14. Our project members share ideas freely with each other	1	2	3	4	5	6	7
15. The communications among functional areas are extensive	1	2	3	4	5	6	7
16. Our employees have a strong feeling of belonging to our organisation	1	2	3	4	5	6	7
17. The communications between supervisors and their subordinates are extensive	1	2	3	4	5	6	7
18. We seek to learn from tracking new market trends in our industry	1	2	3	4	5	6	7

19. We seek to learn from systematically collecting new technologies	1	2	3	4	5	6	7
20. We seek to nurture gatekeepers for various new technologies	1	2	3	4	5	6	7
21. The communications among our firm's functional areas are frequently	1	2	3	4	5	6	7
22. There is frequent communications between supervisors and their subordinates	1	2	3	4	5	6	7
23. The communication of new ideas from one department to another is extensive	1	2	3	4	5	6	7
24. In general, all members in the project are equipped with the ability to explore and absorb new knowledge	1	2	3	4	5	6	7

End of Questionnaire

Thank you for your assistance with this research. If you wish to receive a summary of the research findings, please enter your name and address below or attach a business card.

Name: ______________________ **Tel. No.:** ______________

Company Name: ______________________________________

Address: ______________________________________

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組織吸收潛能與外部連結

對新產品創新程度影響之實證研究

（本問卷請由研發部門主管或新產品專案負責人填寫）

問卷說明

本問卷研究對象係針對　貴公司過去某一項新產品研發專案。

請圈選答案時，依據：

(1)您最近深度參與的某一新產品研發專案（創新度高或低者皆可），

(2) 該專案所研發出的新產品已經上市。

懇請您完全依據該專案當時的狀況，填入自己最認同的情境程度。問卷答案無所謂對錯。我們感興趣的是您對該產品研發專案之當時印象。本問卷所得資料，僅供學術研究用。所有個別公司資訊將被嚴加保護。非常謝謝您的協助，在此謹致上敬意與謝意。[©研究主持單位:國立高雄第一科技大學行銷系與英國 Loughborough University 行銷研究中心]

壹、基本資料

1. 專案基本資料
   (a) 專案或產品名稱：________________________
   (b) 產品類型：(請勾選一)
   ☐ 零組件　☐ 組合件　☐ 系統產品　☐軟體
2. 公司規模 (大約數字即可)
   (a) 總員工人數：__________人
   研發工程人員人數：__________人
   (b) 2000 年總營業額：__________百萬新台幣
3. 過去二年來，平均每年研發經費佔年營業額百分比 (大約)______%
4. 您的工作職稱：________________________
5. 您任職有關新產品研發管理年數：__________年
6. 貴公司獲得那些品保認證 (可複選)：
   ☐ ISO 9001　☐ ISO 9002　☐ ISO 14000 ☐其他(請指示)
7. 貴公司產品產業定位：
   ☐ 電腦週邊設備 ☐半導體 ☐通訊 ☐軟體

貳、外部聯結程度

下列各項敘述，係針對 貴公司進行新產品研發專案時，在各階段研發活動中，透過與公司外部聯結合作對象進行各種正式或非正式交流活動(指一般觀察、諮詢、授權、研發外包、股權／資金介入、共同研發、合資、併購...等等)以獲取相關技術(如：研發技術、製造技術、行銷技術)，致使該項新產品能順利研發完成。

請依據您所選擇的新產品開發專案，請針對下列各種聯結合作對象（A.顧客、B.供應商、C.專業顧問/合作公司、D.工業研究單位、E.學術研究單位），圈選最能代表您同意程度的數字。(1＝非常低，7=非常高，其它數字則介於1到7之間，代表不同程度之低與高)

A. 我們的顧客(指終端使用者,國際/國內經銷商,代理商,下游製造商,但不包括OEM/ODM顧客)參與該新產品開發專案下列活動之程度：

	非常低	相當低	有點低	普通	有點高	相當高	非常高
1. 初期產品規格訂定。	1	2	3	4	5	6	7
2. 初步市場評估分析。	1	2	3	4	5	6	7
3. 初步技術評估分析。	1	2	3	4	5	6	7
4. 細部市場分析研究。	1	2	3	4	5	6	7
5. 財務或策略分析(並影響該專案進行或不進行之決策)。	1	2	3	4	5	6	7
6. 產品工程設計與研發。	1	2	3	4	5	6	7
7. 實驗室(或控制環境下)之工程測試。	1	2	3	4	5	6	7
8. 顧客使用測試。	1	2	3	4	5	6	7
9. 試銷。	1	2	3	4	5	6	7
10. 試產。	1	2	3	4	5	6	7
11. 上市前相關之經營分析。	1	2	3	4	5	6	7
12. 大規模量產之設立。	1	2	3	4	5	6	7
13. 新產品上市。	1	2	3	4	5	6	7

B. 我們的供應商參與該新產品開發專案下列活動之程度：

	非常低	相當低	有點低	普通	有點高	相當高	非常高
1. 初期產品規格訂定。	1	2	3	4	5	6	7

2. 初步市場評估分析。	1 2 3 4 5 6 7
3. 初步技術評估分析。	1 2 3 4 5 6 7
4. 細部市場分析研究。	1 2 3 4 5 6 7
5. 財務或策略分析 (並影響該專案進行或不進行之決策)。	1 2 3 4 5 6 7
6. 產品工程設計與研發。	1 2 3 4 5 6 7
7. 實驗室(或控制環境下)之工程測試。	1 2 3 4 5 6 7
8. 顧客使用測試。	1 2 3 4 5 6 7
9. 試銷。	1 2 3 4 5 6 7
10. 試產。	1 2 3 4 5 6 7
11. 上市前相關之經營分析。	1 2 3 4 5 6 7
12. 大規模量產之設立。	1 2 3 4 5 6 7
13. 新產品上市。	1 2 3 4 5 6 7

C. 我們的專業顧問(指研發/行銷/製造等技術) 或某些合作公司(如 OEM/ODM 產品合作公司, 或某項技術共同開發之公司) **參與該新產品開發專案下列活動之程度:(此問項如不適用於該開發專案請在右□打勾：☐，以下 1-13 題目免答)**

	非常低	相當低	有點低	普通	有點高	相當高	非常高
1. 初期產品規格訂定。	1	2	3	4	5	6	7
2. 初步市場評估分析。	1	2	3	4	5	6	7
3. 初步技術評估分析。	1	2	3	4	5	6	7
4. 細部市場分析研究。	1	2	3	4	5	6	7
5. 財務或策略分析 (並影響該專案進行或不進行之決策)。	1	2	3	4	5	6	7
6. 產品工程設計與研發。	1	2	3	4	5	6	7
7. 實驗室(或控制環境下)之工程測試。	1	2	3	4	5	6	7
8. 顧客使用測試。	1	2	3	4	5	6	7
9. 試銷。	1	2	3	4	5	6	7
10. 試產。	1	2	3	4	5	6	7
11. 上市前相關之經營分析。	1	2	3	4	5	6	7
12. 大規模量產之設立。	1	2	3	4	5	6	7
13. 新產品上市。	1	2	3	4	5	6	7

D. 我們曾與工業研究單位（如工研院、資策會、電信所、等等）共同研發該新產品，他們參與該新產品開發專案下列活動之程度：
(此問項如不適用於該開發專案請在右□打勾：□，以下1-13題目免答)

	非常低	相當低	有點低	普通	有點高	相當高	非常高
1. 初期產品規格訂定。	1	2	3	4	5	6	7
2. 初步市場評估分析。	1	2	3	4	5	6	7
3. 初步技術評估分析。	1	2	3	4	5	6	7
4. 細部市場分析研究。	1	2	3	4	5	6	7
5. 財務或策略分析(並影響該專案進行或不進行之決策)。	1	2	3	4	5	6	7
6. 產品工程設計與研發。	1	2	3	4	5	6	7
7. 實驗室(或控制環境下)之工程測試。	1	2	3	4	5	6	7
8. 顧客使用測試。	1	2	3	4	5	6	7
9. 試銷。	1	2	3	4	5	6	7
10. 試產。	1	2	3	4	5	6	7
11. 上市前相關之經營分析。	1	2	3	4	5	6	7
12. 大規模量產之設立。	1	2	3	4	5	6	7
13. 新產品上市。	1	2	3	4	5	6	7

E. 我們曾與學術研究單位（如大學、研究所等等）共同研發該新產品，他們參與該新產品開發專案下列活動之程度：
(此問項如不適用於該開發專案請在右□打勾：□，以下1-13題目免答)

	非常低	相當低	有點低	普通	有點高	相當高	非常高
1. 初期產品規格訂定。	1	2	3	4	5	6	7
2. 初步市場評估分析。	1	2	3	4	5	6	7
3. 初步技術評估分析。	1	2	3	4	5	6	7
4. 細部市場分析研究。	1	2	3	4	5	6	7
5. 財務或策略分析(並影響該專案進行或不進行之決策)。	1	2	3	4	5	6	7
6. 產品工程設計與研發。	1	2	3	4	5	6	7
7. 實驗室(或控制環境下)之工程測試。	1	2	3	4	5	6	7
8. 顧客使用測試。	1	2	3	4	5	6	7
9. 試銷。	1	2	3	4	5	6	7
10. 試產。	1	2	3	4	5	6	7

11. 上市前相關之經營分析。 1 2 3 4 5 6 7

12. 大規模量產之設立。 1 2 3 4 5 6 7

13. 新產品上市。 1 2 3 4 5 6 7

F. 產品專案貢獻程度：

就以上五種對象，請根據它們對完成此新產品開發專案之個別重要性(綜合研發/製造/行銷等各層面) 填入百分比，其總合應為 100%，請進行查核，謝謝!

A. 顧客 (指終端使用者,國際/國內經銷商,代理商,下游製造商但不包括 OEM/ODM 顧客)	______%
B. 供應商	______%
C. 專業顧問 (指研發/行銷/製造等技術) 或某些合作公司(如 OEM/ODM 產品合作公司，或某項技術共同開發之公司)	______%
D. 工業研究單位 (如工研院、資策會、電信所等等)	______%
E. 學術研究單位 (如大學、研究所等等)	______%

總合: 100 %

參、產品研發技術熟悉程度

本部分旨在瞭解貴公司在該新產品專案開發前與開發後，對下列 20 項有關此新產品研發技術之熟悉程度。請依據所選擇的新產品開發專案分別圈選最適當的答案:

	(專案開發前) 非常低 — 中等 — 非常高	(專案完成後) 非常低 — 中等 — 非常高
1. 初步市場評估	1 2 3 4 5 6 7	1 2 3 4 5 6 7
2. 市場特性與趨勢分析	1 2 3 4 5 6 7	1 2 3 4 5 6 7
3. 產品市場規模與財務分析	1 2 3 4 5 6 7	1 2 3 4 5 6 7
4. 新產品篩選分析技術	1 2 3 4 5 6 7	1 2 3 4 5 6 7
5. 售後服務方案分析	1 2 3 4 5 6 7	1 2 3 4 5 6 7
6. 細部市場研究	1 2 3 4 5 6 7	1 2 3 4 5 6 7
7. 大量上市計畫前的市場試銷	1 2 3 4 5 6 7	1 2 3 4 5 6 7
8. 導入目標市場之銷售/促銷/配送	1 2 3 4 5 6 7	1 2 3 4 5 6 7
9. 研發工程技術評鑑	1 2 3 4 5 6 7	1 2 3 4 5 6 7

	(專案開發前)	(專案完成後)
10. 新產品"區隔訴求特性"之訂定與分析	1 2 3 4 5 6 7	1 2 3 4 5 6 7
11. 產品細部設計與研發	1 2 3 4 5 6 7	1 2 3 4 5 6 7
12. 建立此新產品規格訂定與修改之工程檔案系統	1 2 3 4 5 6 7	1 2 3 4 5 6 7
13. 評估實驗室測試對最後產品功能規格訂定	1 2 3 4 5 6 7	1 2 3 4 5 6 7
14. 雛形品(或樣本品)之產品測試	1 2 3 4 5 6 7	1 2 3 4 5 6 7
15. 產品最後設計規格訂定	1 2 3 4 5 6 7	1 2 3 4 5 6 7
16. 成本下降與品質提昇之設計改善	1 2 3 4 5 6 7	1 2 3 4 5 6 7
17. 初步製造可行性評估	1 2 3 4 5 6 7	1 2 3 4 5 6 7
18. 試製/試產之執行	1 2 3 4 5 6 7	1 2 3 4 5 6 7
19. 更優異的大量投產技術之執行	1 2 3 4 5 6 7	1 2 3 4 5 6 7
20. 更優異的品保工程方案之執行	1 2 3 4 5 6 7	1 2 3 4 5 6 7
21. 對此新產品各技術整體熟悉度	1 2 3 4 5 6 7	1 2 3 4 5 6 7

肆、產品創新度

與公司當時其他產品比較，就該專案新產品的創新程度，請圈選您同意的數字。

	完全不同意 … 完全同意
1. 對本公司而言，該新產品之類別是屬於全新類別。	1 2 3 4 5 6 7
2. 對本公司而言，該新產品之應用（解決某需求）是屬於全新的應用。	1 2 3 4 5 6 7
3. 對本公司而言，該新產品之競爭者是屬於全新的競爭者。	1 2 3 4 5 6 7
4. 對本公司而言，該新產品之顧客群是屬於全新的顧客群。	1 2 3 4 5 6 7
5. 對本公司而言，該新產品之生產製造技術是屬於全新的生產製造程序。	1 2 3 4 5 6 7
6. 對本公司而言，該新產品之設計開發技術是屬於全新的設計開發技術。	1 2 3 4 5 6 7
7. 對本公司而言，該新產品之通路與銷售人員是屬於全新的通路與銷售人員。	1 2 3 4 5 6 7
8. 對本公司而言，該新產品之廣告與促銷推廣是屬於全新的廣告與促銷推廣。	1 2 3 4 5 6 7
9. 對本公司而言，該新產品之創新程度非常高	1 2 3 4 5 6 7

伍、組織吸收潛能

本部分旨在瞭解貴公司整體之組織吸收潛能，請逐項圈選您同意程度的數字。

	非常不同意	相當不同意	有點不同意	普通	有點同意	相當同意	非常同意
1. 我們的工程師具備高水準的一般技術知識。	1	2	3	4	5	6	7
2. 我們的工程師具備高水準的解決問題能力。	1	2	3	4	5	6	7
3. 當解決技術問題時，我們經理人員具備適當的知識。	1	2	3	4	5	6	7
4. 當吸收新技術時，我們經理人員具備適當的知識。	1	2	3	4	5	6	7
5. 我們的工程師技術背景甚佳	1	2	3	4	5	6	7
6. 我們的工程師具備高水準的工作能力。	1	2	3	4	5	6	7
7. 當進行商業決策時，我們經理人員具備適當的知識。	1	2	3	4	5	6	7
8. 我們不斷地尋求本產業裡優秀者的管理方法做比對學習。	1	2	3	4	5	6	7
9. 我們尋求並培養跨各種技術領域的專長人員。	1	2	3	4	5	6	7
10. 公司研發專案人員傾向彼此信任。	1	2	3	4	5	6	7
11. 公司研發專案人員彼此互相幫助。	1	2	3	4	5	6	7
12. 我們不斷地尋求從嘗試新科技中學習。	1	2	3	4	5	6	7
13. 我們不斷地尋求從顧客與供應商處學習。	1	2	3	4	5	6	7
14. 公司研發專案人員彼此自由地交流新意見。	1	2	3	4	5	6	7
15. 公司各功能部門間溝通廣泛且順暢。	1	2	3	4	5	6	7
16. 公司研發專案人員對組織有強烈的認同感。	1	2	3	4	5	6	7
17. 公司主管與部屬間溝通廣泛且順暢。	1	2	3	4	5	6	7
18. 我們不斷地從追蹤本產業市場趨勢中學習。	1	2	3	4	5	6	7
19. 我們有制度地從蒐尋相關技術資訊中學習。	1	2	3	4	5	6	7
20. 我們尋求並培養各種相關新技術的掌門人員。	1	2	3	4	5	6	7
21. 公司各功能部門間溝通頻繁。	1	2	3	4	5	6	7
22. 公司主管與部屬間溝通頻繁。	1	2	3	4	5	6	7
23. 公司內新意見／看法從某一部門到另外一部門溝通廣泛且順暢。	1	2	3	4	5	6	7
24. 總體上，本公司所有參與專案的相關人員具備探索與吸收新觀念的優質能力。	1	2	3	4	5	6	7

---------------------------------問 卷 結 束---------------------------------

非常謝謝您填寫本研究問卷！如果您希望獲得本研究之結果，煩請填寫以下資料。

大　名：________________

電　話：________________

公司名稱：____________________________

地　址：____________________________

E-mail：____________________________

----------- Cover Letter ----------

XX 科技公司

XXX 副總經理 鈞鑒：

新產品技術/知識的獲取已成為研發導向企業的重要課題，但是企業如何有效地吸取外部知識，並將它代為新產品發展的成果？答案可能潛藏在組織對所預獲取的〝吸收潛能〞。

隨函檢附本人博士論文學術問卷—**"組織吸收潛能與外部連結對新產品創新影響"**。主要是探討國內資訊產業在新產品發展過程中，公司與外部連結程度以及其吸收潛能，與產品創新度之間的關係。

此問卷內所填各項資料純供論文研究之用，只作整體性之分析，不各別對外披露，故絕不會影響問卷公司機密。本論文研究完成後，將奉贈研究報告摘要予問卷公司參考。故懇請您惠予協助提供適當廠商/ 公司名單供本研究之進行。

若有任何疑問，請與本人連絡:

電話(臺灣): (O) 07-6011000 轉 4212（國立高雄第一科技大學）
Fax: 07-6011043
E-mail: stshu@ccms.nkfust.edu.tw

順 頌

業 祺

英國 Loughborough University 商學院
博士後選人
國立高雄第一科技大學行銷系講師
徐 世 同 敬上

......Cover Letter (English Translation) ......

Dear ------

Acquiring the new product technology/knowledge has always been one of major tasks of R&D-intensive firms. How can firms effectively absorb external new knowledge and convert it into their NPD results? The answer could lie in their absorptive capacity for the pursued technology.

This study aimed at exploring *the impact of external linkages and absorptive capacity on new product innovativeness* is an international research project conducted jointly by Loughborough University and National Kaohsiung First University. Your company has been recognized as one of the leading high-tech firms in IT industry; hence we would be pleased if you could response to the questionnaire enclosed.

The current study is deemed important, as it will help to generate a profile of Taiwanese IT firms' tendency in the process of new technology acquisition and enhance the implementation and effectiveness of the external networking for NPD.

Please be assured that the information provided will be treated in the strictest confidence. No individual cases will ever be reported. If you would like to have a summary of the results, please indicate accordingly at the end of questionnaire.

I greatly appreciate your help in advancing this research endeavour. Should you have any question, please feel free to contact me at: (office) 07-6011000 extension 4212; (home) 07-7400763; and (e-mail) s.t.shu@lboro.ac.uk.

Sincerely,

Shih-Tung Shu
Doctoral Researcher
Business School
Loughborough University

Appendix B

An Outline of the Taiwanese IT Industry

1. A Glance at Taiwan's Foreign Trade and IT Industry

Taiwan is an island with scarce natural resources and a small-scale domestic market. Its economic development largely depends on the export of its products. According to the 2000 yearbook of Global Trade of the World Trade Organisation, Taiwan is ranked as the 13th largest trading country in the world. In 2000, Taiwan's total trading amount was US$288.3 billion with a trade surplus of US$8.3 billion. By way of trade volume, its 10 major trading countries are U.S.A., Germany, Japan, France, U.K., Canada, China, Italy, Netherlands, and Hong Kong respectively. Also in 2000, Taiwan ranked as the third largest player in the Japanese import market, enjoying 4.69 % of share and as the eighth largest in US the import market, with 3.33% share.[1]

The major import and export trading items for Taiwan are electronics products, production machines, electrical products, telecommunications products, and home appliances, all of which accounted for 54.42% and 44.34% of 2001 import and export value respectively. Electronic and telecommunication products consistently dominate export value (see Table 1). The percentage of production equipment in the total import volume remained stable at more than 10% each year from 1998 to 2001, indicating a highly manufacturing-oriented economy. However, this pattern of economic growth through the export of IT products has been gradually changing. Notably in comparsion with the export figure of 2000, Taiwan suffered an export growth of –17.17% in 2001. This is mainly due to two causes: (1) worldwide economic recession, and (2) most Taiwanese IT firms now export products not directly from Taiwan but from Chinese plants to the global market in order to take advantage of cheaper land and labour cost. Currently, Taiwan is the fourth largest investor in China,

[1] Source: Quarterly Economic Review (2001), Department of Statistics, Ministry of Economic Affairs, Taiwan, p. 25

following Hong Kong, Japan and U.S.A. Most investment comes directly from Taiwanese IT firms. These firms have developed a business operation model which keeps the functions of R&D, marketing and finance in headquarters and focuses manufacturing and purchasing activities in China. Therefore, it is estimated that China's IT hardware export will have a quantum leap in next few years, whereas Taiwan's export of IT products will slow down.

Table 1 Major Import/Export by Commodity in Taiwan

(Year)	1998	1999	2000	2001
Aggregated total (Import)	104665.3	110689.9	140013.6	107242.9 (100%)
Machineries & Electrical equipments	42925.8	50598.4	66034.2	47549.5 (44.34%)
1.Electronic products	18055.0	19818.1	27282.8	21027.9 (19.61%)
2.Production machineries	12050.3	13517.5	17604.7	10488.2 (9.78%)
3.Electrical products	3969.5	4146.0	5354.7	4282.8 (3.99%)
4.Information & communication products	5296.5	8524.2	11282.5	8119.6 (7.58%)
5. Home appliances	395.3	421.4	504.2	448.5 (0.42%)
Aggregated total (Export)	110582.3	121591.0	148375.9	122901.5 (100%)
Machineries & Electrical equipments	55274.0	64161.9	82601.8	66876.1 (54.42%)
1.Electronics products	16900.6	21832.5	31.699.4	23610.2 (19.21%)
2.Production machineries	7807.3	7921.1	9676.2	8345.4 (6.71%)
3.Electrical products	4351.4	4601.1	5394.3	4667.1 (3.80%)
4.Information & communication products	13757.8	15141.7	19556.0	15670.3 (12.75%)
5. Home appliances	663.8	690.9	650.5	575.4 (0.47%)

Source: Annual statistics, Taiwan, available at www.moea.gov.tw/meco/stat/, 01 June, 2002. (Unit: in million US dollars)

In terms of the overall IT industry, Taiwan has an output of US$21,023 million which ranks it as the world's third largest IT producer, widening its lead over Singapore (see Table 2). However, its offshore production, most of which comes from

China, rose quickly. Market Intelligence Center (MIC), a non-profit IT market survey agency in Taiwan, claimed that China's overall IT hardware production exceeded Taiwan's in 2001. On the other hand, the development and integration of offshore plants in China has further strengthened Taiwanese IT firms' competitive edge in global market. This tendency keeps Taiwan as a major hub for the worldwide IT industry. It will still dominate production in areas such as semiconductors, PCs and peripherals, and data communications equipment, even with extensive division of labour between Taiwan and China.

Table 2 Major IT Hardware Producers Worldwide

1999 Rank	Country	1999 (unit: in US$ million)
1	USA	96161
2	Japan	44051
3	Taiwan	21023
4	Singapore	18474
5	China	18455

Source: Asia IT Report (2000), Market Intelligence Center, Institute for Information Industry, Taiwan, p. 35

2. Characteristics of the Taiwanese IT Industry

Taiwan's first wave of electronics production developed in the early 1960's, stimulated by television manufacturing investments by Philips, Matsushita, NEC, Sanyo and Mitsubishi. The ensuing light industry skills base was utilised over subsequent years to extend production beyond black and white televisions into tape recorders, transistor packaging and transistor radios. But it was not until late 1966 that US firms opened the island's first semiconductor assembly line. In 1969, there was an electronic trade-balance shift to positive for the first time when Taiwan shipped its first domestically manufactured colour television. Throughout the 1970's and 1980's electronic manufacturing in Taiwan continued to boom with advancements in producing electronic watches and calculators in addition to earlier product lines. This was reinforced by developing sophisticated electronic components such as Integrated Circuits (IC), Cathode Ray Tubes (CRTs), colour monitors and magnetic drums for VCRs.

Taiwan's second wave of electronics production started with the establishment of the Hsinchu Science-based Industrial Park (HSIP) in the early 1980's. This rapidly became a key driver for the development of island's high-technology products. Due to the timely mixture of incentives and cluster-effects, the HSIP became a giant magnet that drew in overseas investment and proved a fertile spawning ground for local start-ups. For instance, the world's top two chip-foundry operations, Taiwan Semiconductors Manufacturing Company and United Microsystem Corporation which specialised in semiconductor components for all IBM clones, were established here in 1980's. Both companies went on to revolutionise worldwide semiconductor productions by offering dedicated wafer foundry services to global IC designers through manufacturing process management from the possession of propriety technologies. By the late 1980s, the electronics industry had become the island's number one export sector and the island had become the fifth-largest supplier of PC and peripherals in the worldwide market.

In the mid 1990s, Taiwan emerged as a world computer-manufacturing centre, with a diverse range of companies specialising in activities throughout the value line. This includes opto-electronics sector and digital storage industry sector. Two major areas of optoelectonic potential are the advanced display technology and fiber optic communications equipment. According to the China External Development Council (CETRA), the island's thin-film-transistor liquid-crystal-display (TFT-LCD) production was worth US$702 million in 2000, and attracted about US$3.6 billion in investment. In 2000, Taiwan produced about 11 million digital and PC cameras, worth about US$812 million, and 25 million scanners, worth about US$1.35 billion. These constituted about 92% of the world production. CETRA also noted that in 2000, Taiwan manufactured about 48% of the world's CD-ROM drives, worth US$1.85 billion. Since 2000, in addition to wireless communication products, IC design has emerged as a key growth sector in Taiwan. With US$3.4 billion in sales, Taiwan ranked second behind the U.S. in revenues of chip-design companies in 2001.[2]

What makes Taiwan a major IT producer in global market? The unique characteristics of the Taiwanese IT industry, compared with those of other developed countries, can be attributed to: (1) focusing on OEM/ODM type of business model and maintaining long-term strategic partnerships with major international vendors (2) flexibility or the ability to react quickly, (3) a complete upstream, midstream and downstream clustering of manufacturing systems, (4) production sites that extend worldwide (mainly in low-cost labour countries, such as China, Thailand, Malaysia and the former Eastern Block).

The OEM/ODM business model has prevailed in Taiwan's garment and shoe industries since 1960's. Taiwanese IT firms applied this model to establish business relationships with global IT competitors such as IBM, Dell, H.P. Under this business model, Taiwanese IT firms receive product specifications from customers and concentrate on the design, manufacturing and delivery of finished products. Customers market the products under their own brand names. From the perspective of the value chain, the process of OEM/ODM-oriented new product development can be divided into five major functions: product definition, detailed development, product manufacturing, logistics and distribution, and product marketing. Taiwan IT firms particularly specialise in middle-process functions: detailed development, product manufacturing and logistics and distribution. OEM/ODM customers excel at product

[2] Sources: BusinessWeek, 25 February, 2002, p.27.

definition and product marketing. The specialist capabilities of both Taiwanese IT firms and OEM/ODM vendors are highly complementary. They form strategic alliances and compete with other similar alliances in the global market.

Taiwan manufacturers are not skilled at brand and distribution management so they have been unable to develop their own brands in the down-stream PC market. For instance, MIC statistics show that OEM/ODM orders represented more than 65% of IT exports in 1999. The share of OEM/ODM shipments in 1999 for desktop PCs was 77% and for notebook PCs, 87%. The largest Taiwanese notebook PC maker-Quanta Computer- does not own its product brand, but designs and manufactures products for nine of the top ten international notebook PC brands. It produced more than 4 million units of notebook PCs in 2001.[3] This may explain why few international IT brands originate from Taiwan. These Taiwanese firms zero in on different stages of the IT value chain. As there is no direct conflict with brand name IT players, Taiwanese IT firms therefore have established trusting long-term relationships with international OEM/ODM partners.

Taiwanese IT firms compete in the global market not only offering low-cost manufacturing, but also providing services with very short NPD cycles by integrating their own specialist technologies, thus forming a highly efficient supply chain. Responding rapidly to market changes, this supremely flexible system handles everything from research and development to manufacturing, assembly and delivery of goods. This manufacturing system is more vertically integrated and more flexible than that of the Silicon Valley, Japan and Korea. Upstream sectors handle design, production, and packaging of integrated circuits, as well as the design and manufacture of active and passive components and connectors for computers. The

[3] Source: IT Market Report (2001), Market Intelligence Center (MIC), Institute for Information Industry, Taiwan, available at www.complutex.com.tw/roundup, April 03, 2002

midstream sector designs and manufactures intermediate goods such as motherboards, printed-circuit boards, displays and power supplies. The downstream sector researches, develops and manufactures terminal products such as personal computers, monitors, scanners, CD-ROM drives, PC mice, cable and telecommunications equipment, and customer-premise equipment. The tight vertical integration between the different sectors of this manufacturing system allows these small to medium-sized Taiwanese IT companies to focus on key R&D areas, manufacturing and logistics. Any international IT firms which intend to grab a fast-to-market advantage gain leverage from Taiwan's unique, fast manufacturing system. For instance, Dell and Apple turn to Quanta Computer for outsourcing production of notebook PCs. Nokia signed Hon-Hai Precision Inc. (the largest connector maker in Taiwan and the number 2 in worldwide market) to make their mobile phones. Sony has its PlayStation2 manufactured by ASUSTEK COMPUTER. It is not simply that Apple, Dell, Nokia and Sony count on the manufacturing or designing ability of these individual Taiwanese firms but rather that they rely on the unique capability of a complete upstream, midstream and downstream clustering of IT manufacturing systems in Taiwan.

Western IT firms' continuous search for low-cost solutions to compete in the global market results in more reliance on outsourcing production to Taiwanese firms. Taiwanese IT firms have long been accustomed to focusing resources on competitive strength in areas of cost and speedy design/development. By 2001, more than 74 percent of Taiwanese firms have invested in China[4]. Manufacturing in Chinese plants further enhances these firms' low-cost competitive ability. They have also taken advantage of a low-cost engineering workforce by setting up R&D facilities in China. Both low labour cost and super-efficient manufacturing ability enables Taiwanese IT

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4 Source: Daily Roundup News, available at www.computex.com.tw/roundup, March 12, 2002.

firms to attract more OEM/ODM arrangements with international brand name players. In this regard, Taiwan plays an international role in designing and manufacturing IT products for brand name players who look to outsourcing production or product development when a price war begins.

3. The Current Status of the Taiwanese IT Industry

Taiwanese hardware products that garnered a greater than 60% share of their respective product's global production volume in 1999 were: notebook PCs (60%), motherboards (64%), communication hubs (66%), keyboards (68%), power supply units (70%), PC cabinets (75%), and scanners (91%)[5]. Among these products, Notebook PCs, monitors, desktop PCs and motherboards remained as the top four in island's 2000 IT production list (see Table 3). The top four products accounted for 85% of Taiwan's IT hardware output. However, still more of these products were manufactured outside Taiwan. Currently, Notebook PCs, special ICs, telecommunications equipment and opto-electronics sectors have gained importance at locally manufactured IT products. IC design, IC foundry service and TFT/LCD related sub-sectors have emerged as the next wave of major investment. For instance, the building of 12-inch wafer plants, each of which costs at least US$30 billion, will be focal projects in next few years. It is estimated that in the next five years, Taiwan will have ten 12-inch wafer plants, which will make it the pre-eminent centre for 12-inch wafer plants using the advanced wafer manufacturing technology. Due to the formation of a complete manufacturing cluster, an increasing demand for flat screens and large panels, and Japanese firms' withdrawal from the market, local TFT/LCD manufacturers have speeded up their investment in the building of new generation

5 Source: Asia IT Report (2000), Market Intelligence Center, Institute for Information Industry, Taiwan

plants. According to ITIS, five major TFT-LCD makers in Taiwan forecast shipment if around 28 million panels in 2002, generating a total revenue of NT$ 253 billion, up from NT$ 102.7 billion last year. The IC design sub-sector with a high growth rate as well as a well-developed local wafer foundry service will become a lucrative, new area of IT investment. In contrast, there will be less investment in other sectors manufacturing products such as PC motherboards, switching power supply, scanners, keyboards, PC mouse and other add-on cards. This is because the majority of these products are now being manufactured in China.

Table 3 1999 Sales of Taiwan's Major IT Hardware Products

Ranking	Product	Value (in US$ million)	Volume (in 1000 units)
1	Notebook PC	10,198	9,355
2	Monitor	9,330	58,729
3	Desktop PC	7,188	19,457
4	PC Motherboard	4,854	64,378
5	Switching Power Supply	1,744	80,221
6	CD/DVD	1,740	48,190
7	PC Cabinets	1,423	75,768
8	Scanner	925	21,901
9	Graphic Card	848	18,583
10	Keyboard	512	79,445
11	Universal Power Supply	370	3,008
12	PC Mouse	155	68,160
13	Sound Card	78	8,481
14	Video Card	33	1,102

Source: The Retrospect and Prospect of Taiwanese Manufacturing Industry (2001), Industrial Technology Information Service (ITIS), Taiwan, pp. 107-122

3.1 Semiconductor (IC) sector

Taiwan is the fourth IC vendor worldwide next to the US, Japan, and Korea. The revenue of the Taiwan IC industry in 2000 reached NT$714.4 billion, a growth of 68.7 percent or about NT$290 billion more than 1999 (see Table 4). Of the total revenue, the IC design segment contributes NT$115.2 million, a growth of 55.3 percent, IC packaging NT$97.8 billion, 48.4 percent, and IC testing NT$32.8 billion, 77.3 percent.

The production value of IC manufacturing accounted for 66 percent of total 2001 IC output, which was primarily contributed by the IC foundry service.

Table 4 Taiwan IC Industry Performance (Unit: in billion NT dollars)

Year	1999	2000	2001	2002[e]
Design	74.2	115.2	84.4	104.8
Manufacturing	264.9	468.6	356.7	404.9
Packaging	65.9	97.8	77.6	90.9
Testing	18.5	32.8	23.6	25.8
Total	423.5	714.4	542.3	608.5

Source: The Retrospect and Prospect of Taiwanese Manufacturing Industry (2001), Industrial Technology Information Service, Taiwan, pp. 9-26
[e] : estimated.

The world's top two IC foundries, Taiwan Semiconductor Manufacturing Corporation and United Microelectronics Corporation, dominate the foundry service, having more than 70 percent worldwide share. Both have state-of-the-art wafer fabrication labs located near many chip-design firms in the Hinchu science park, Taiwan's high-tech hub. With this advantage, the Taiwan IC-design sector has grown quickly. This sector's revenue in 1999 was about NT$74.2 billion and expected to reach to NT$104.8 billion by 2002. At present, the output of the Taiwan IC design industry remains second only to the US in the global market. Nearly 70 percent of Taiwanese products are concentrated in the field of information[6], which primarily consists of internal memory ICs, logic and analogue ICs. However, local IC designer houses have also advanced into the markets of network and communication wafers. Strategically important products include wafer groups, network wafers and wafers for ordinary consumers. In addition, Taiwan is a key supplier of wafers for video-disc recorders and wafers for ordinary consumers in global market. Facing the challenge of moderate growth in the global PC market, these IC design houses need to compete with other western countries. Key strategic moves for major IC design firms will be:

[6] Source: The Prospect and Retrospect of Taiwanese Manufacturing Industry (2001), Industrial Technology Information Service, Taiwan, p.9-25

focusing on communication and system-on-chip design; and, establishing a model of division of labour on primary and advanced design between China and local R&D centers.

In 2002, Taiwanese IC firms' capital investments will reach US$90 billion, ranking it third in the global IC industry. The focus of the IC foundry service is the major capital investment where three 12-inch wafer plants are to be in operation by 2003, while fewer investments concentrate on DRAM and non-DRAM memory ICs. Large capital expenditure in the fifth-generation wafer plants maintains Taiwan's lead in foundry service and may further boost the local fabless IC design industry.

Table 5 Capital Investments in the Global IC Industry

Market	1998	1999 Capital Investment	1999 Growth Rate	2000 Capital Investment	2000 Growth Rate	2001 Capital Investment	2001 Growth Rate	2002 Capital Investment	2002 Growth Rate
S. Korea	12.4	19.9	+60.2%	27.9	+41.0%	35.7	+28.1%	42.1	+17.9%
Taiwan	32.3	45.2	+39.9%	62.7	+37.6%	78.7	+24.6%	90.0	+12.5%
Japan	46.6	55.2	+18.4%	76.0	+37.6%	94.7	+24.6%	106.4	+12.5%
N. America	74.9	74.4	-0.5%	100.7	+35.2%	122.6	+21.8%	134.5	+9.7%
Europe	28.3	32.4	+14.2%	42.9	+32.5%	122.6	+21.8%	134.5	+9.7%
Others	20.8	27.9	+34.1%	38.3	+37.5%	48.6	+28.1%	55.6	14.4%

Source: www.computex.com.tw/roundup, 18 February, 2002

3.2 Telecommunications Sector

Taiwan's communication industry has been at a stage of high growth since 1999. Key component technologies for new products in this sector have been gradually perfected. In particular, mobile telephone and wireless broadband receiving products, are seen to bring rapid growth. According to ITIS Survey, the domestic production value of the top ten products reached up to NT$177.67 billion in 2001, up 28.5%

since 2000 (see Table 6). Among the top ten communication products, broadband receiving and wireless products, such as ADSL and WLAN, etc., showed high growth in 2001. The sharp increase, particularly in WLAN products, in combination with the production of mobile phones not only makes wireless products the largest-scale communication sector, but also greatly elevates the production value of communication industry.

Of the top ten products, the mobile phone is the largest value contributor with an annual value of NT$36.76 billion, up 113.7% since 2000, while modems, which held number one in 2000, fell to third place in 2001 due to continued price decreases. The growth rate of modems, with an annual value of production of NT$15.25 billion in 2001, dropped by 41.7% as compared with that in 2000. WLAN achieves a production value of NT$12.1 billion in 2001, up 204% since 2000 and putting it in fifth place. According to estimates of the Information Technology Research Institute (ITRI), Taiwan's WLAN products account for 50-60% of the global market in 2001 and that will grow to 80% by 2005.

Table 6 Taiwan's Top Ten Communication Products

Product	Rank in 2001	Rank in 2000	2000 Production Value (in NT$ 100 million)	2001 Production Value (in NT$ 100 million)	Ratio (2001)	Growth Rate
Mobile Phone	1	2	17.2	367.6	20.7%	113.7%
LAN Switch	2	3	109.3	179.0	10.1%	64.5%
Modem	3	1	261.4	152.5	8.6%	-41.7%
ADSL	4	13	31.6	130.8	7.4%	314.6%
WLAN	5	12	39.8	121.0	6.8%	204.2%
Ethernet Adapters	6	4	106.0	107.2	6.0%	1.1%
Cable Modem	7	5	105.4	90.2	5.1%	-14.4%
Hub	8	6	94.7	80.2	4.5%	-15.3%
Router	9	8	65.0	71.2	4.0%	9.6%
GPS	10	7	93.2	68.9	3.9%	-1.4%
Others			272.6	407.3	22.9%	24.2%
Total			1382.9	1776.7	100%	28.5%

Source: The Retrospect and Prospect of Taiwanese Manufacturing Industry (2001), Industrial Technology Information Service, Taiwan, pp. 89-106.

3.3 PC Sector

Taiwan's global market share for notebook PCs was estimated to reach 56.3% in 2001 with production of around 13 million units. The next nearest manufacturers were Japan and South Korea. The mature manufacturing system cluster for notebook PCs has made Taiwan the major outsourcing production centre for international IT flagships, such as Dell, Hewlett Packard, Compaq, Apple, IBM and eMachines. MIC claim that Taiwanese notebook manufacturers are set to control 60 percent of global notebook market in 2002 due to their production bases in China. As prices of notebook PCs are falling and coming close to those of desktop PCs, more outsourcing production orders will maintain Taiwan's lead in the global market because of excellent cost-down capability of local firms. MIC estimate that Taiwan's annual output of notebook PCs will reach 20.33 million units and hold a market share of 63 percent in 2003.

Table 7 A Comparison of Global Notebook PC Production

Country	1999	2000	2001[e]
Taiwan	48.8%	52.5%	56.3%
Japan	35.2%	33.7%	31.9%
South Korea	1.8%	3.8%	4.2%
Others	15.8%	10%	7.6%

Source: The Retrospect and Prospect of Taiwanese Manufacturing Industry (2001), Industrial Technology Information Service, Taiwan, pp. 107-122

[e]: estimated

The wave of Internet popularity has increased PC demand particularly for the low-priced or free PC model. This trend will boost the production of Taiwan's desktop PCs to more than 28 million units in 2002 according to the MIC market report (Table 8). In addition, the improving global logistics systems of Taiwanese PC companies have prompted local producers to shift assembly closer to end markets (the US and Europe) and to low-cost areas, such as China. Thus, as low-cost PCs lead the growth of the desktop PC market, OEM/ODM sales continue to be the main business for

Taiwan desktop PC makers. Taiwanese PC makers' adeptness in fulfilling orders for low-cost PCs will continue to be their key competitive advantage.

The output of Taiwan's motherboard industry in 2001 was around 81 million units, a drop of 4.5% compared with the 84.37 million produced in 2000. The output value reduced to UD$ 5.6 billion. Taiwan's motherboard producers, in general, have solid R&D ability, large-scale production lines, complete components supply chain and competitive cost and product quality. Therefore, the market share of Taiwanese motherboard producers in the global OEM/ODM market grew from 49% in 1998 to 74% in 2000[7]. However, the majority of motherboard makers now manufacture products in China. ITIS confirms that China's motherboard output exceeded Taiwan's in 2001 although the aggregated domestic and overseas production units by Taiwanese makers still maintain the lead in global share.

Table 8 Taiwan's Notebook PC, Desktop PC and Motherboard Production

Segment	2000		2001[e]		2002[f]	
	Volume (in 1000 units)	Value (in UD$ million)	Volume (in 1000 units)	Value (in UD$ million)	Volume (in 1000 units)	Value (in UD$ million)
Notebook PC	12,707	13,548	12,934	12,078	13,543	11,570
Desktop PC	27,660	7,797	25,829	6,612	28,722	7,209
Motherboard	84,372	5,674	80,566	5,646	85,439	5,625

Source: Taiwan Hardware IT Survey (2001), MIC, Institute for Information Industry
e: estimated, f: forecasted

3.4 Opto-electronic Sector

The top eight segments of Taiwan's opto-electronics industry, by value, were TFT-LCDs, recordable compact disks (CD-Rs), image scanners, read-only memory compact-disk drives, light emitting diodes (LEDs), digital cameras, printers, LCOS projectors. Of all segments, TFT-LCD has the highest growth rate at 273% with an output value of NT$98.1 billion (see Table 9). A recent prediction by the Industrial

7 Source: Asia IT Report (2001), MIC, Institute for Information Industry

Economics and Knowledge Center (IEK) argues that Taiwanese makers of large-size thin TFT-LCD panels will become the third, fourth, and fifth-largest suppliers in the world. They are AU Optronics Corp., Chi-Mei Optoelectronics Corp., and Chunghwa Picture Tubes Ltd., which produce 12.3 %, 11%, and 7.7 % of global TFT-LCD panel supplies respectively. Taiwan is also expected to unseat Japan as the second-largest producer of TFT-LCD panels, in terms of value and volume, as the island's share of the global market grows to 36% by 2002.

Taiwan occupied 57.8 percent of worldwide CD-ROM market with an output of 59 million units in 2000[8]. However, up to 98 percent of this quantity was produced at overseas sites. The production of DVD-ROM did not grow as fast as that of CD-ROM, capturing a global market share of only 4.5 percent. The low growth of this segment was due to the fact that most key components of DVD-ROM are still tightly supplied and controlled by Japanese manufacturers. Local DVD-ROM makers now concentrate resources on the research and development of laser diode, optic pick-up head, micro motor and special application chips in order to build a complete key component supply system. Taiwan exported 3,578 million CD-R disks in 2000 with a global market share of 86.3 percent. ITIS estimate that output of CD-R disks could reach 4,017 million units in 2001, maintaining a share of 86 percent.

Along with the global PC growth, Taiwan scanner makers have produced 25.3 million units of image scanners in 2000 with more than 90 percent of global share. OEM/ODM business is the focus of this segment. Because of low-profit margins, scanner makers have directed R&D resources to the development of Internet-based application models and have moved factories to China in order to further lower manufacturing costs. As optic technologies are quite similar, local big-size scanner

8 Source: The Retrospect and Prospect of Taiwanese Manufacturing Industry (2001), Industrial Technology Information Service, Taiwan, p.45-46

firms have advanced into the research and development of digital camera, multi-platform machine and LCOS projectors.

Taiwan's annual output of digital cameras reached 4 million units in 2000, with 31.5 percent global market share. However, these manufacturers mainly dominate low-end models such as those with less than 1 million pixels. Local firms face a supply problem in that key components come from Japan, such as auto-zoom lens and CCD sensor, and the development of these will decide future growth of this segment.

Table 9 Taiwan's Output of Opto-electronic Industry in 2000

Segment	1999 (in NT$100 million)	2000 (in NT$100 million)	Growth Rate (%)
LCD Display	395	981	273
CD-ROM/DVD-ROM	503	609	21
Image Scanner	399	447	12
CD-R Disk	374	423	13
LED	236	295	25
Digital Camera	123	268	217
Printer	91	154	73
LCOS Projector	56	85	151

Source: The Retrospect and Prospect of Taiwanese Manufacturing Industry (2001), Industrial Technology Information Service, Taiwan, p.44

3.4 Software Sector

Taiwan's domestic market for the software industry was NT$152.2 billion in 2001 (Table 10). It is estimated that an aggregated 28.2% growth rate would be expected in 2002 with an output value of NT$195.1 billion. Of the three segments, the service segment (i.e., networking and processing services) was estimated to have a high growth rate, at 48 percent. This was primarily a result of the improvement of B-to-C environments, the entrance of more application service providers (ASP), and the coming of low-priced and broadband services. This high growth is expected to continue for the next few years.

The software product segment (i.e., packaged software and turnkey system) is expected to have a relatively low growth rate of 18% in 2002 as e-commerce gradually replaces the traditional channel of packaged software. However, of the three segments, the packaged software remains the dominant export item, representing 86% of total software export sales revenue in 2001, with a value of NT$ 87 million. Of this, 41% was contributed by anti-virus software. The rest was contributed by multi-media software and font-generating software[9]. Some multinational companies, such as Cisco System, Intel and Computer Associates are now forging alliances with the Taiwanese government and local leading software firms. Most are focusing on Chinese language related software projects in order to penetrate the Asian regional markets for both commercial and e-commerce service software.

The project segment (i.e., system integration and professional services) is expected to achieve a 29% growth rate in 2002. The services of this segment mainly limits in the domestic market. The export of software-related projects and services is dependent upon customers' requirements for particular system developments, which usually involves a large amount of labour hours. Taiwan's software companies, to some extent, are not as competitive as countries such as China and India in this segment.

Table 10 Taiwan's 1997-2001 Software Market (unit: NT$ million) and Growth Rate

Segment	1997	1998	1999	2000	2001(e)	2002-2001 (Growth %)
Network Service & Processing service (Service Segment)	9,576	14,291	19,781	28,089	41,571	48%
System integration & Professional service (Project Segment)	19,646	20,213	26,816	33,520	43,240	29%
Packaged software & Turn-key system (Product Segment)	28,596	38,887	48,840	57,119	67,400	18%
Total	57,818	73,391	95,437	118,728	152,212	28.2%

Source: The Retrospect and Prospect of Taiwanese Manufacturing Industry (2001), Industrial Technology Information Service, Taiwan, p.133

[9] Source: The Retrospect and Prospect of Taiwanese Manufacturing Industry (2001), Industrial Technology Information Service, Taiwan, pp. 123-150

4 Summary

The OEM/ODM business model characterises the Taiwanese IT industry. The low priced PC theme has created opportunities that make Taiwan one of the top three IT hardware producers. Major brand players continue their outsourcing practices with Taiwan. On the one hand, these OEM/ODM arrangements stimulate the growth of Taiwan's IT industry. On the other hand, Taiwan's increasing reliance upon these companies will increase the risk of being tied to the ups and downs of these partners. Taiwanese IT firms are often confronted a severe choice once these brand players have a dominant market share. Therefore, it is critical that Taiwanese IT firms, in addition to continuously slashing costs, examine whether this OEM/ODM relationship has developed at the expense of their businesses' flexibility and competence.

Although Taiwanese IT firms dominate major IT hardware production, they still cannot capitalise upon the profit from software application, product marketing or unique product design. Facing the shift from quantity to quality in the IT industry and to cope with future challenges, Taiwanese IT firms should focus on renovating manufacturing and marketing practices as well as restructuring product positioning and channel strategies.

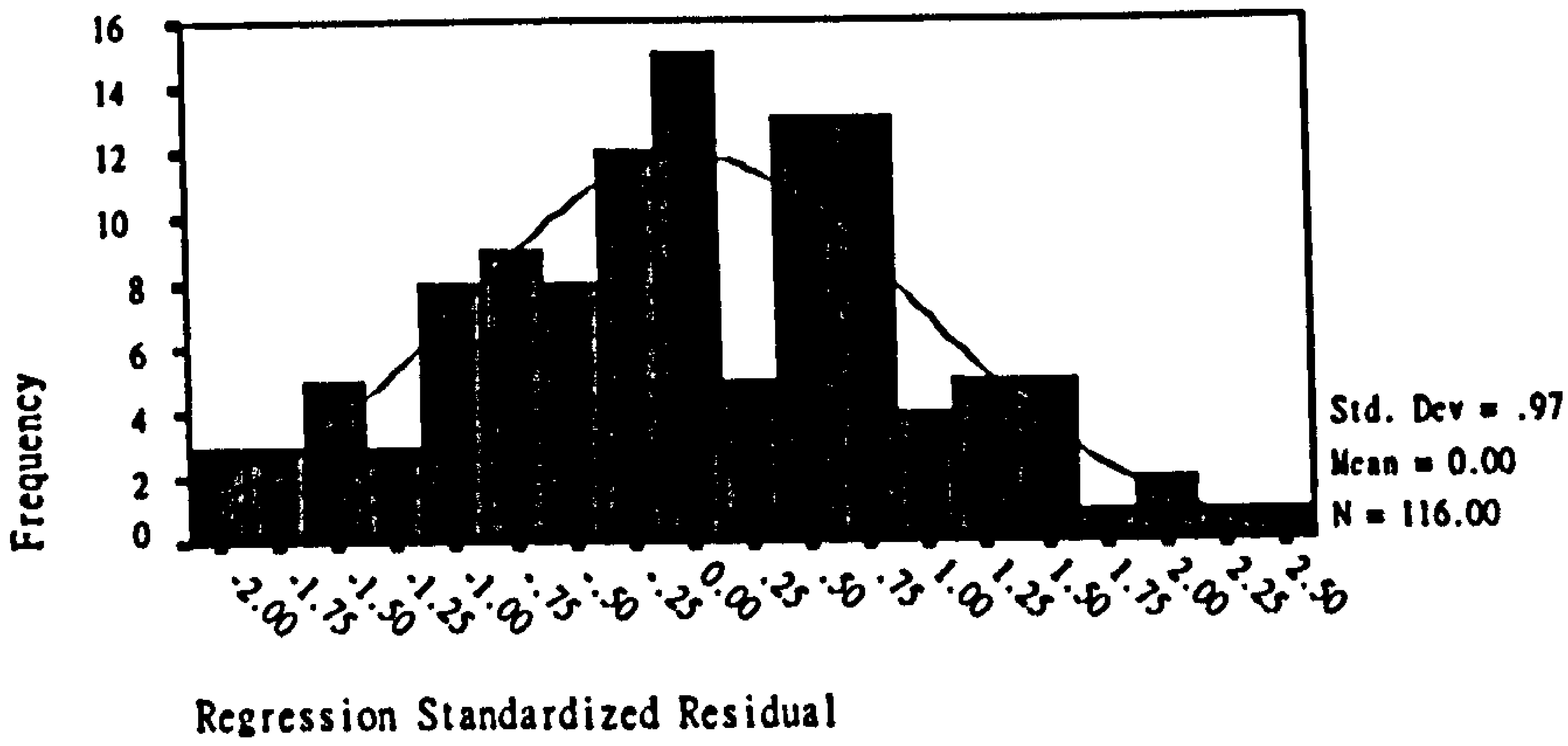
Most Taiwanese IT firms have taken the advantage of international divisions of labour by deploying manufacturing sites in China, which further strengthen their competitive edge in global OEM/ODM business. These practices also enable Taiwanese IT firms to develop their own channels or brands in the Chinese market. With the scale economy of this market, it may be that Taiwanese firms could begin to practice and develop their own brand marketing skills before taking the full step into global marketing.

Appendix C

Residual Plots for Regression Equations

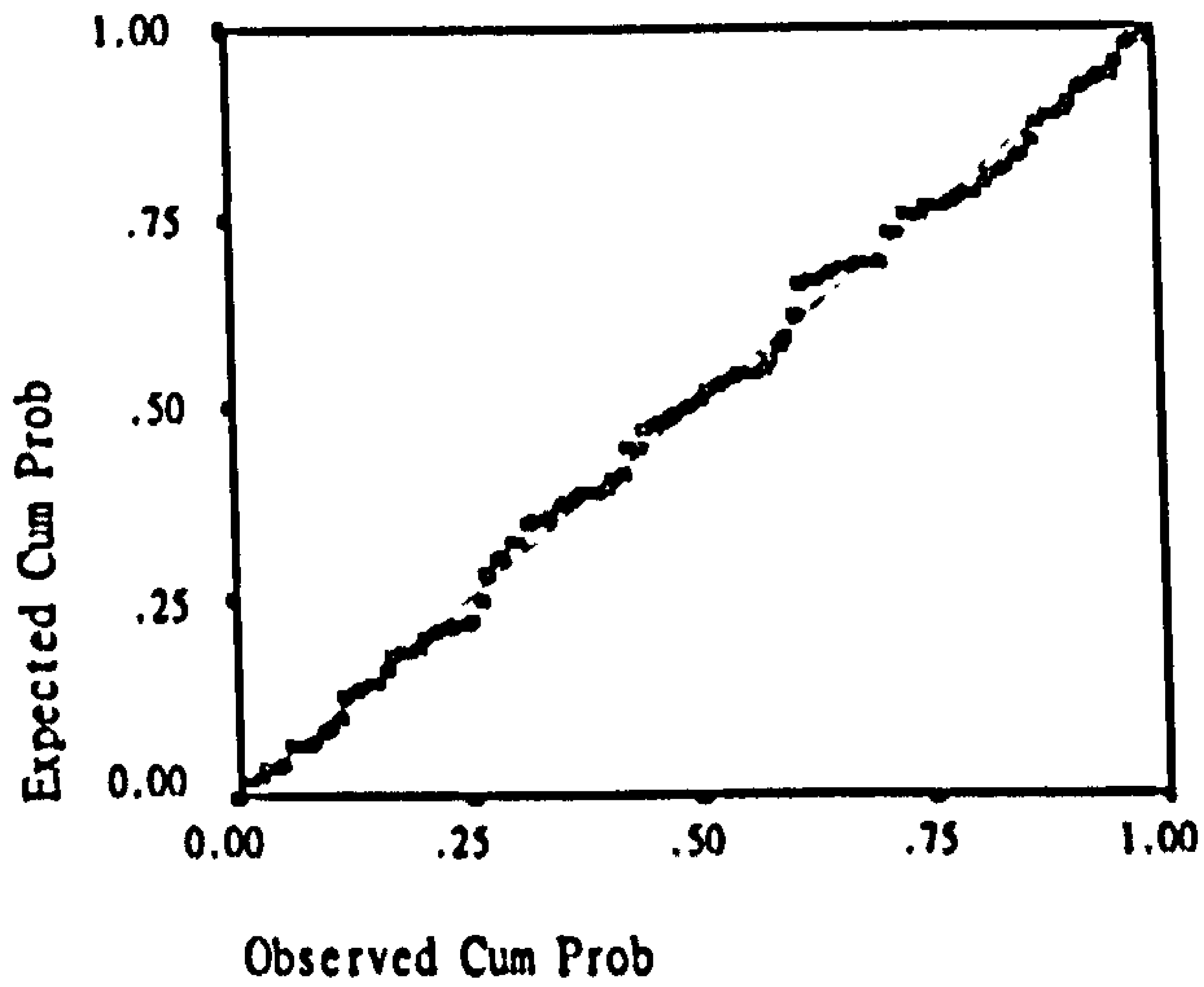
Histogram Of Residuals

Dependent Variable: R&D Knowledge



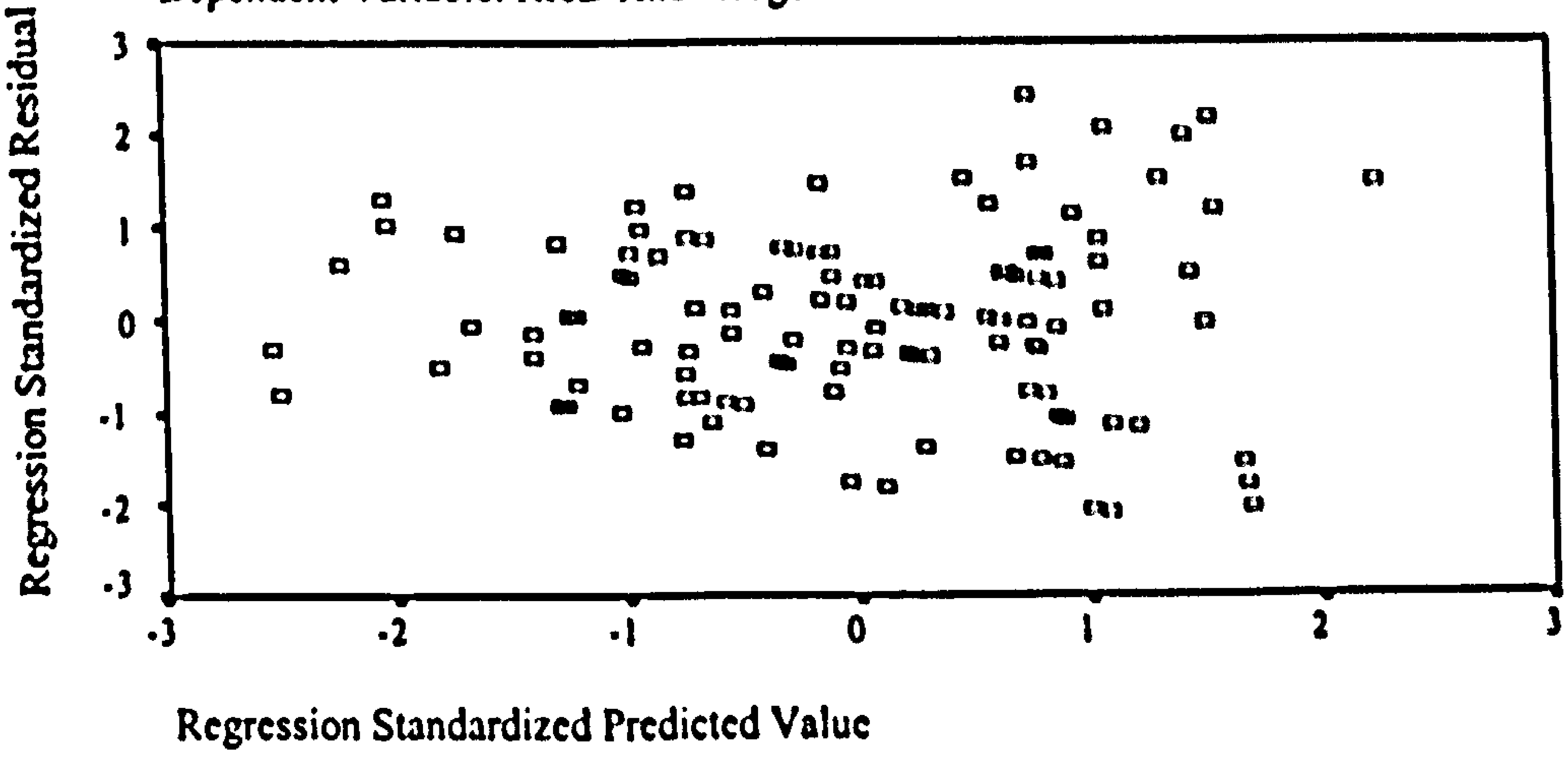
Normal P-P Plot of StandardizedResidual

Dependent Variable: R&D Knowledge



Scatterplot

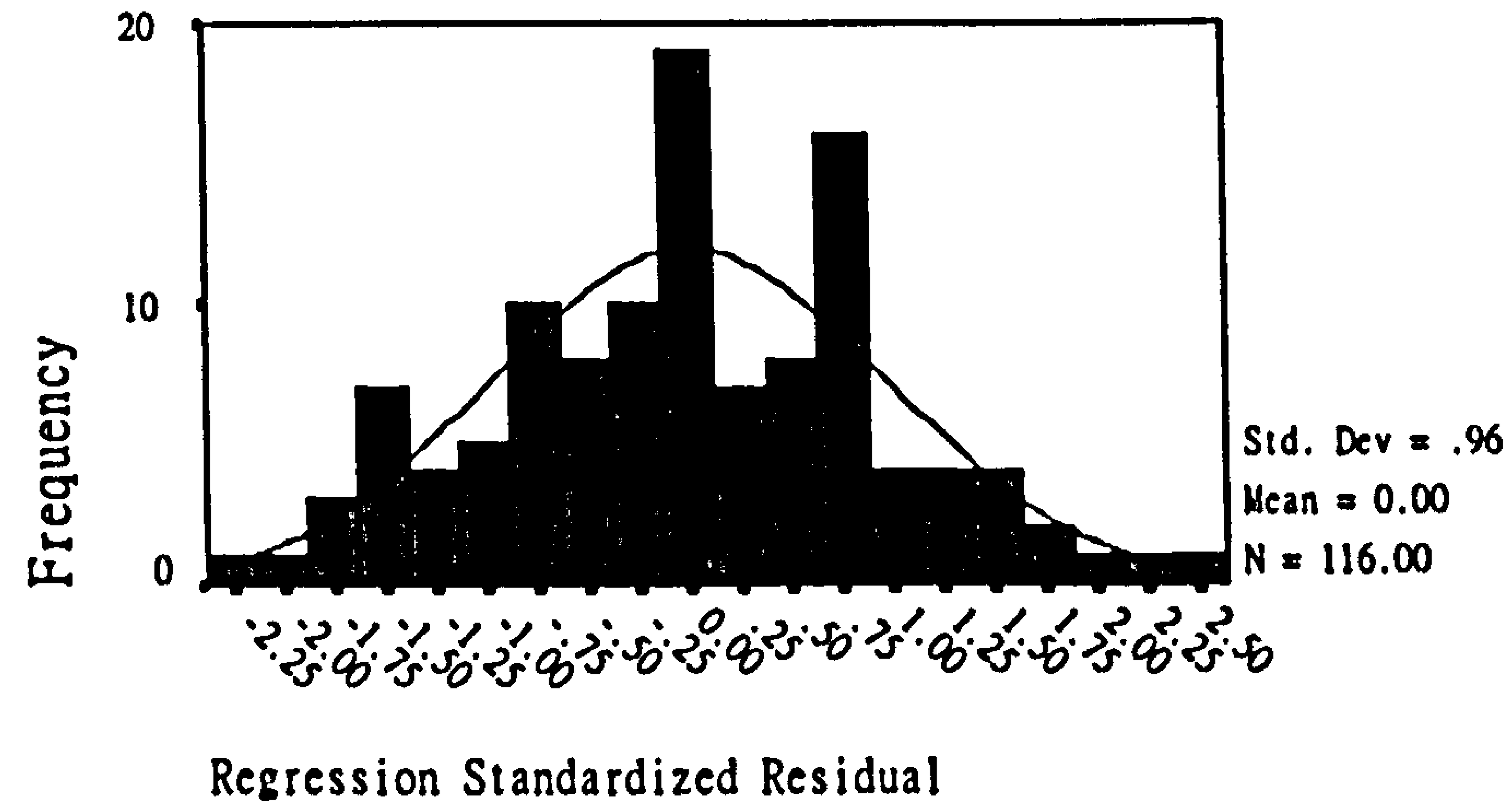
Dependent Variable: R&D Knowledge



Regression Model 1-1 of Table 6.4.2

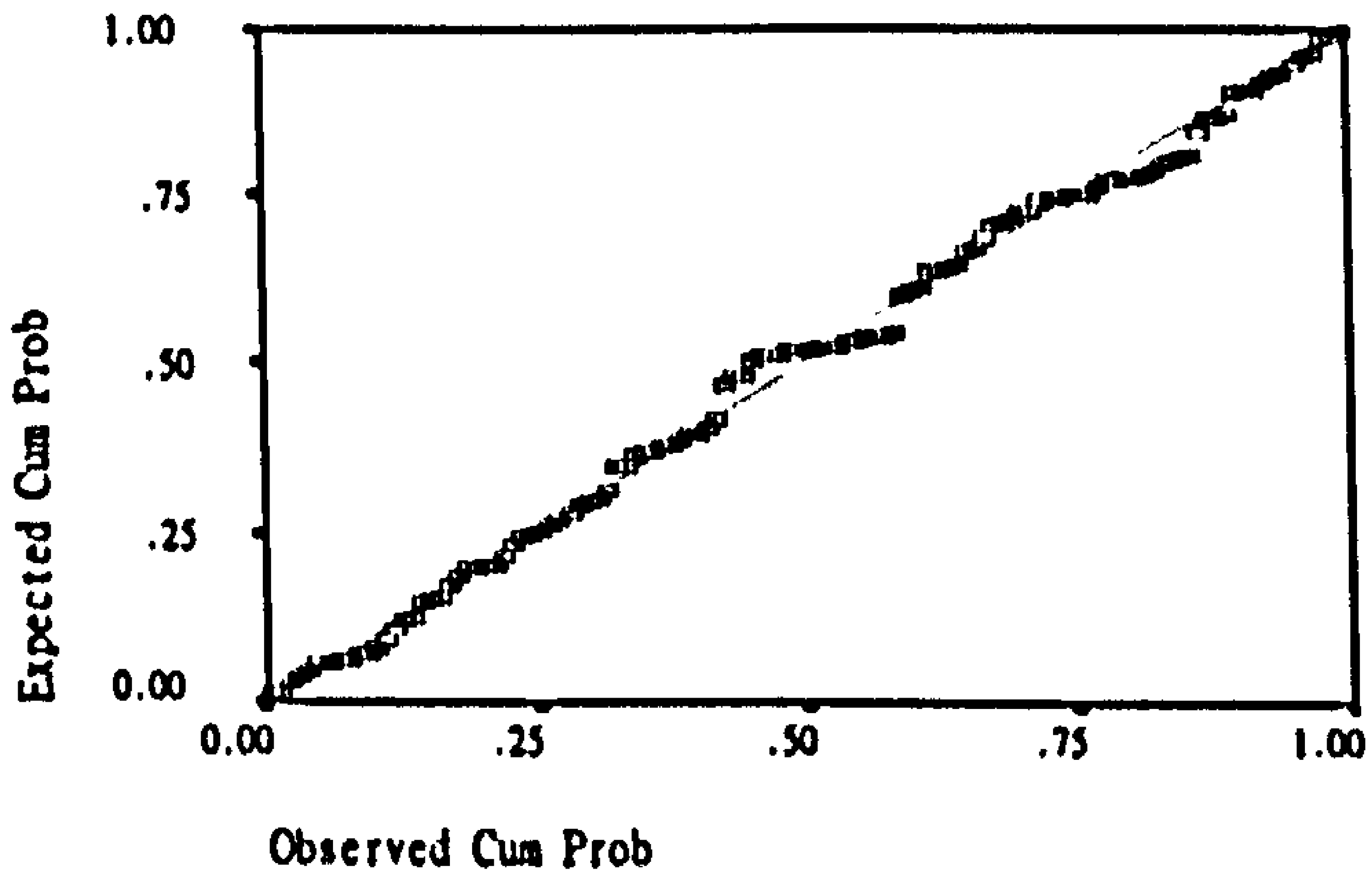
Histogram of Residuals

Dependent Variable: R&D Knowledge



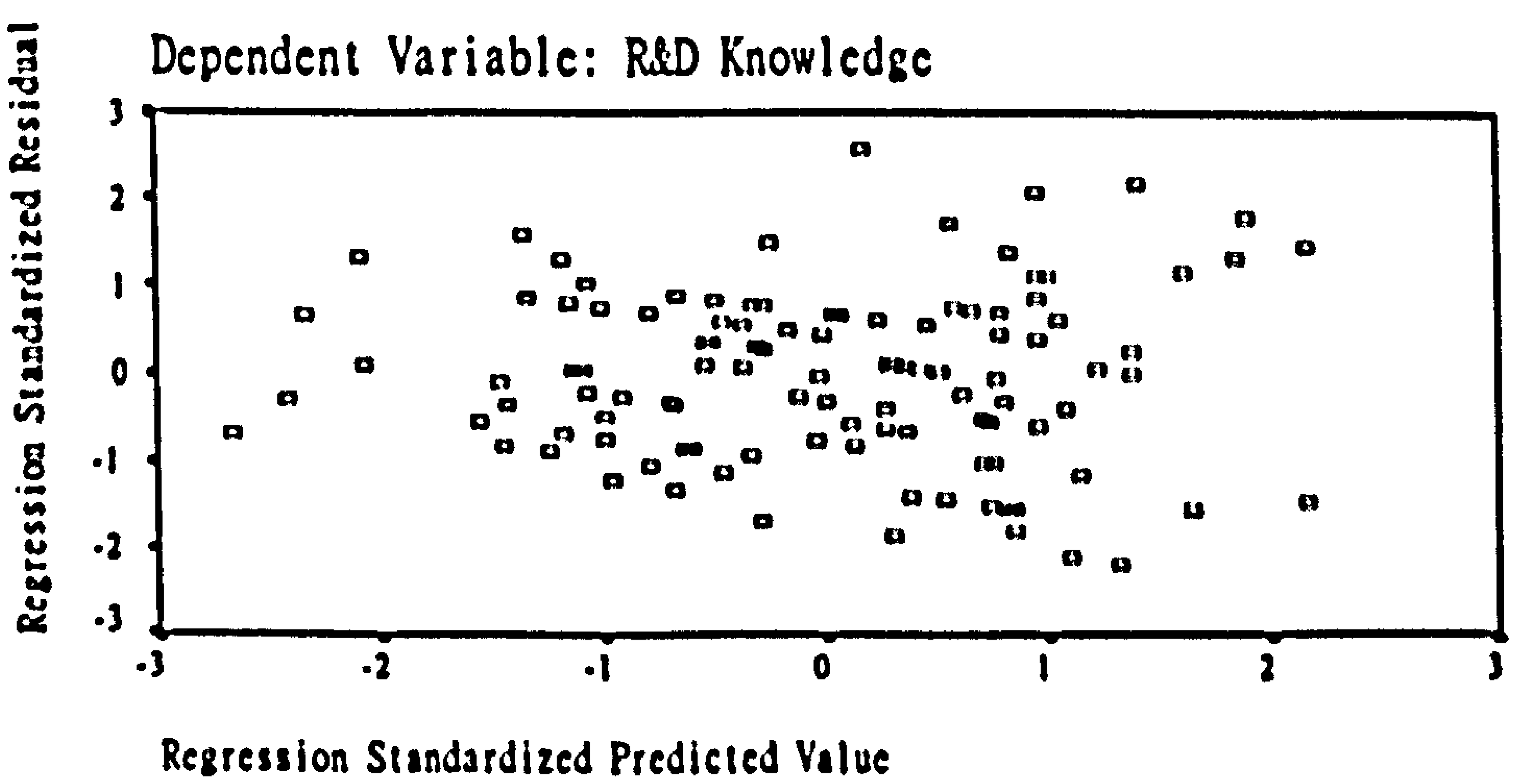
Mormal P-P Plots of Standardized Residual

Dependent Variable: R&D Knowledge



Scatterplot

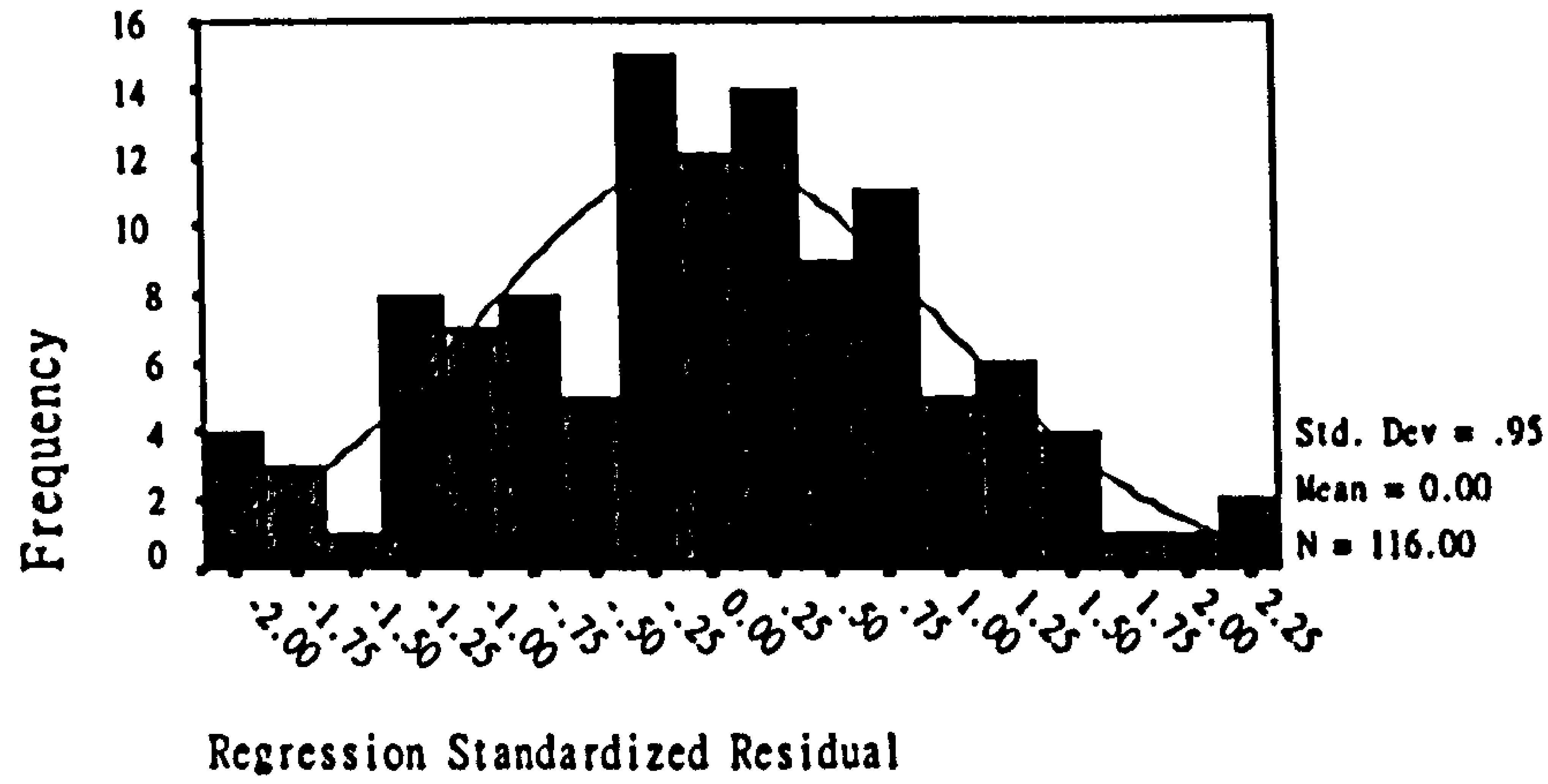
Dependent Variable: R&D Knowledge



Regression Model 1-2 of Table 6.4.2

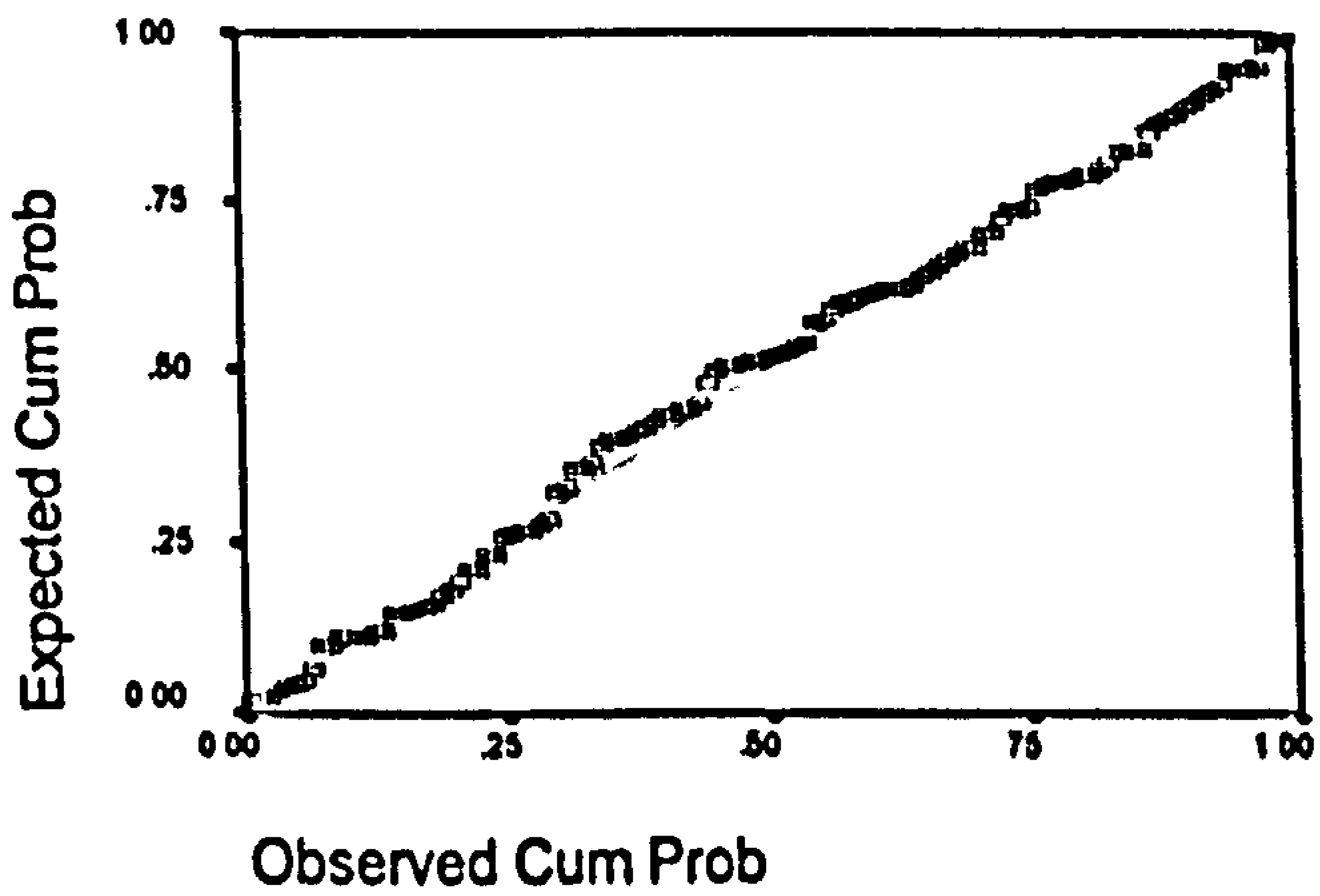
Histogram of Residuals

Dependent Variable: R&D Knowledge



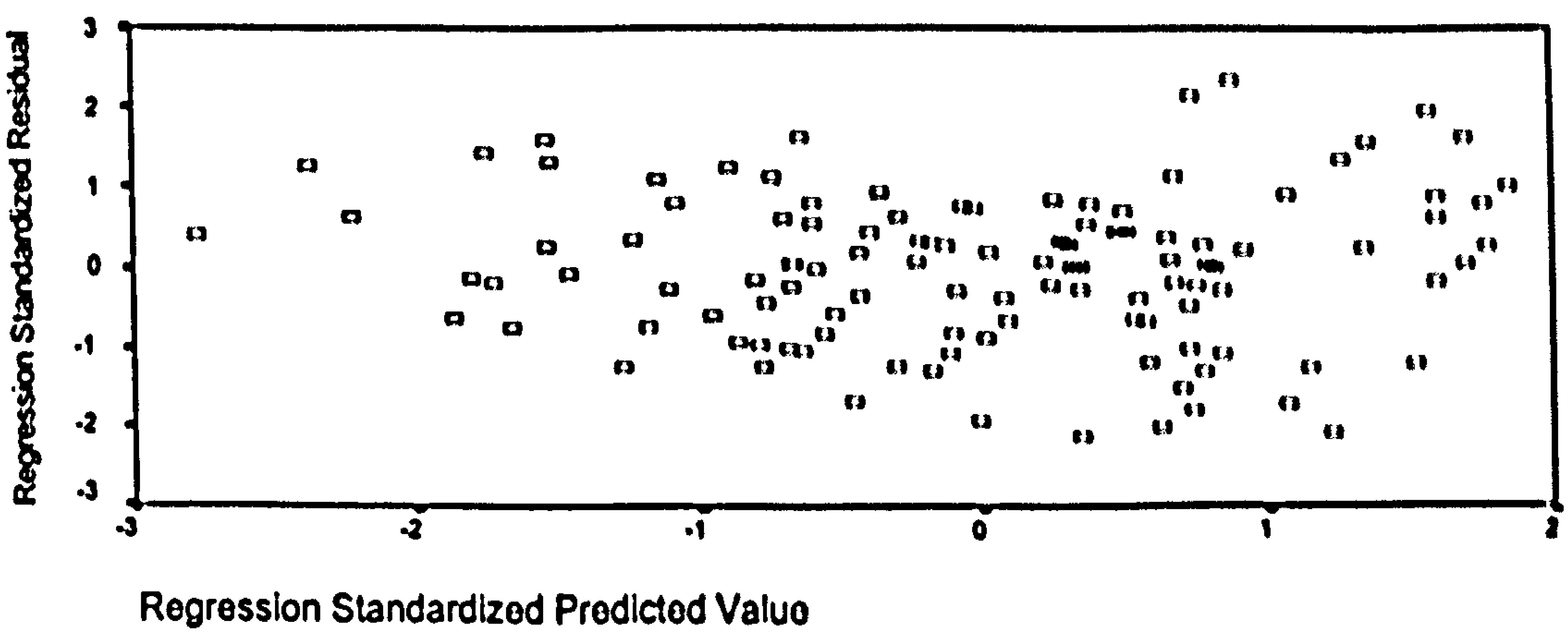
Normal P-P Plot of Standardized Residual

Dependent Variable: R&D Knowledge



Scatterplot

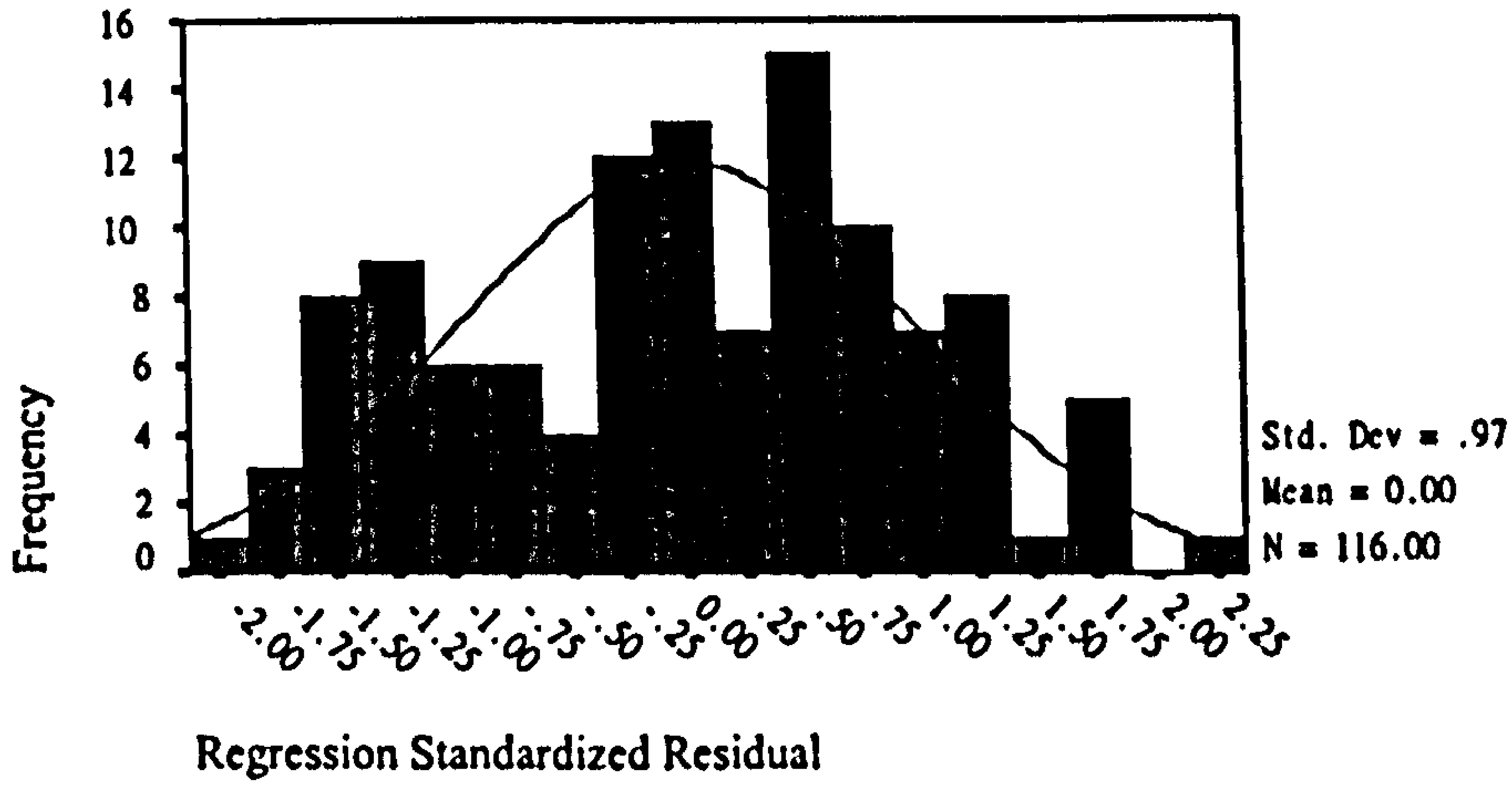
Dependent Variable: R&D Knowlodgo



Regression Model 1-3 of Table 6.4.2

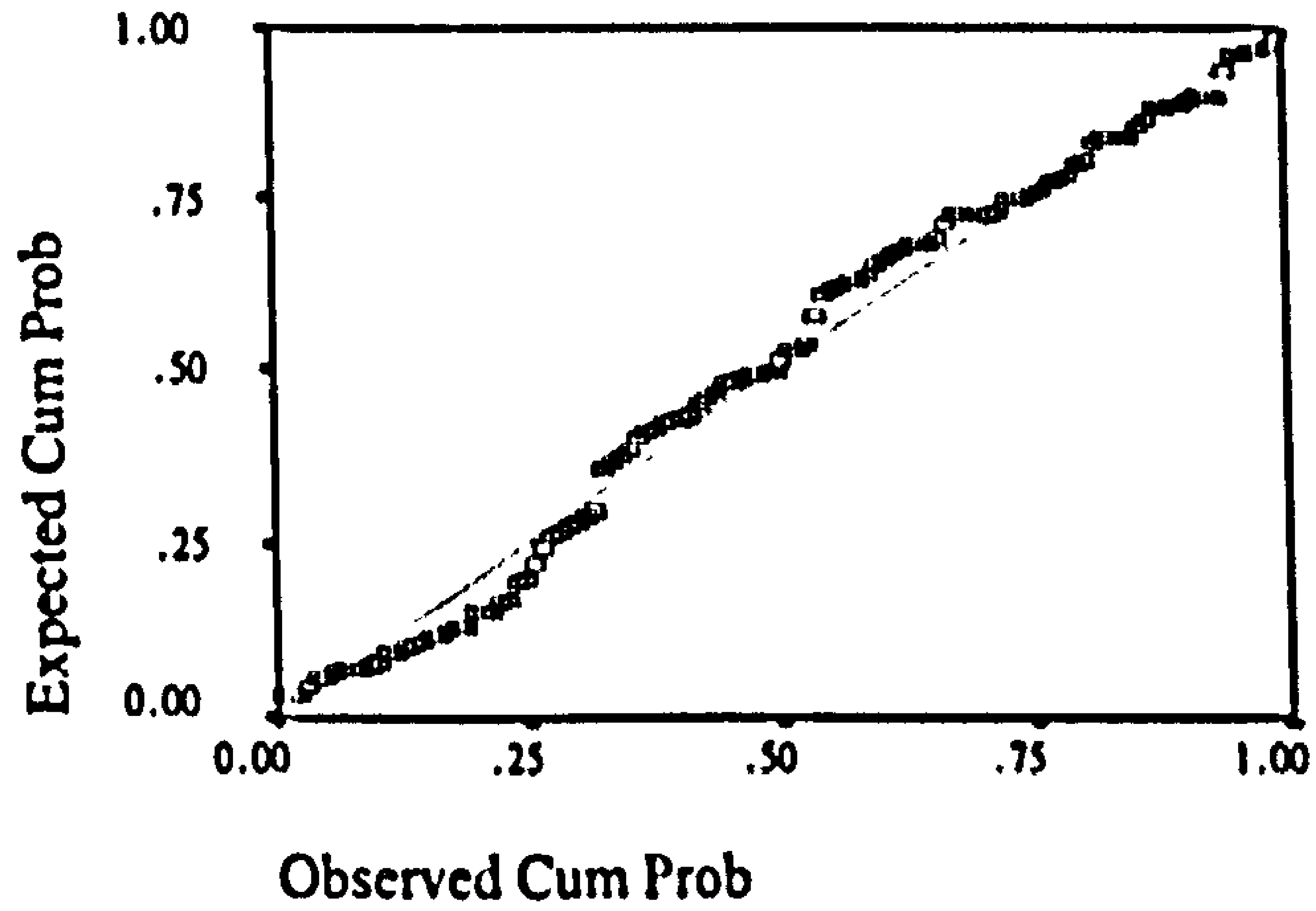
Histogram of Residuals

Dependent Variable: Manufacturing Knowledge



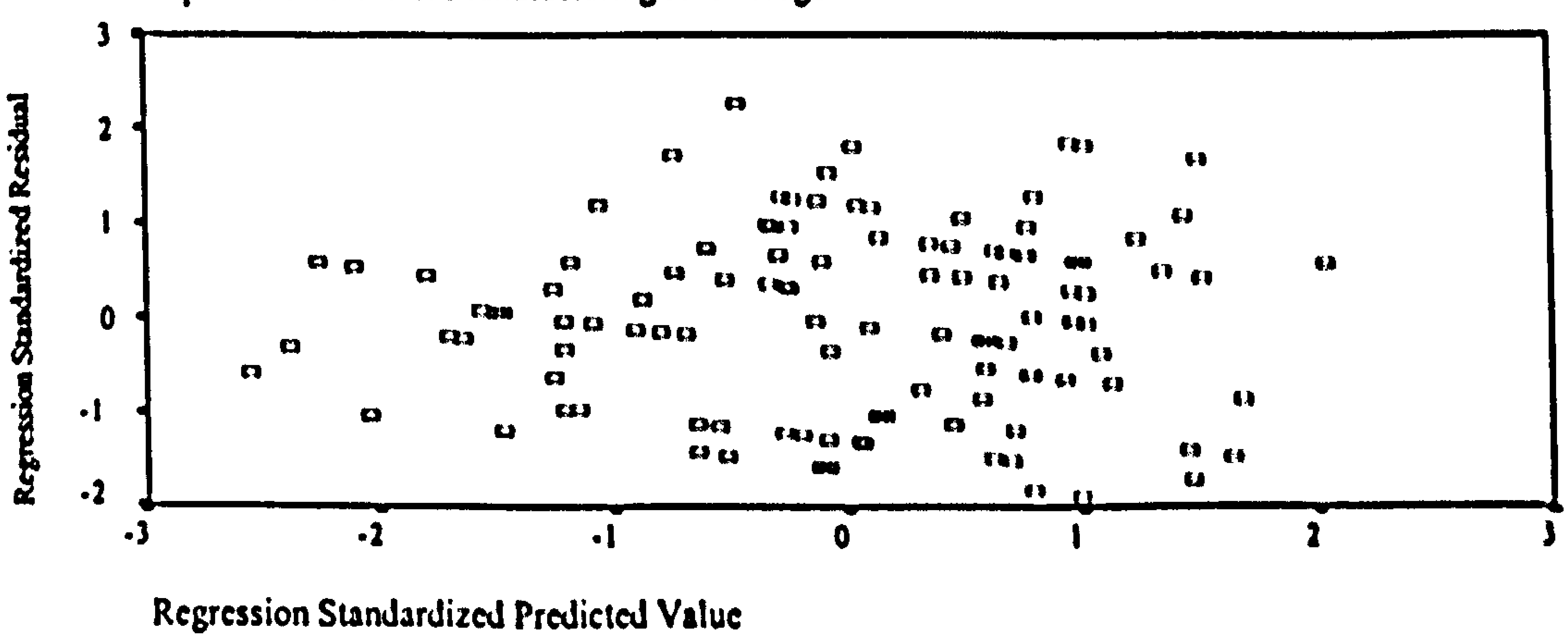
Normal P-P Plot of Standardized Residual

Dependent Variable: Manufacturing Knowledge



Scatterplot

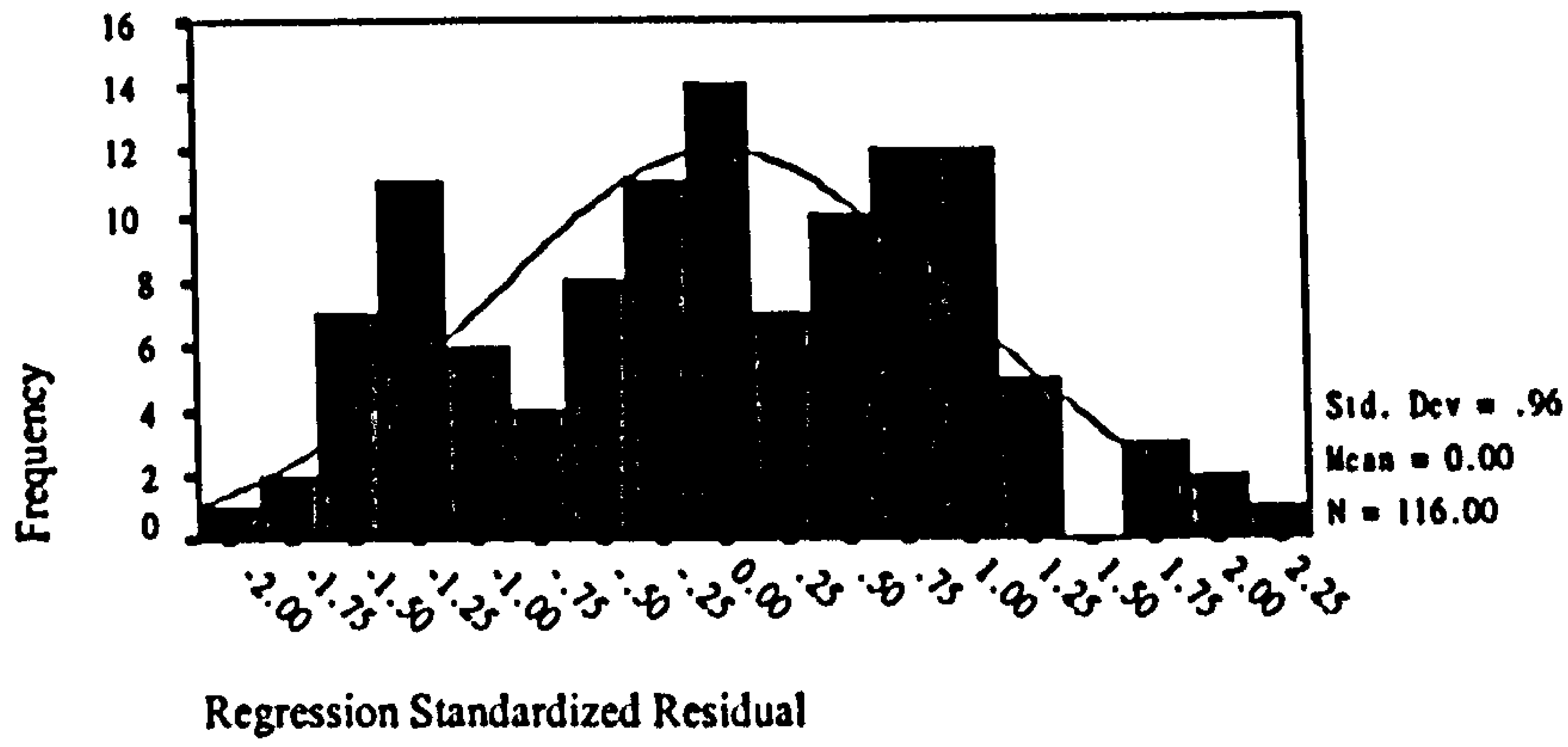
Dependent Variable: Manufacturing Knowledge



Regression Model 2-1 of Table 6.4.2

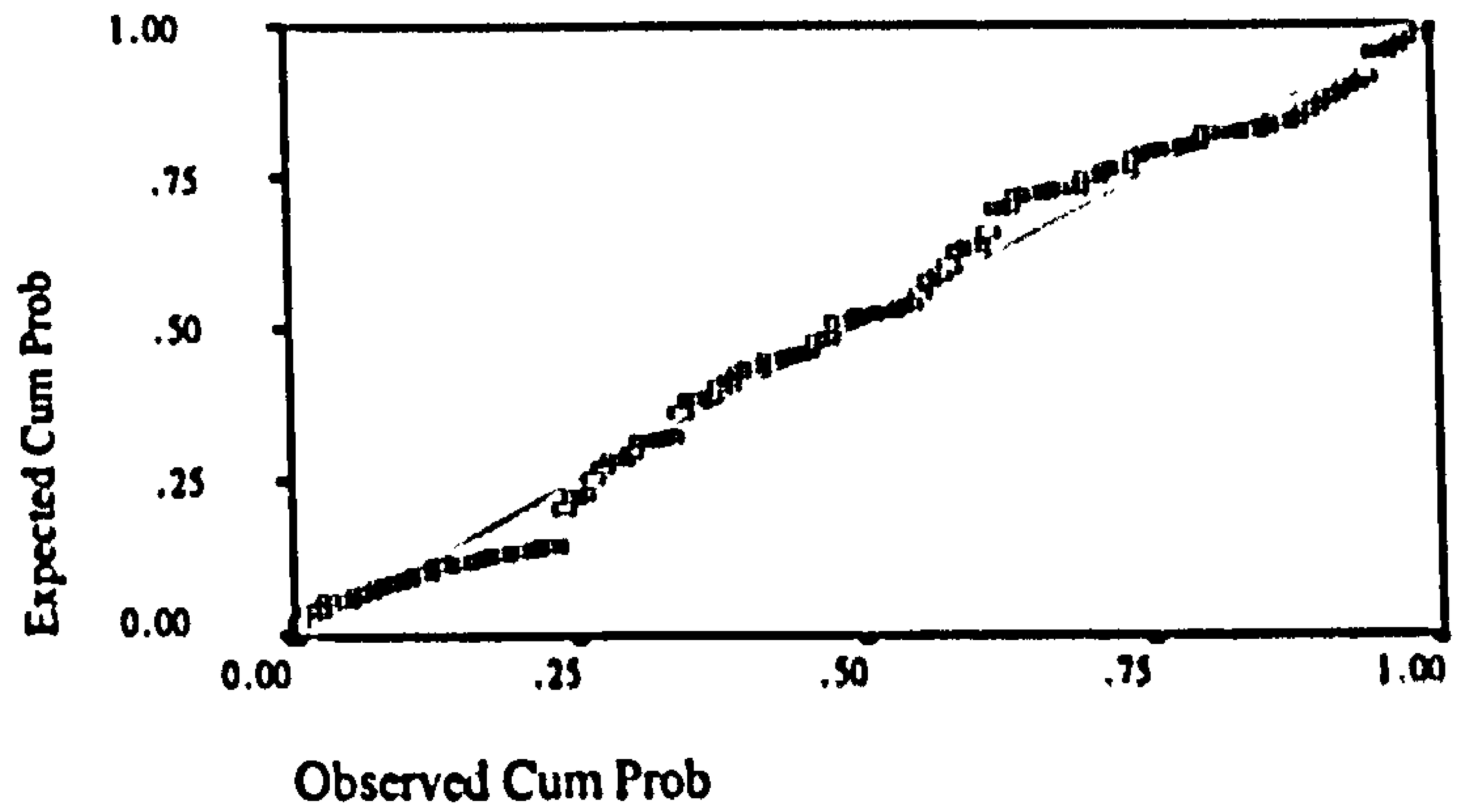
Histogram of Residuals

Dependent Variable: Manufacturing Knowledge



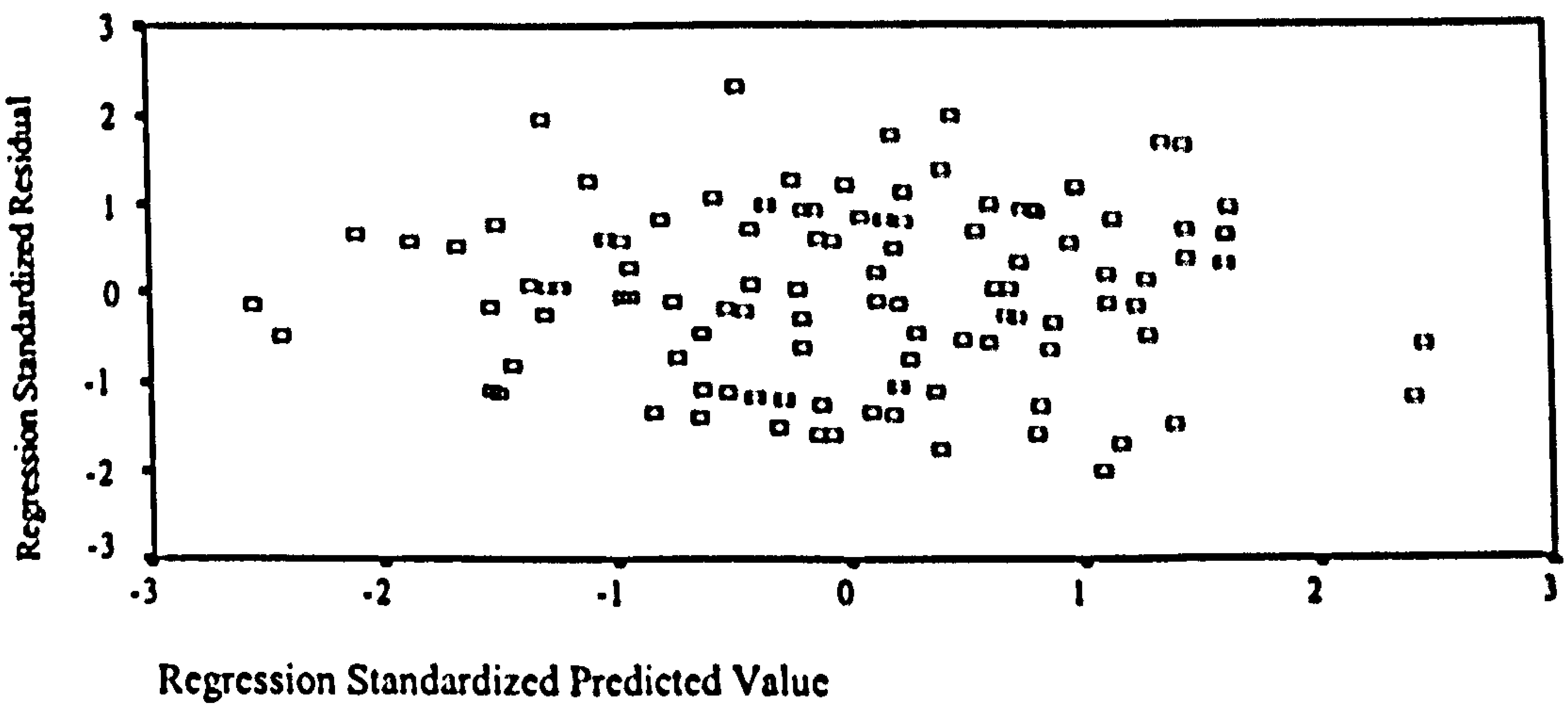
Normal P-P Plot of Standardized Residual

Dependent Variable: Manufacturing Knowledge



Scatterplot

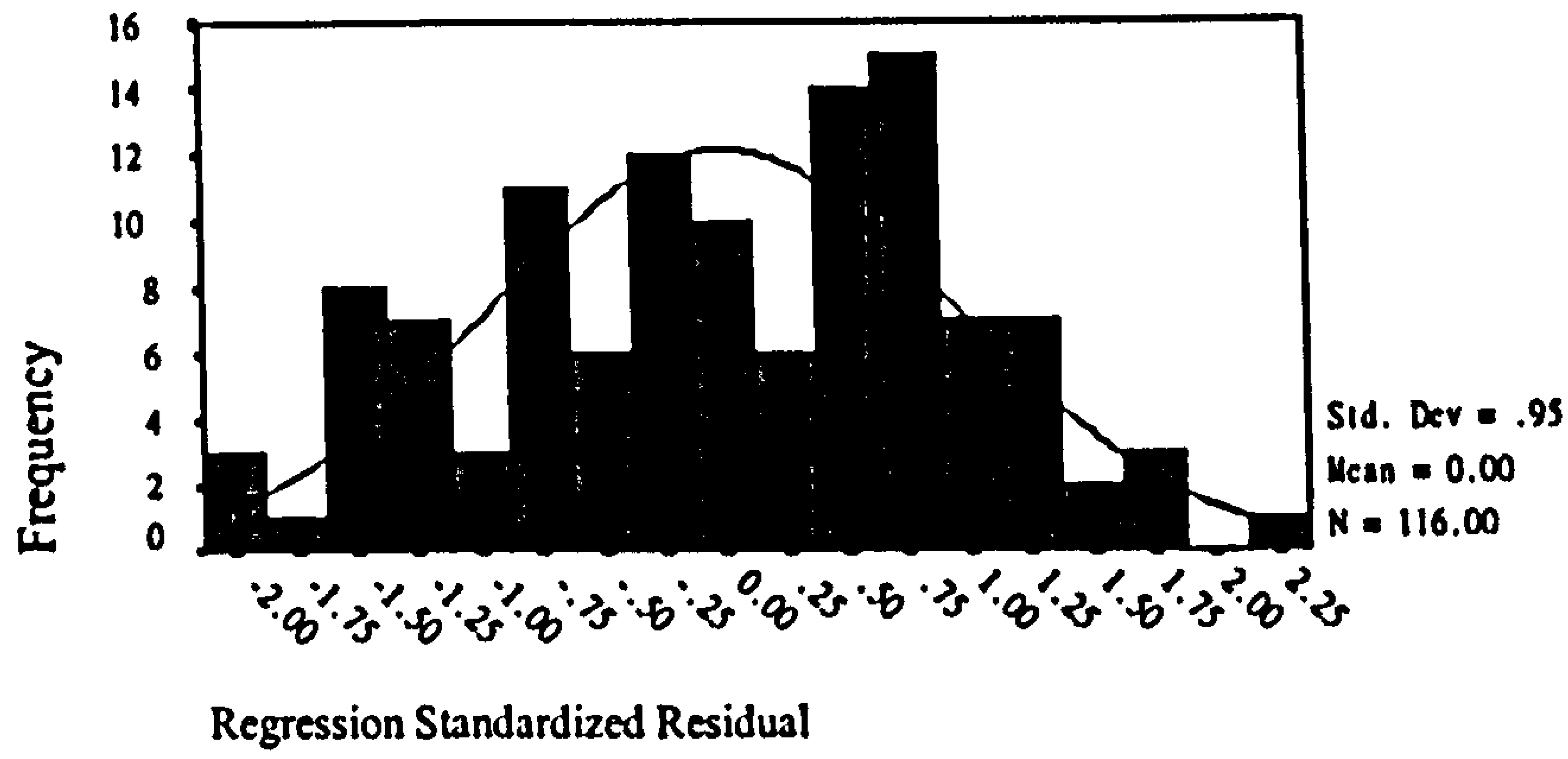
Dependent Variable: Manufacturing Knowledge



Regression Model 2-2 of Table 6.4.2

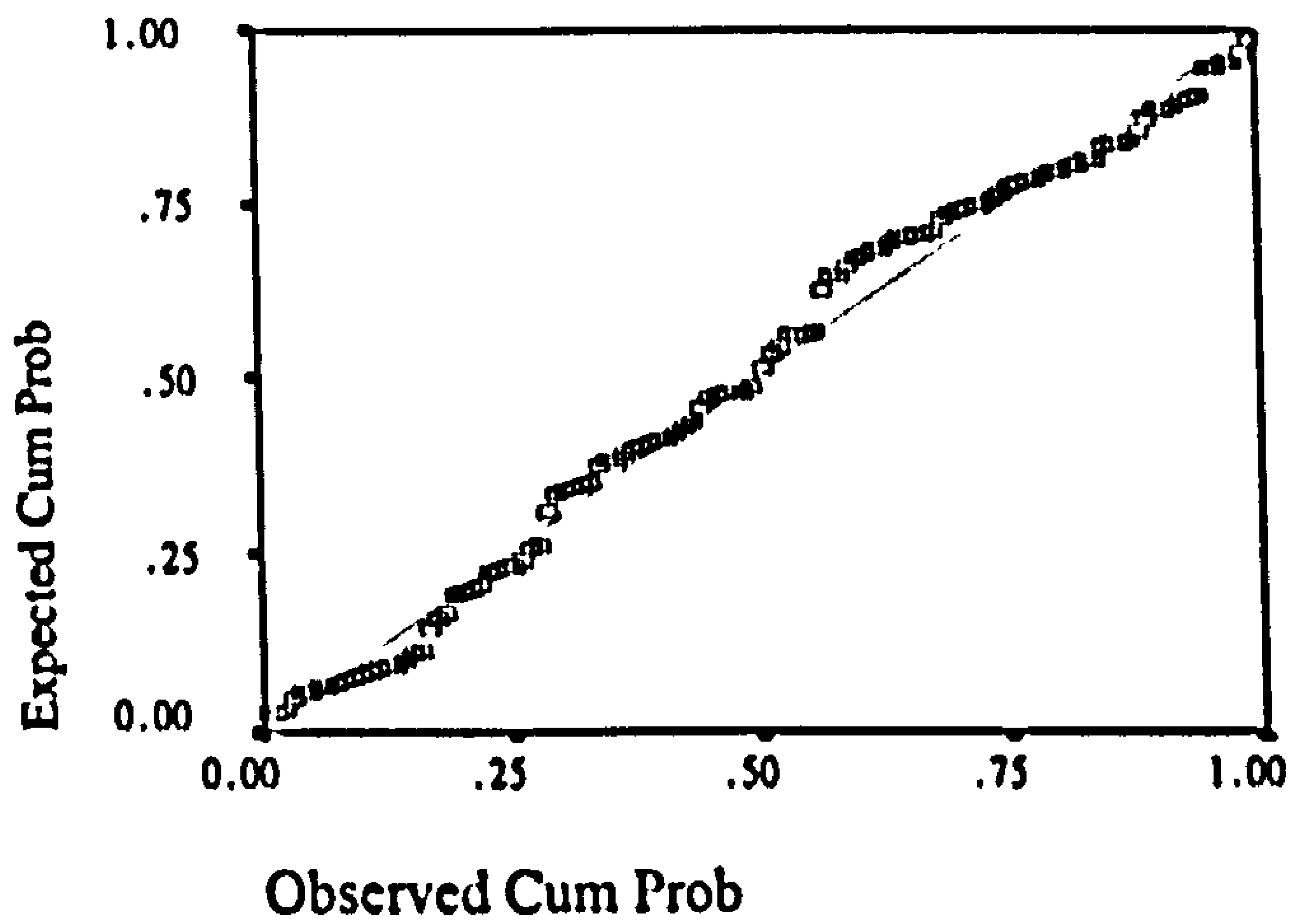
Histogram of Residuals

Dependent Variable: Manufacturing Knowledge



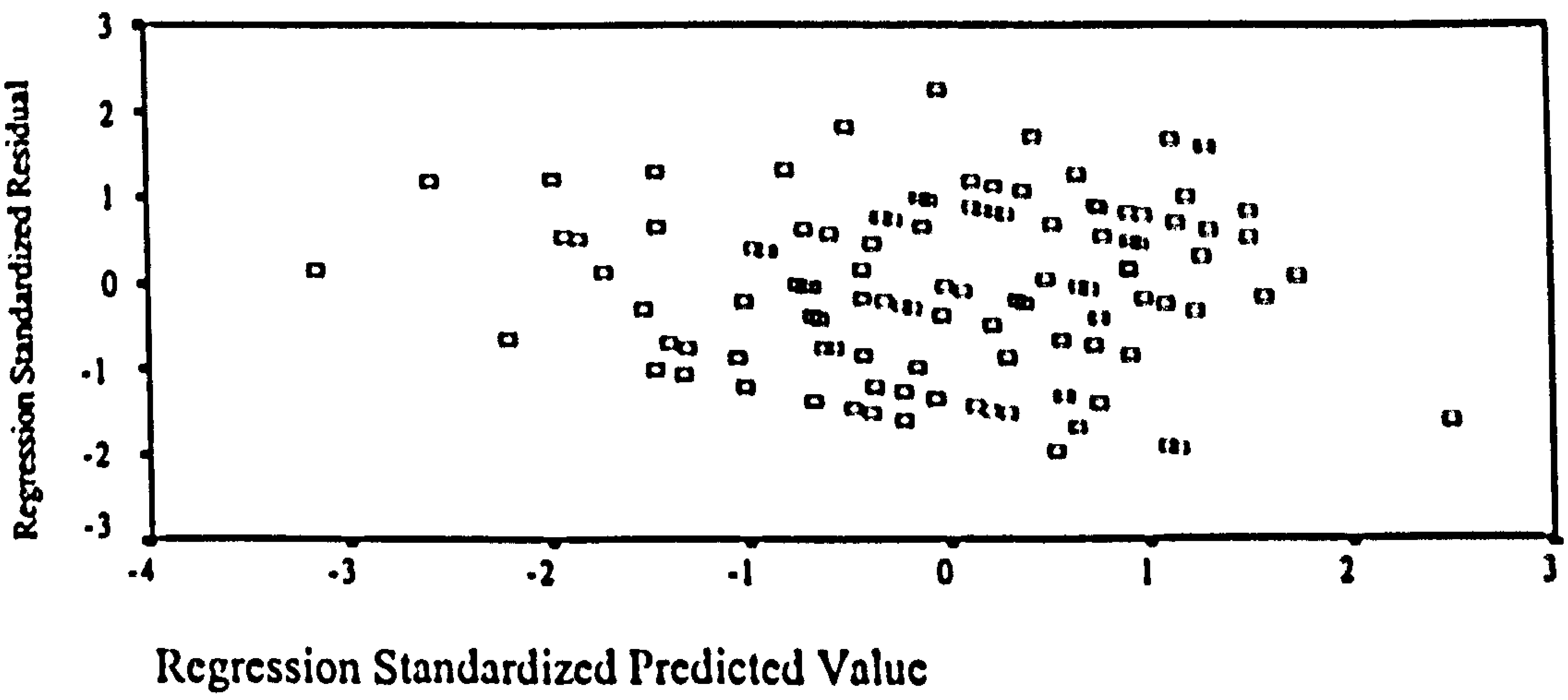
Normal P-P Plot of Standardized Residual

Dependent Variable: Manufacturing Knowledge



Scatterplot

Dependent Variable: Manufacturing Knowledge

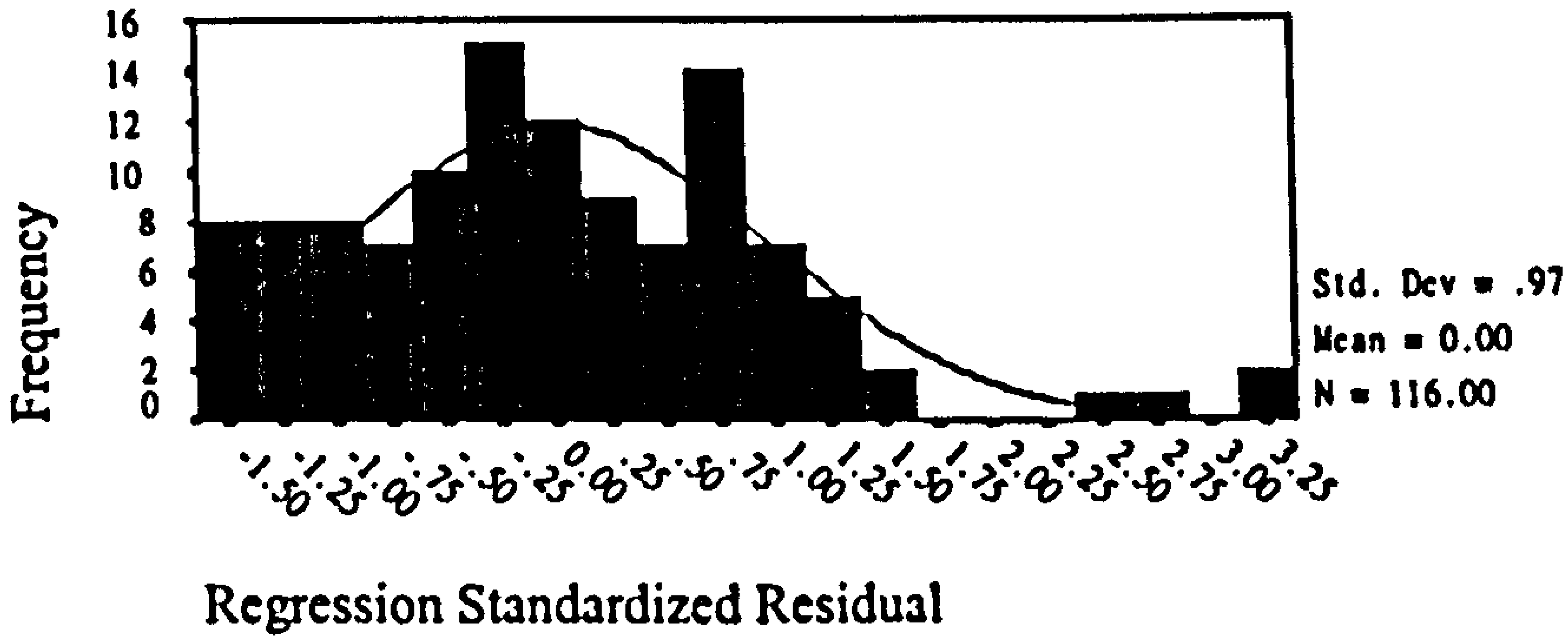


Regression Model 2-3 of Table 6.4.2

Histogram of Residuals

Dependent Variable:

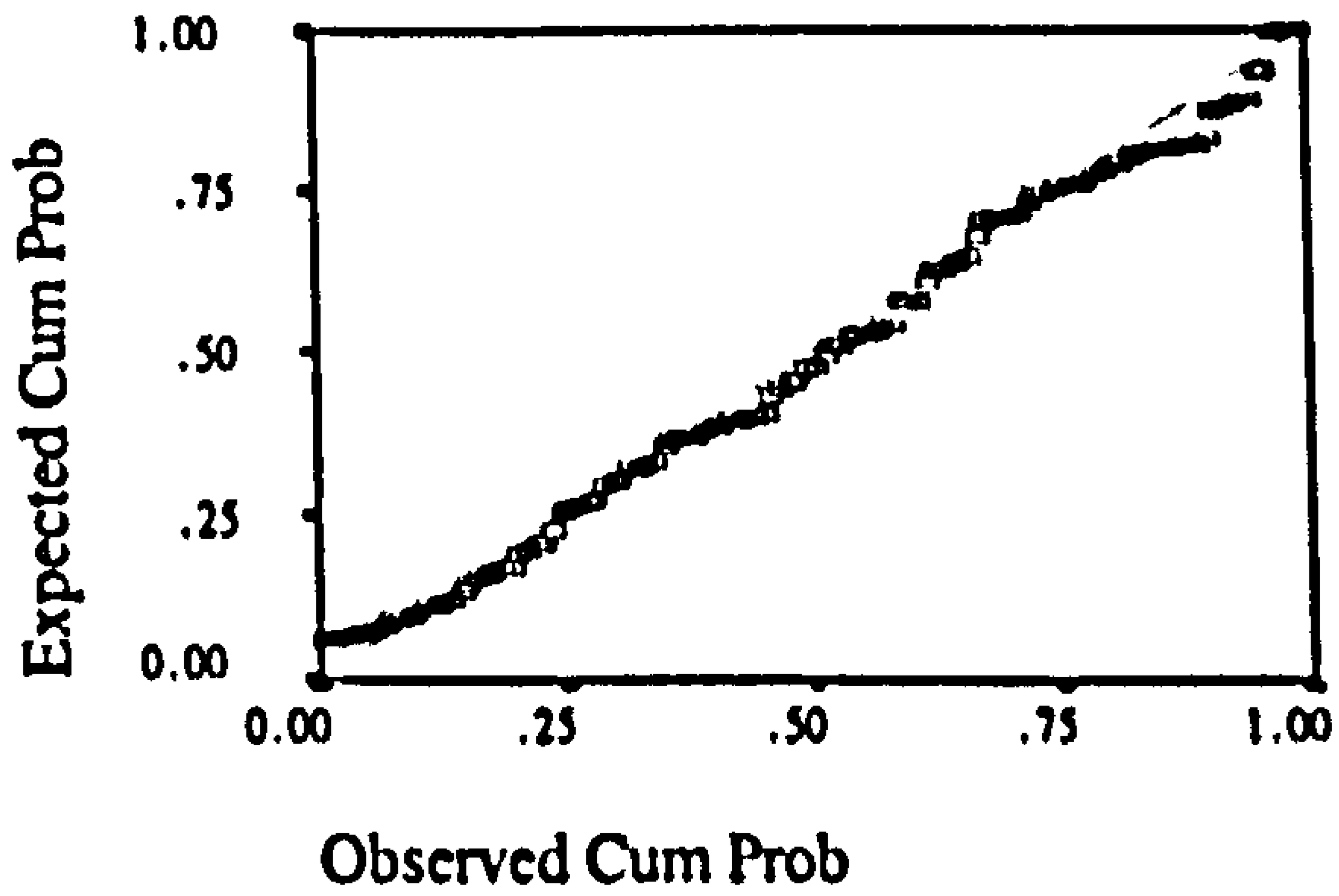
Pre-development Assessment Knowledge



Normal P-P Plot of Standardized Residual

Dependent Variable:

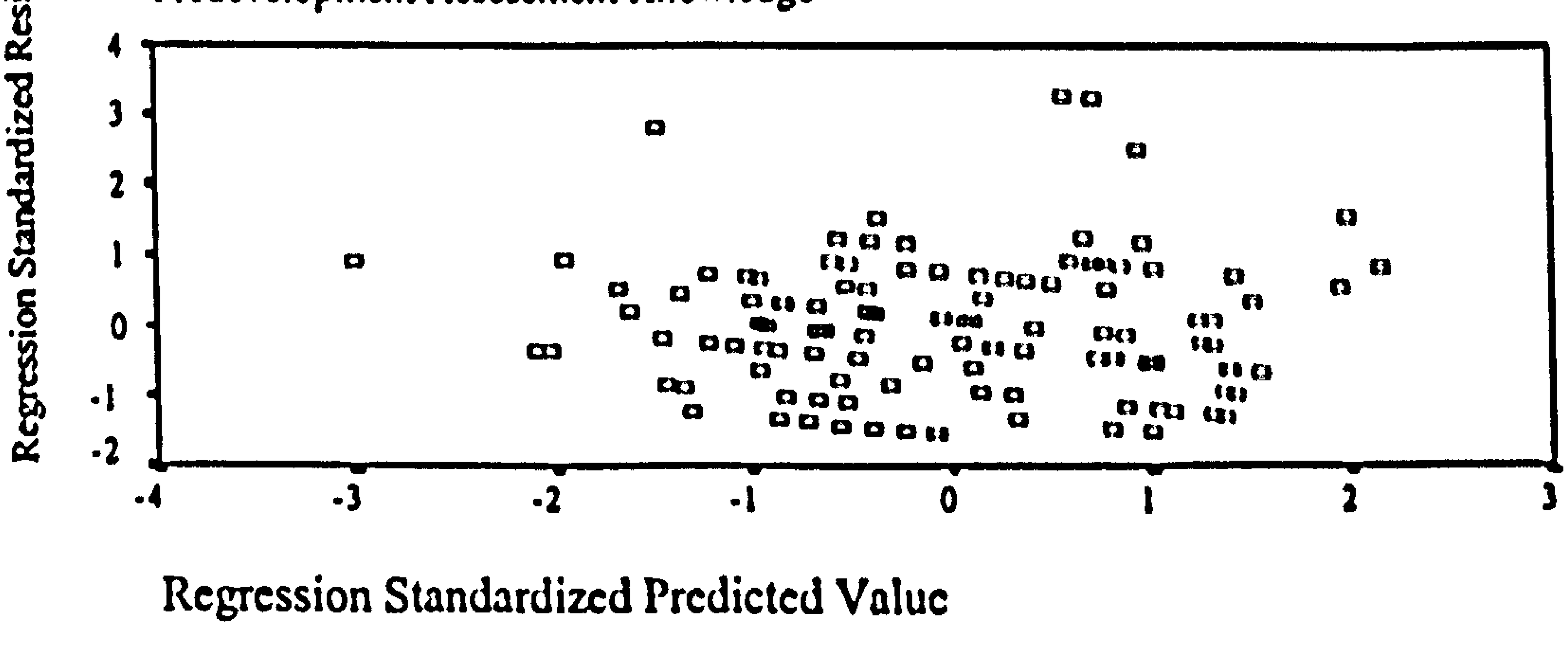
Pre-development Assessment Knowledge



Scatterplot

Dependent Variable:

Predevelopment Assessment Knowledge

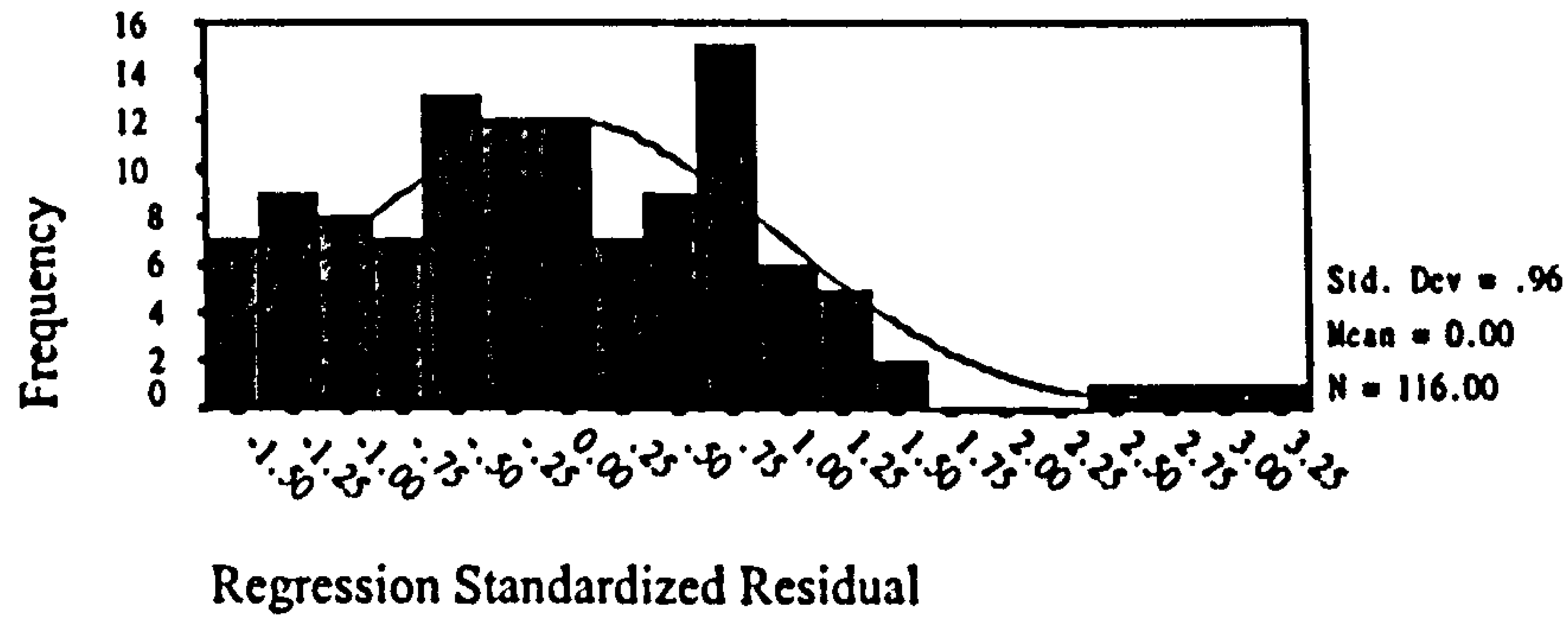


Regression Model 3-1 of Table 6.4.3

Histogram of Residuals

Dependent Variable:

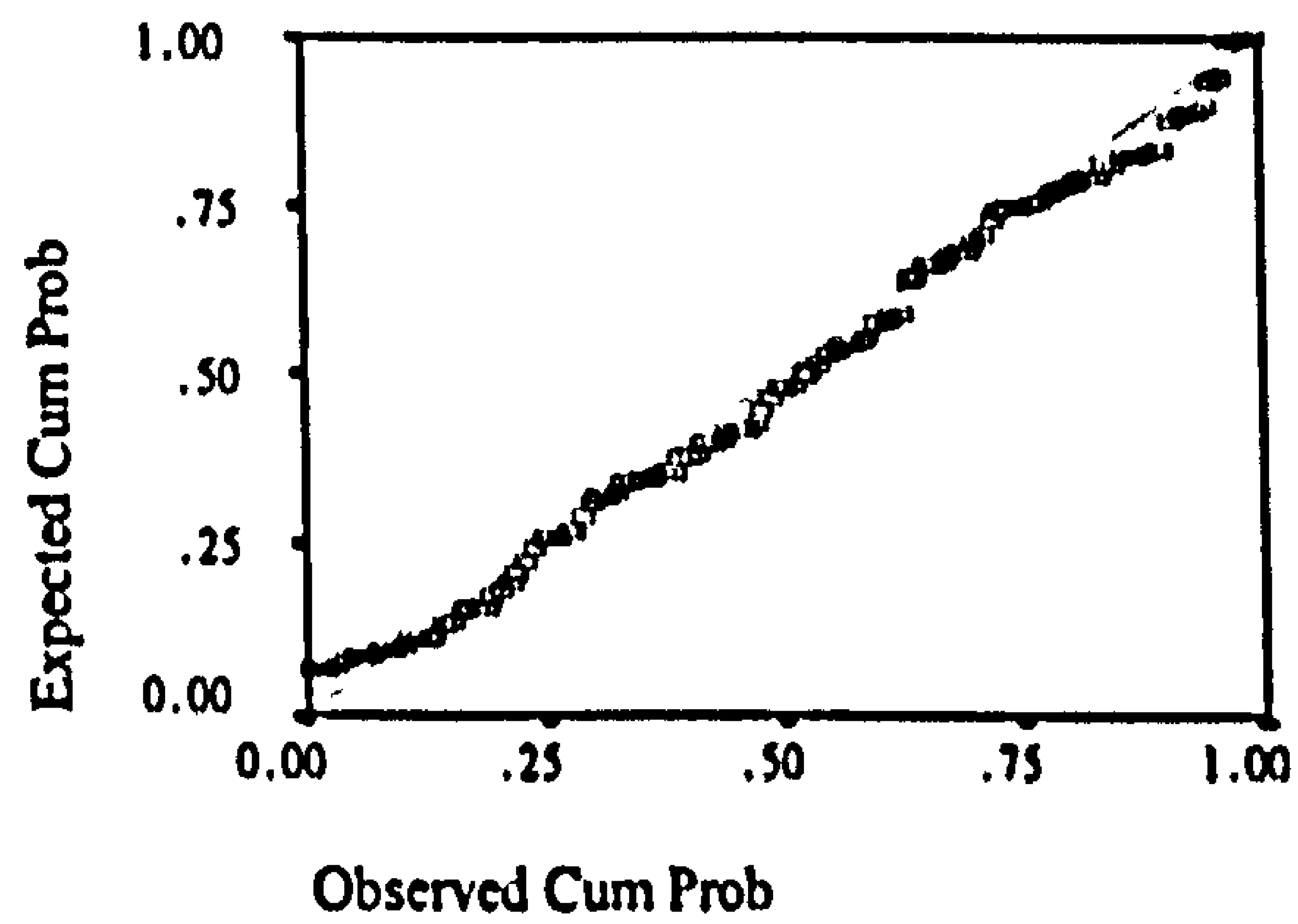
Predevelopment Assessment Knowledge



Normal P-P Plot of Standardized Residual

Dependent Variable:

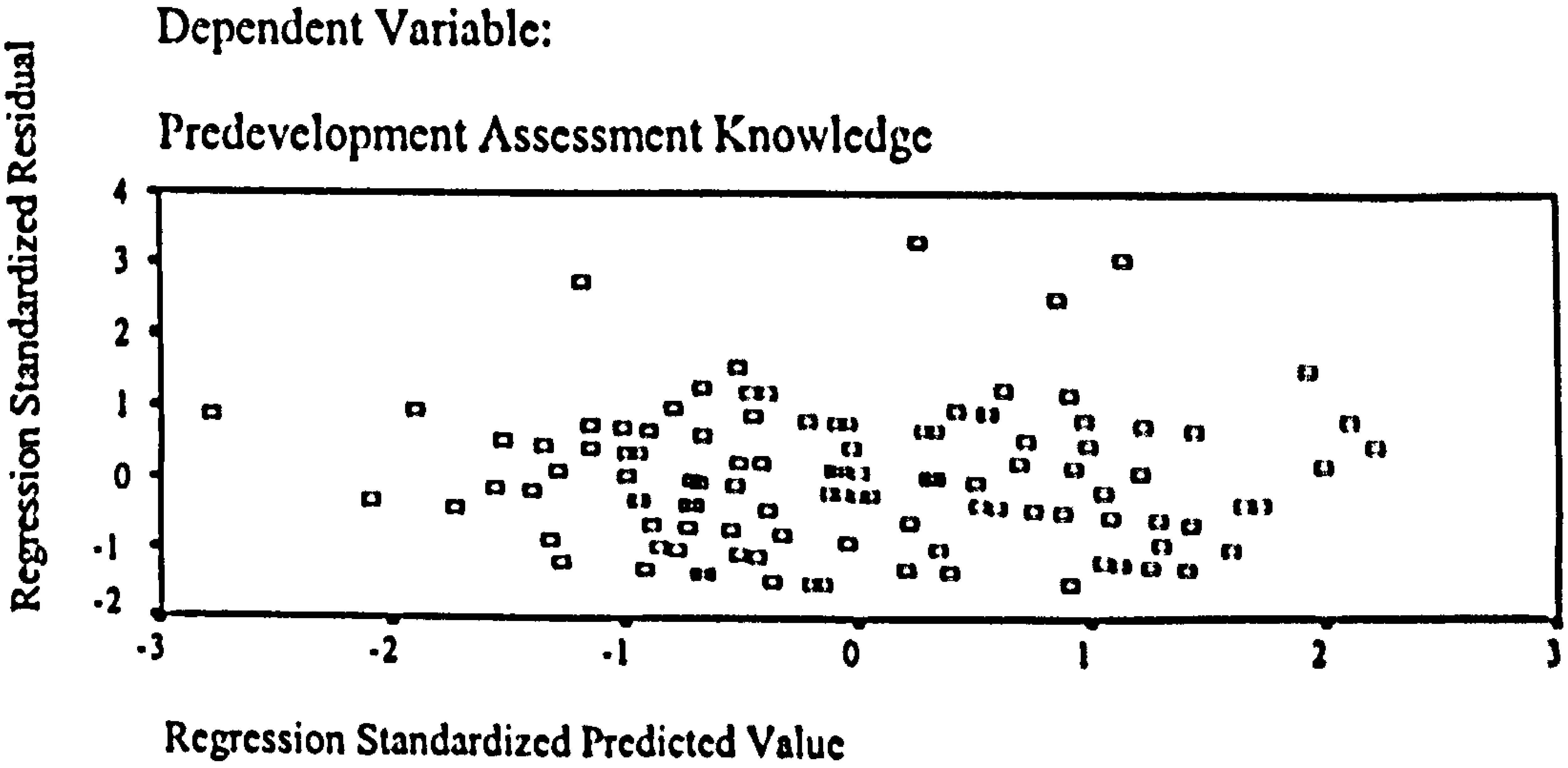
Predevelopment Assessment Knowledge



Scatterplot

Dependent Variable:

Predevelopment Assessment Knowledge

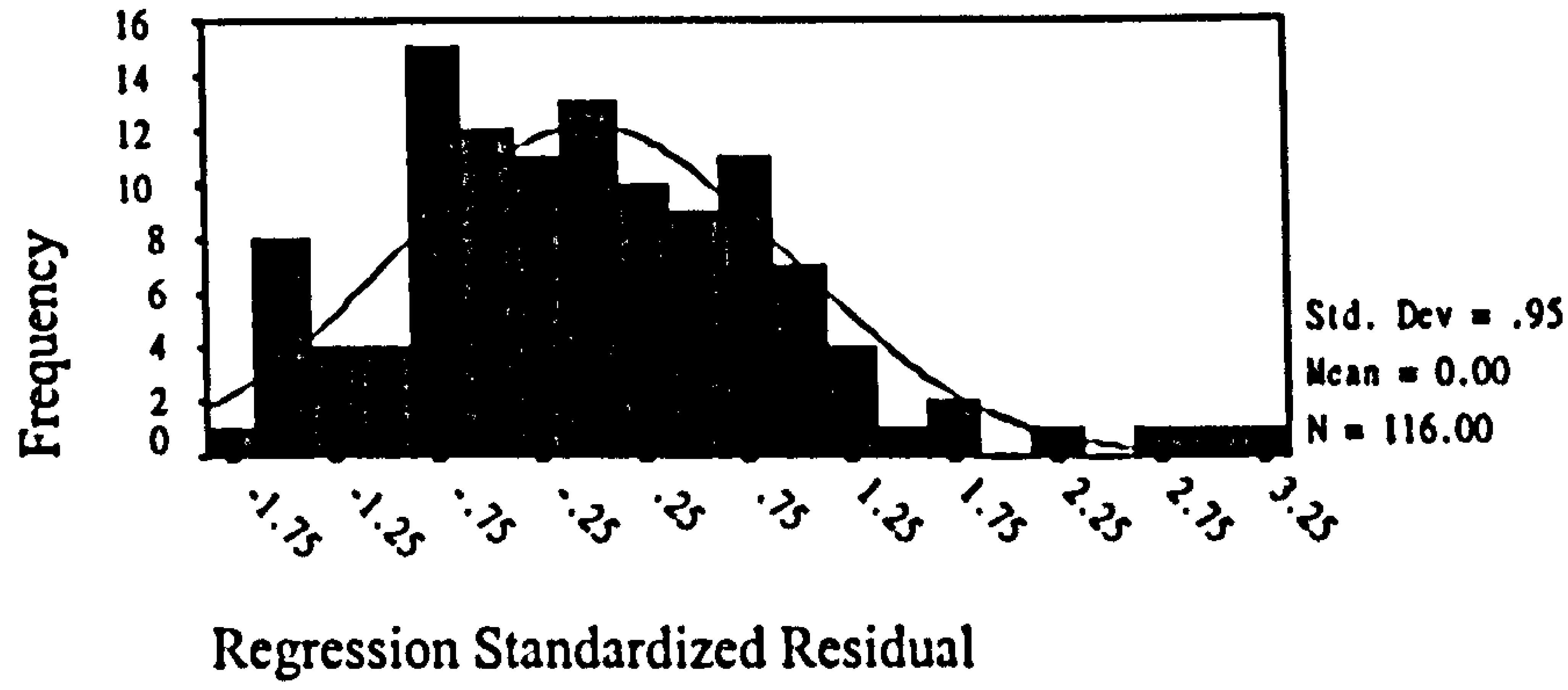


Regression Model 3-2 of Table 6.4.3

Histogram of Residuals

Dependent Variable:

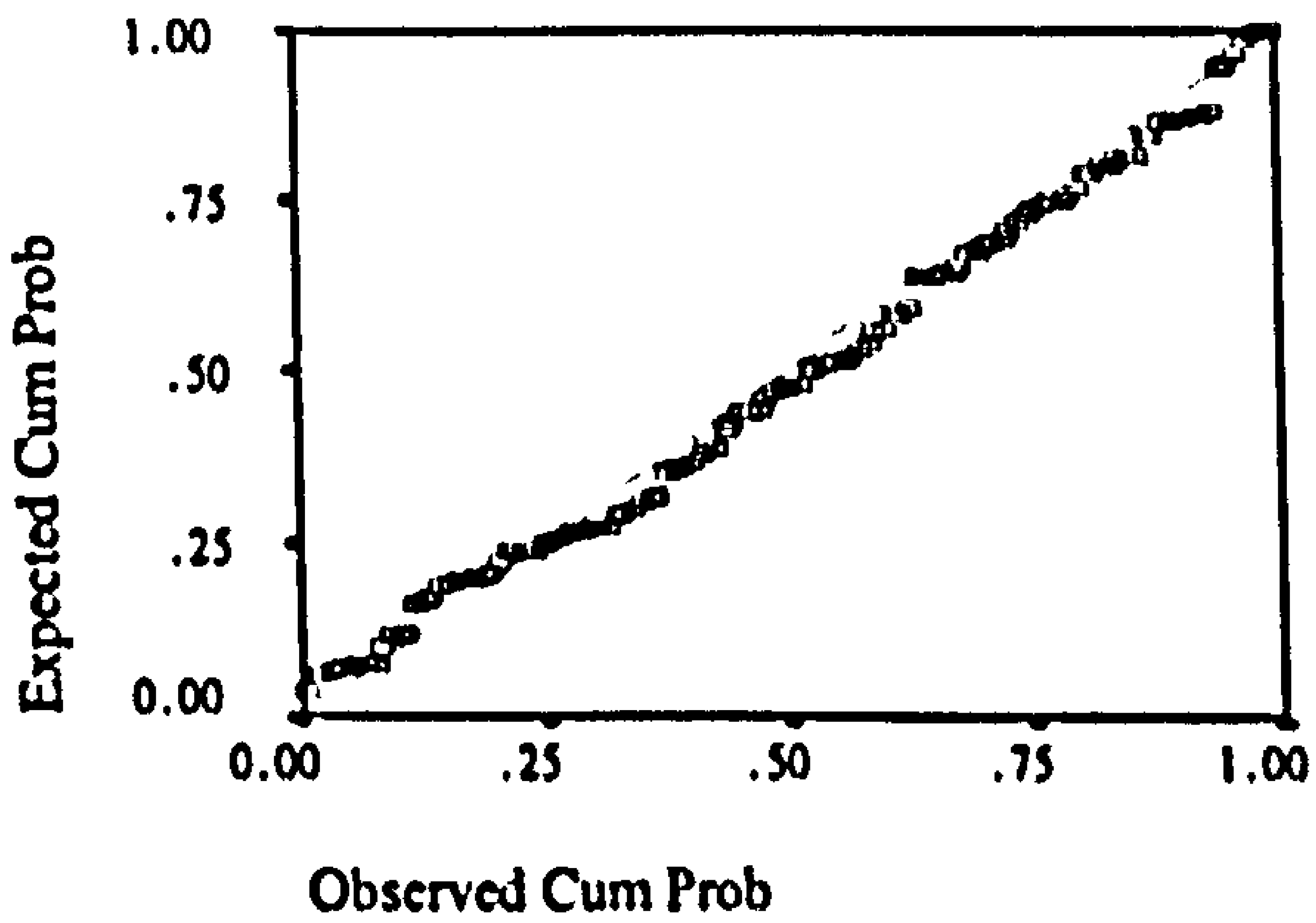
Predevelopment Assessment Knowledge



Normal P-P Plot of Standardized Residual

Dependent Variable:

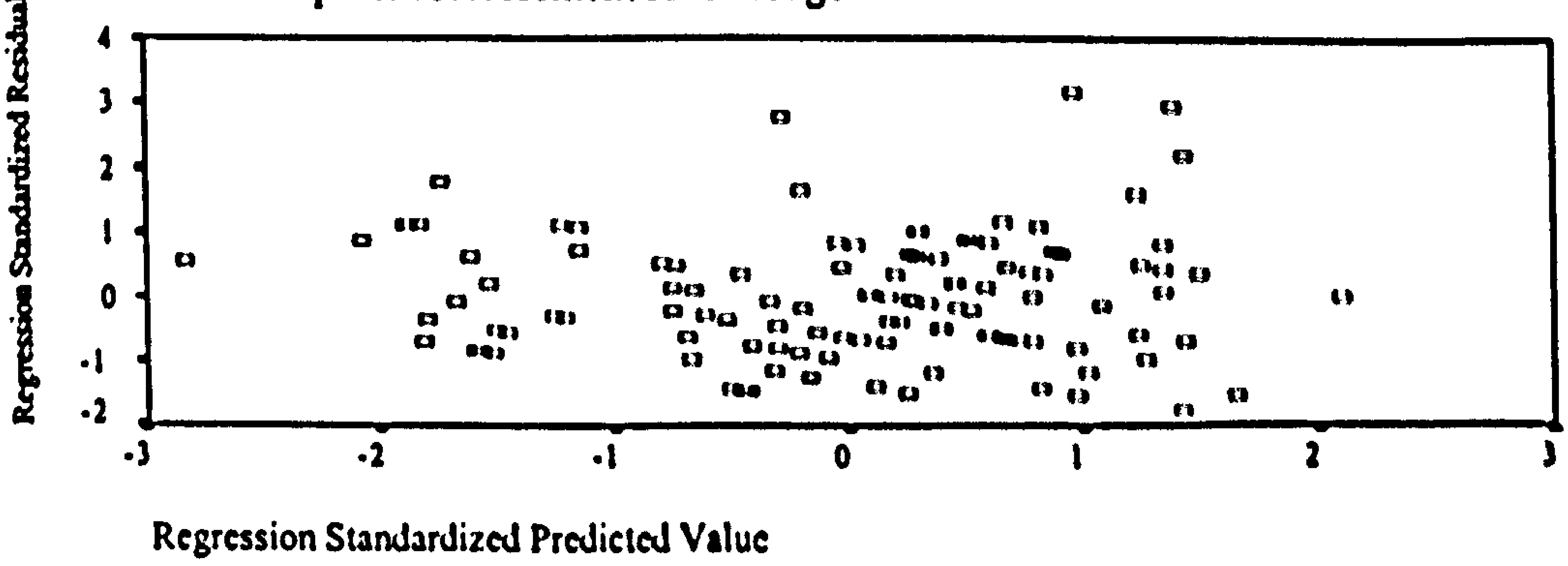
Predevelopment Assessment Knowledge



Scatterplot

Dependent Variable:

Predevelopment Assessment Knowledge

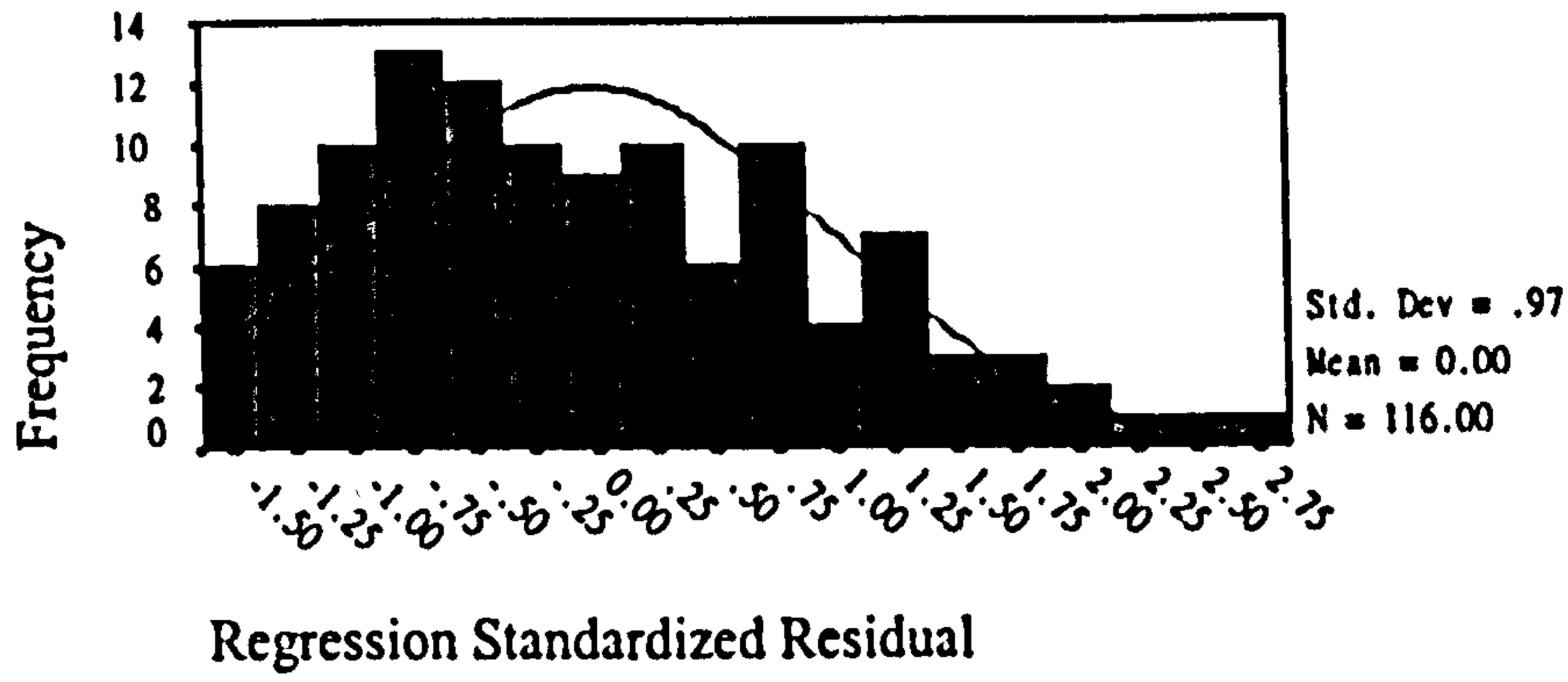


Regression Model 3-3 of Table 6.4.3

Histogram of Residuals

Dependent Variable:

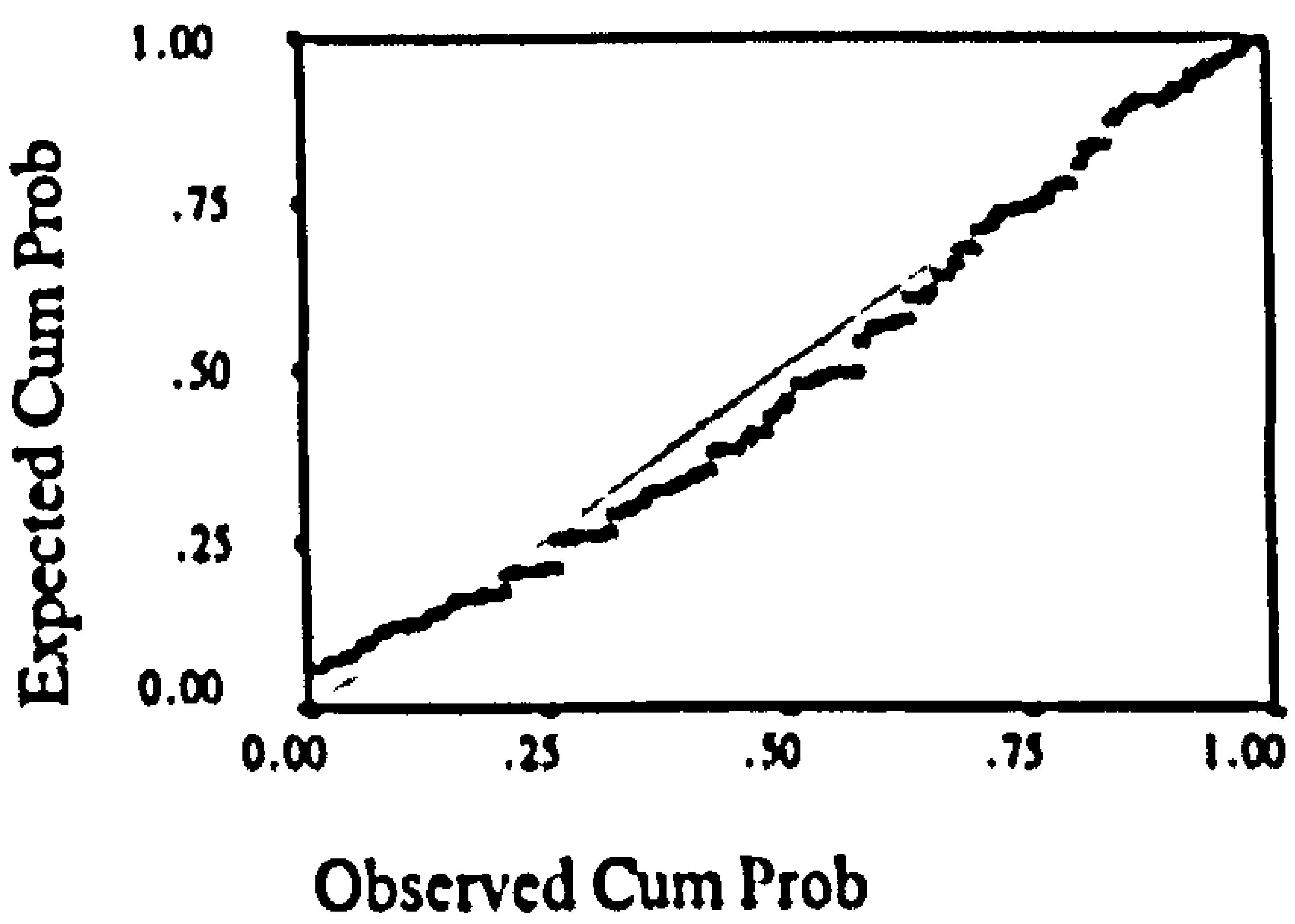
Marketing Knowledge



Normal P-P Plot of Standardized Residual

Dependent Variable:

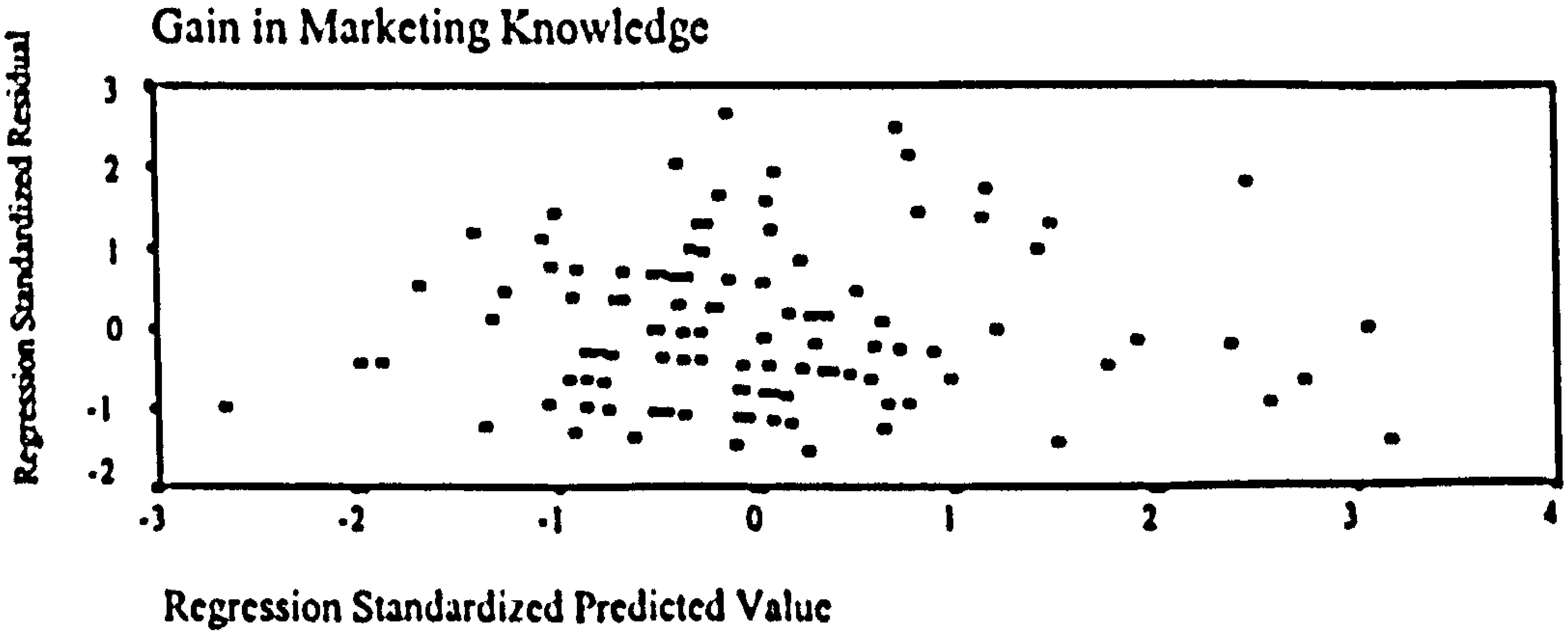
Gain in Marketing Knowledge



Scatterplot

Dependent Variable:

Gain in Marketing Knowledge

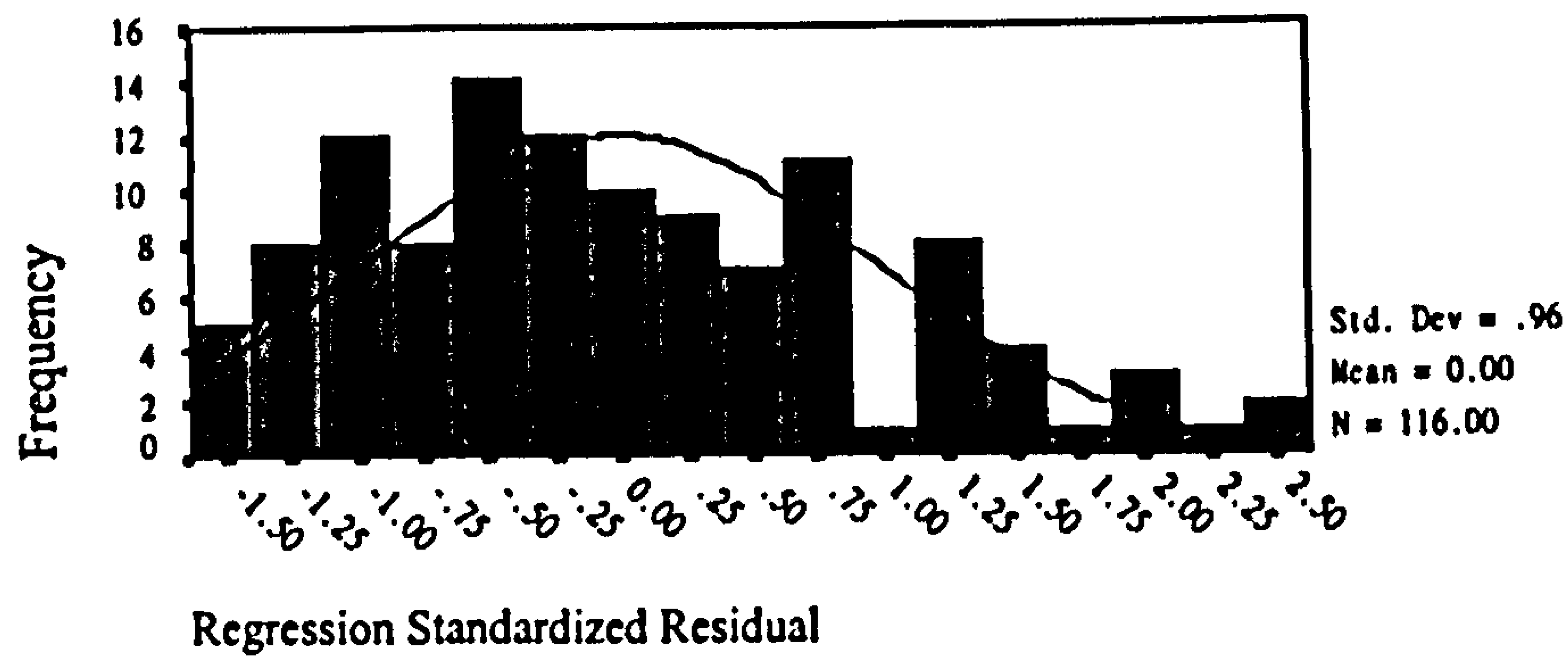


Regression Model 4-1 of Table 6.4.3

Histogram of Residuals

Dependent Variable:

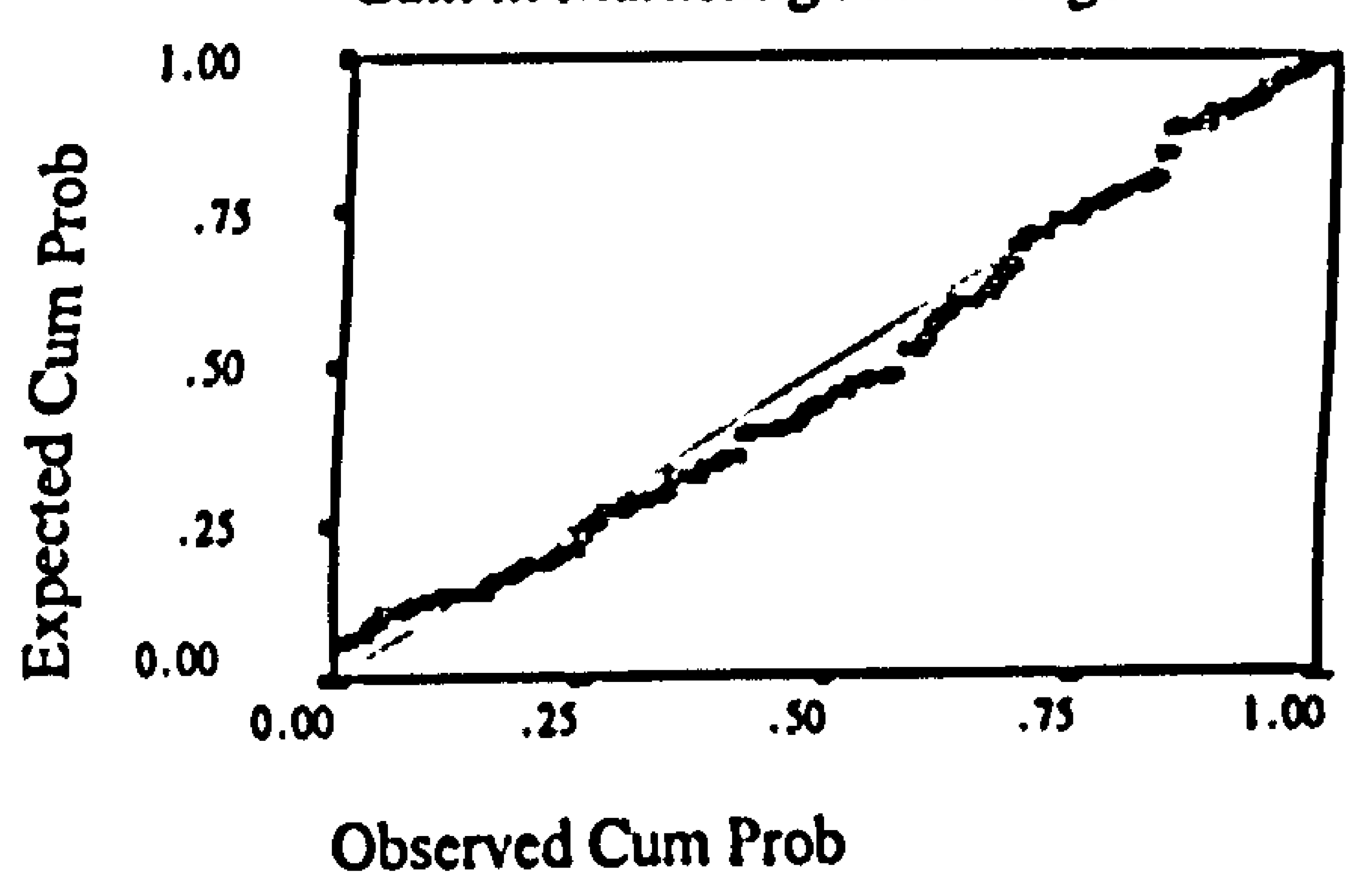
Gain in Marketing Knowledge



Normal P-P Plot of Standardized Residual

Dependent Variable:

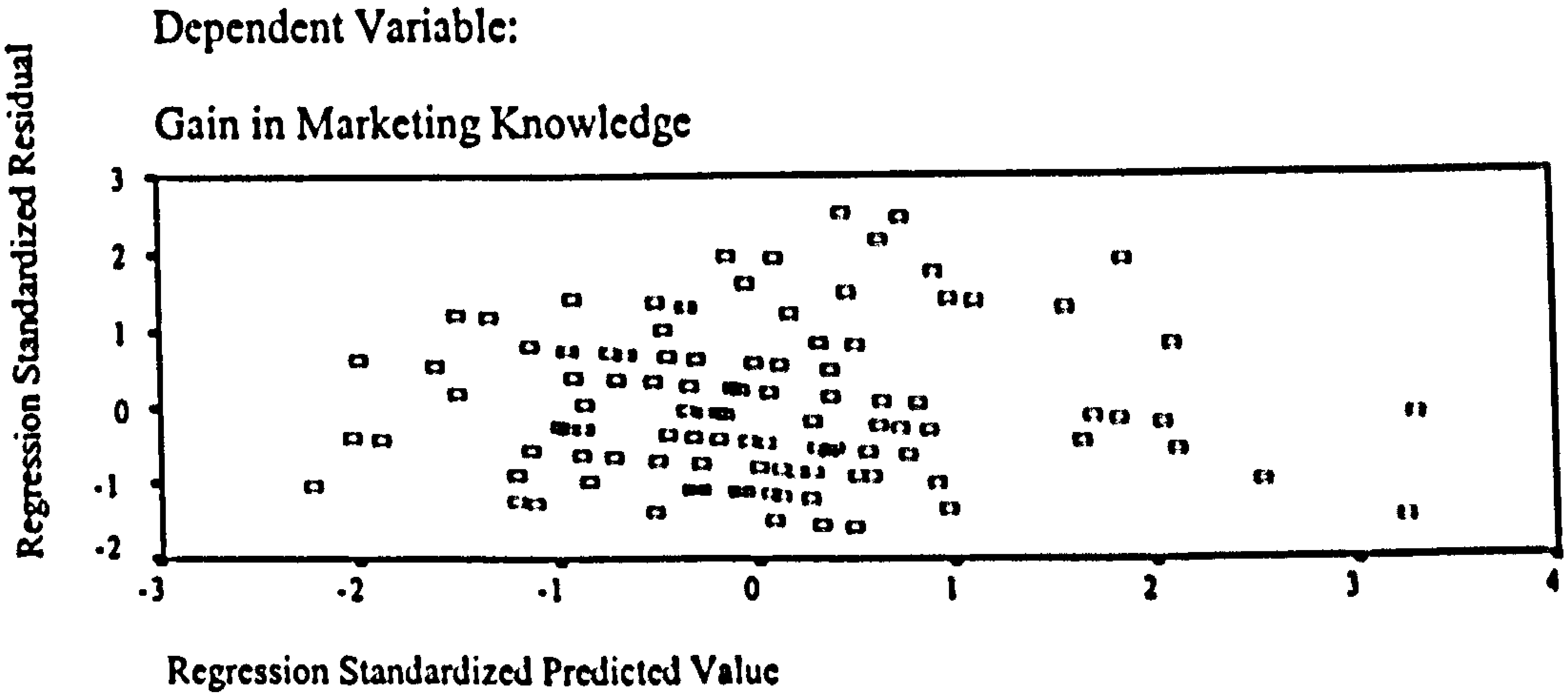
Gain in Marketing Knowledge



Scatterplot

Dependent Variable:

Gain in Marketing Knowledge

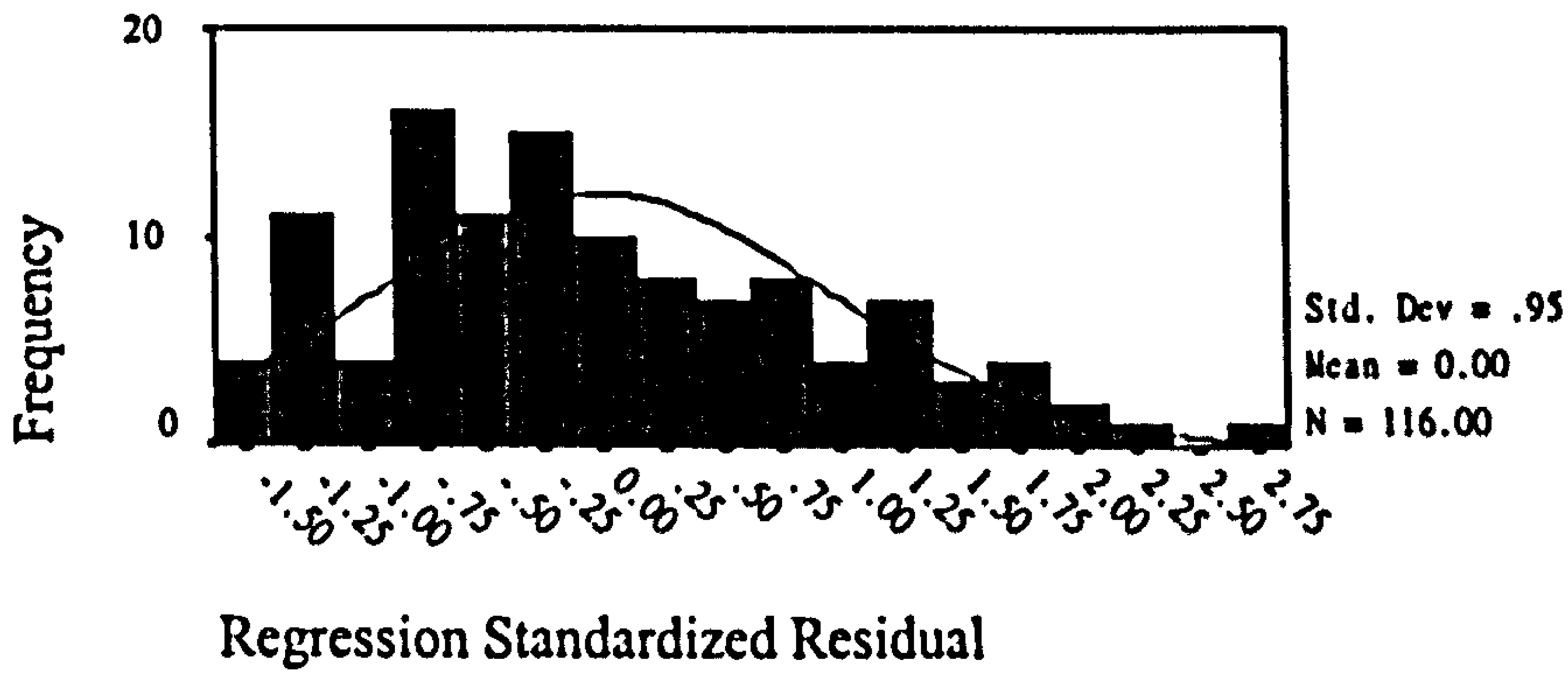


Regression Model 4-2 of Table 6.4.3

Histogram of Residuals

Dependent Variable:

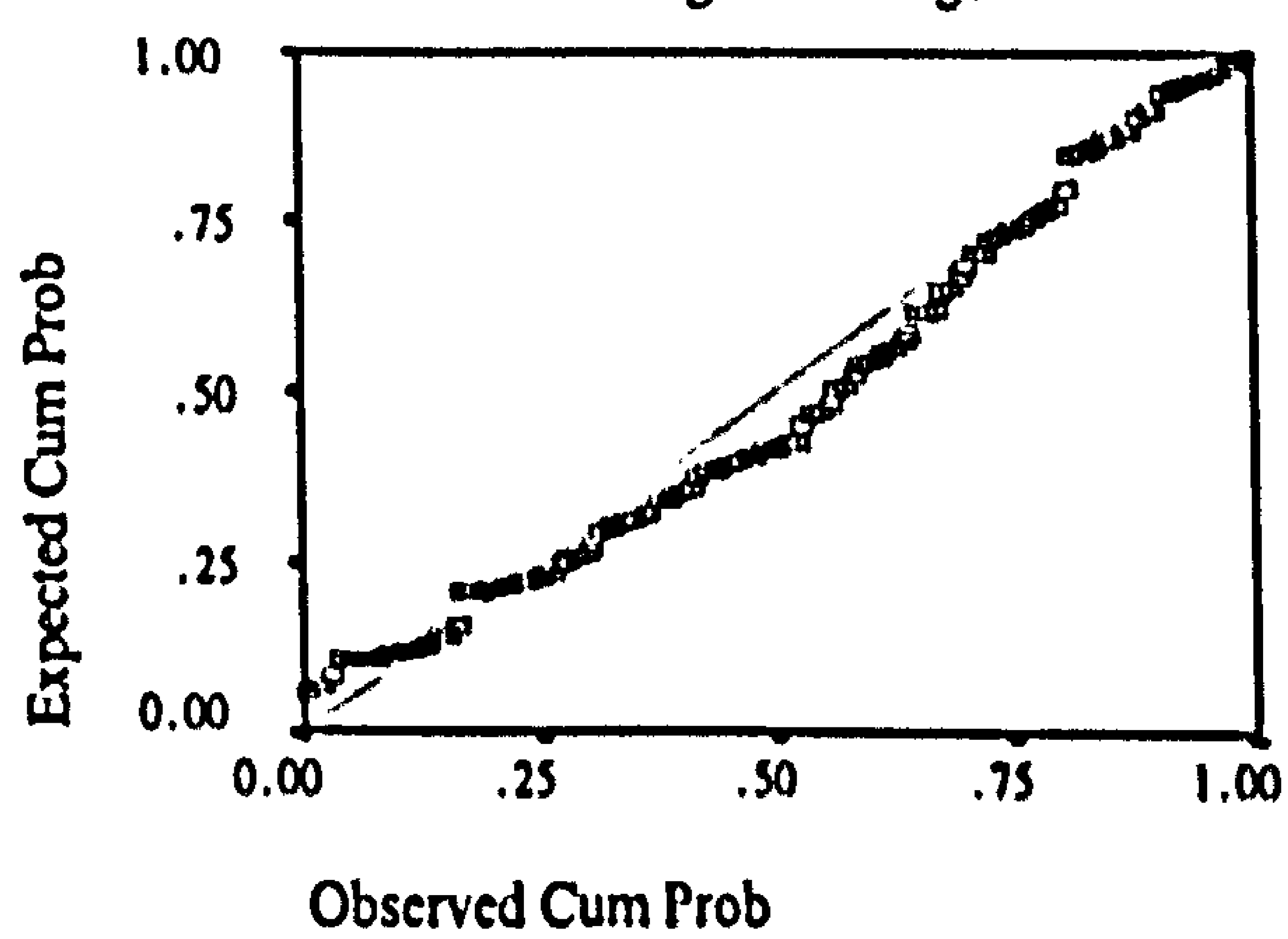
Gain in Marketing Knowledge



Normal P-P Plot of Standardized Residual

Dependent Variable:

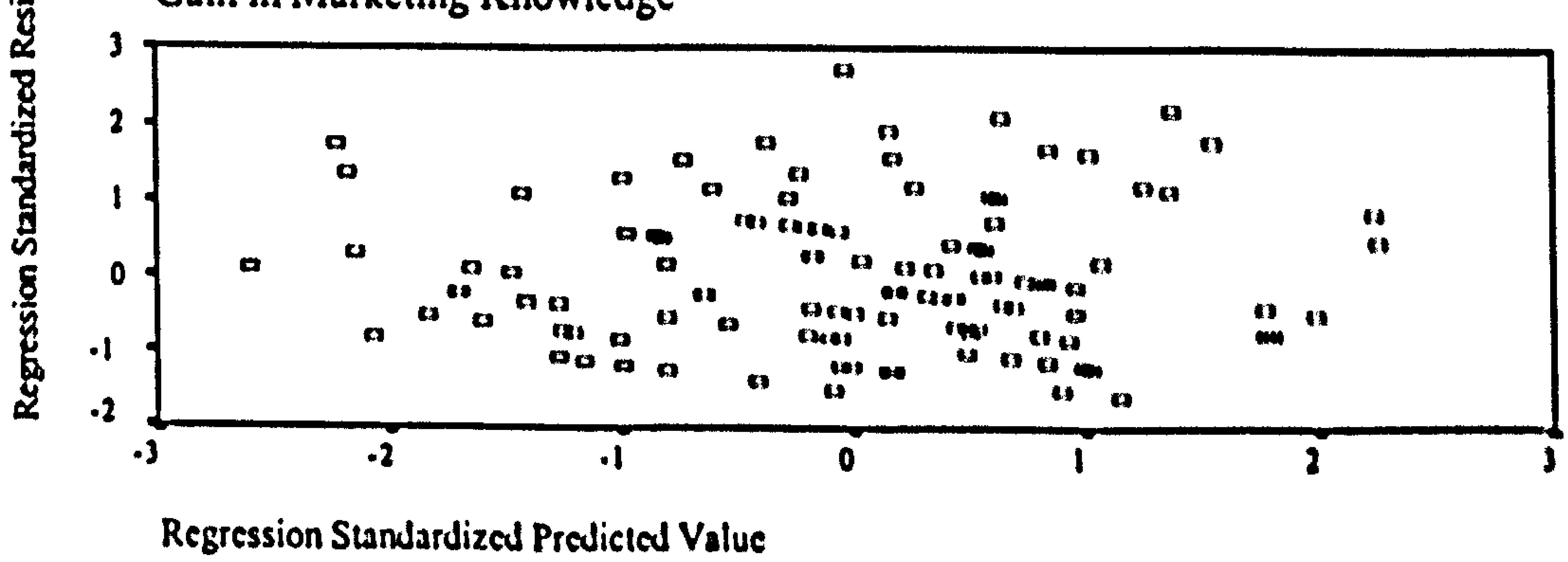
Gain in Marketing Knowledge



Scatterplot

Dependent Variable:

Gain in Marketing Knowledge

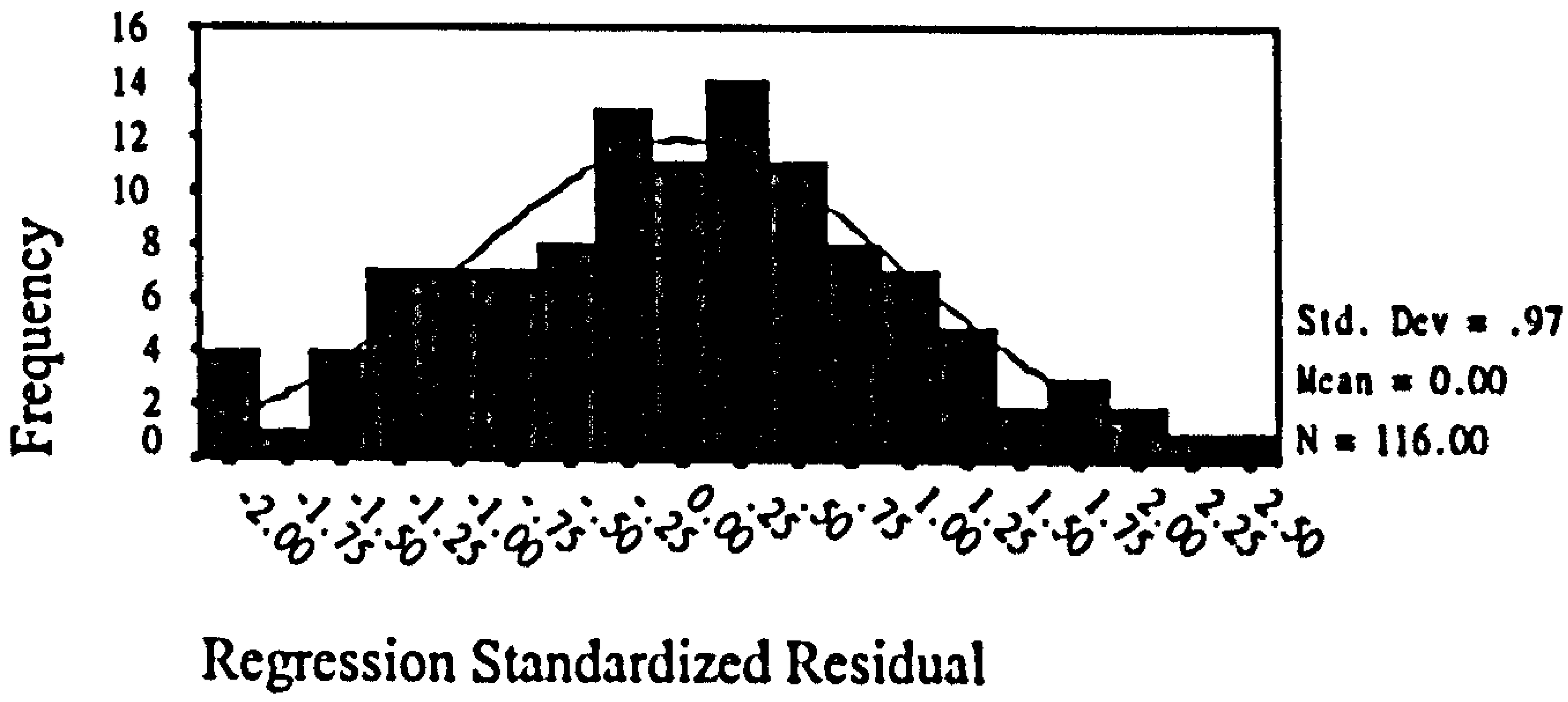


Regression Model 4-3 of Table 6.4.3

Histogram of Residuals

Dependent Variable:

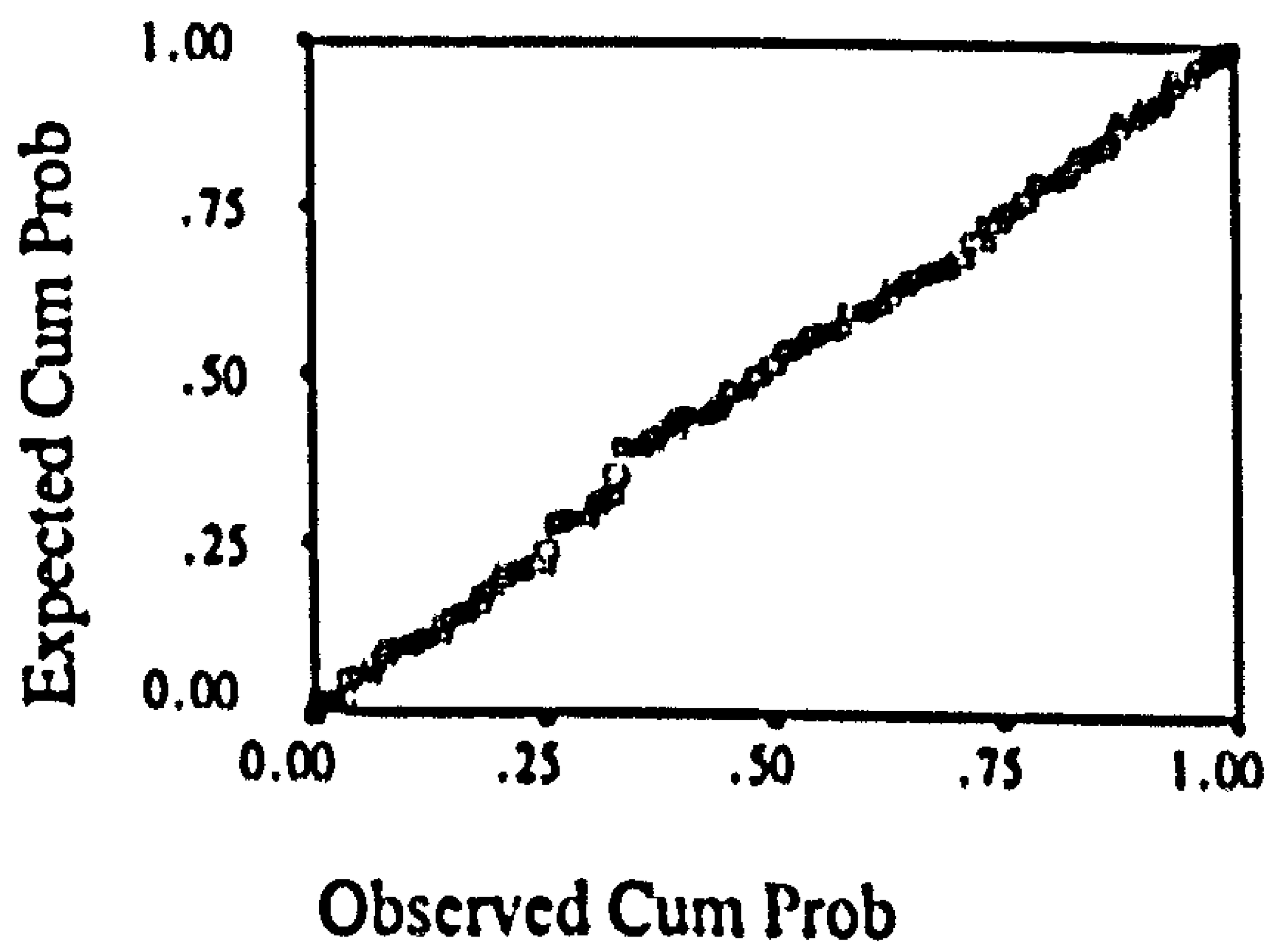
Gain in R&D Knowledge



Normal P-P Plot of Standardized Residual

Dependent Variable:

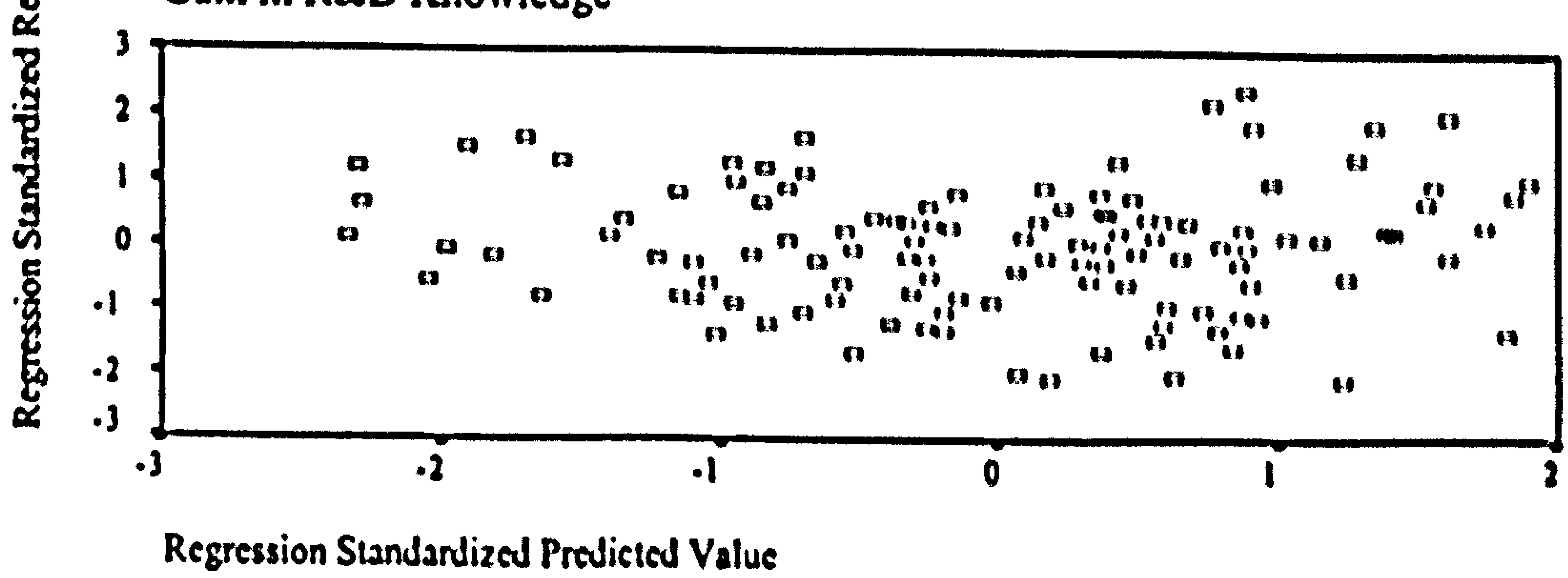
Gain in R&D Knowledge



Scatterplot

Dependent Variable:

Gain in R&D Knowledge

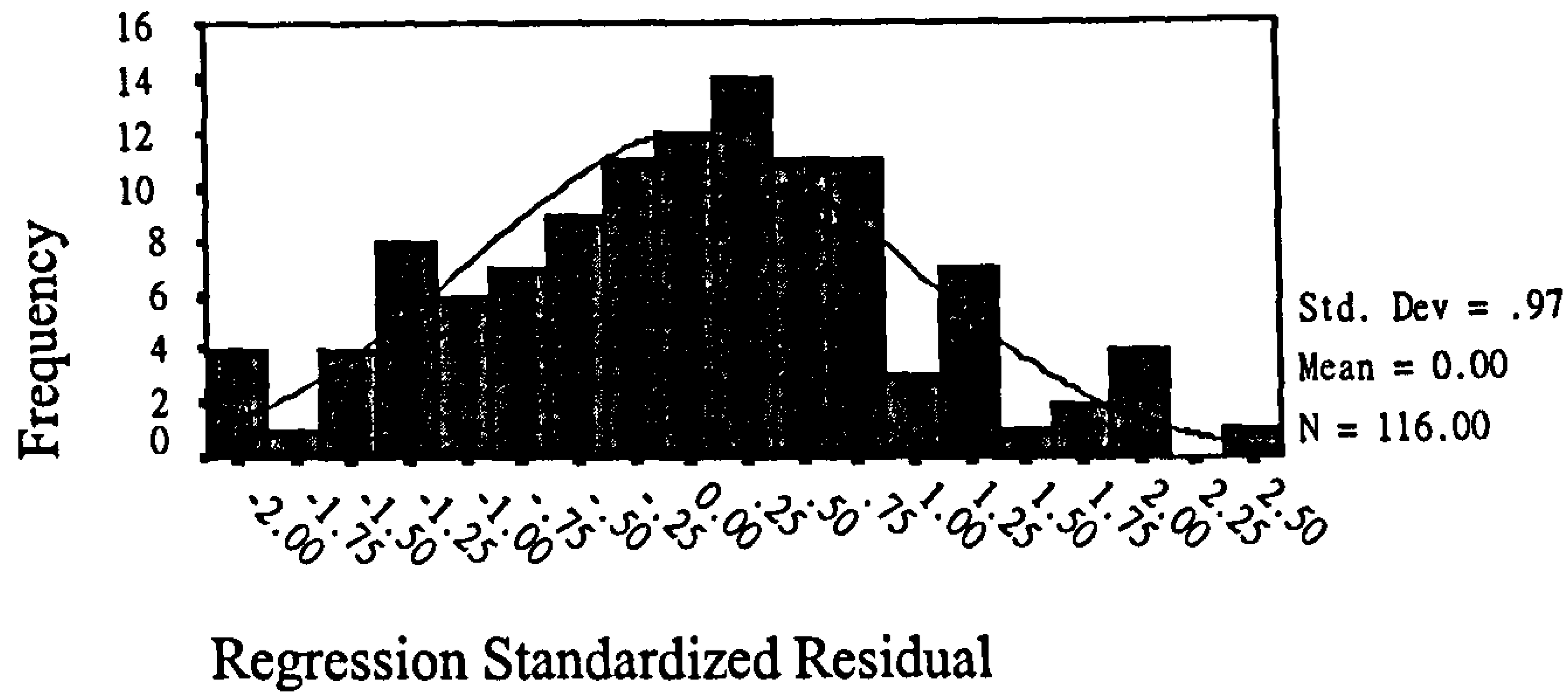


Regression Model 1 of Table 6.5.2.2

Histogram of Residuals

Dependent Variable:

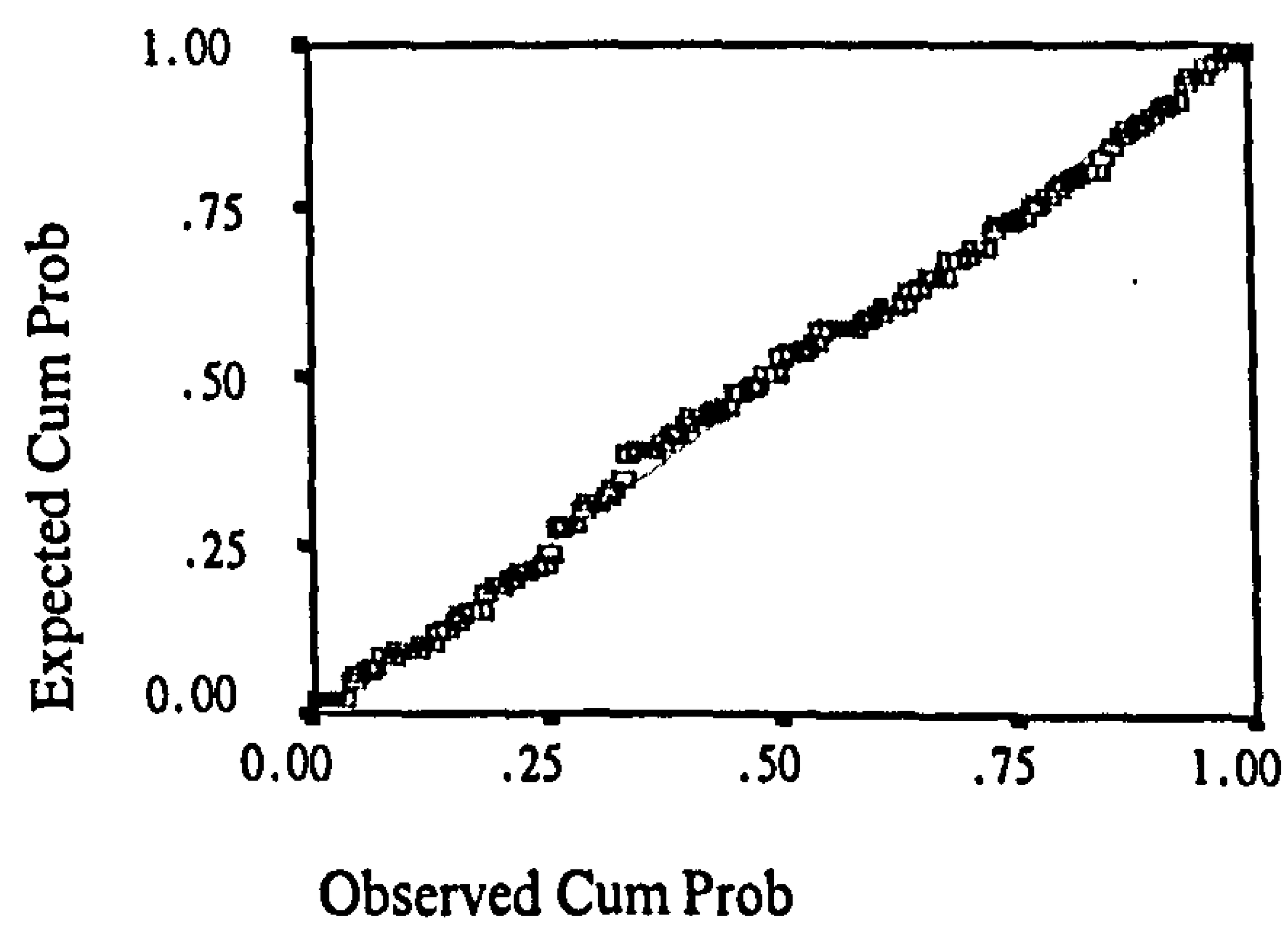
Gain in R&D Knowledge



Normal P-P Plot of Standardized Residual

Dependent Variable:

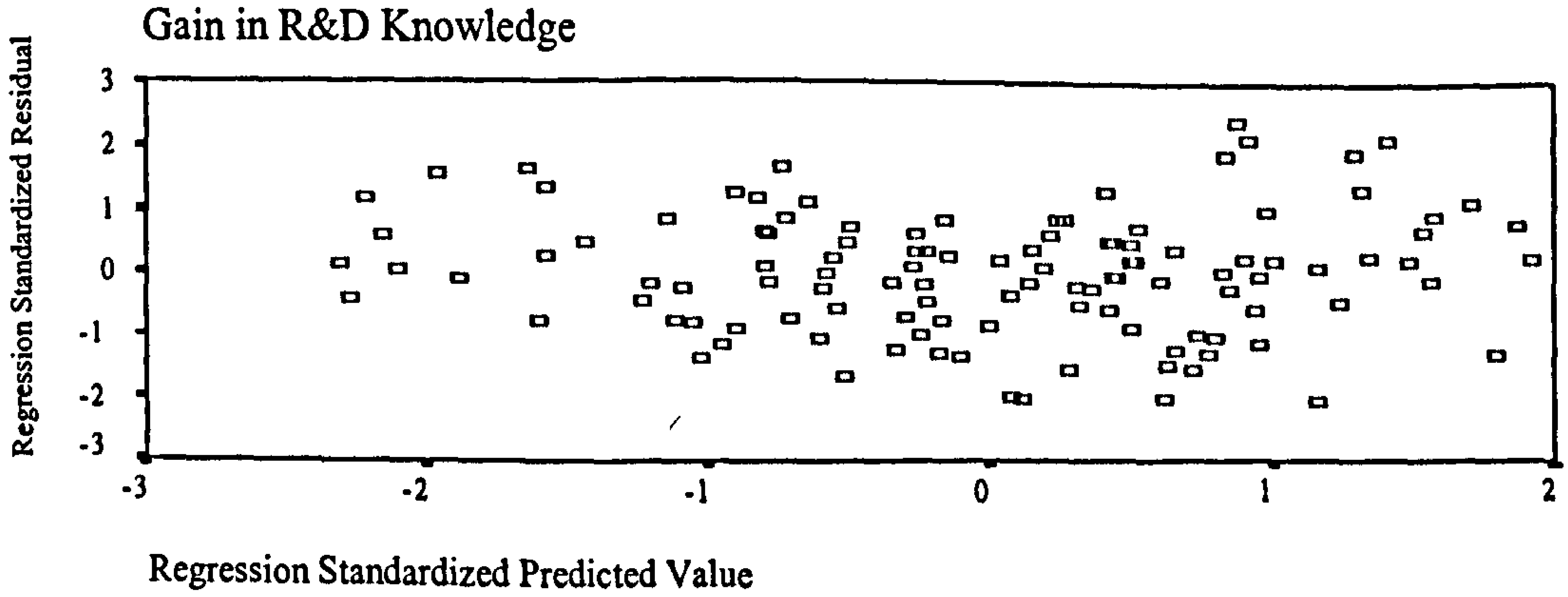
Gain in R&D Knowledge



Scatterplot

Dependent Variable:

Gain in R&D Knowledge

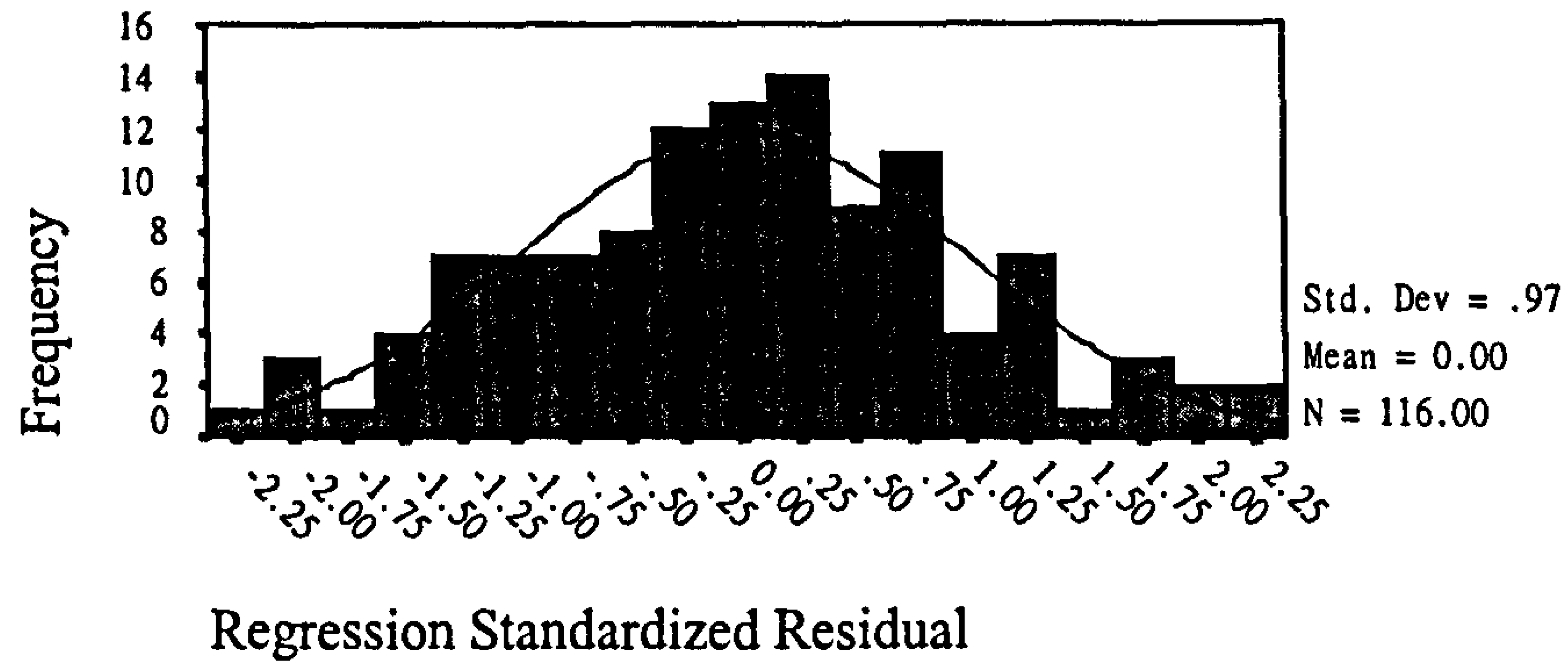


Regression Model 2 of Table 6.5.2.2

Histogram of Residuals

Dependent Variable:

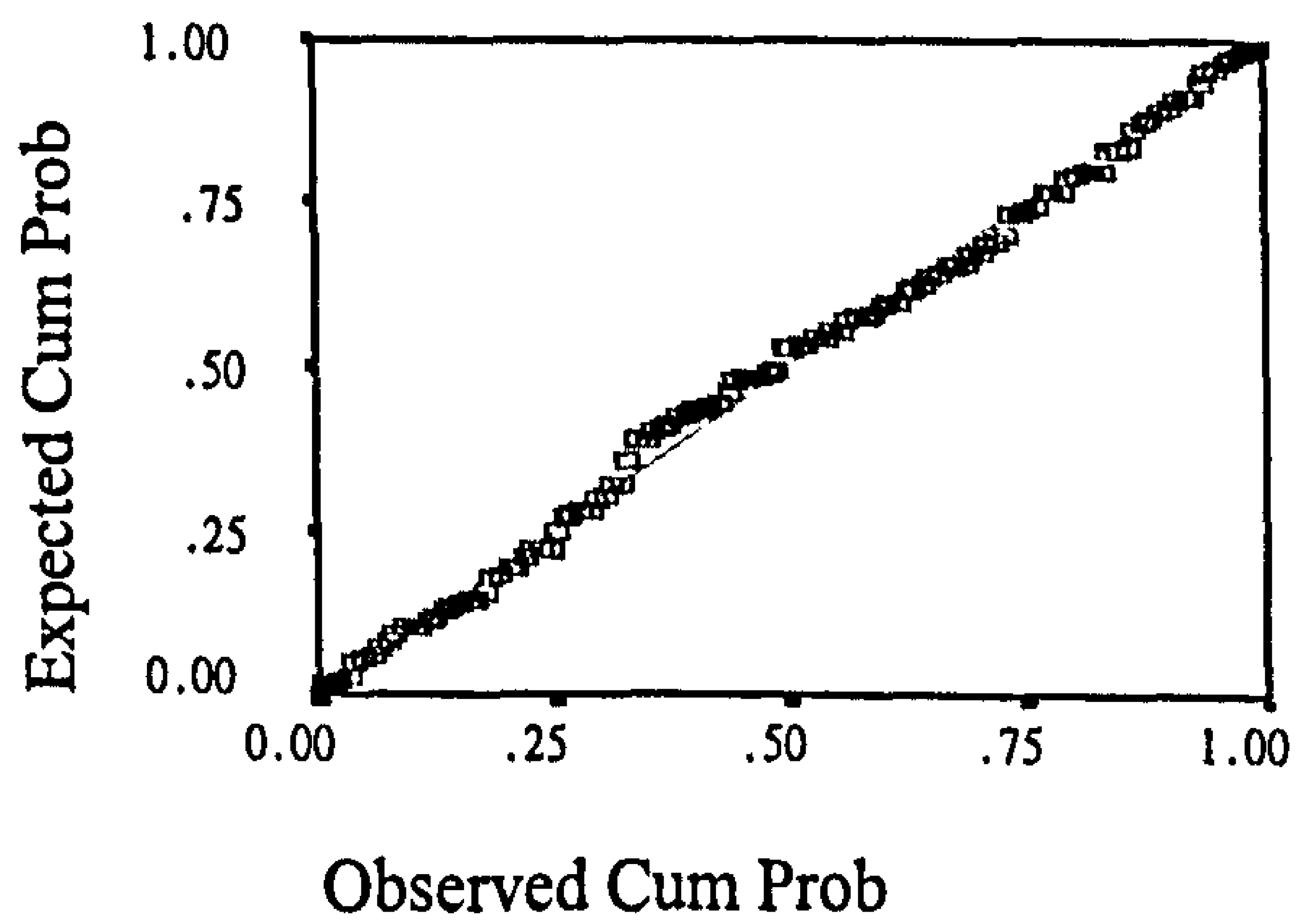
Gain in R&D Knowledge



Normal P-P Plot of Standardized Residual

Dependent Variable:

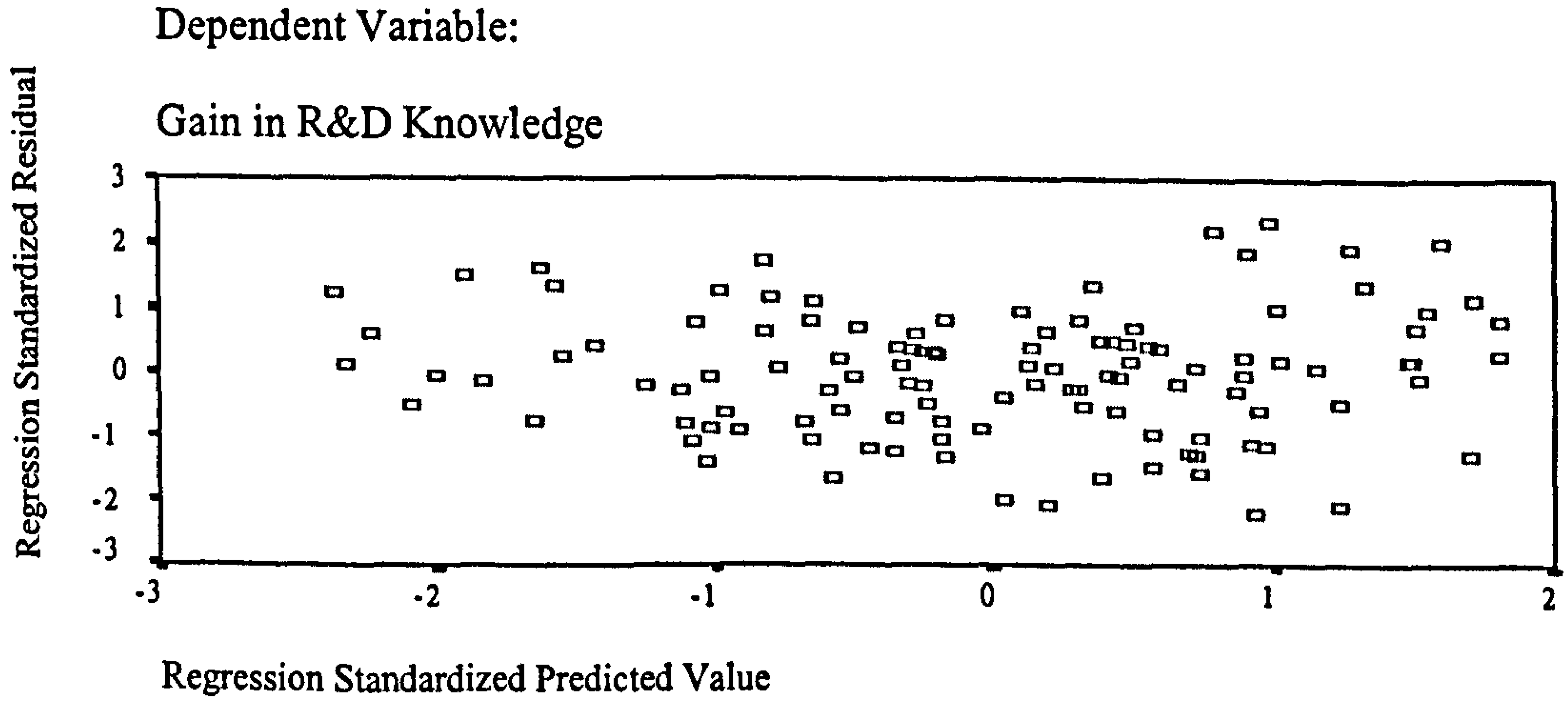
Gain in R&D Knowledge



Scatterplot

Dependent Variable:

Gain in R&D Knowledge

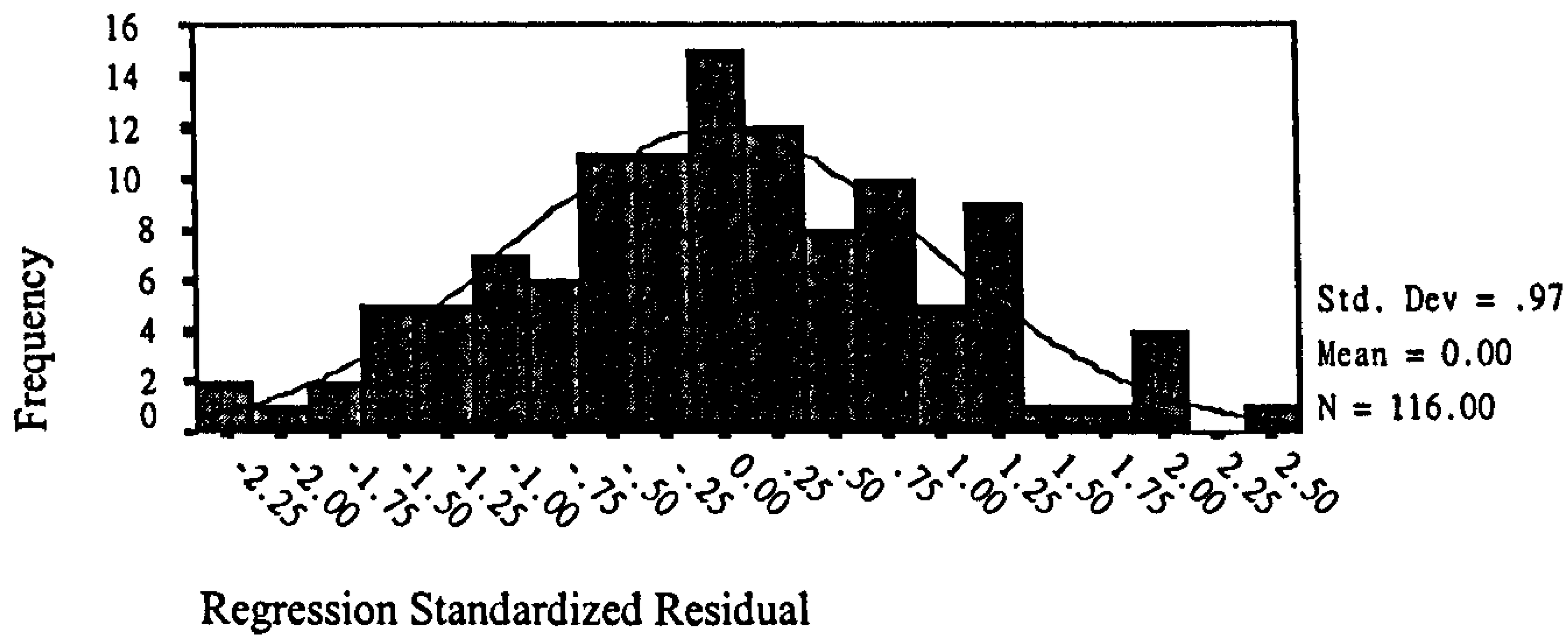


Regression Model 3 of Table 6.4.3

Histogram of Residuals

Dependent Variable:

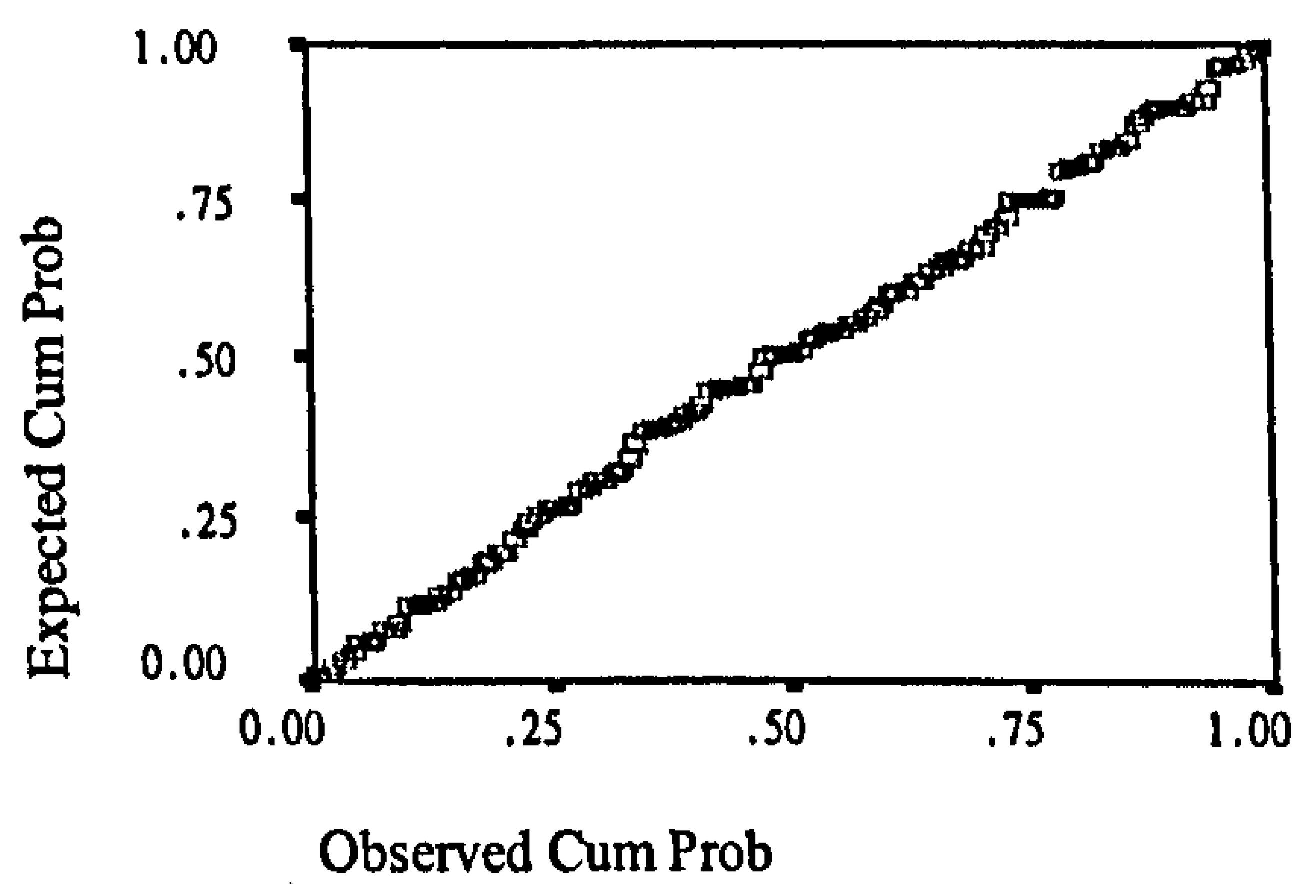
Gain in R&D Knowledge



Normal P-P Plot of Standardized Residual

Dependent Variable:

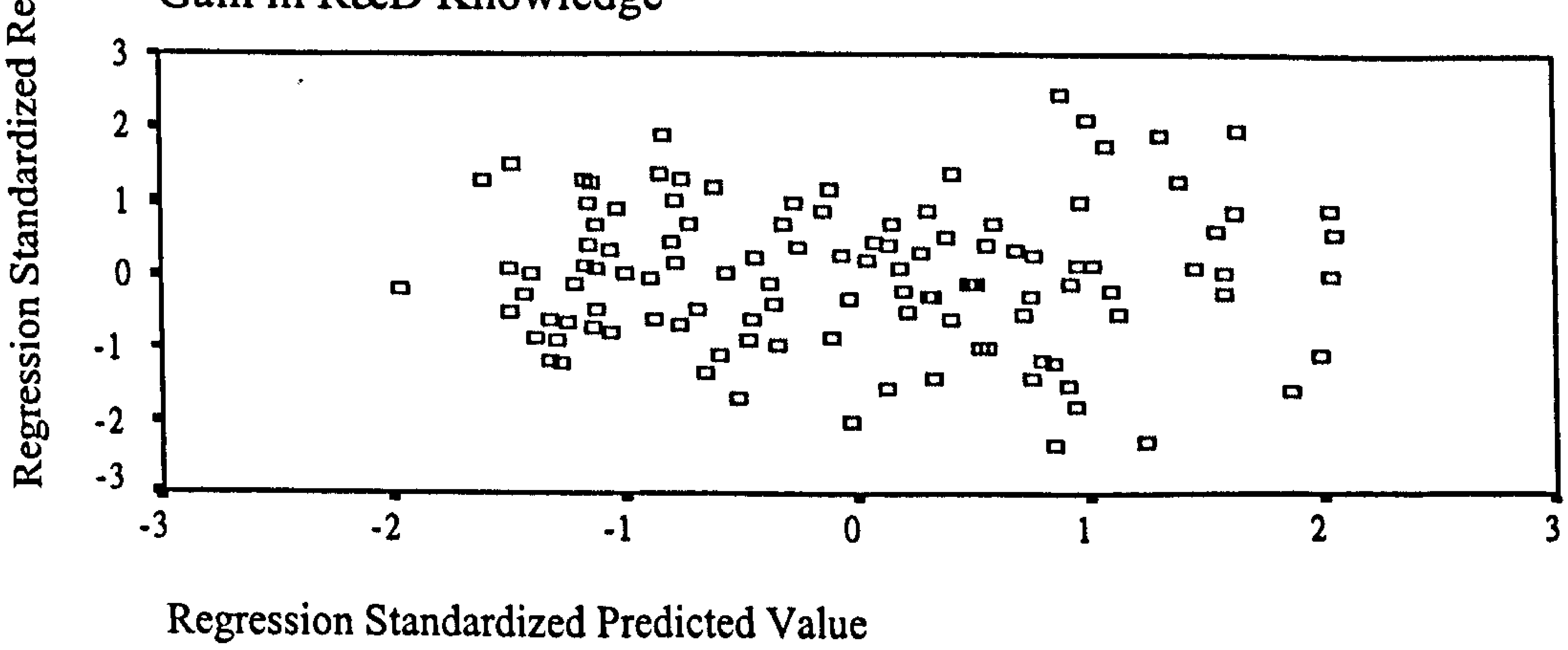
Gain in R&D Knowledge



Scatterplot

Dependent Variable:

Gain in R&D Knowledge

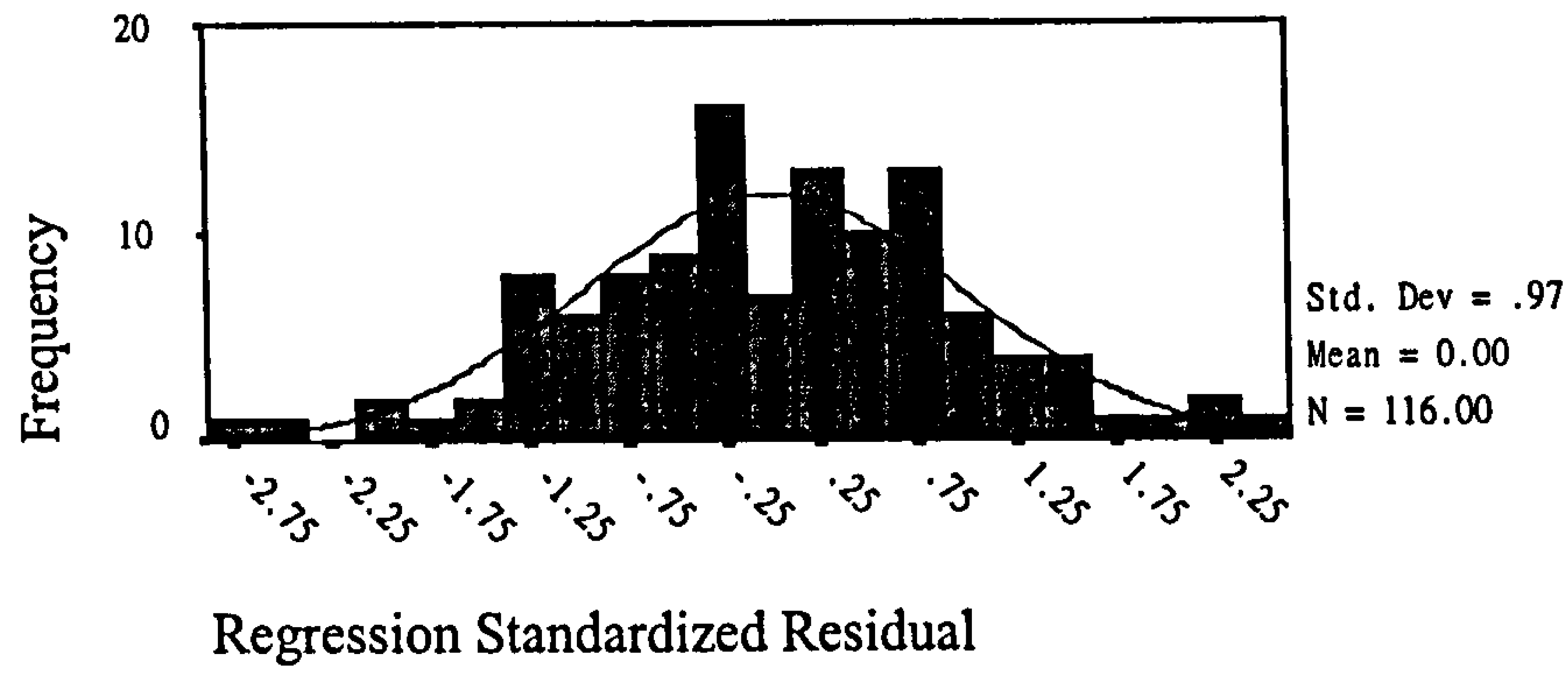


Regression Model 4 of Table 6.5.2.2

Histogram of Residuals

Dependent Variable:

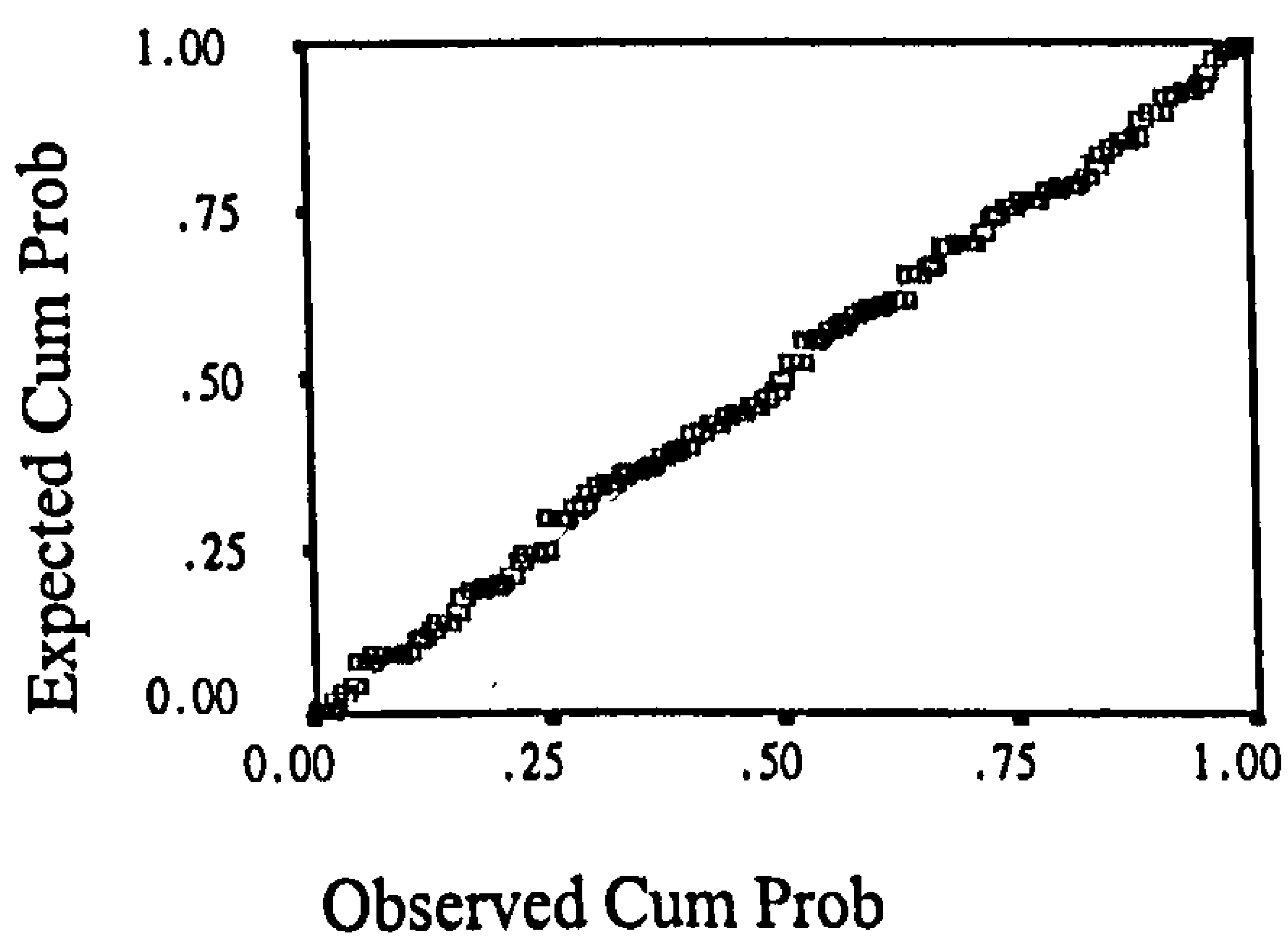
Gain in R&D Knowledge



Normal P-P Plot of Standardized Residual

Dependent Variable:

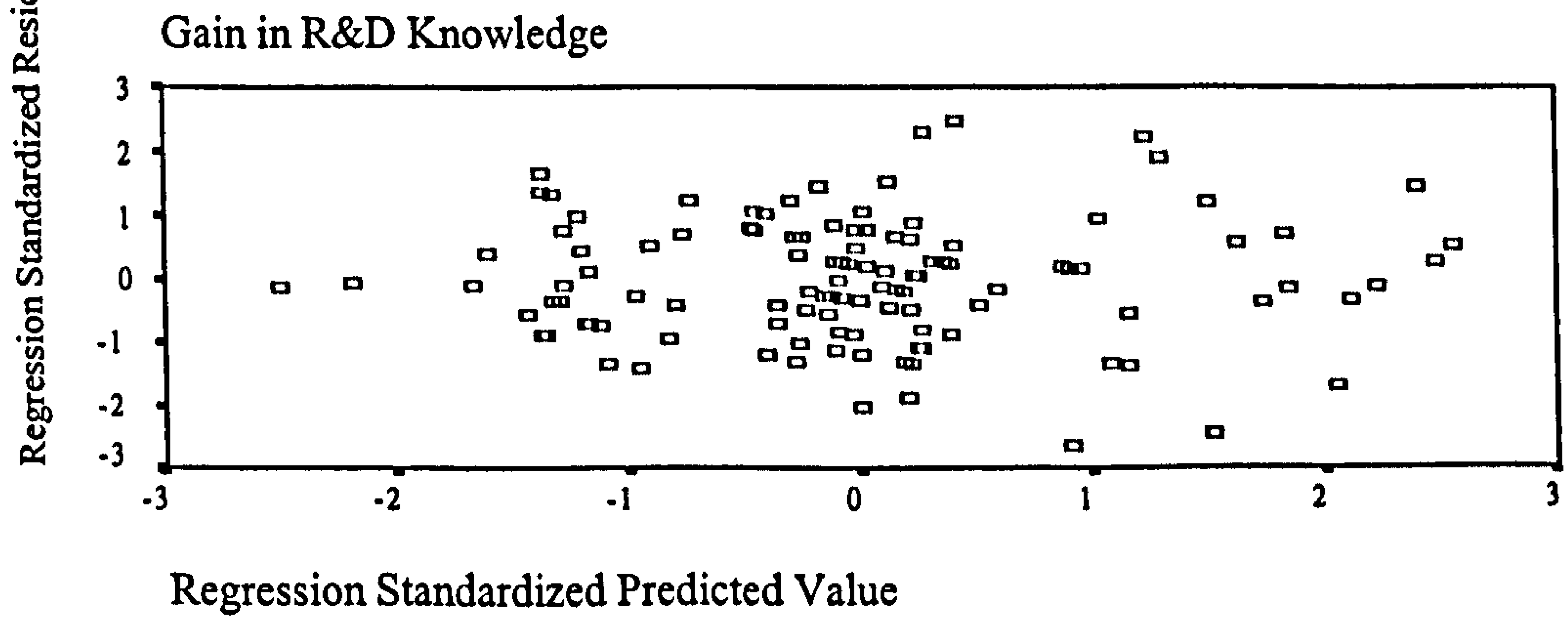
Gain in R&D Knowledge



Scatterplot

Dependent Variable:

Gain in R&D Knowledge

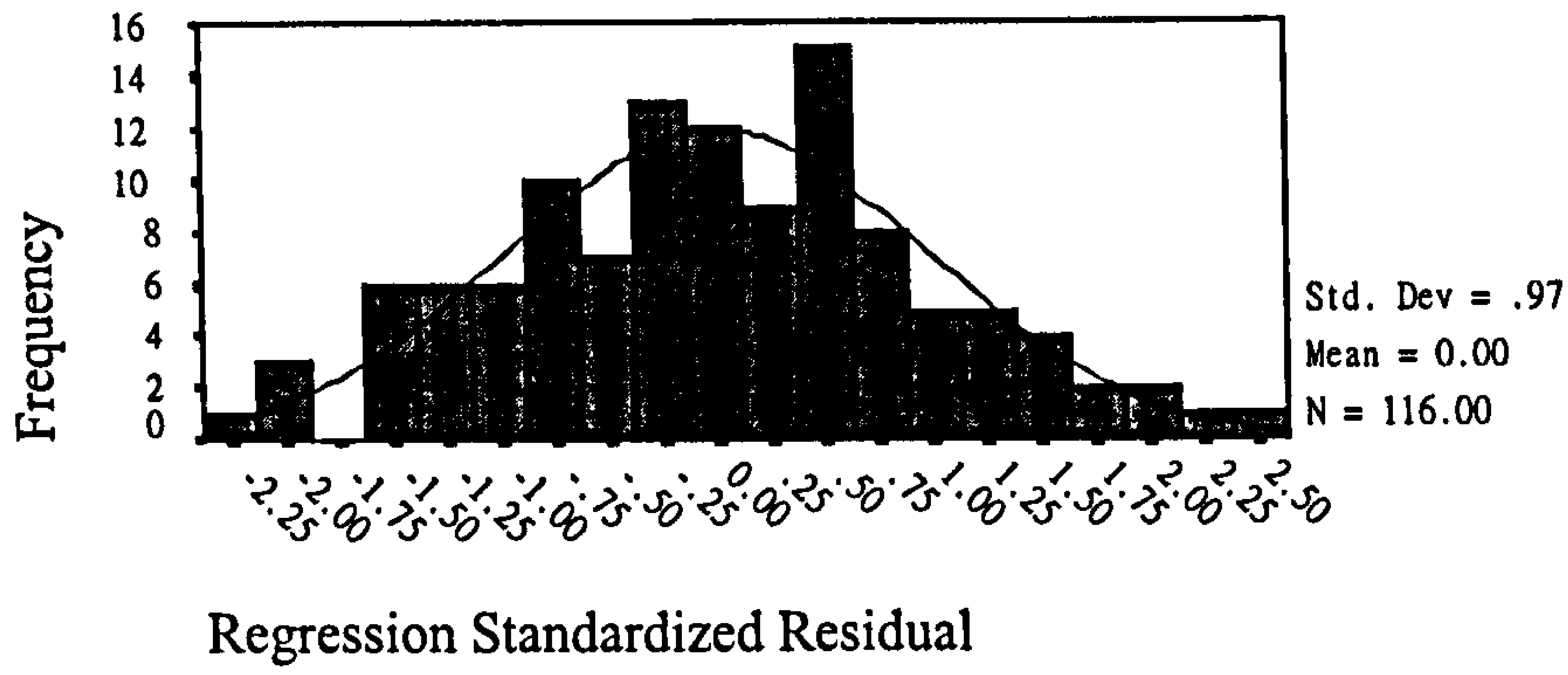


Regression Model 5 of Table 6.5.2.2

Histogram of Residuals

Dependent Variable:

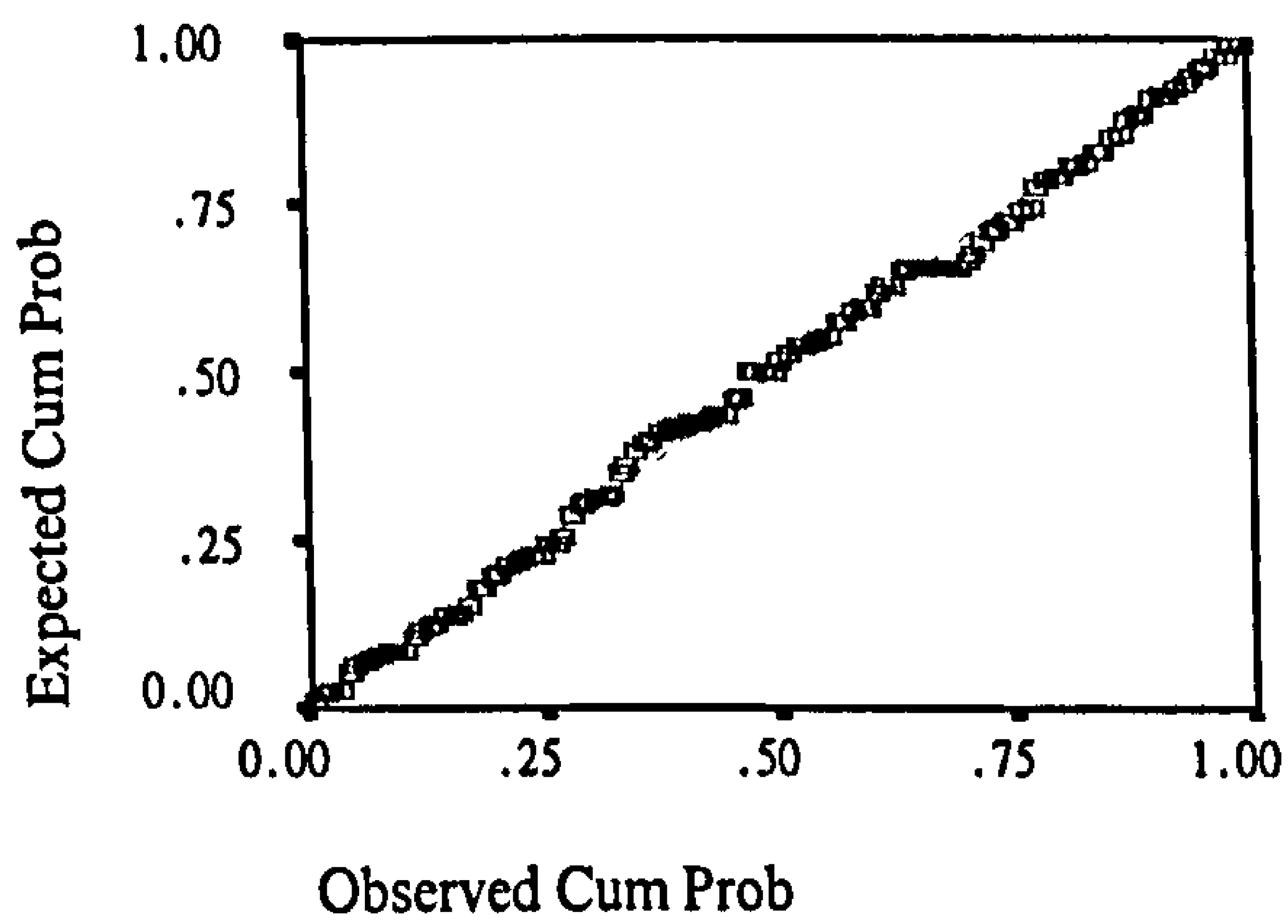
Gain in R&D Knowledge



Normal P-P Plot of Standardized Residual

Dependent Variable:

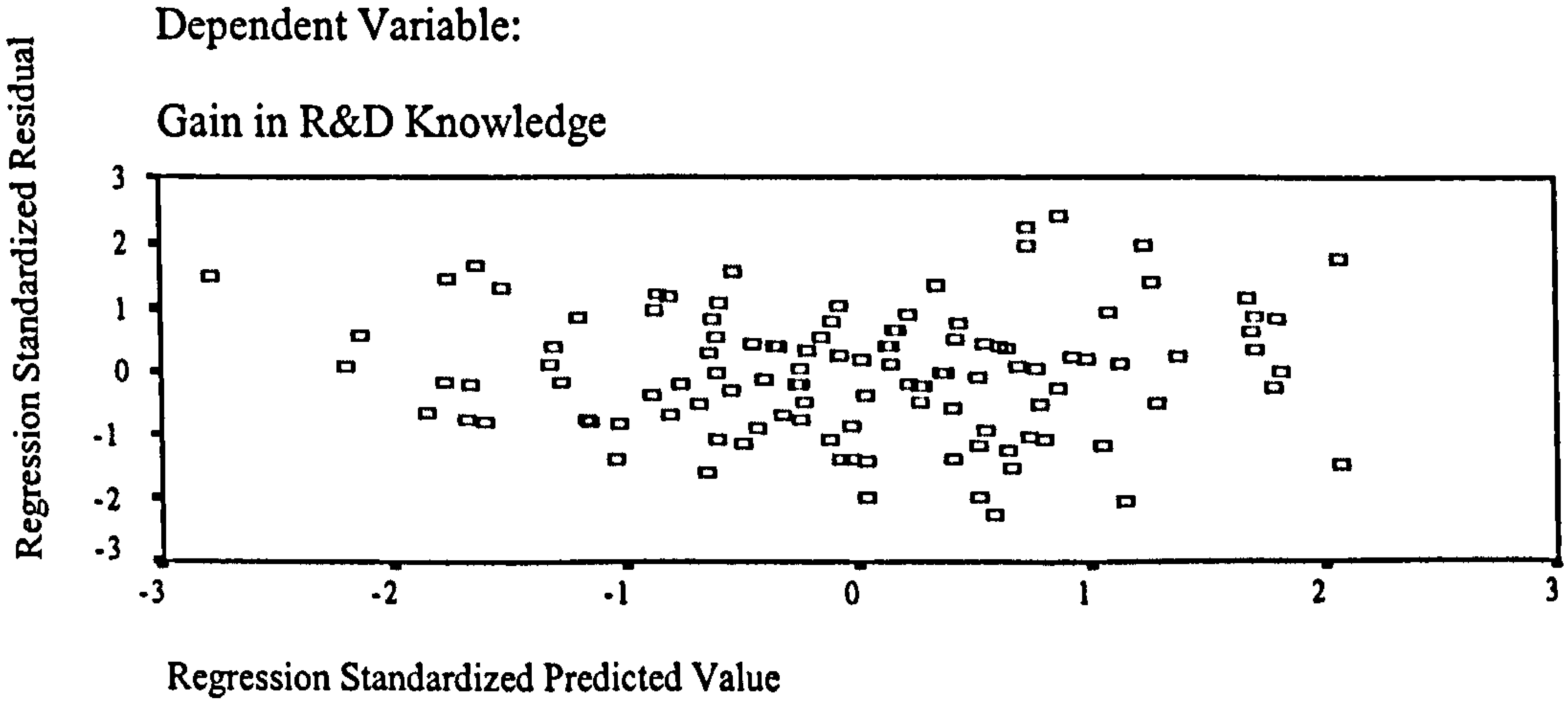
Gain in R&D Knowledge



Scatterplot

Dependent Variable:

Gain in R&D Knowledge

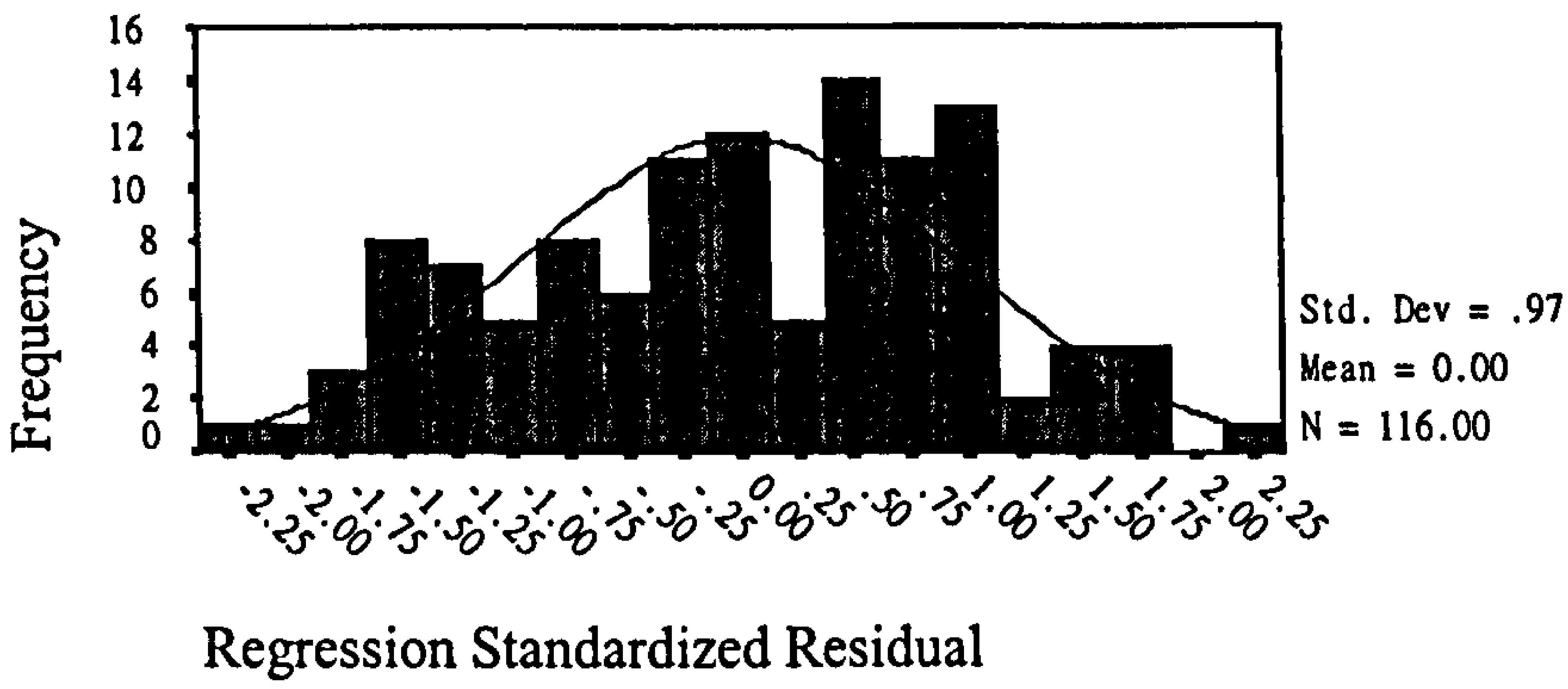


Regression Model 6 of Table 6.5.2.2

Histogram of Residuals

Dependent Variable:

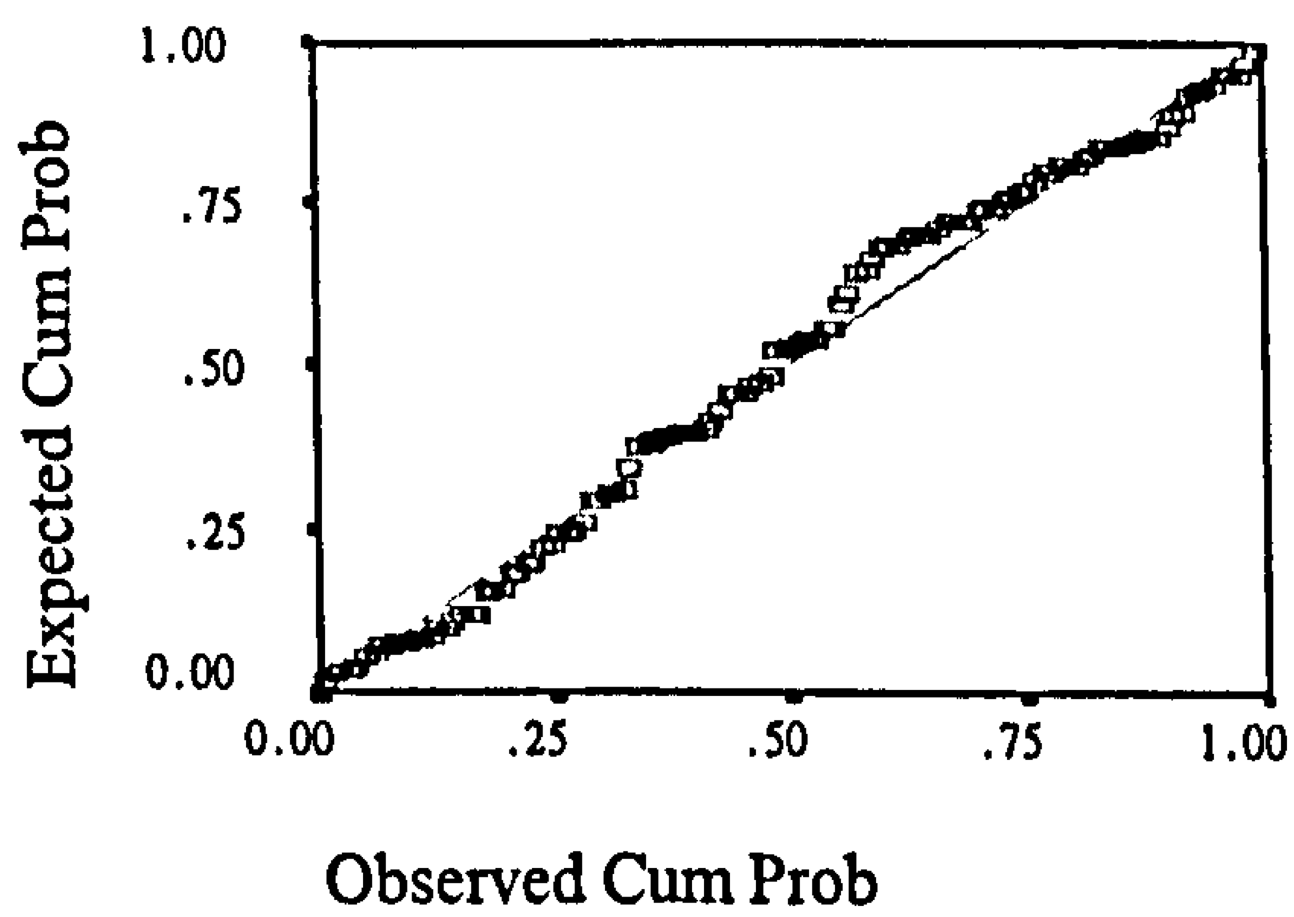
Gain in Manufacturing Knowledge



Normal P-P Plot of Standardized Residual

Dependent Variable:

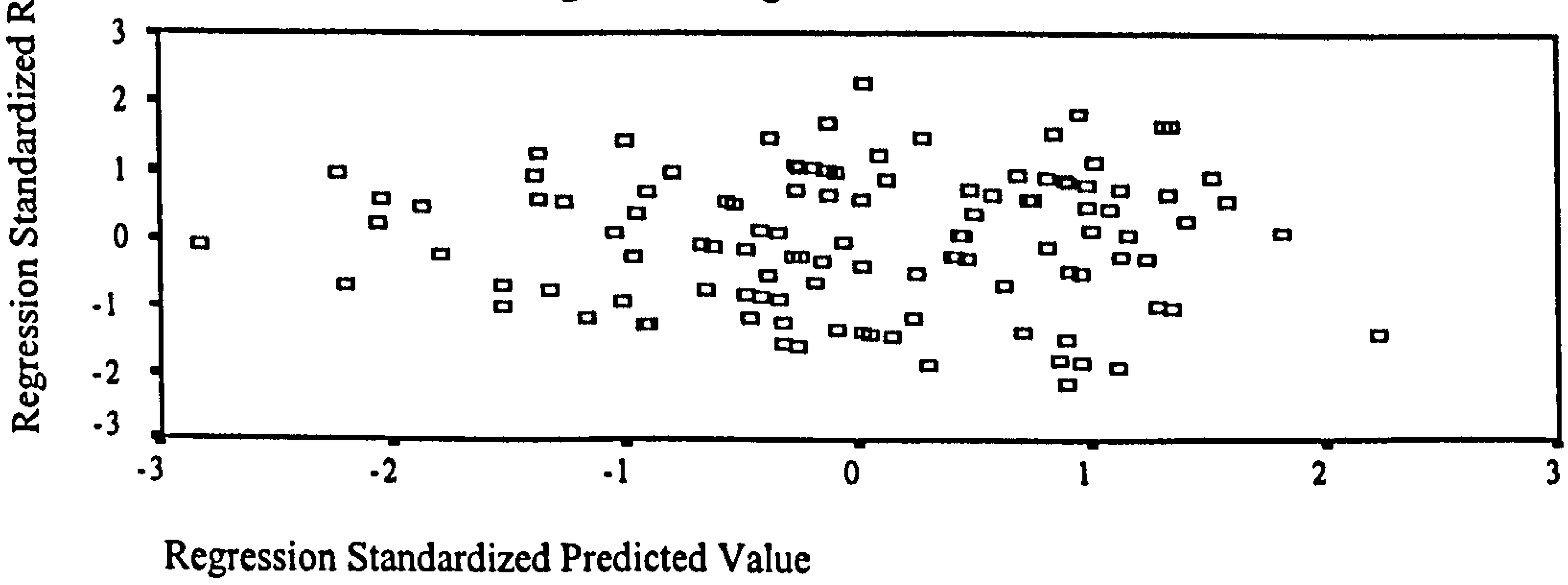
Gain in Manufacturing Knowledge



Scatterplot

Dependent Variable:

Gain in Manufacturing Knowledge

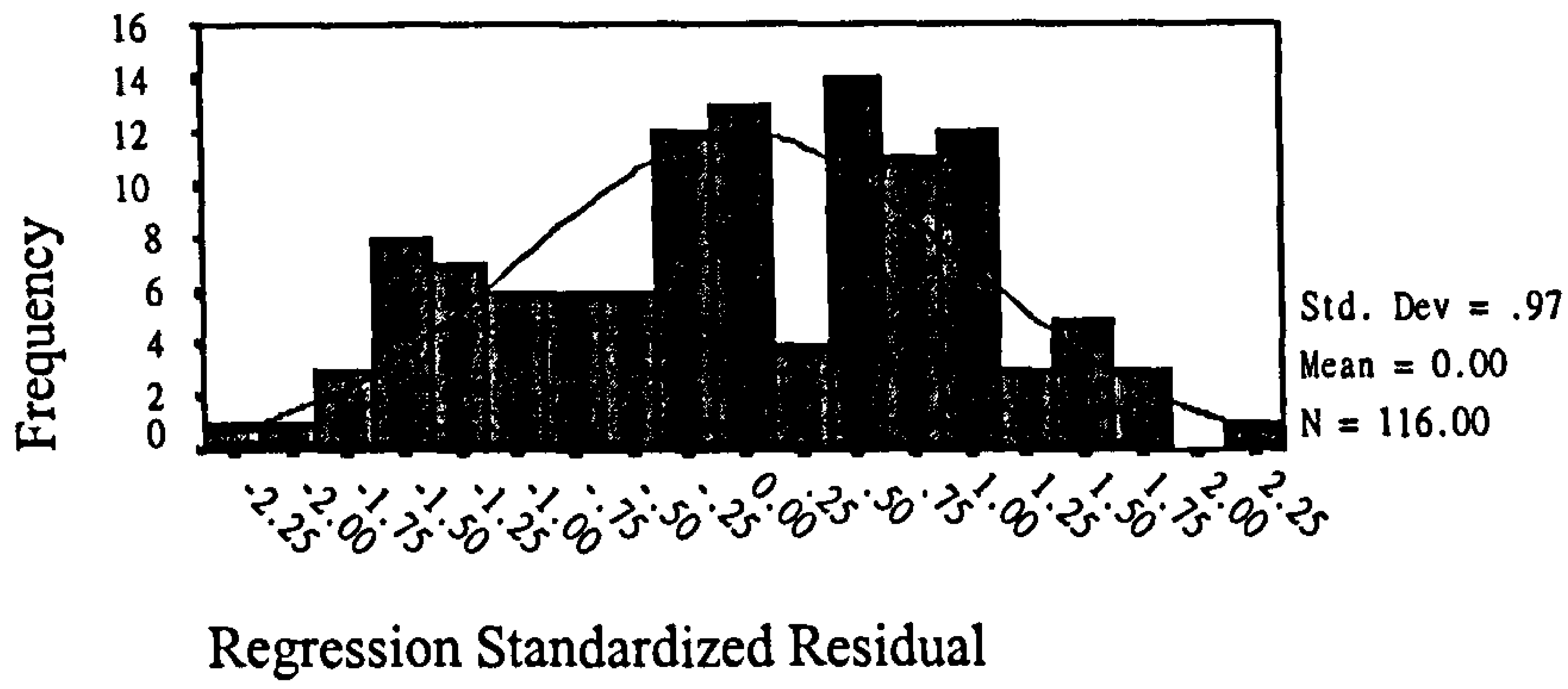


Regression Model 1 of Table 6.5.2.3

Histogram of Residuals

Dependent Variable:

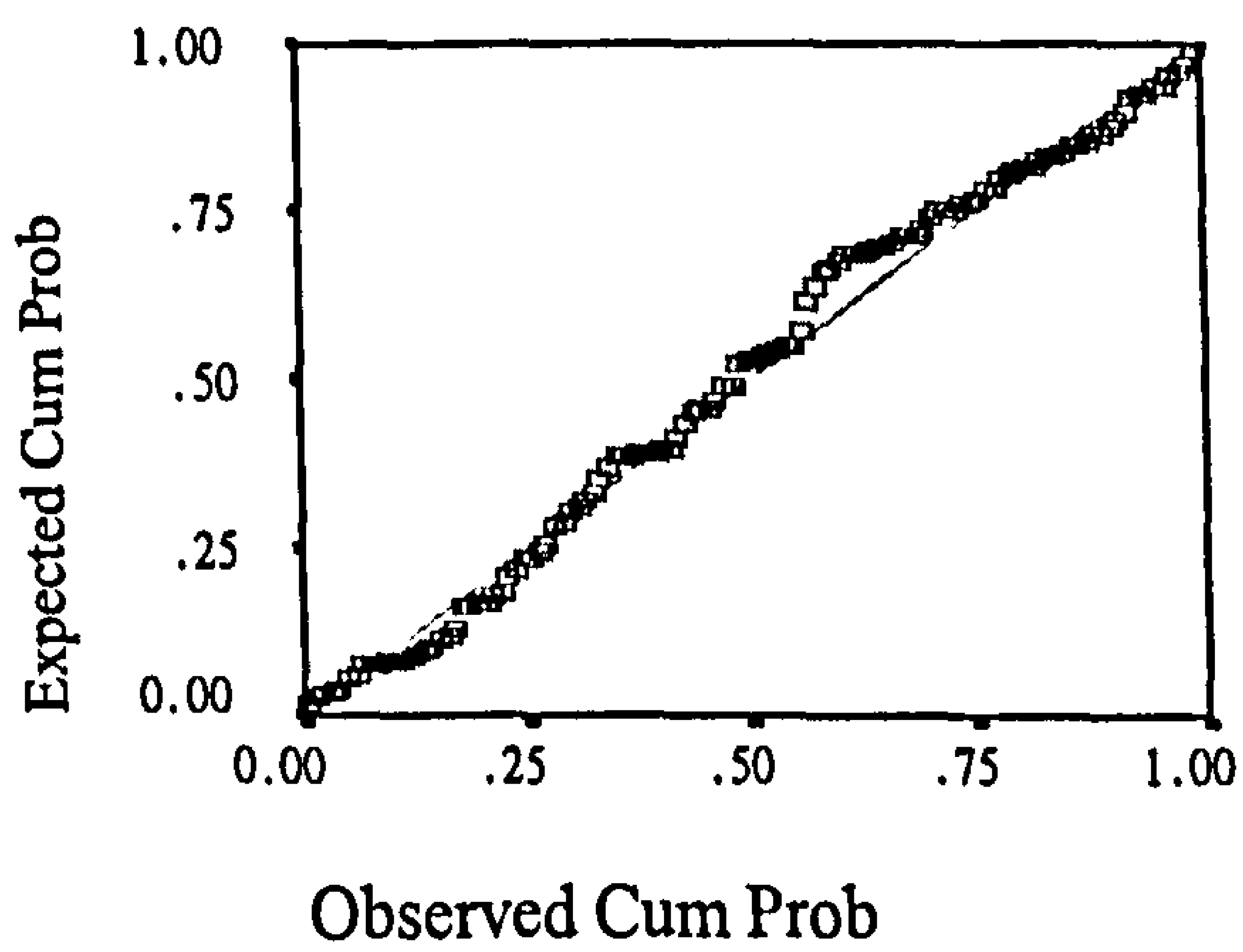
Gain in Manufacturing Knowledge



Normal P-P Plot of Standardized Residual

Dependent Variable:

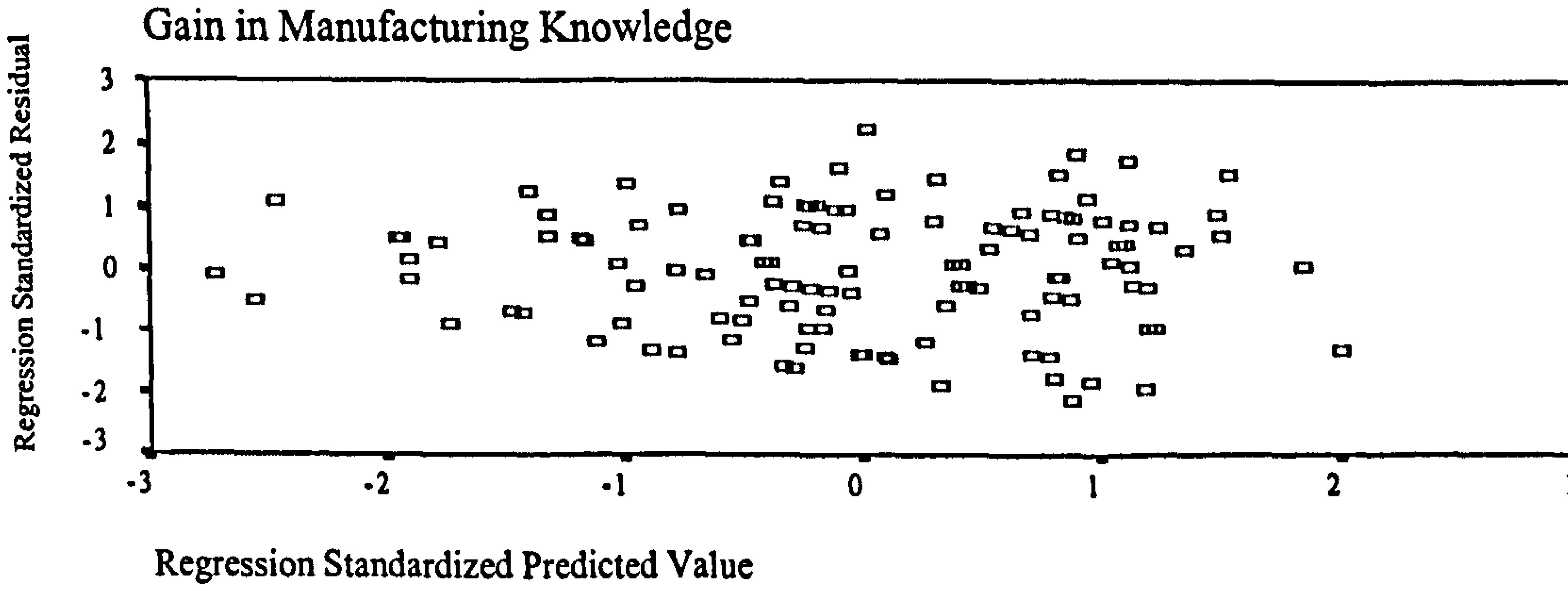
Gain in Manufacturing Knowledge



Scatterplot

Dependent Variable:

Gain in Manufacturing Knowledge

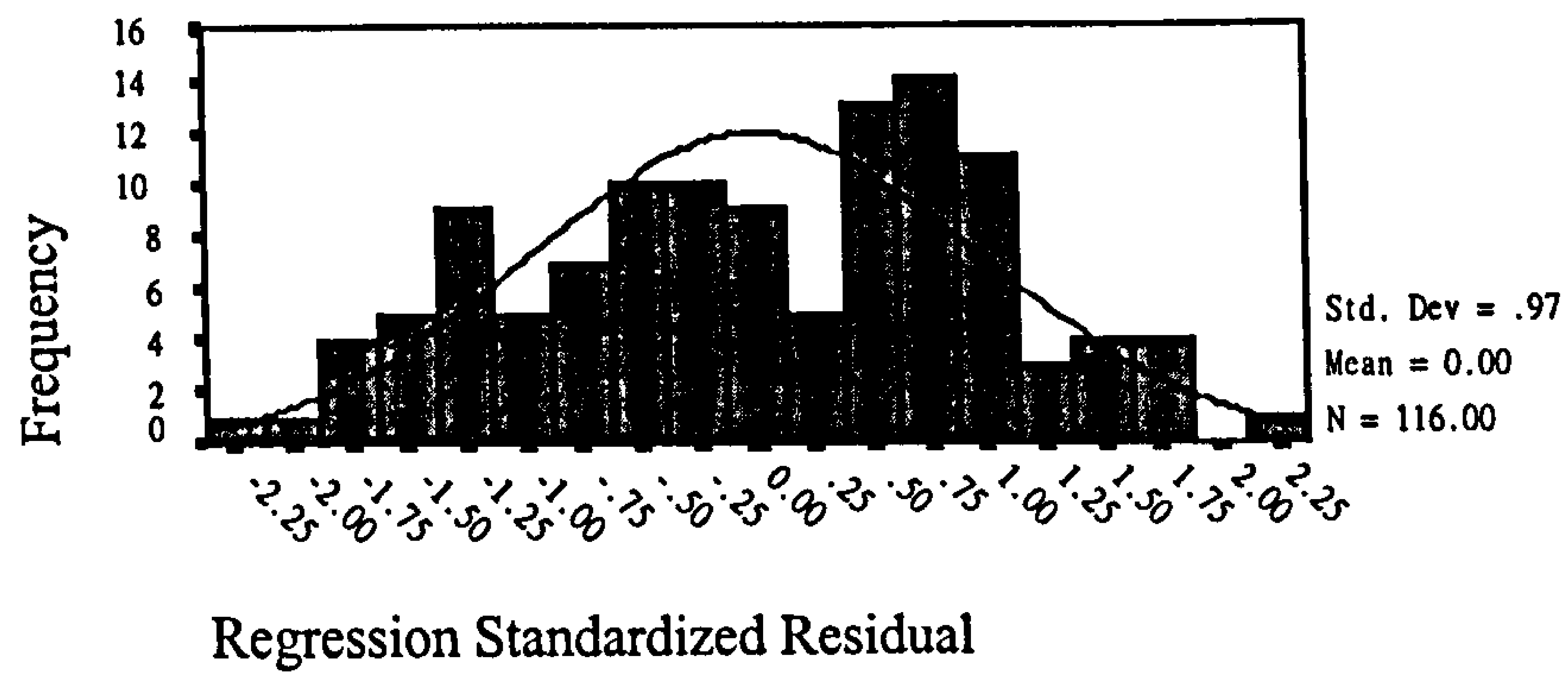


Regression Model 2 of Table 6.5.2.3

Histogram of Residuals

Dependent Variable:

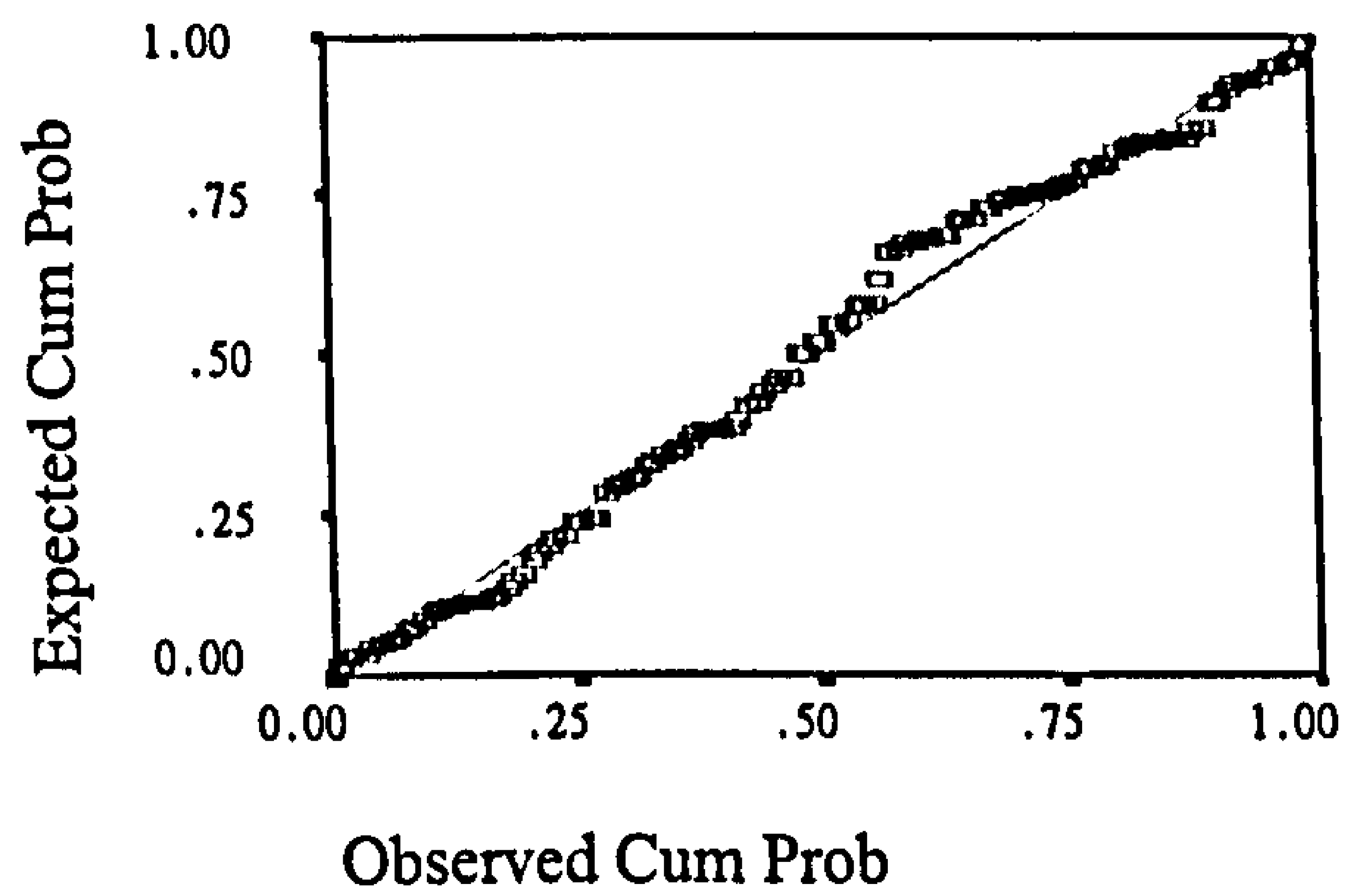
Gain in Manufacturing Knowledge



Normal P-P Plot of Standardized Residual

Dependent Variable:

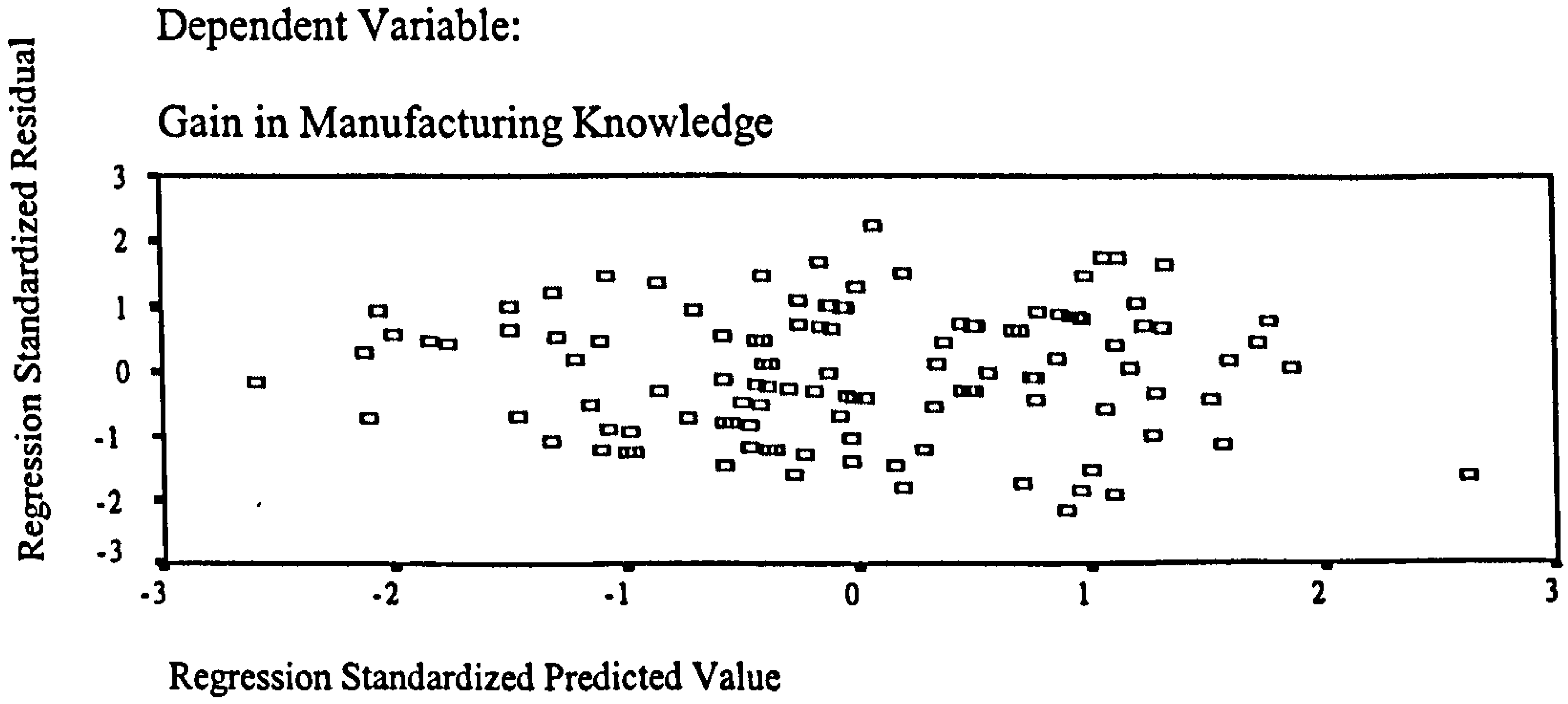
Gain in Manufacturing Knowledge



Scatterplot

Dependent Variable:

Gain in Manufacturing Knowledge

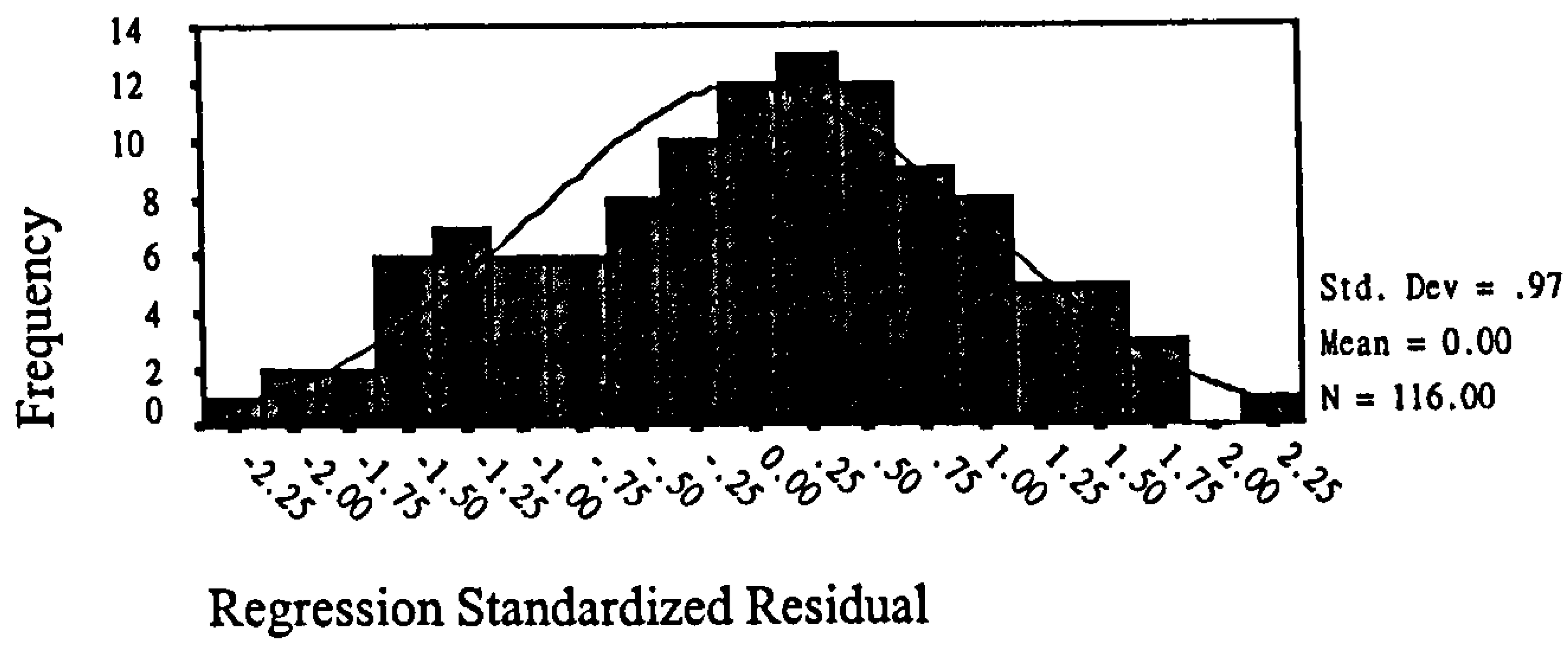


Regression Model 3 of Table 6.5.2.3

Histogram of Residuals

Dependent Variable:

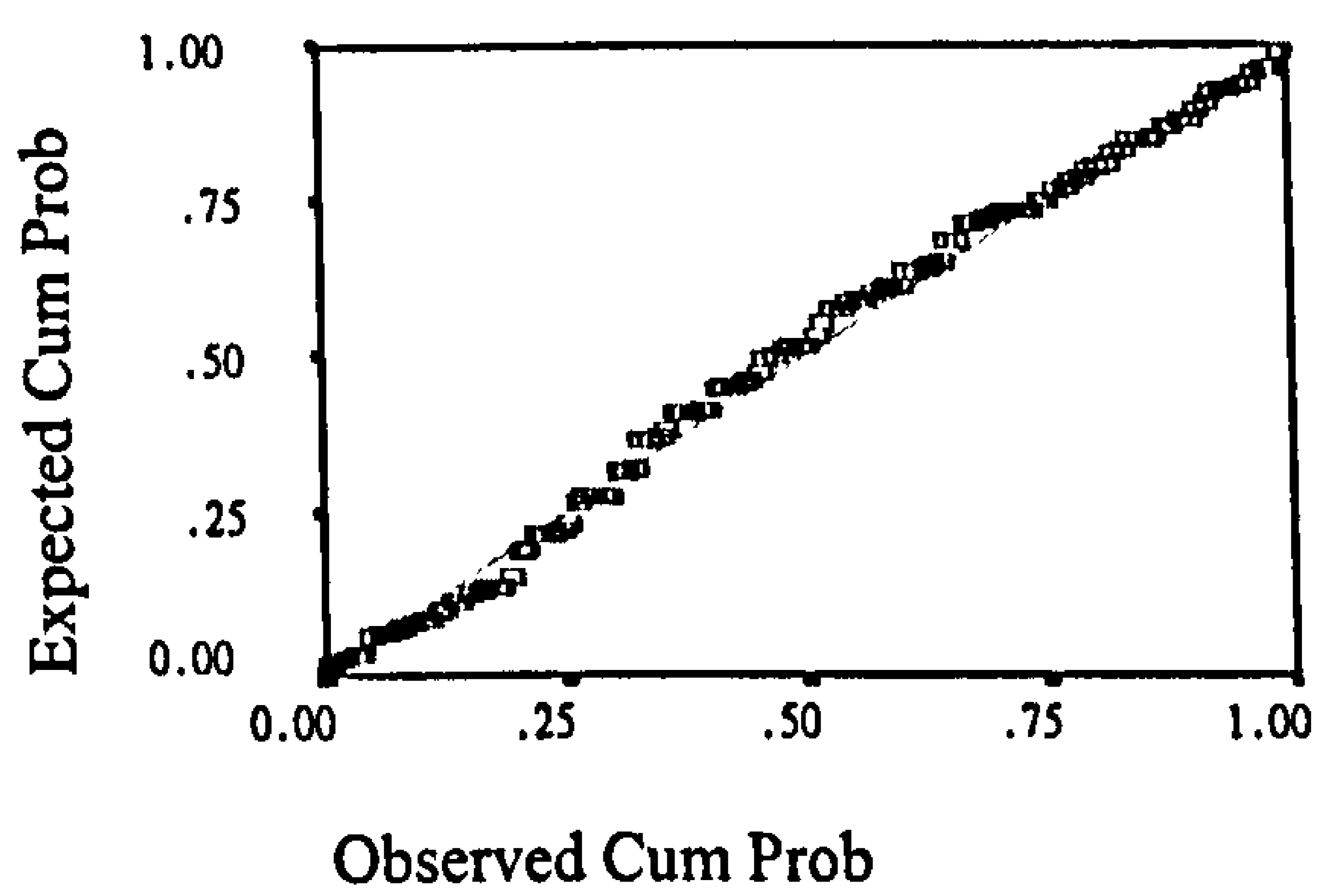
Gain in Manufacturing Knowledge



Normal P-P Plot of Standardized Residual

Dependent Variable:

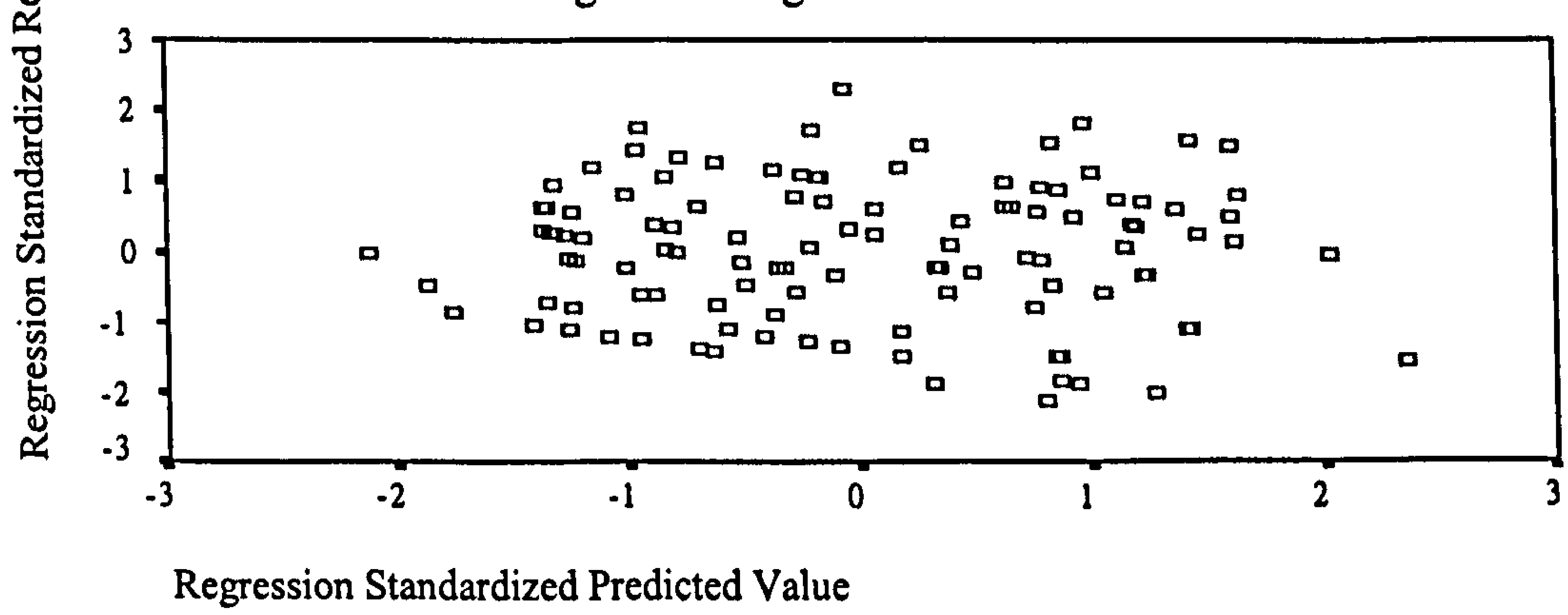
Gain in Manufacturing Knowledge



Scatterplot

Dependent Variable:

Gain in Manufacturing Knowledge

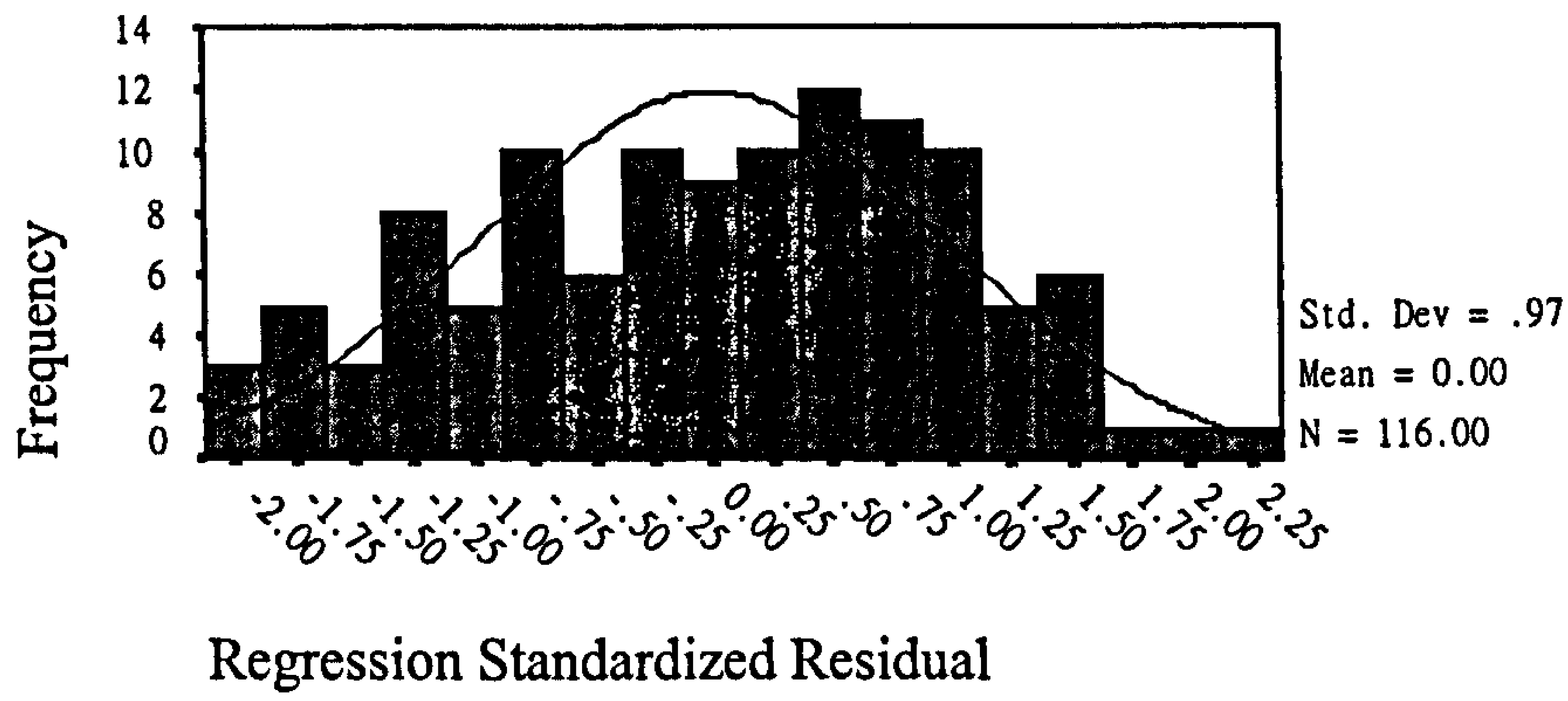


Regression Model 4 of Table 6.5.2.3

Histogram of Residuals

Dependent Variable:

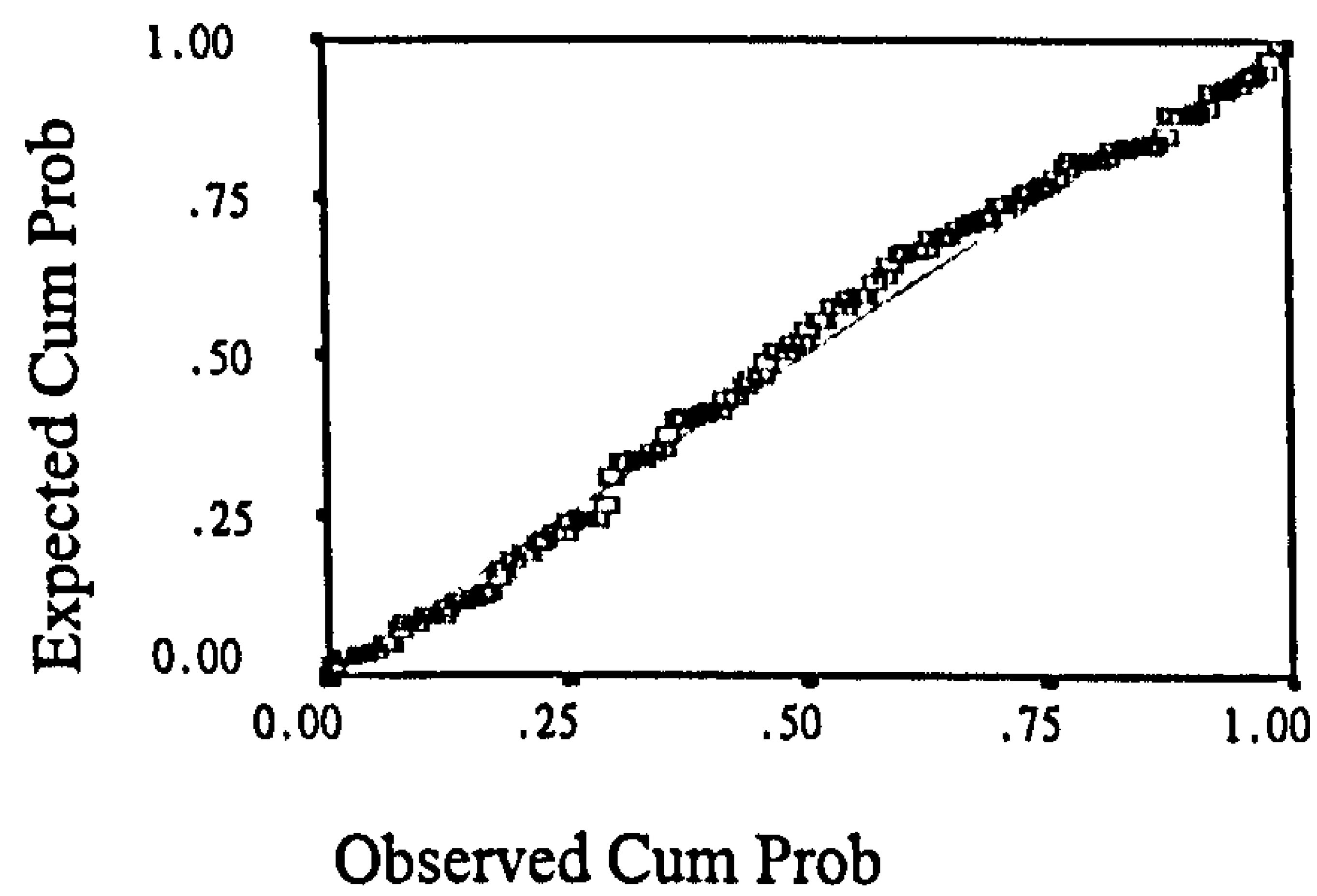
Gain in Manufacturing Knowledge



Normal P-P Plot of Standardized Residual

Dependent Variable:

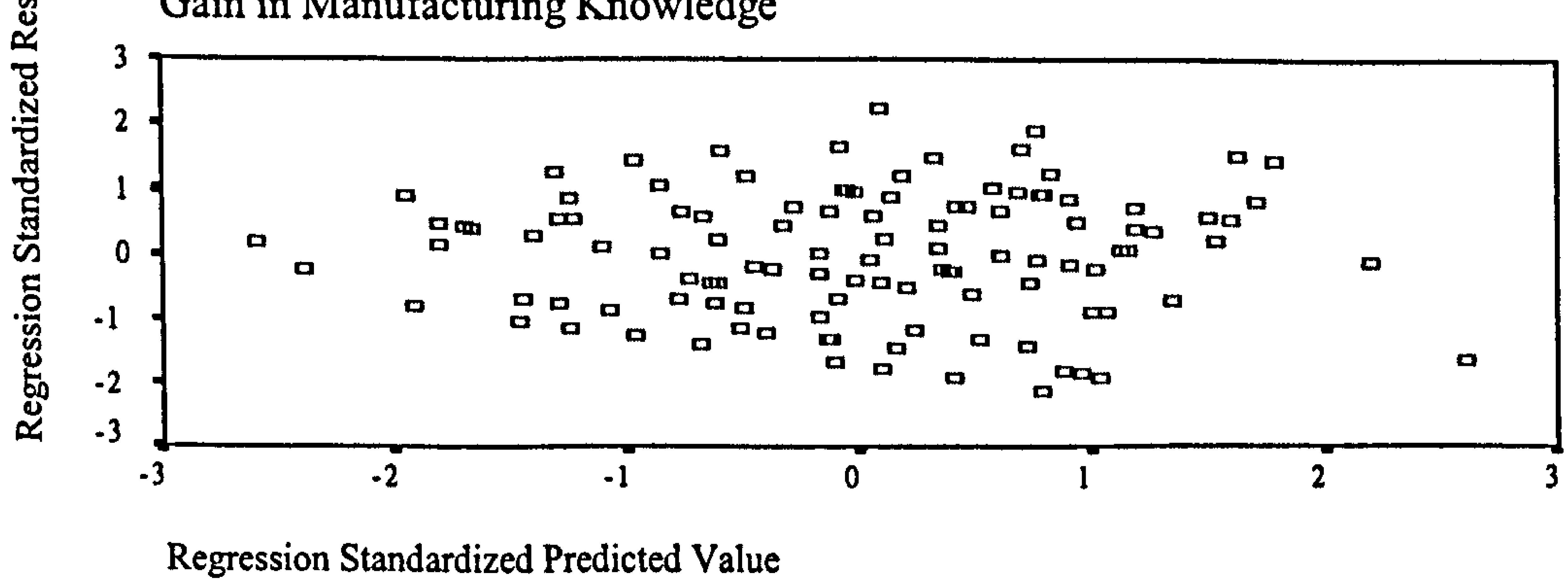
Gain in Manufacturing Knowledge



Scatterplot

Dependent Variable:

Gain in Manufacturing Knowledge

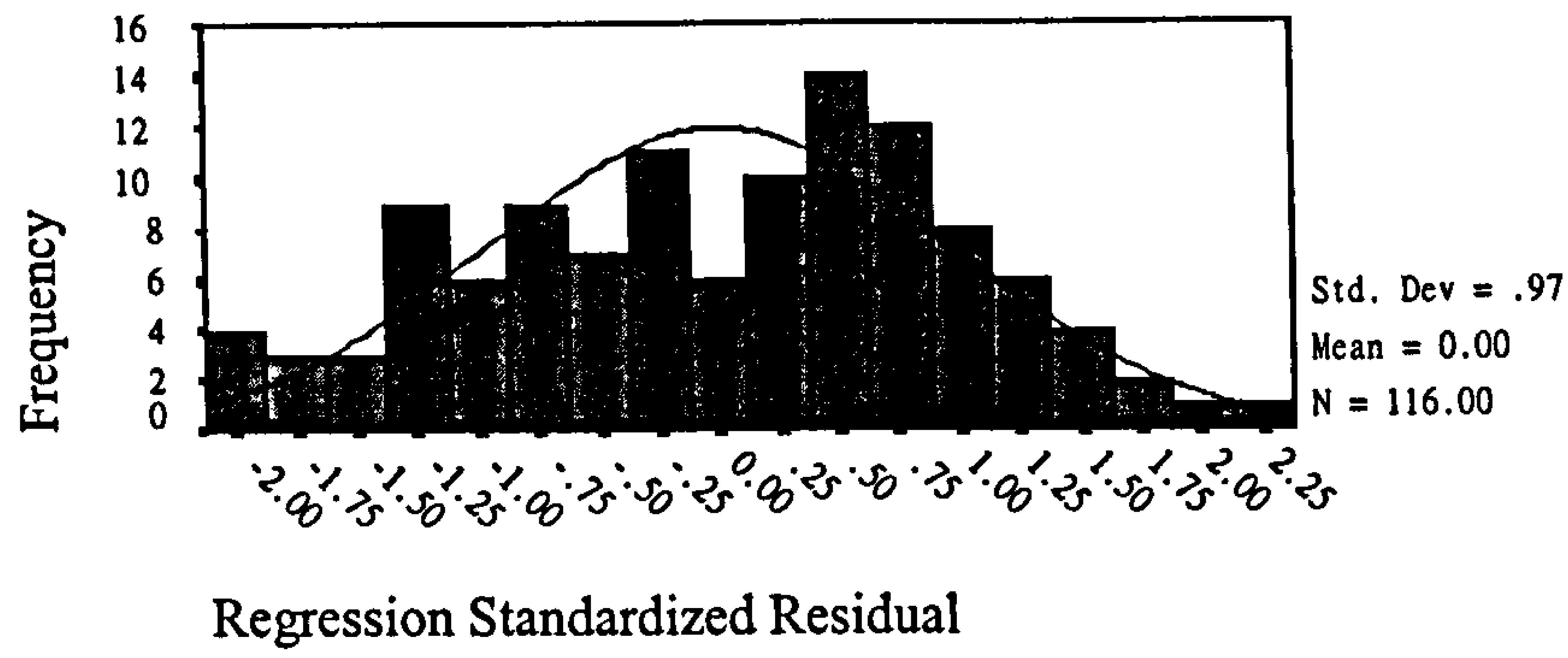


Regression Model 5 of Table 6.5.2.3

Histogram of Residuals

Dependent Variable:

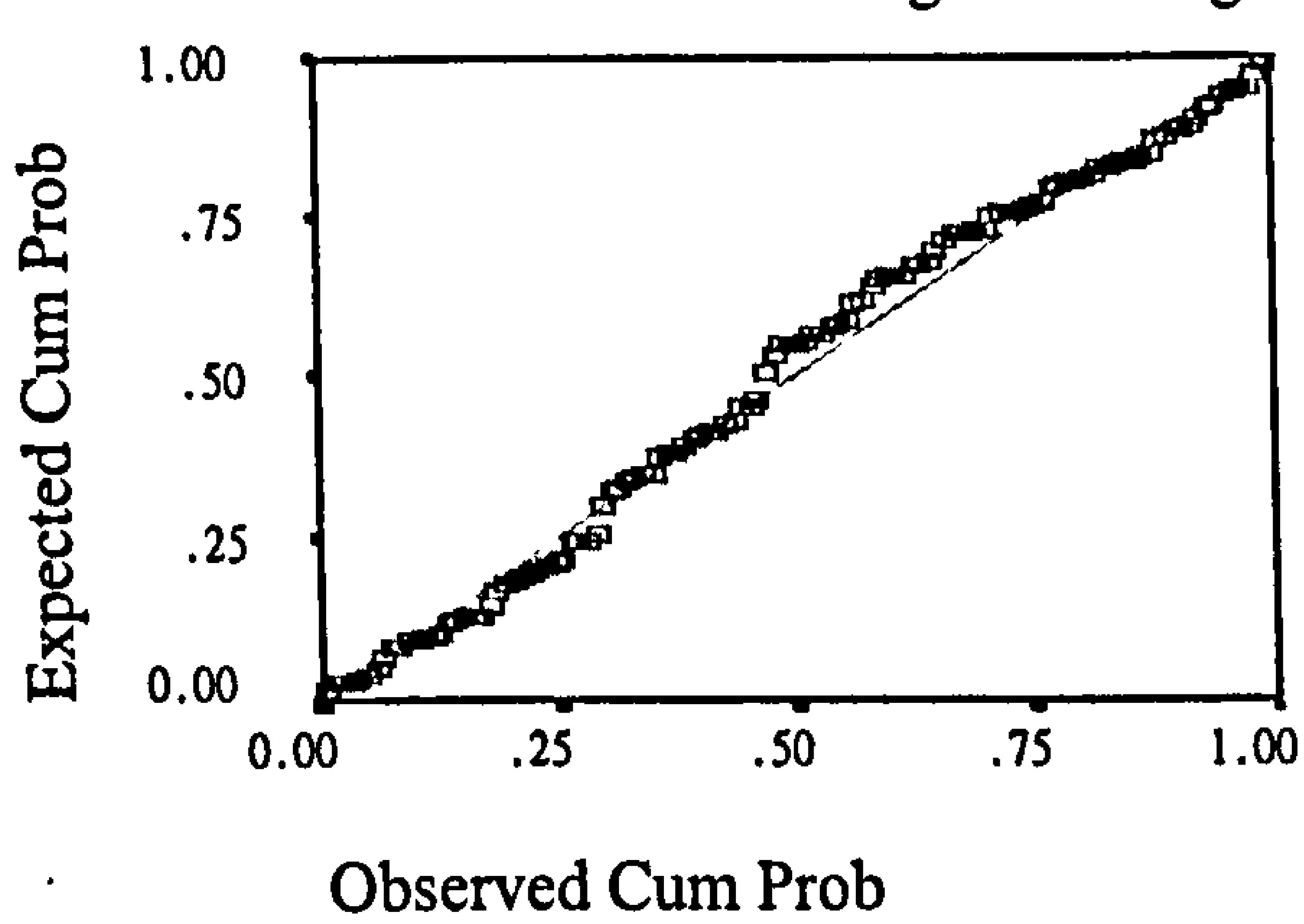
Gain in Manufacturing Knowledge



Normal P-P Plot of Standardized Residual

Dependent Variable:

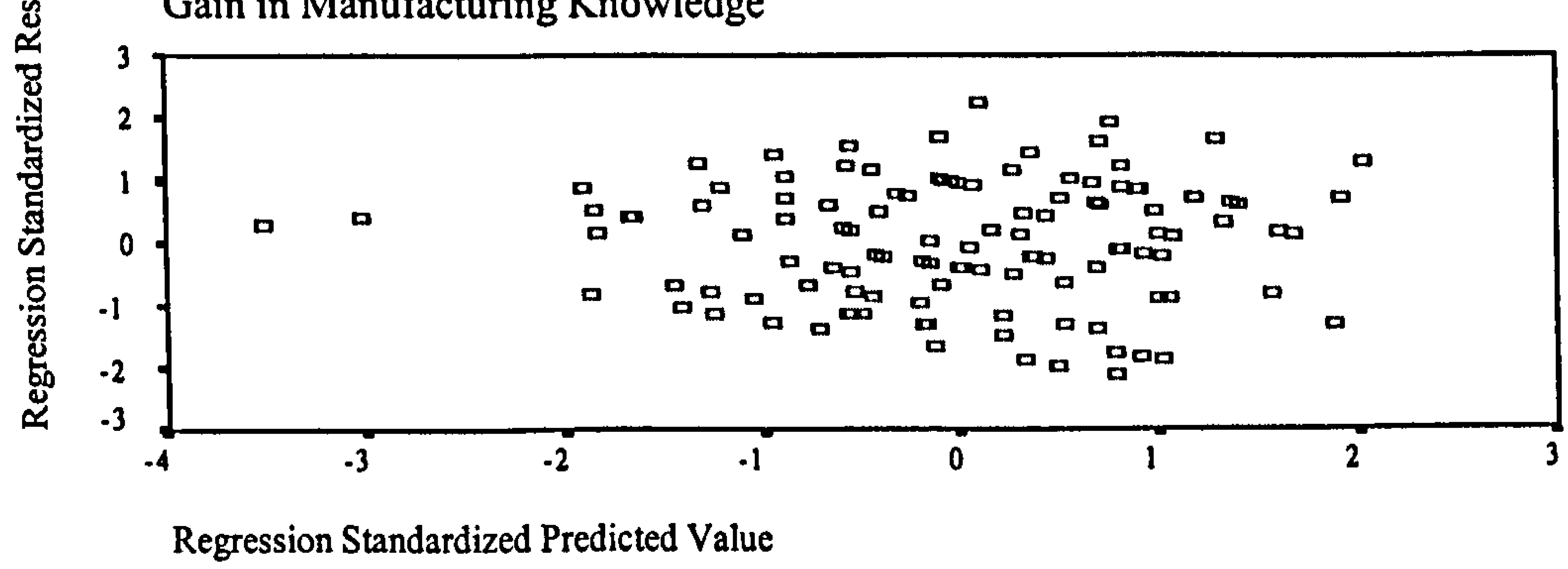
Gain in Manufacturing Knowledge



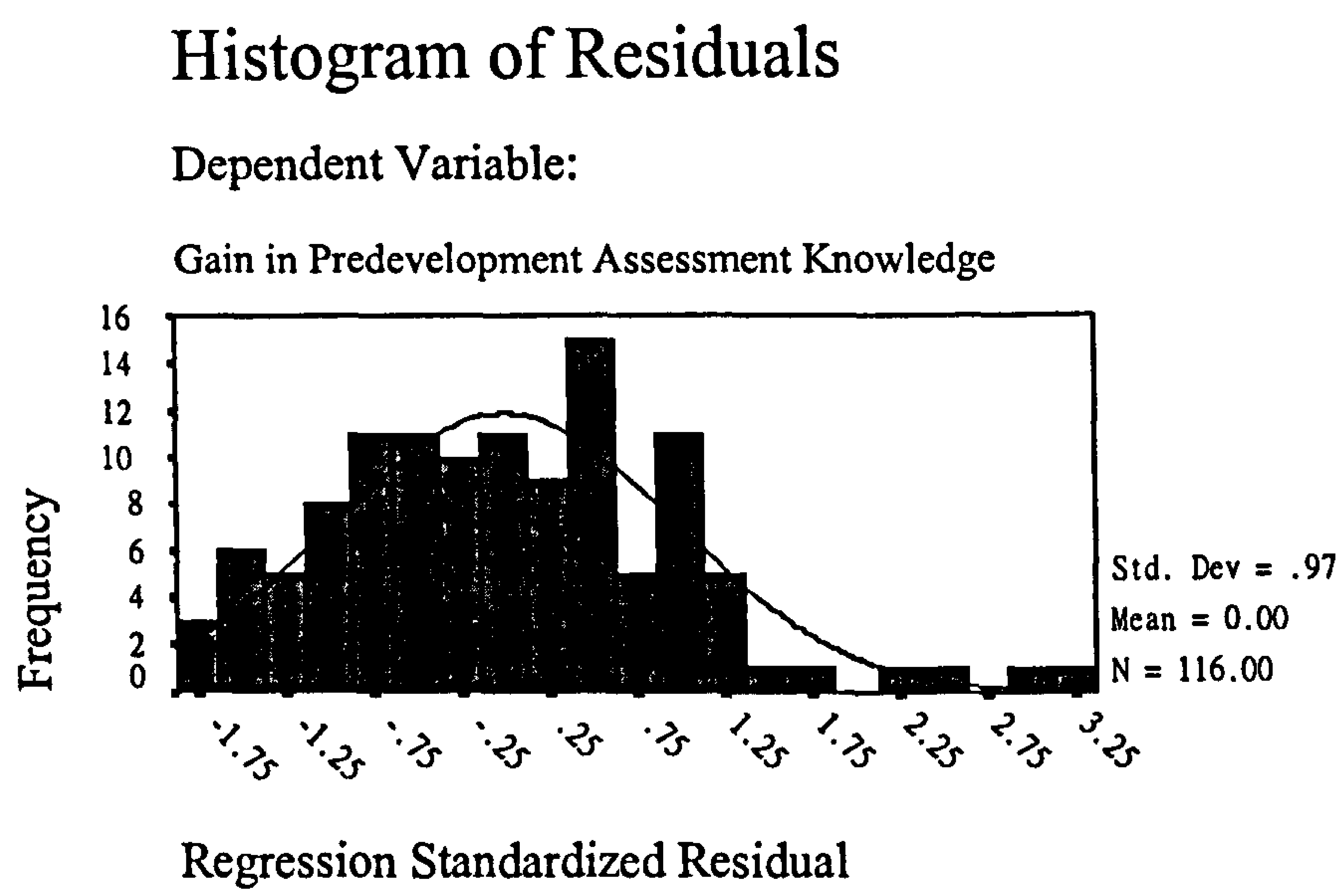
Scatterplot

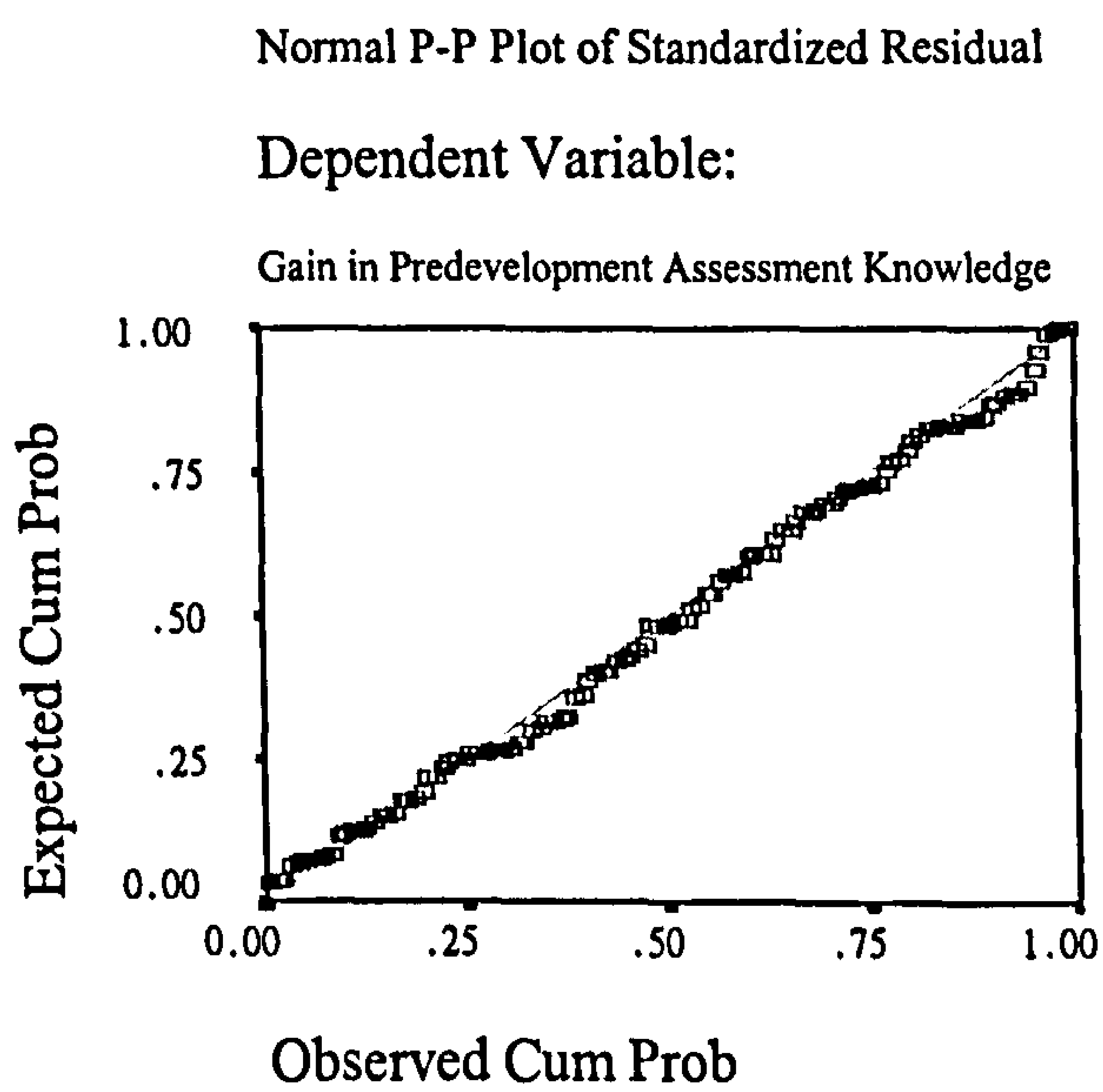
Dependent Variable:

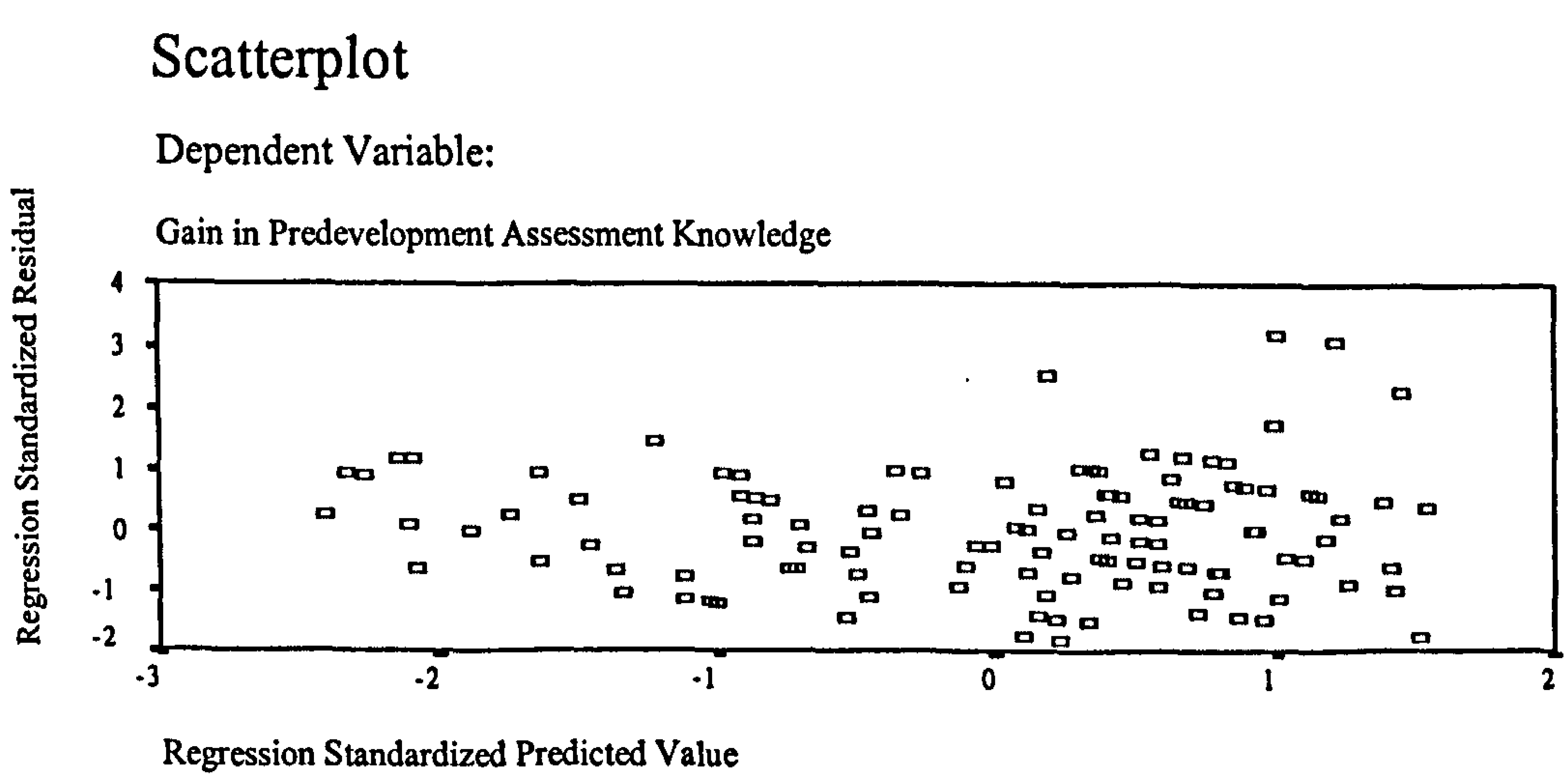
Gain in Manufacturing Knowledge



Regression Model 6 of Table 6.5.2.3





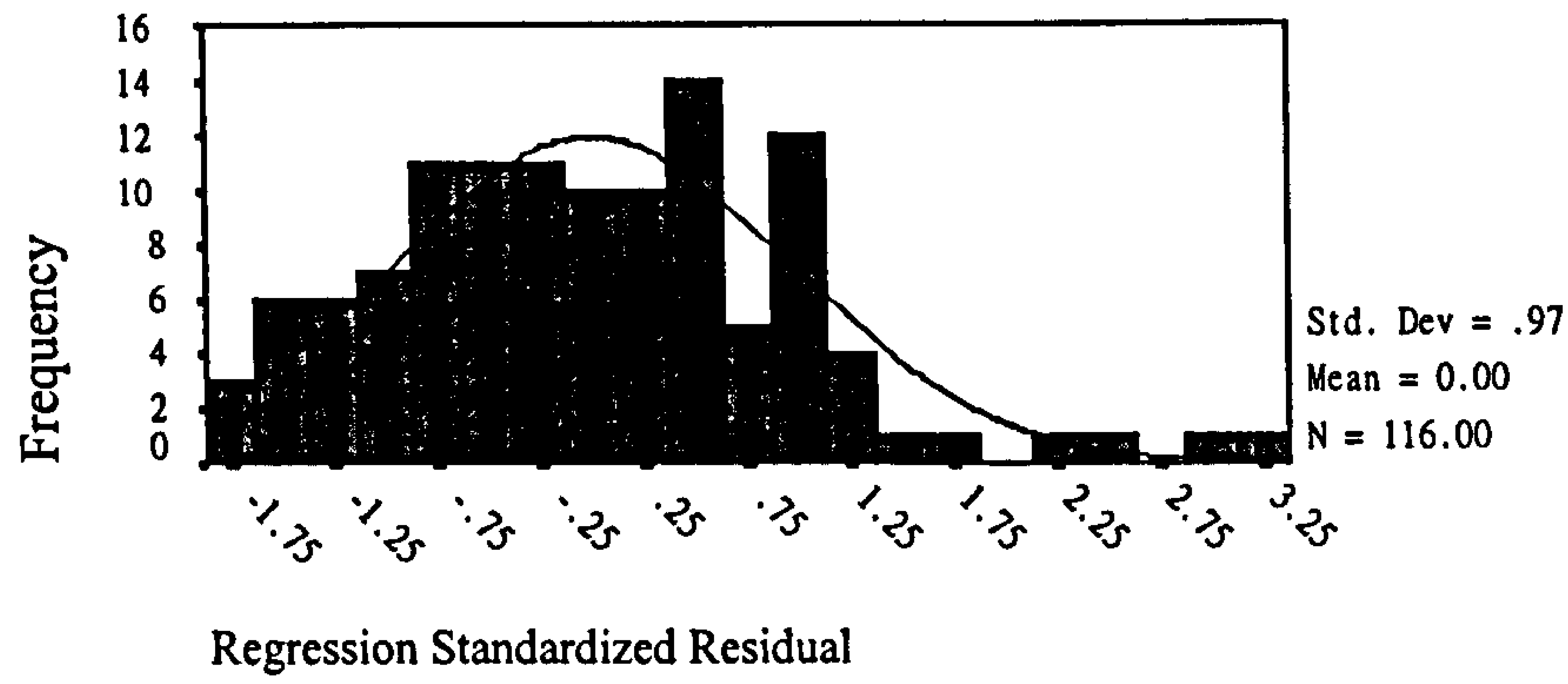


Regression Model 1 of Table 6.5.2.4

Histogram of Residuals

Dependent Variable:

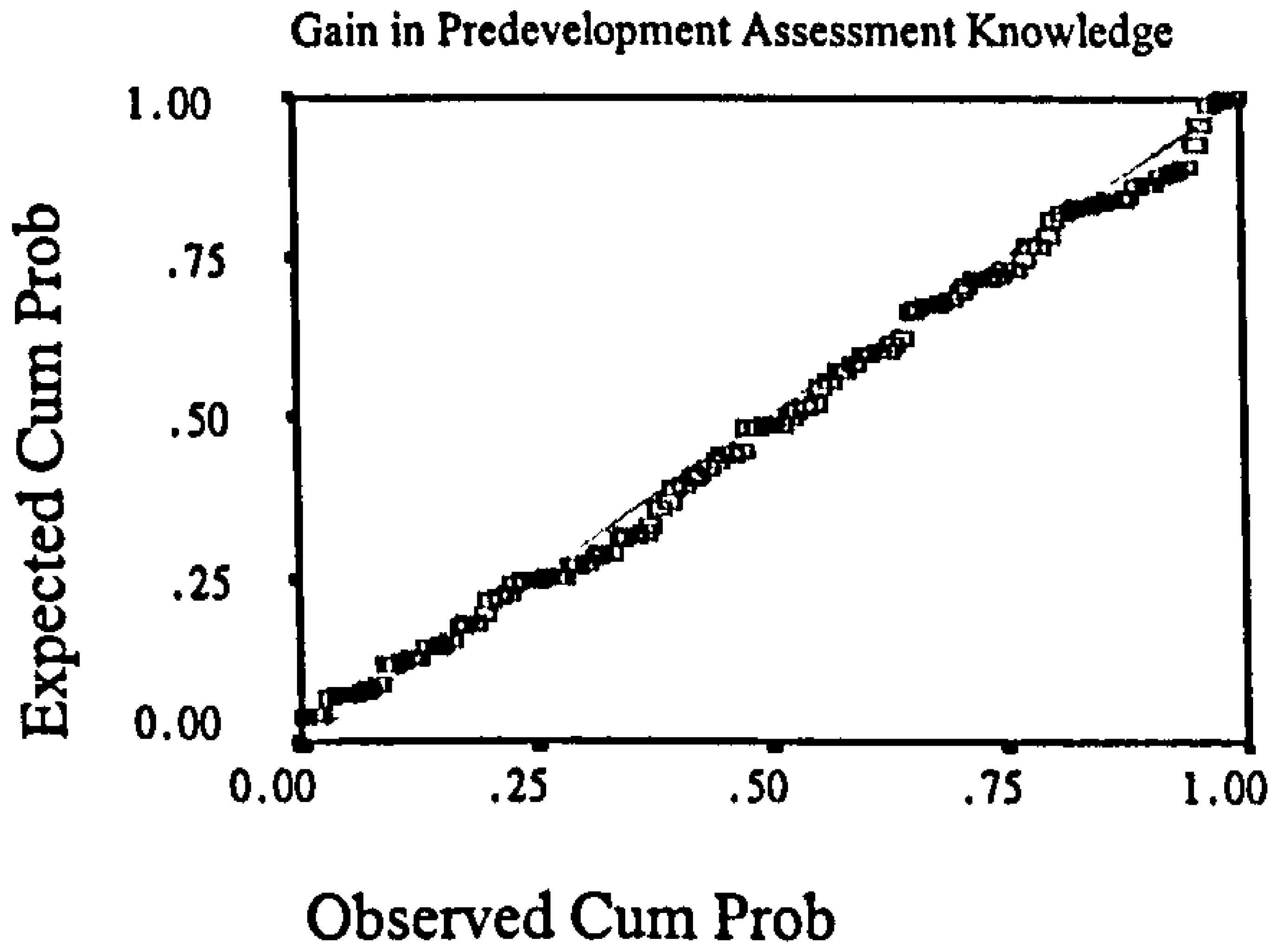
Gain in Predevelopment Assessment Knowledge



Normal P-P Plot of Standardized Residual

Dependent Variable:

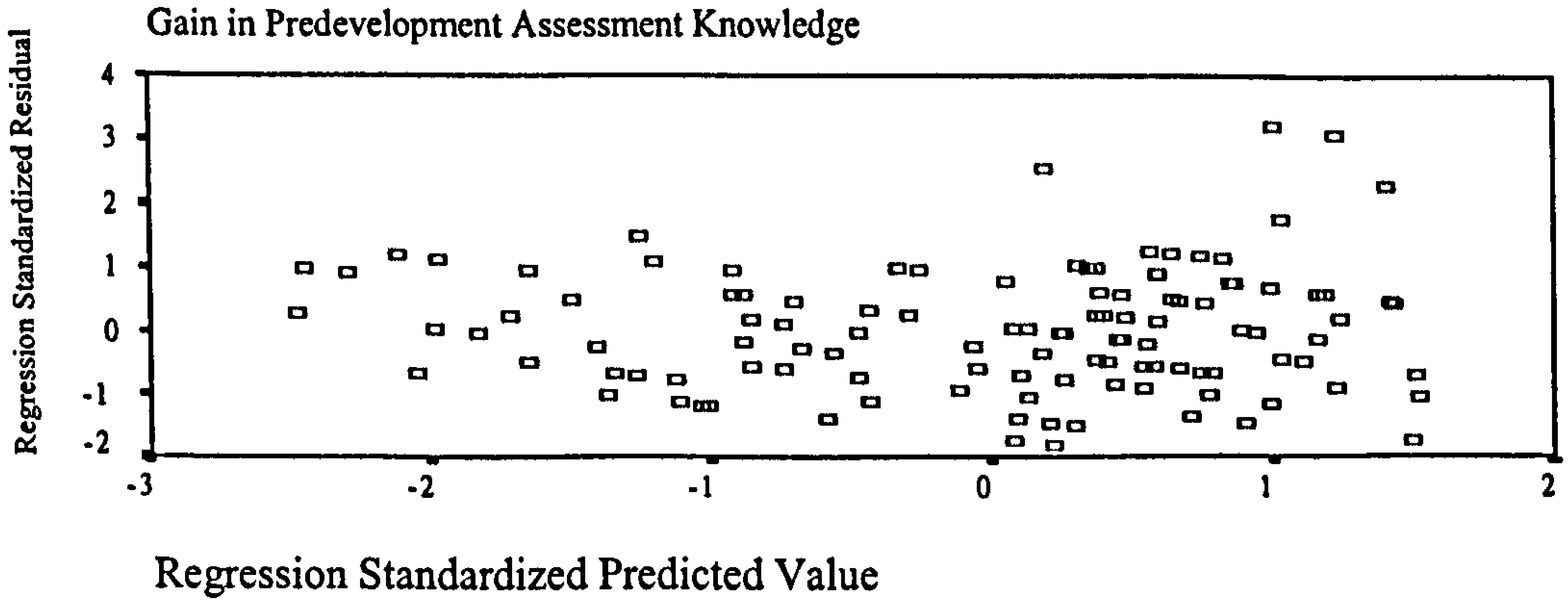
Gain in Predevelopment Assessment Knowledge



Scatterplot

Dependent Variable:

Gain in Predevelopment Assessment Knowledge

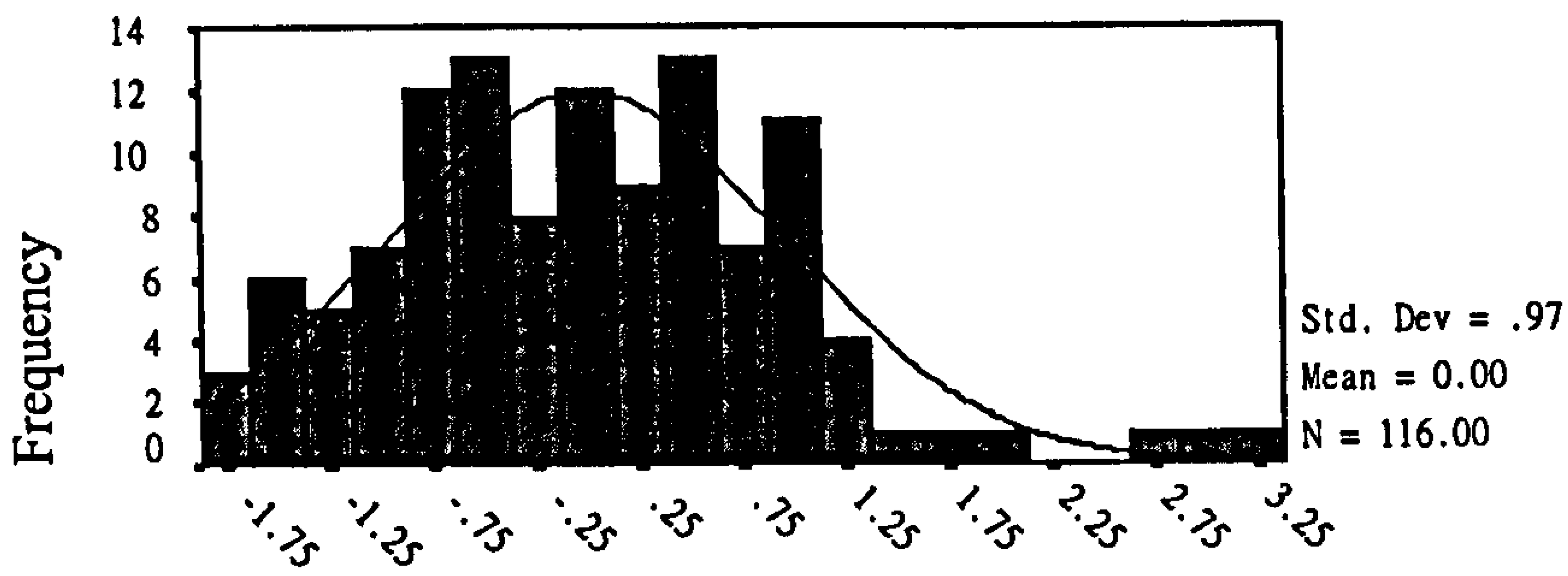


Regression Model 2 of Table 6.5.2.4

Histogram of Residuals

Dependent Variable:

Gain in Predevelopment Assessment Knowledge

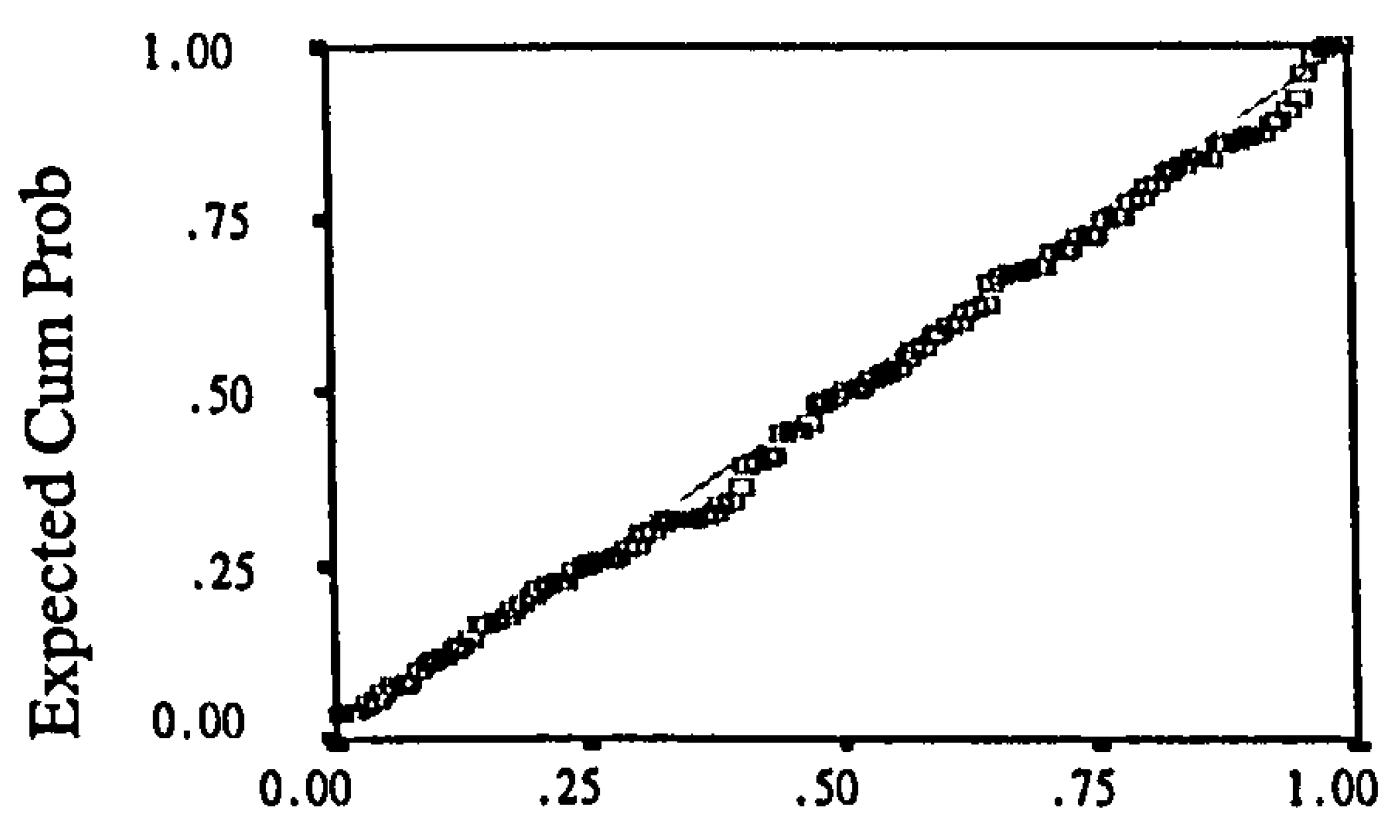


Regression Standardized Residual

Normal P-P Plot of Standardized Residual

Dependent Variable:

Gain in Predevelopment Assessment Knowledge

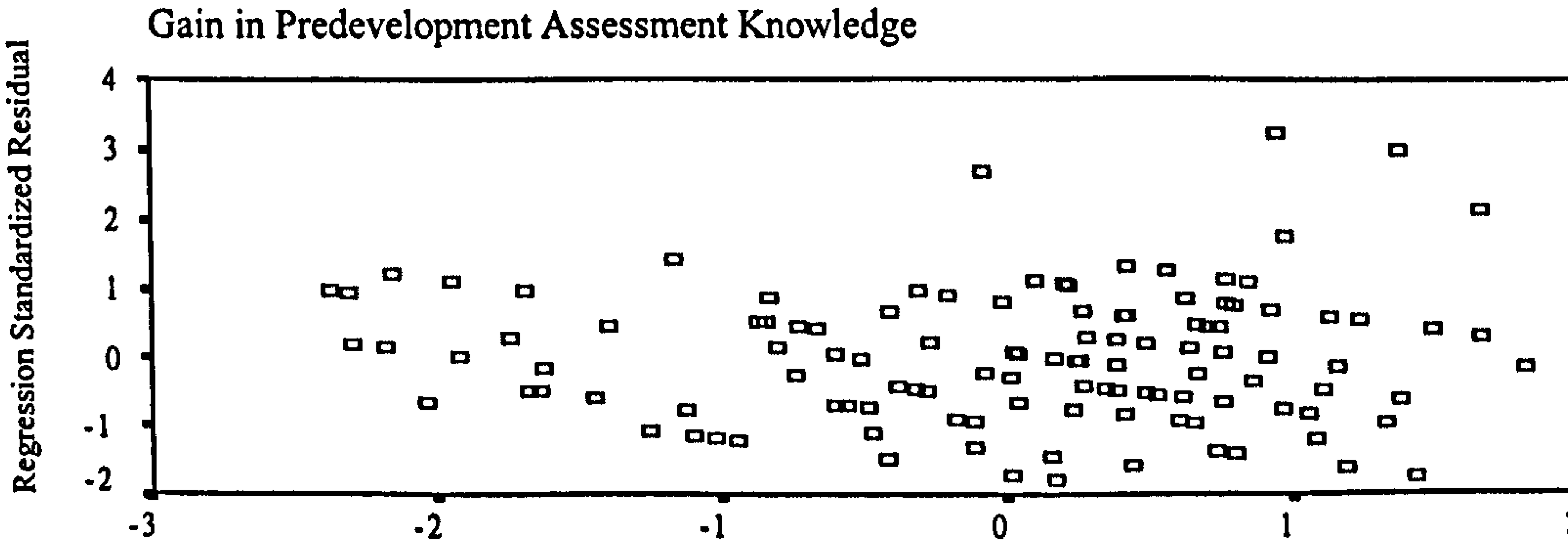


Observed Cum Prob

Scatterplot

Dependent Variable:

Gain in Predevelopment Assessment Knowledge



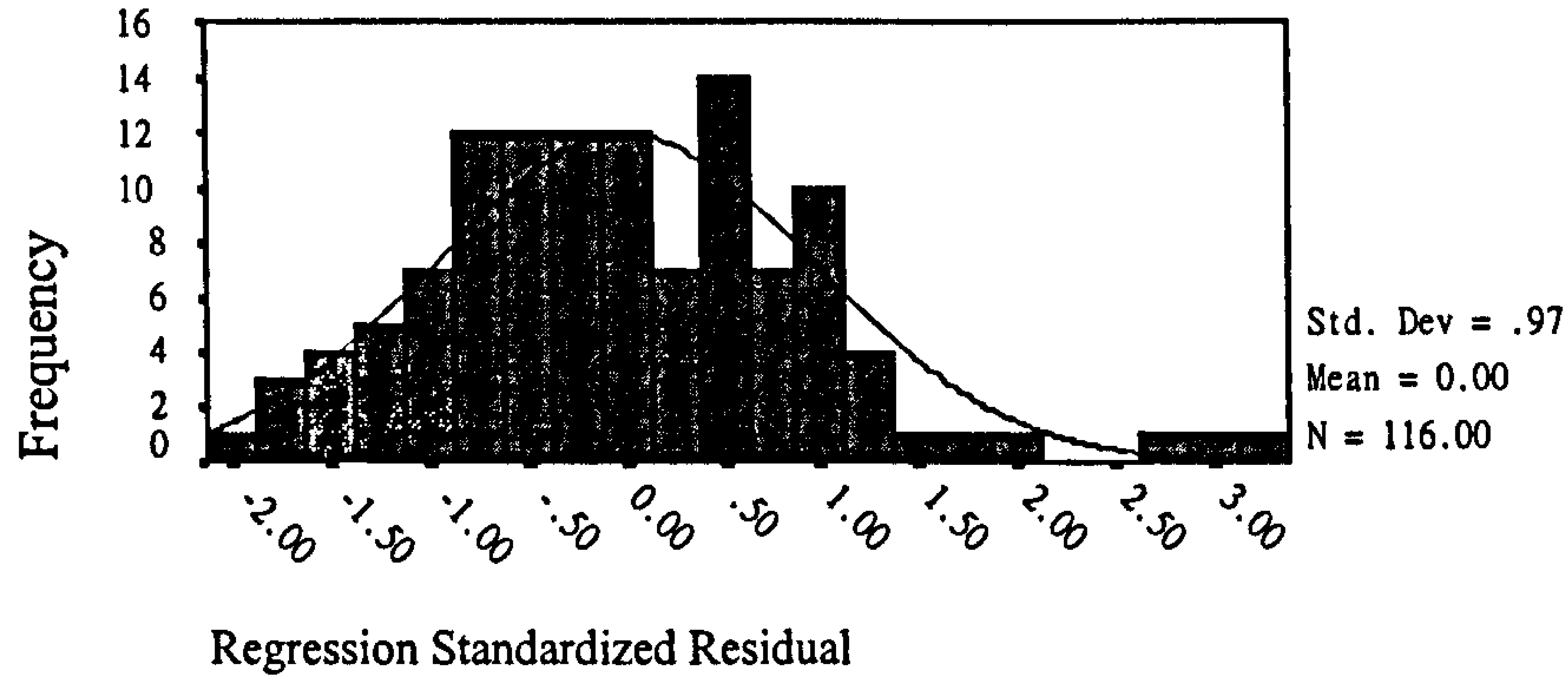
Regression Standardized Predicted Value

Regression Model 3 of Table 6.5.2.4

Histogram of Residuals

Dependent Variable:

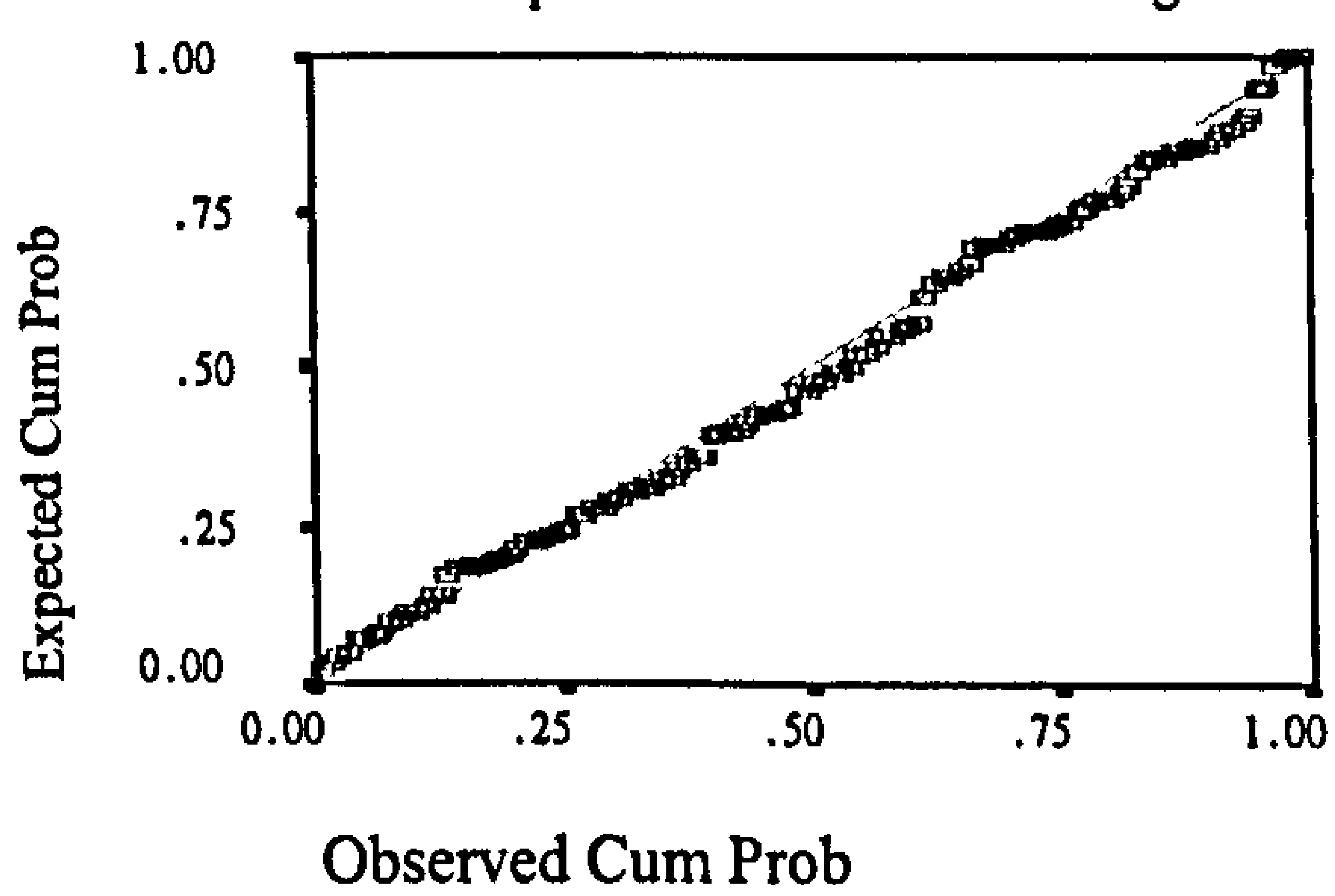
Gain in Predevelopment Assessment Knowledge



Normal P-P Plot of Standardized Residual

Dependent Variable:

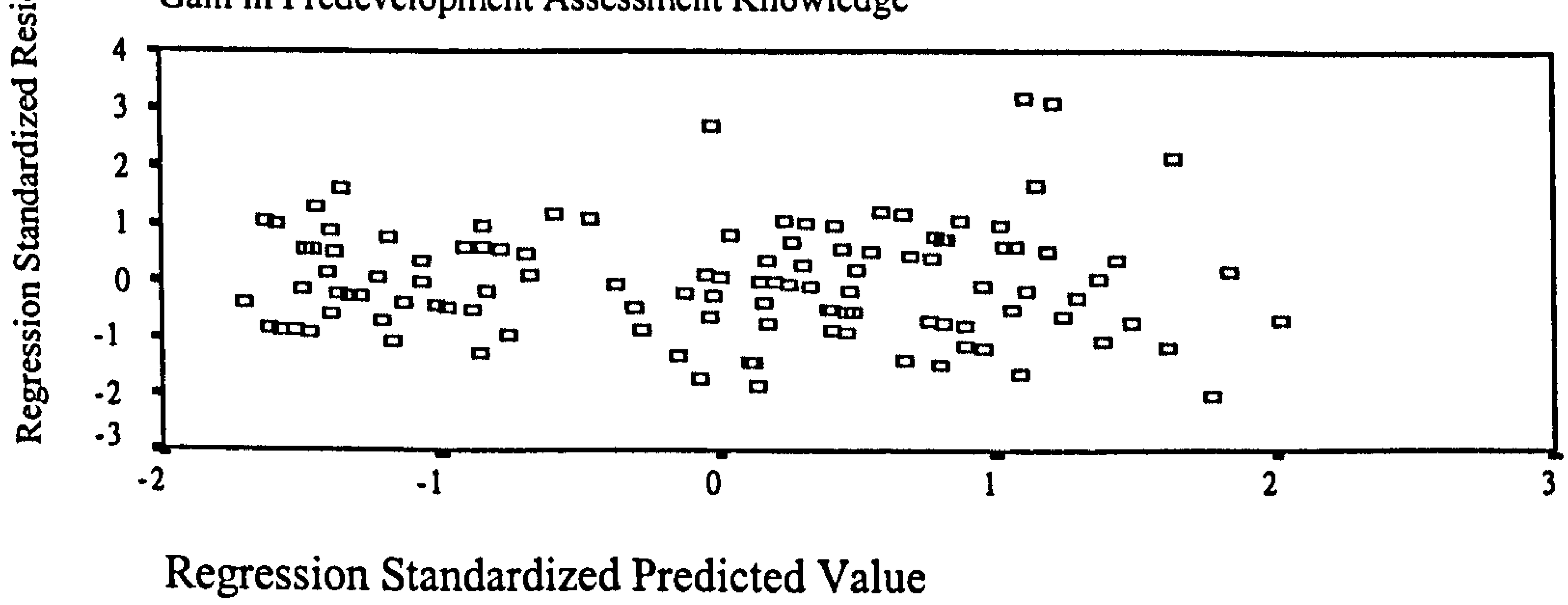
Predevelopment Assessment Knowledge



Scatterplot

Dependent Variable:

Gain in Predevelopment Assessment Knowledge

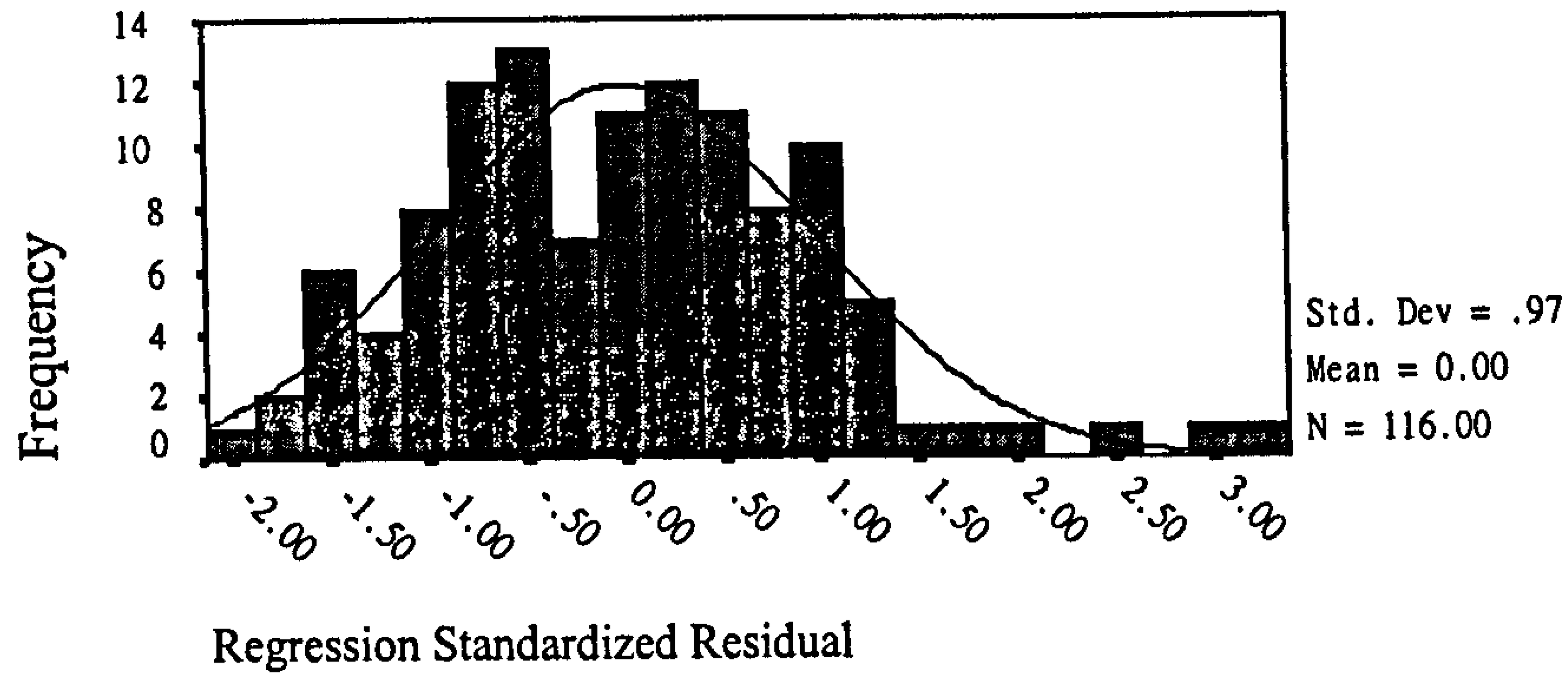


Regression 4 of Table 6.5.2.4

Histogram of Residuals

Dependent Variable:

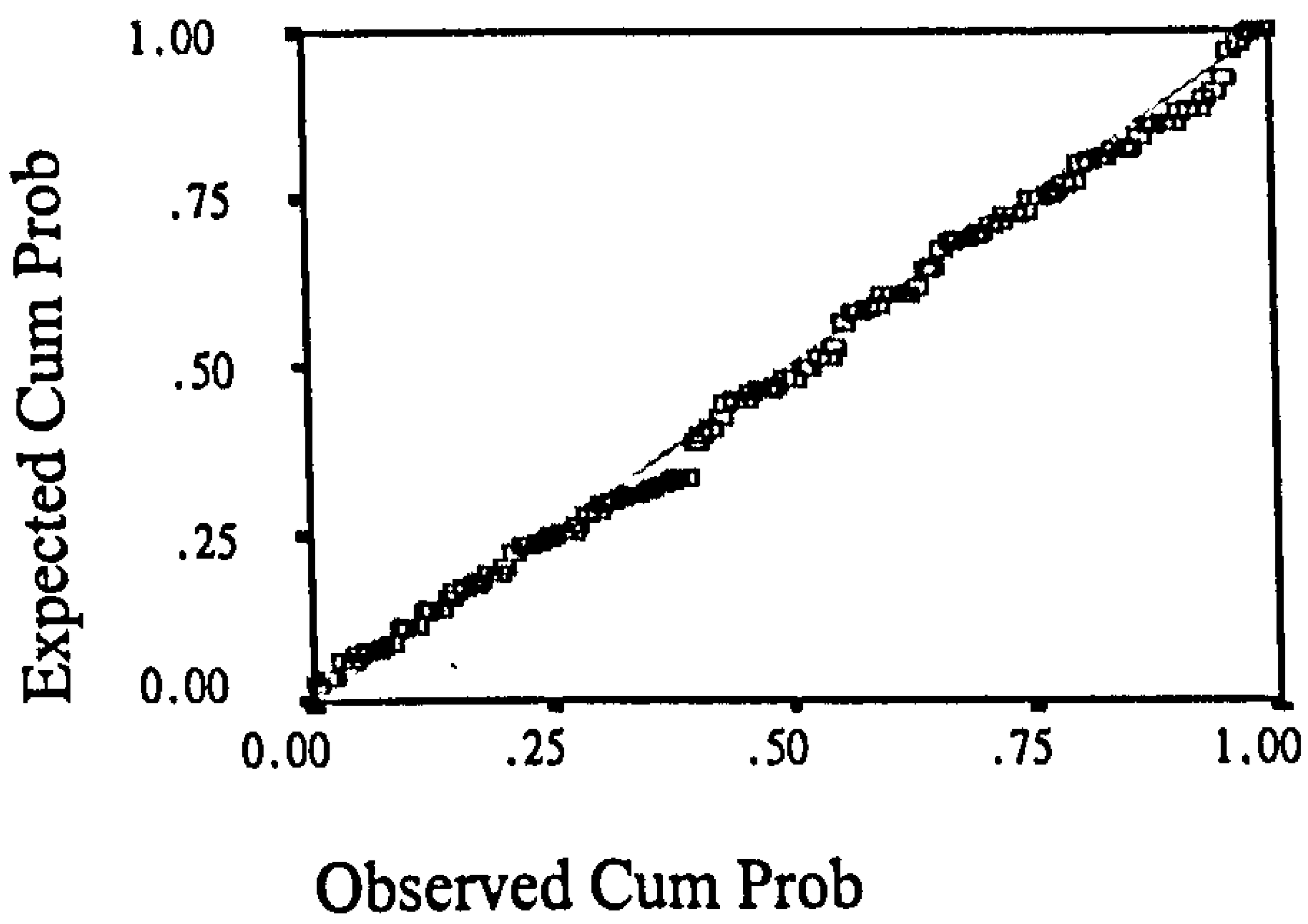
Gain in Predevelopment Assessment Knowledge



Normal P-P Plot of Standardized Residual

Dependent Variable:

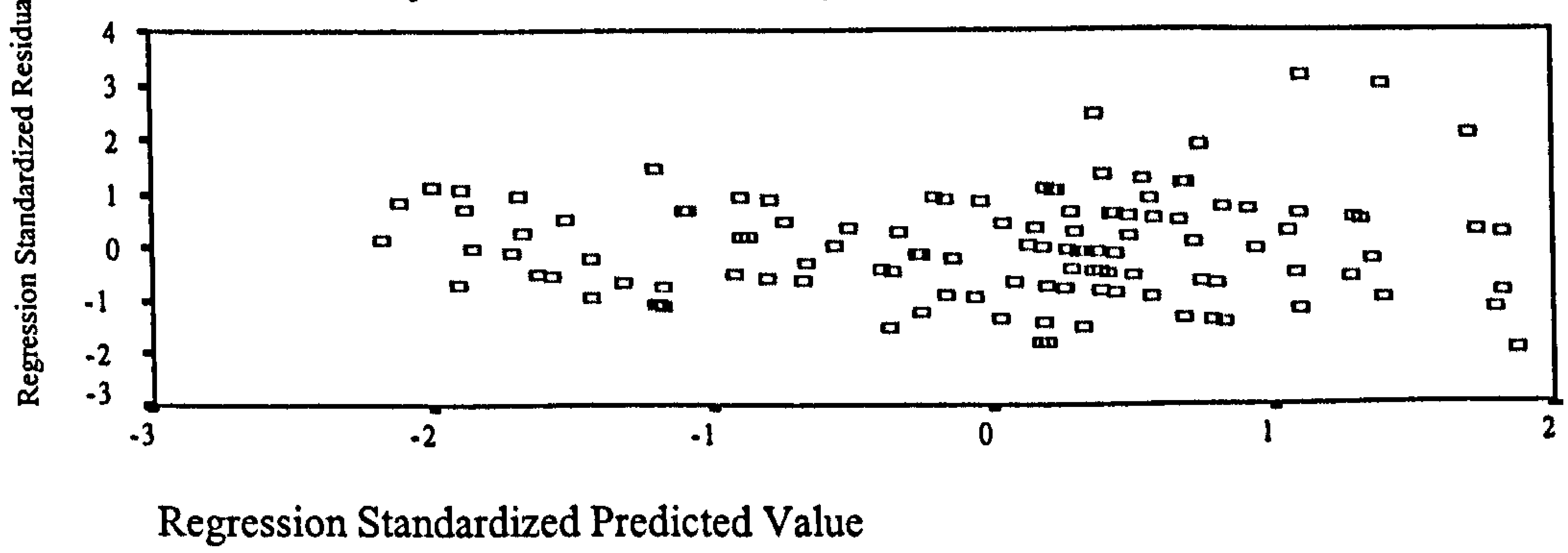
Gain in Predevelopment Assessment Knowledge



Scatterplot

Dependent Variable:

Gain in Predevelopment Assessment Knowledge

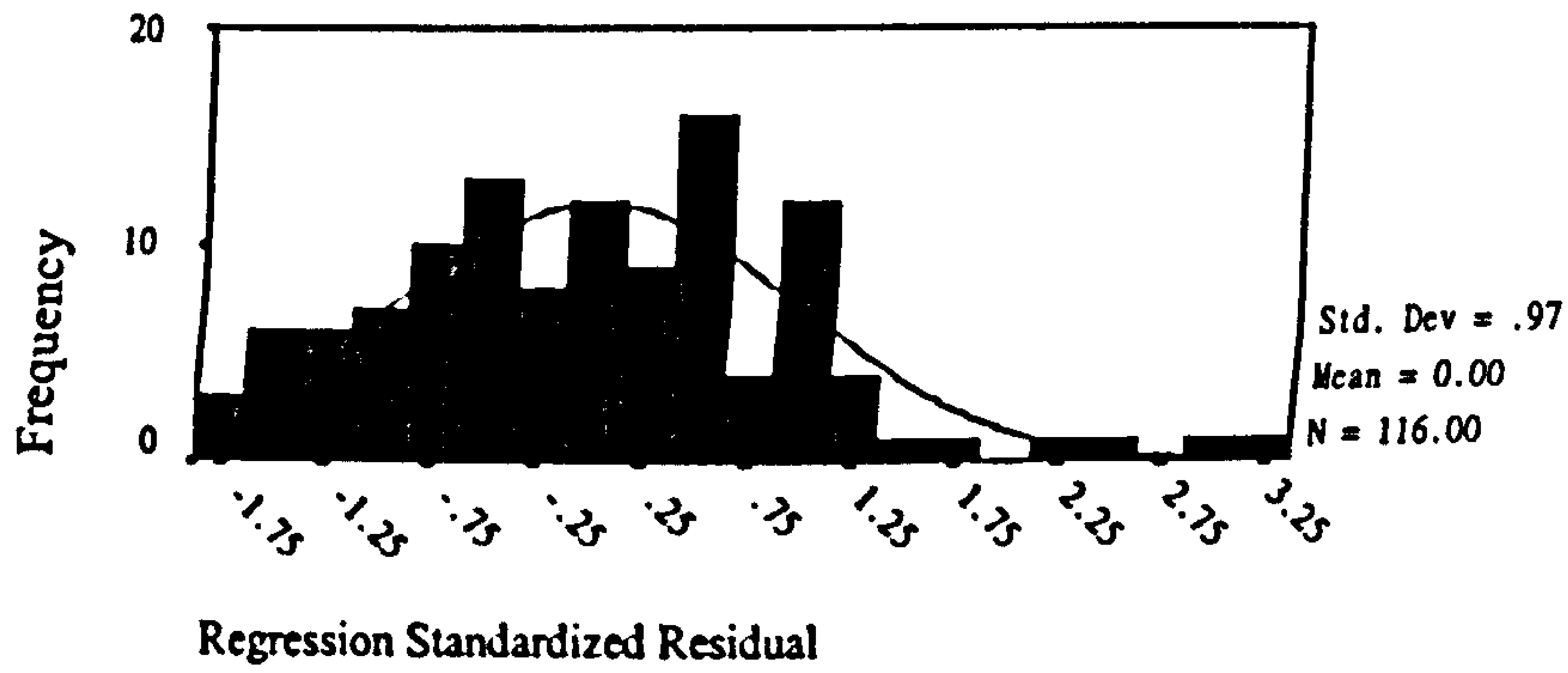


Regression Model 5 of Table 6.5.2.4

Histogram of Residuals

Dependent Variable:

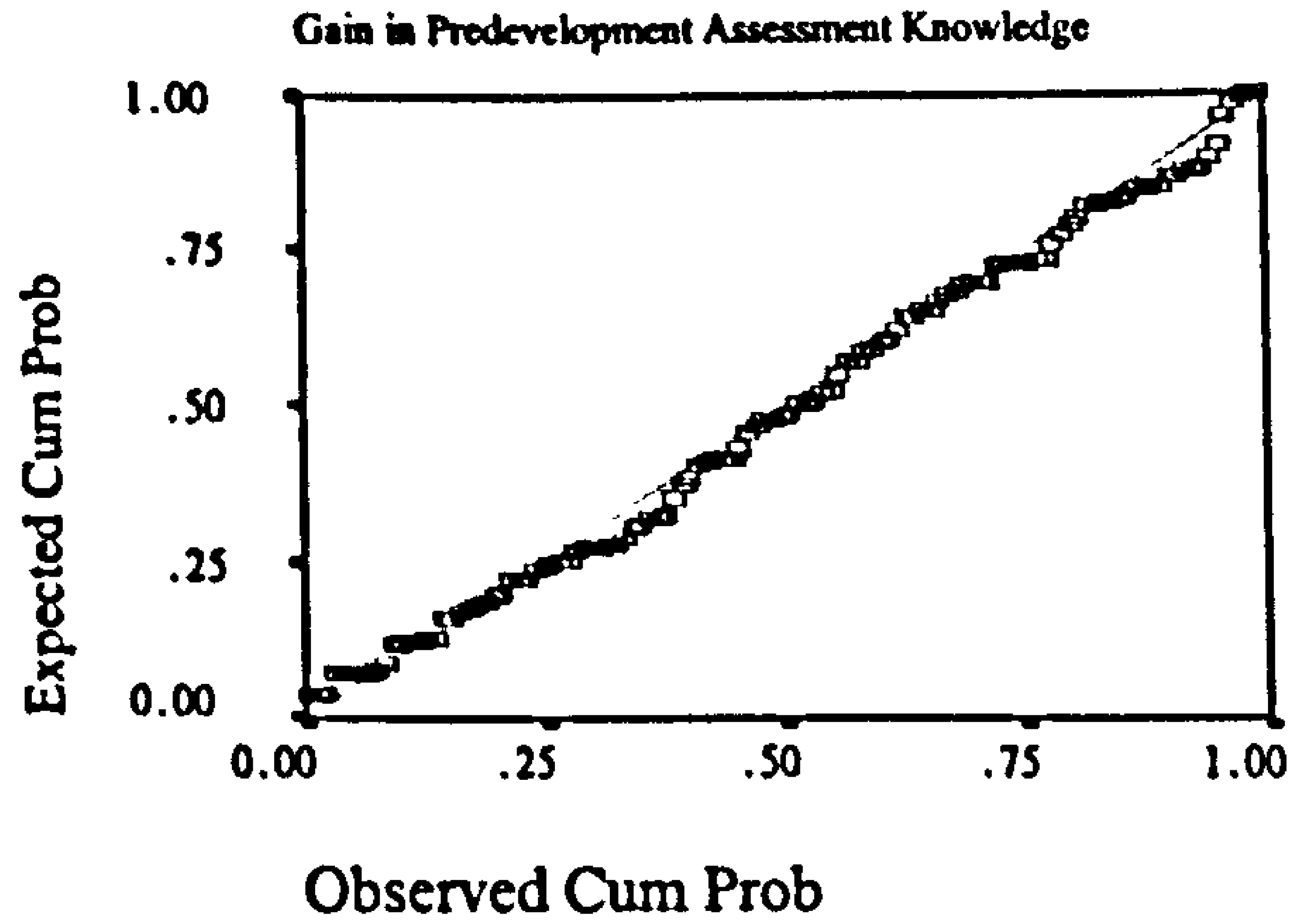
Gain in Predevelopment Assessment Knowledge



Normal P-P Plot of Standardized Residual

Dependent Variable:

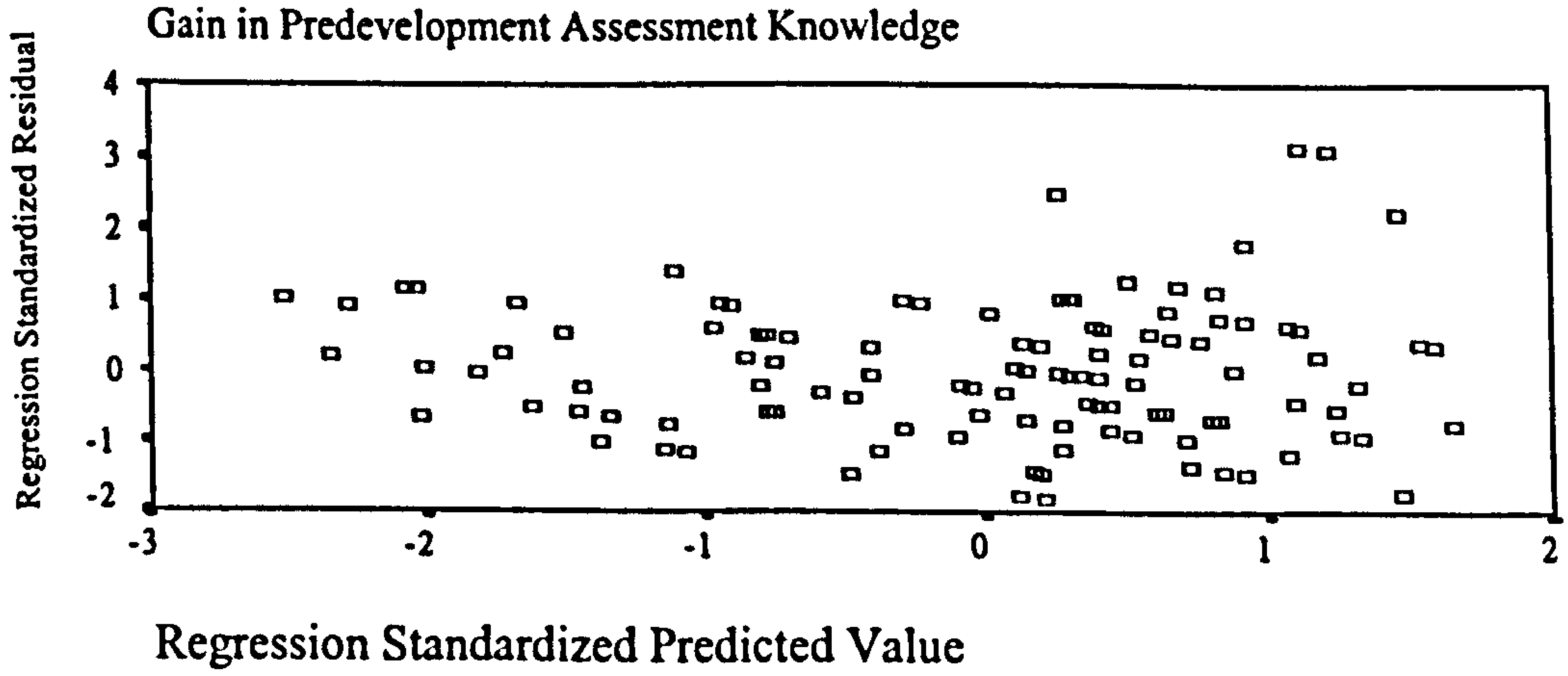
Gain in Predevelopment Assessment Knowledge



Scatterplot

Dependent Variable:

Gain in Predevelopment Assessment Knowledge

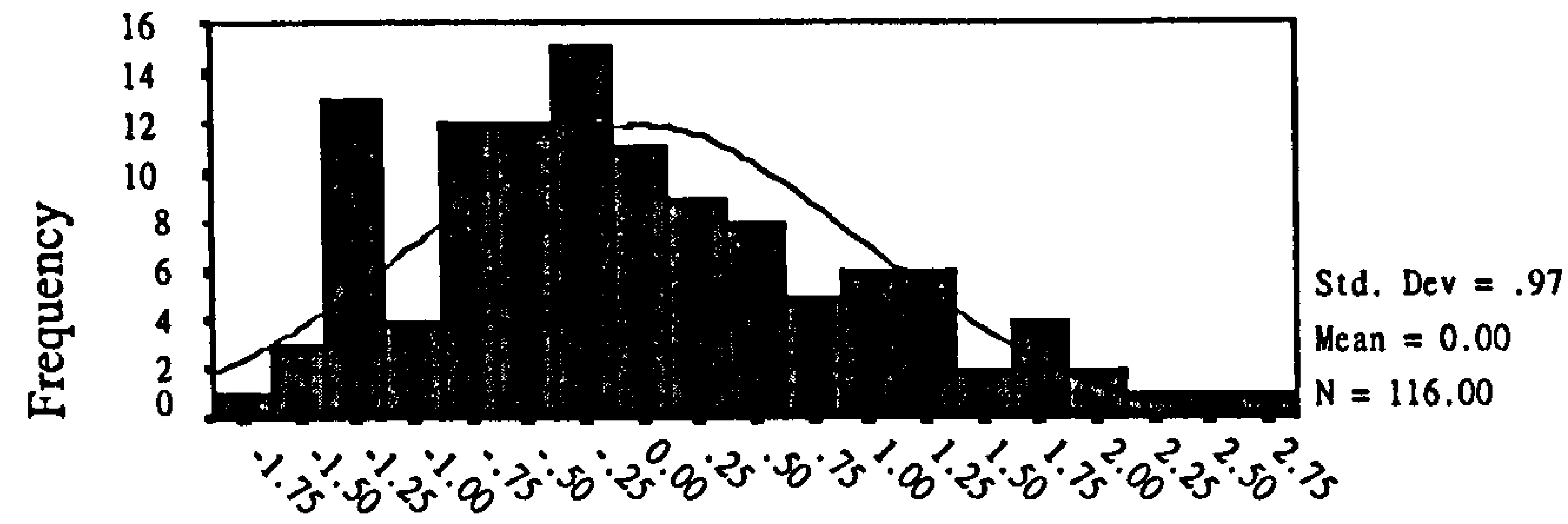


Regression Model 6 of Table 6.5.2.4

Histogram of Residuals

Dependent Variable:

Gain in Marketing Knowledge

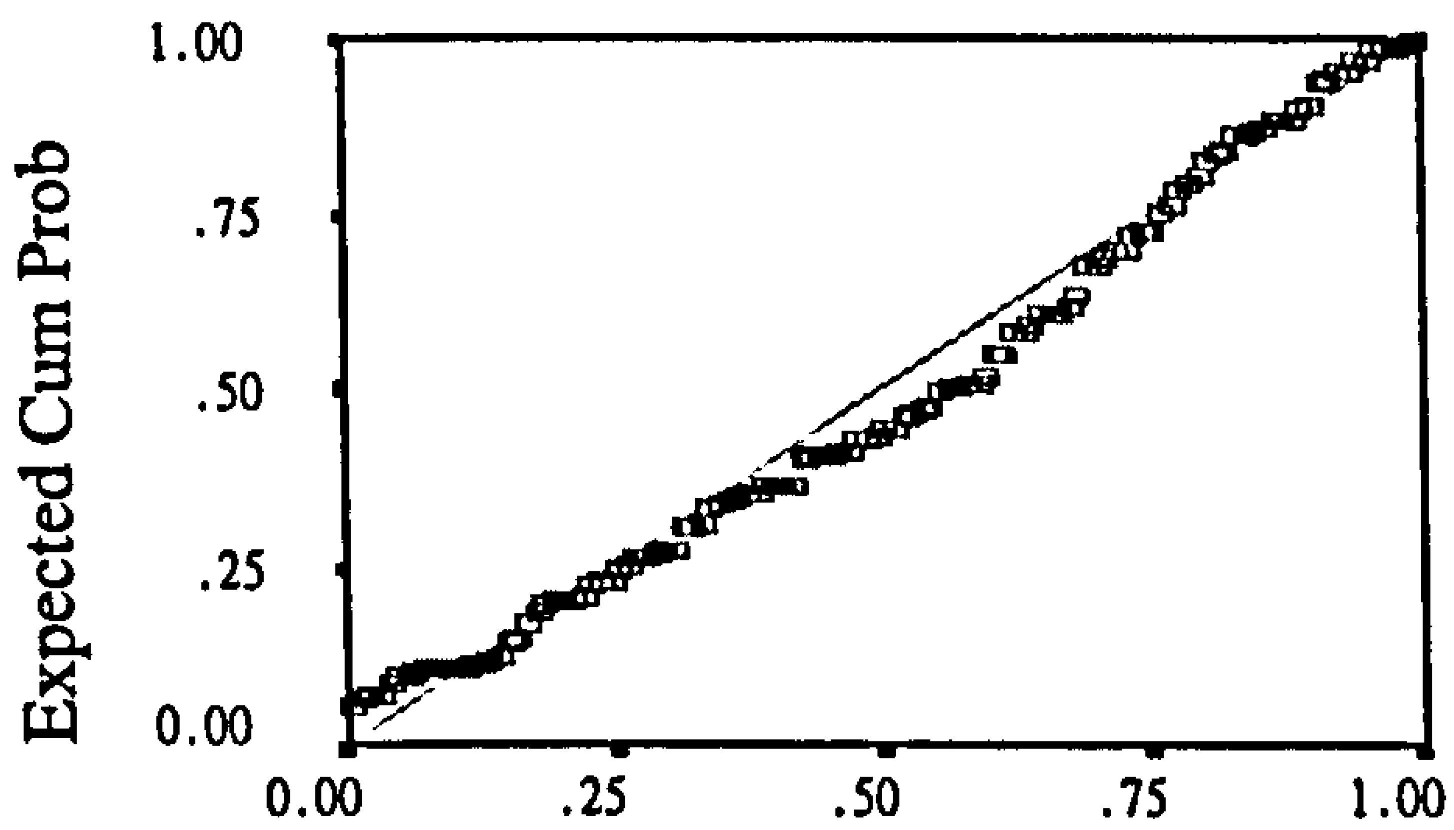


Regression Standardized Residual

Normal P-P Plot of Standardized Residual

Dependent Variable:

Gain in Marketing Knowledge

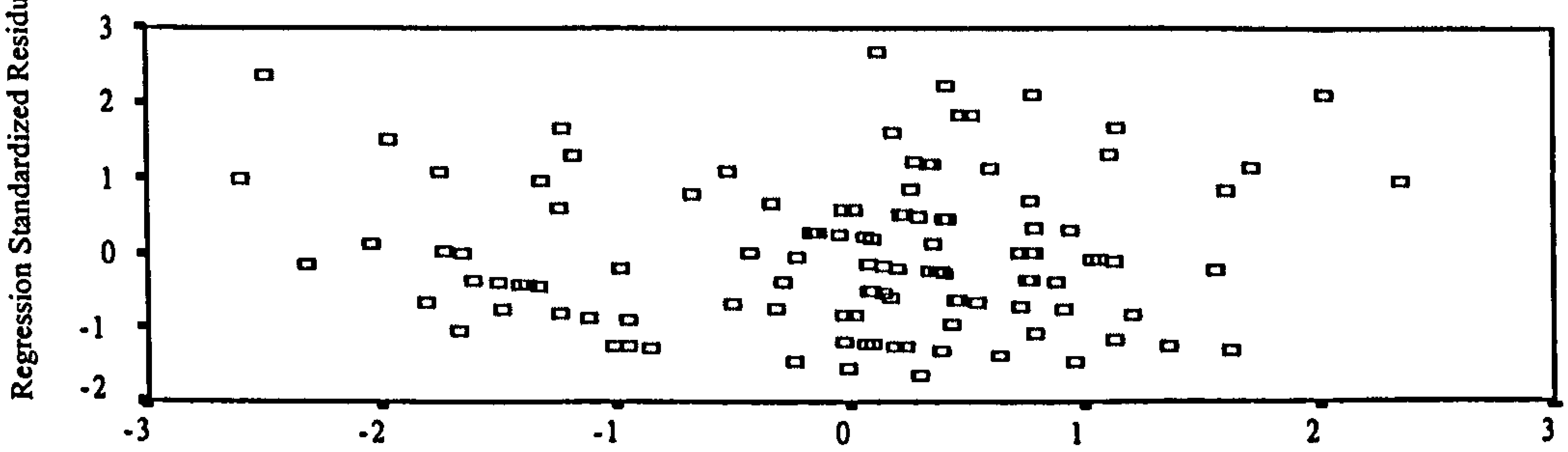


Observed Cum Prob

Scatterplot

Dependent Variable:

Gain in Marketing Knowledge



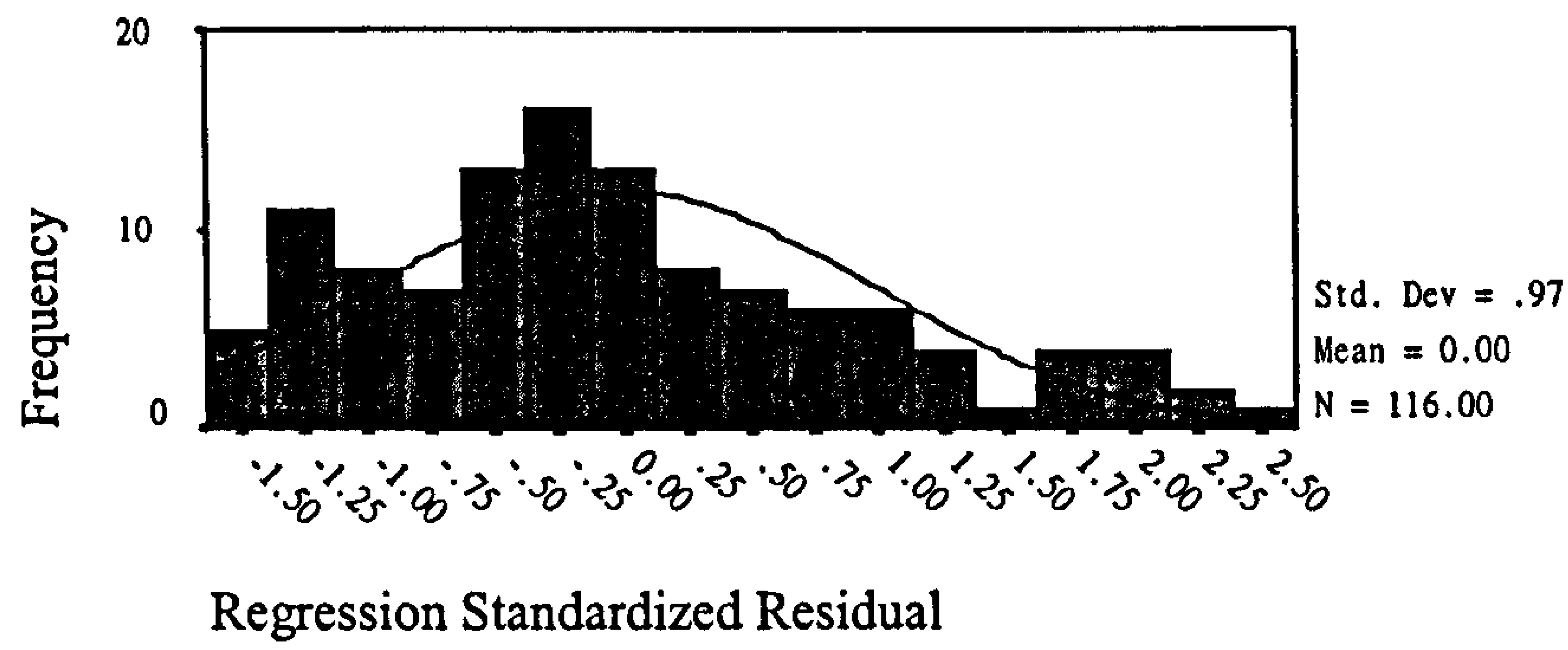
Regression Standardized Predicted Value

Regression Model 1 of Table 6.5.2.5

Histogram of Residuals

Dependent Variable:

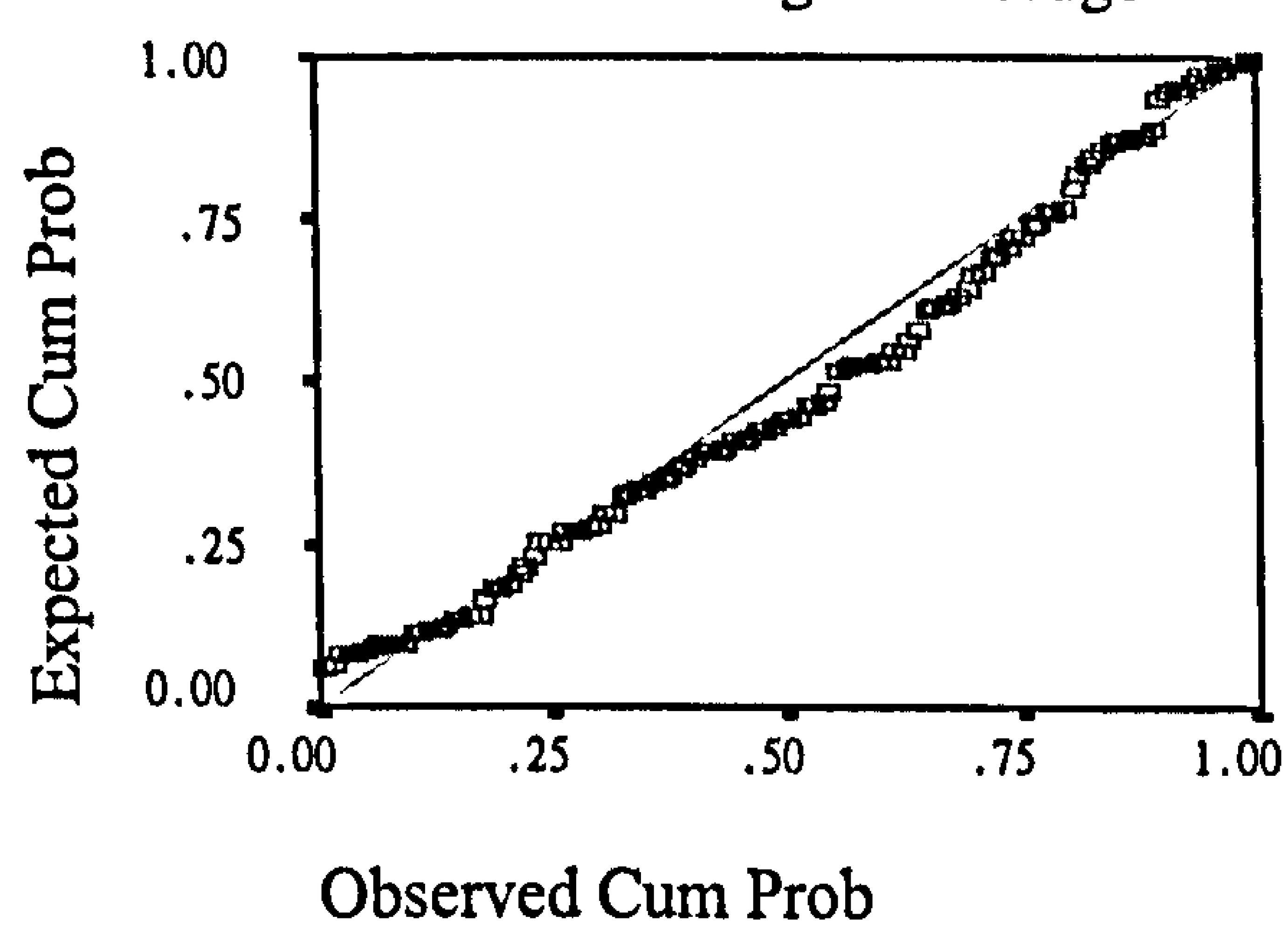
Gain in Marketing Knowledge



Normal P-P Plot of Standardized Residual

Dependent Variable:

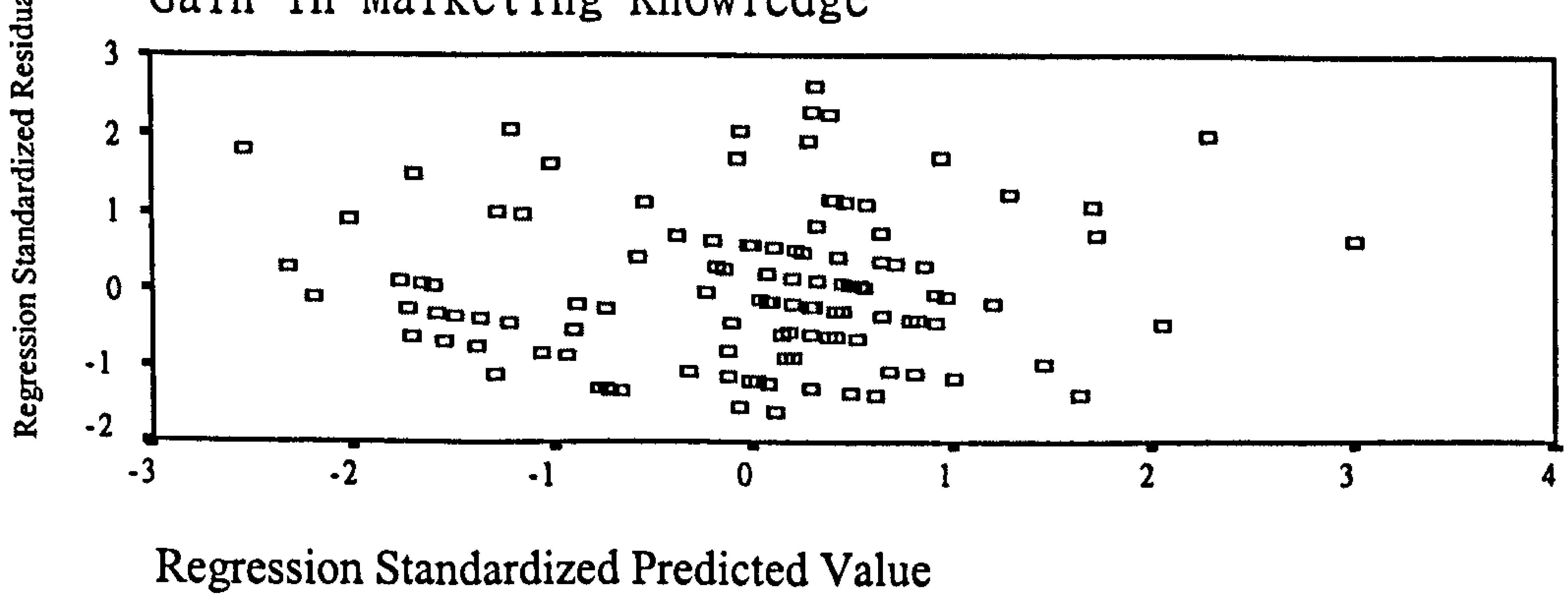
Gain in Marketing Knowledge



Scatterplot

Dependent Variable:

Gain in Marketing Knowledge

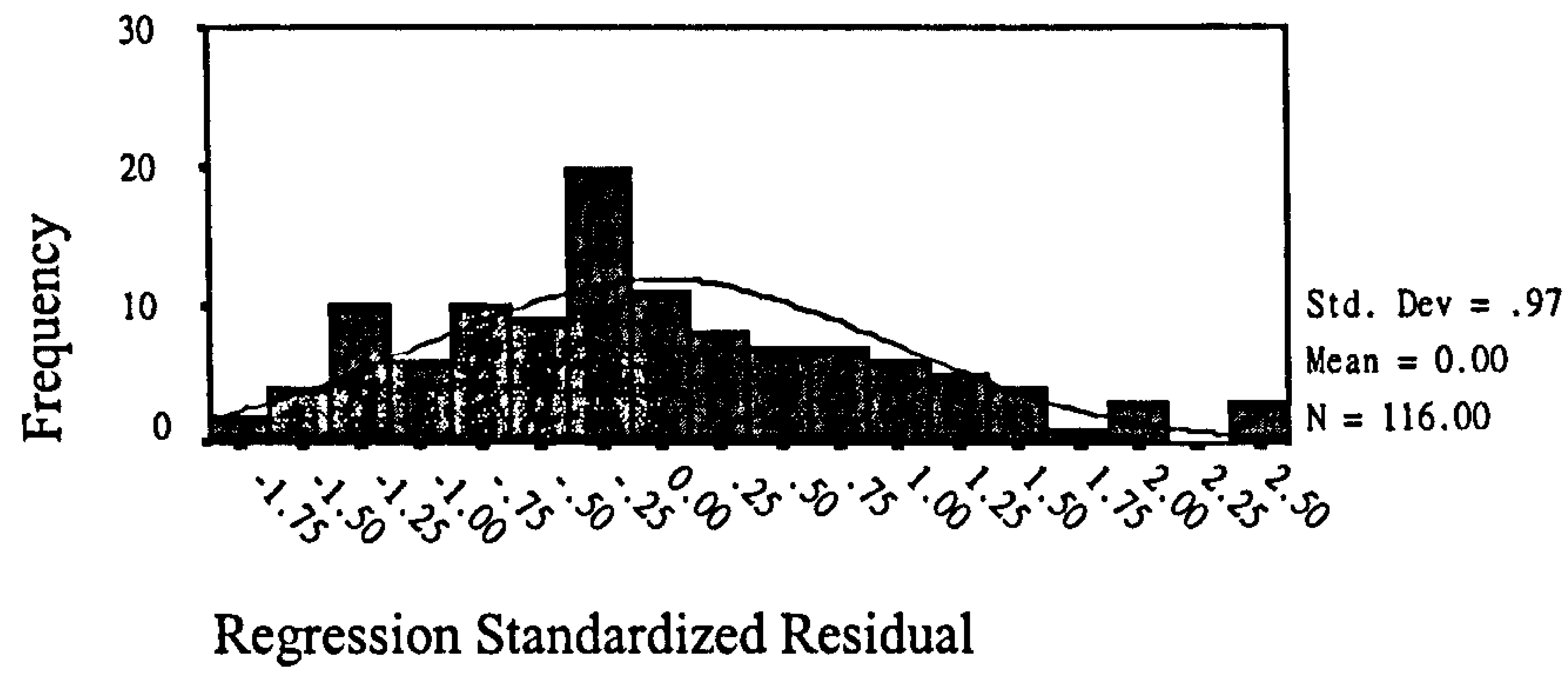


Regression Model 2 of Table 6.5.2.5

Histogram of Residuals

Dependent Variable:

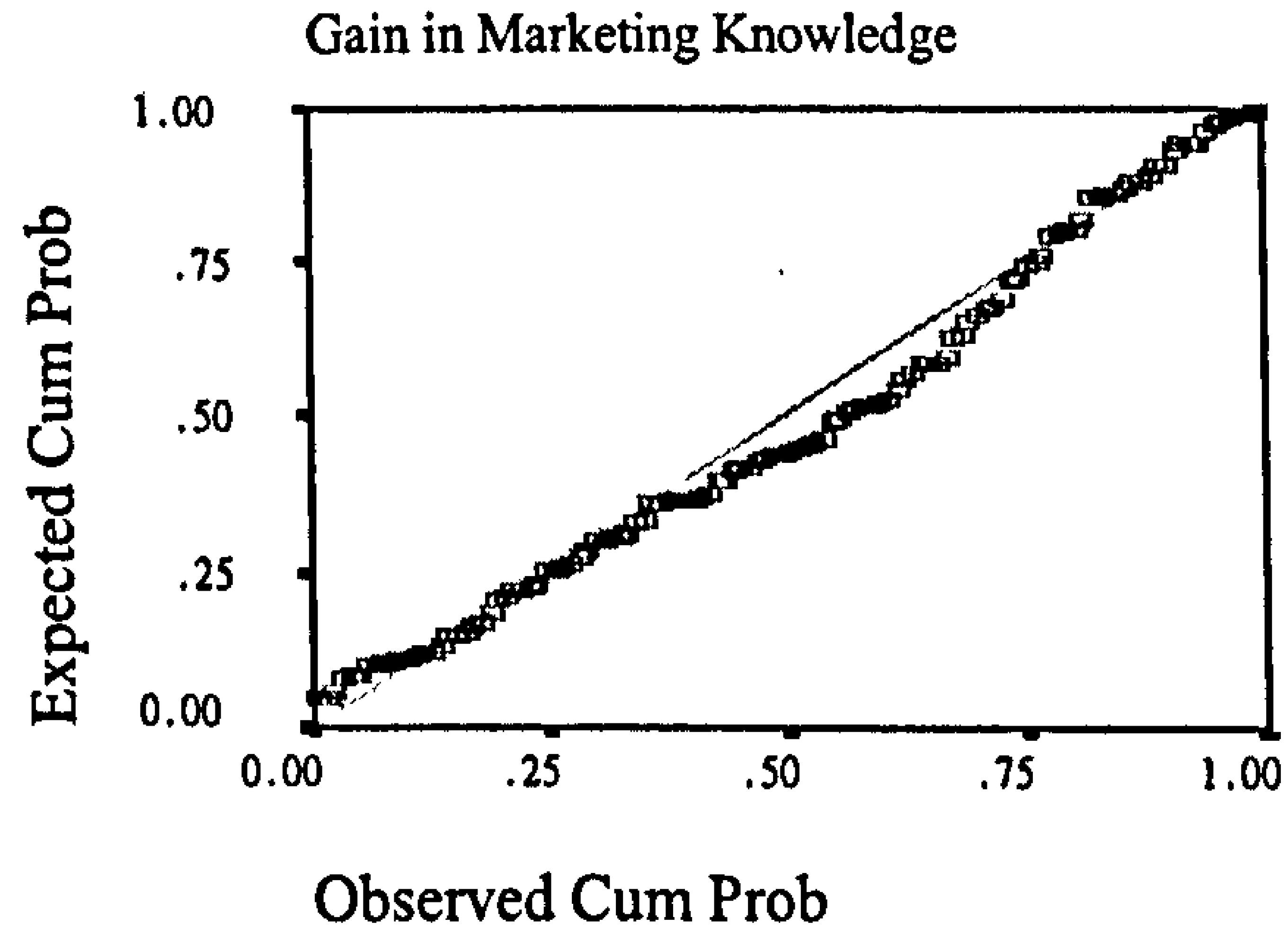
Gain in Marketing Knowledge



Normal P-P Plot of Standardized Residual

Dependent Variable:

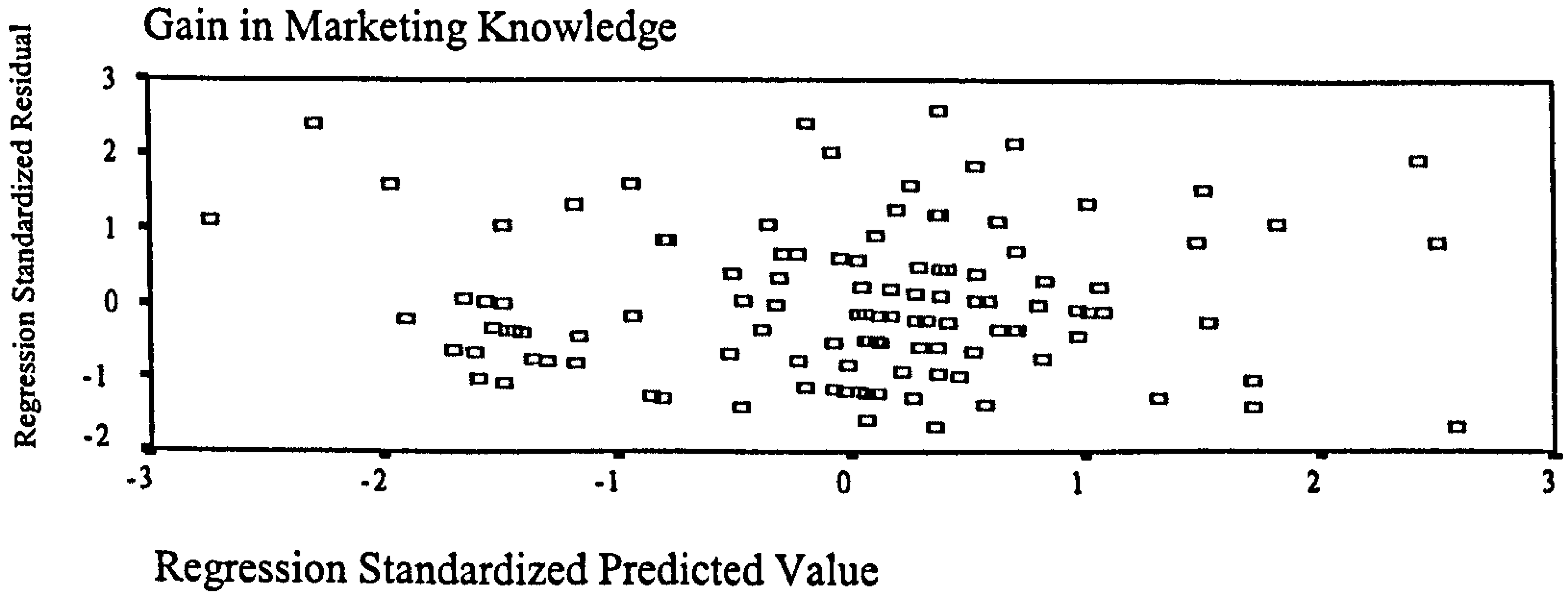
Gain in Marketing Knowledge



Scatterplot

Dependent Variable:

Gain in Marketing Knowledge

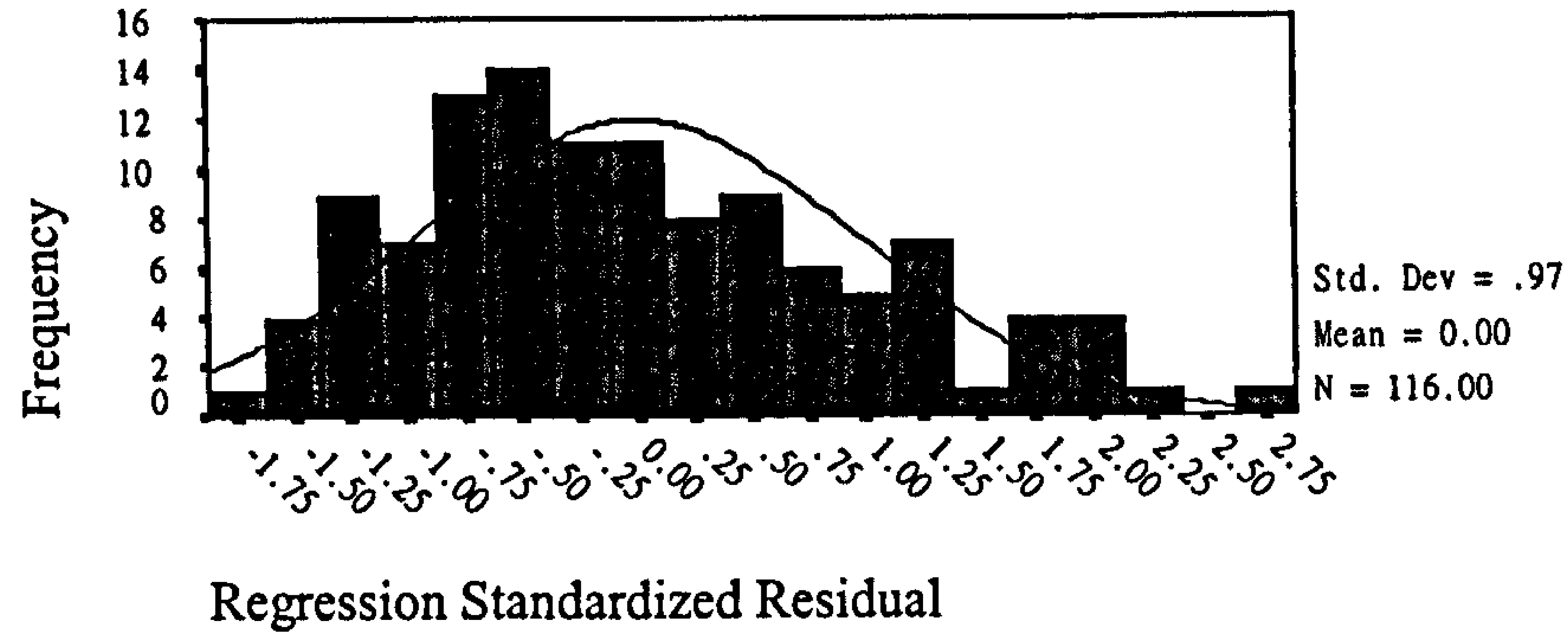


Regression Model 3 of Table 6.5.2.5

Histogram of Residuals

Dependent Variable:

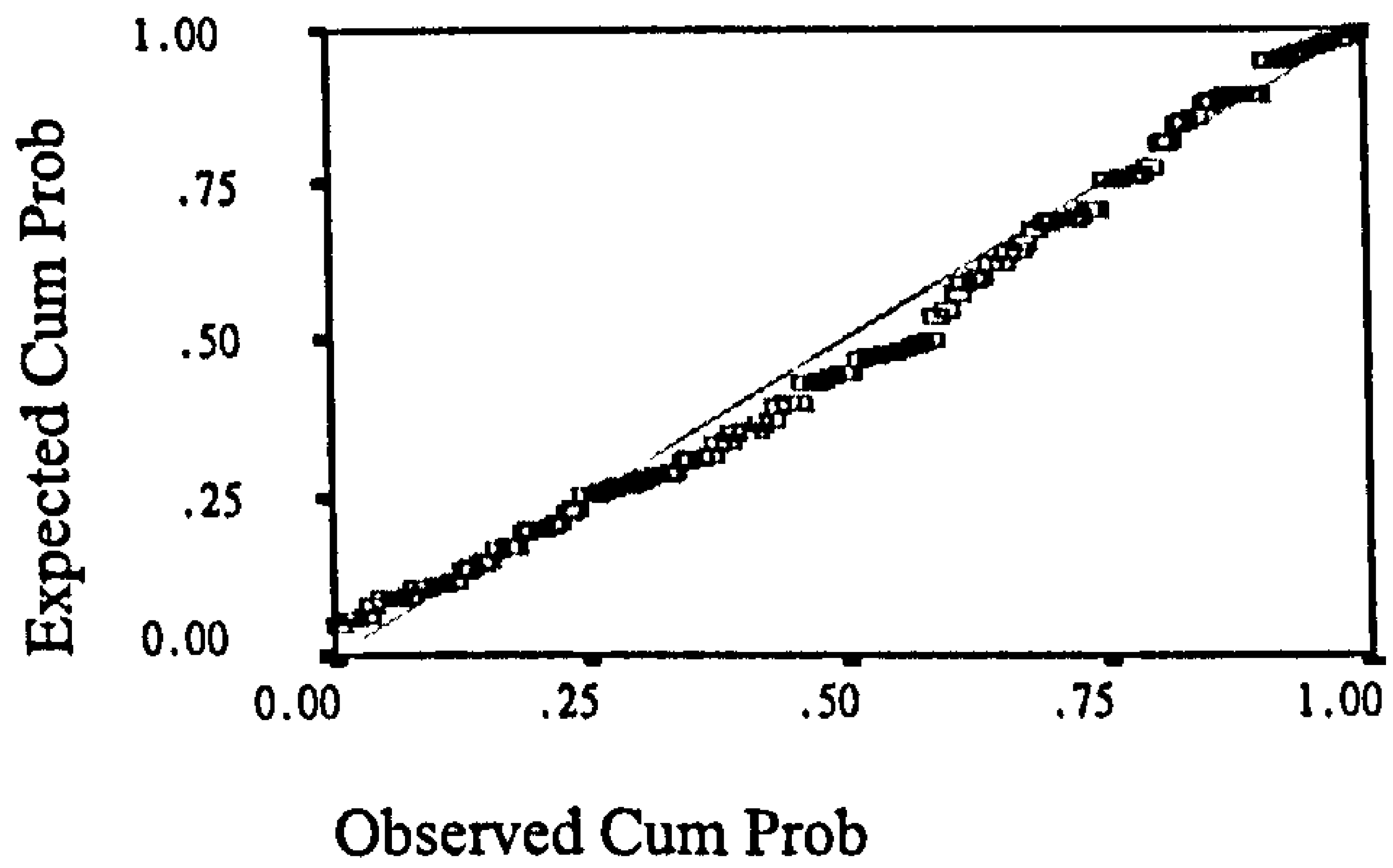
Gain in Marketing Knowledge



Normal P-P Plot of Standardized Residual

Dependent Variable:

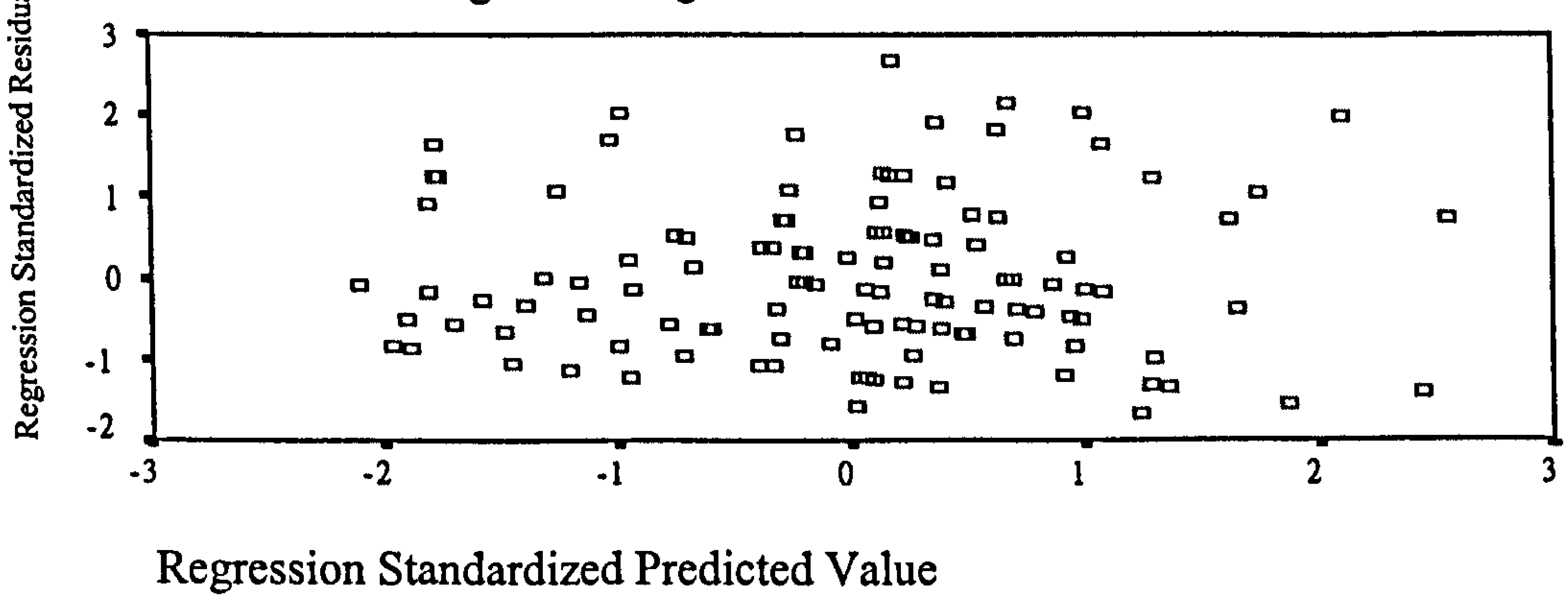
Gain in Marketing Knowledge



Scatterplot

Dependent Variable:

Gain in Marketing Knowledge

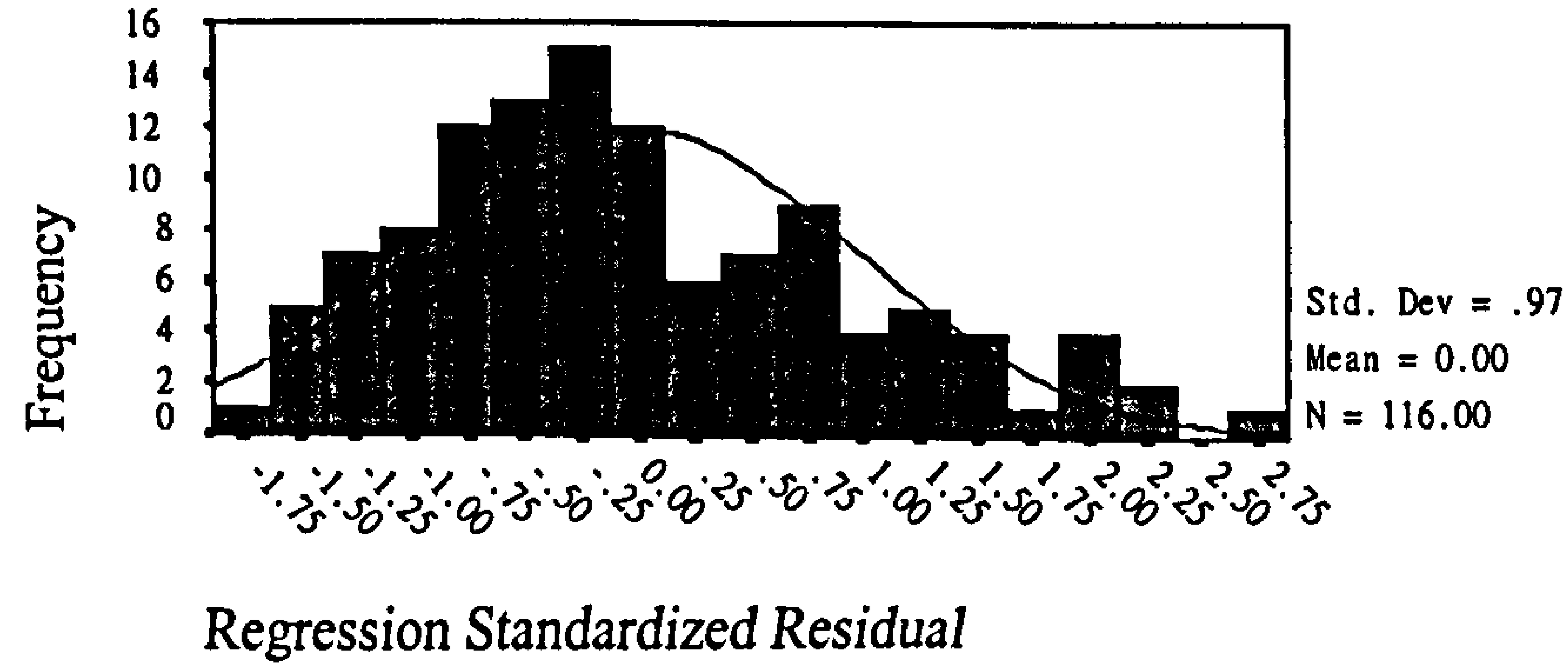


Regression Model 4 of Table 6.5.2.5

Histogram of Residuals

Dependent Variable:

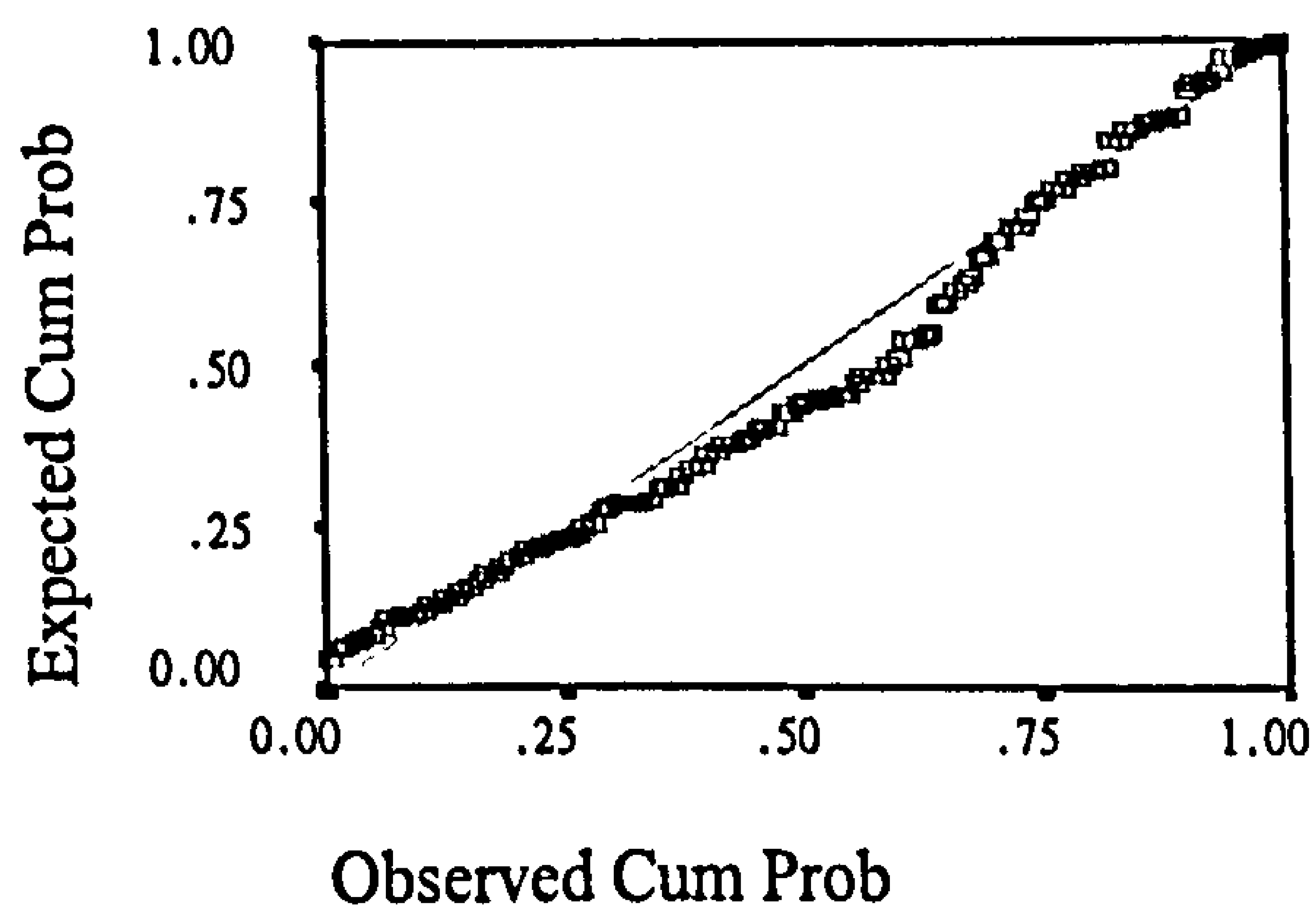
Gain in Marketing Knowledge



Normal P-P Plot of Standardized Residual

Dependent Variable:

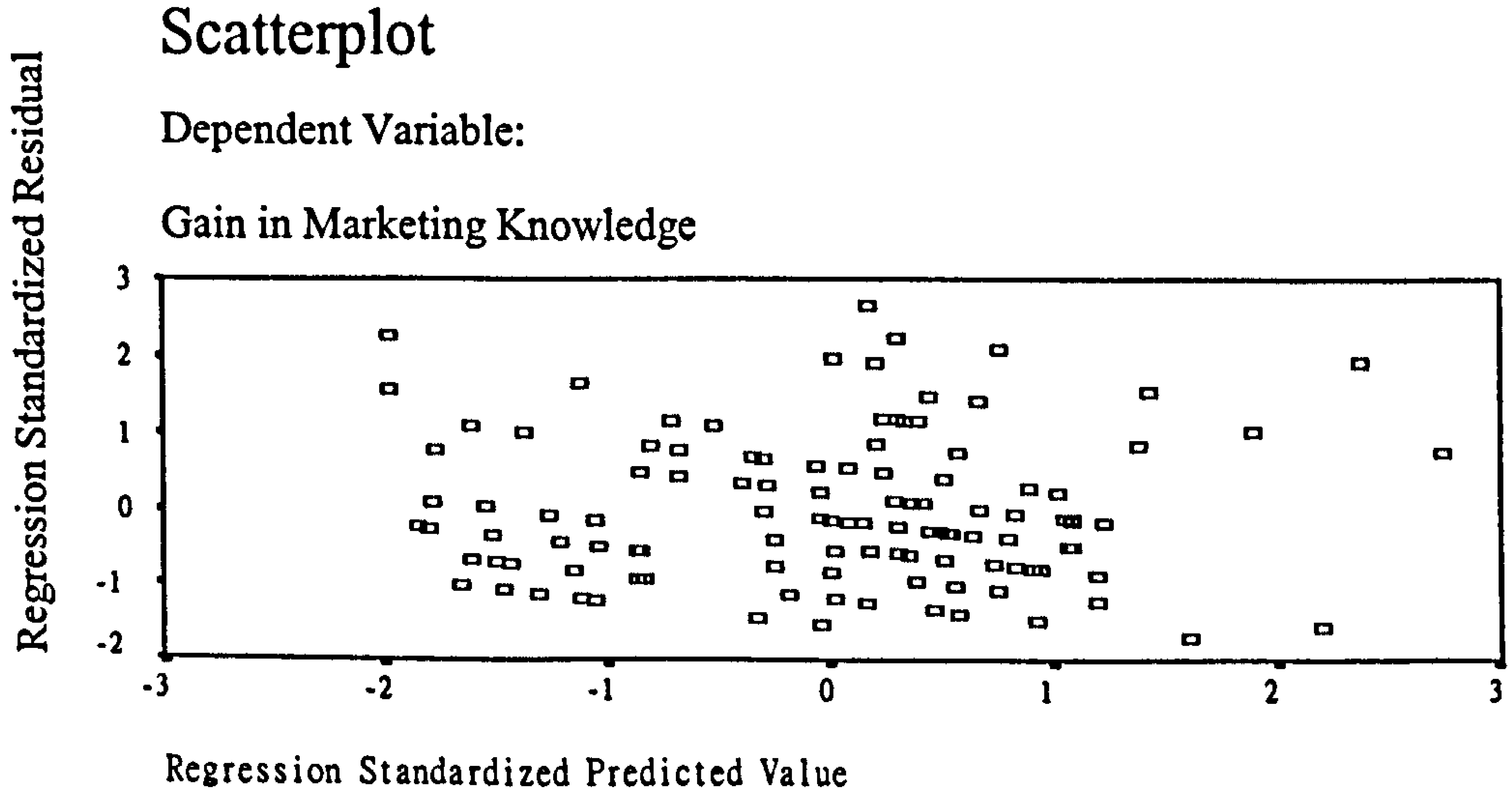
Gain in Marketing Knowledge



Scatterplot

Dependent Variable:

Gain in Marketing Knowledge

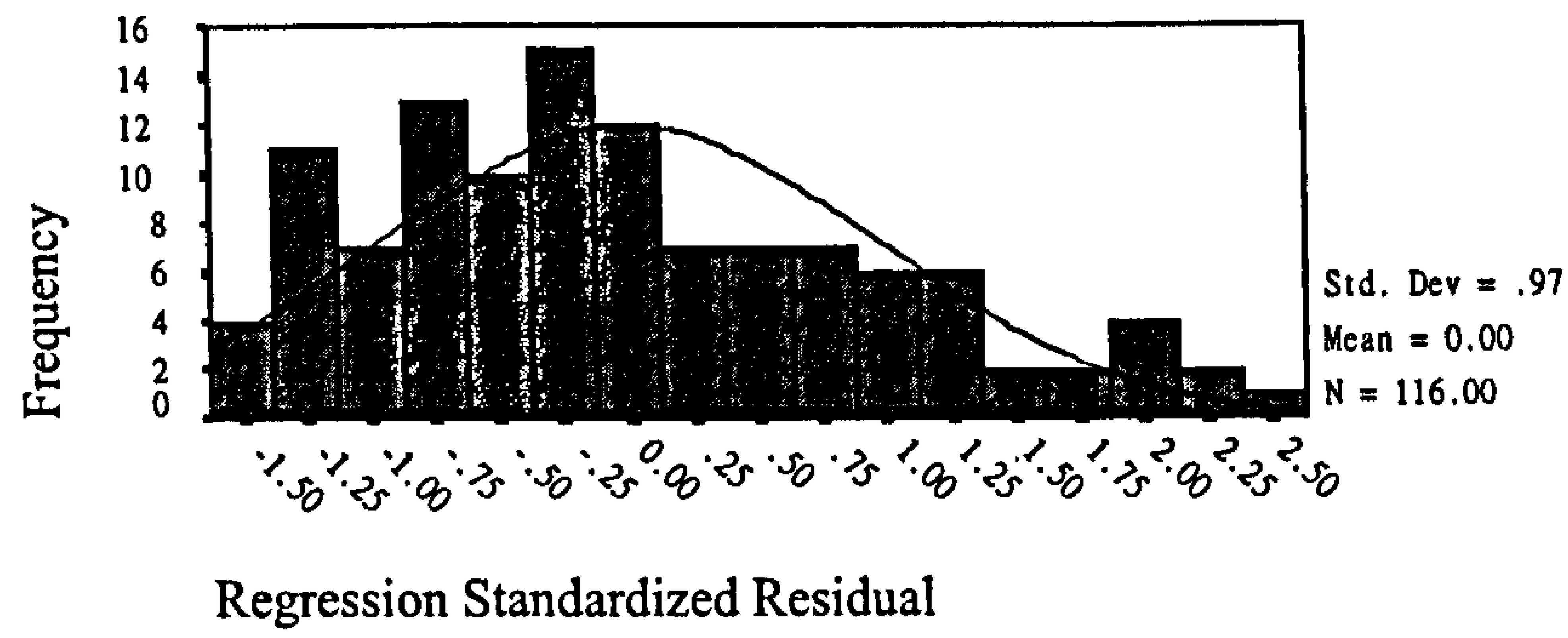


Regression Model 5 of Table 6.5.2.5

Histogram of Residuals

Dependent Variable:

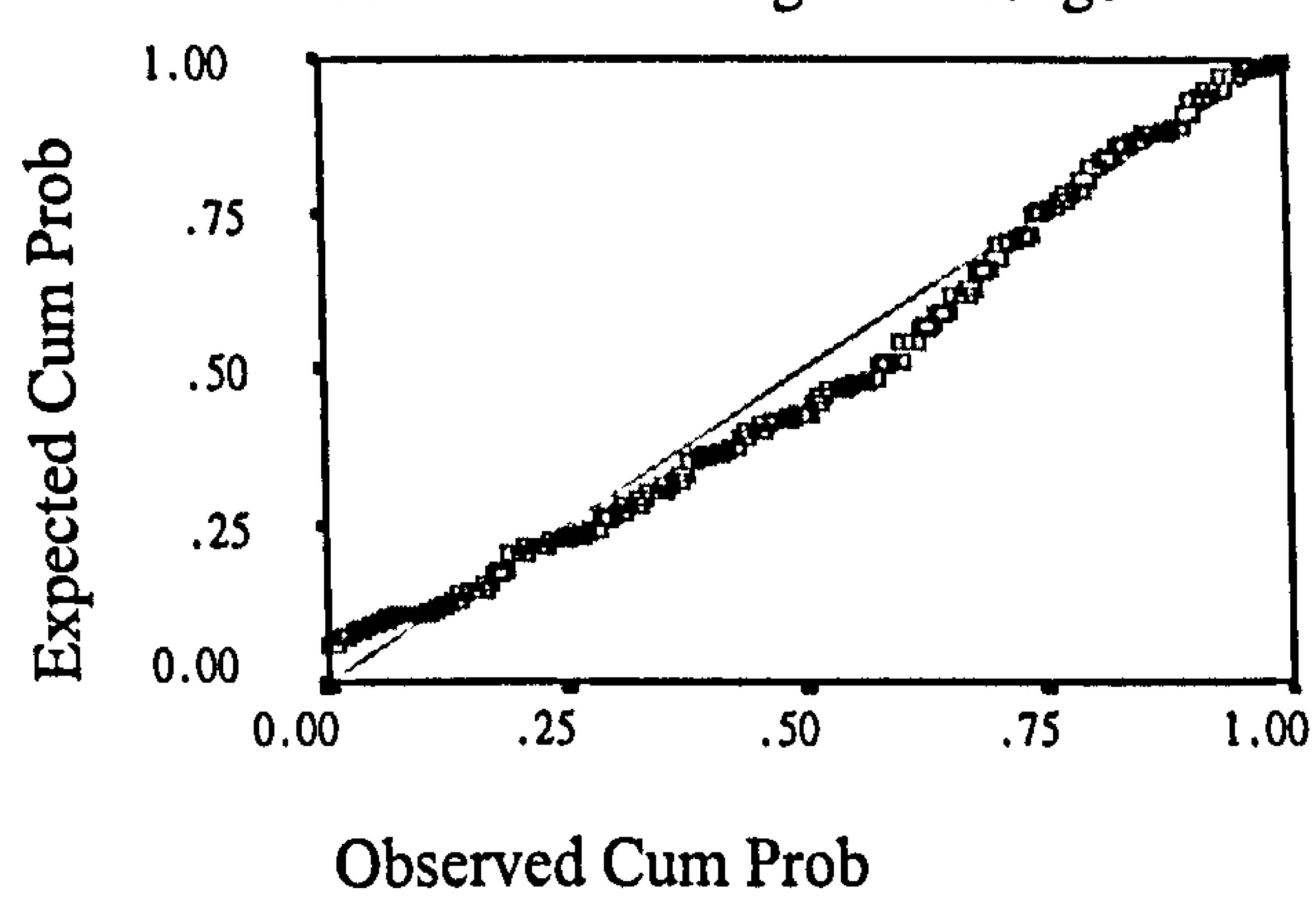
Gain in Marketing Knowledge



Normal P-P Plot of Standardized Residual

Dependent Variable:

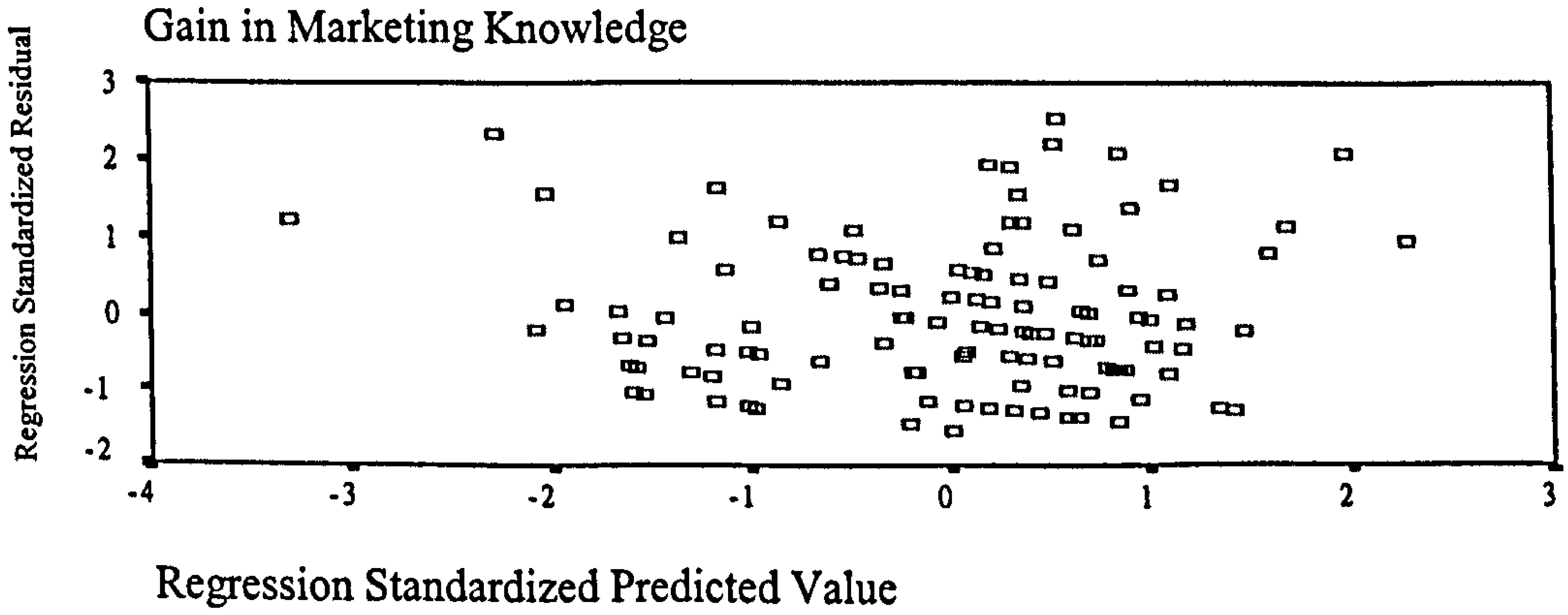
Gain in Marketing Knowledge



Scatterplot

Dependent Variable:

Gain in Marketing Knowledge

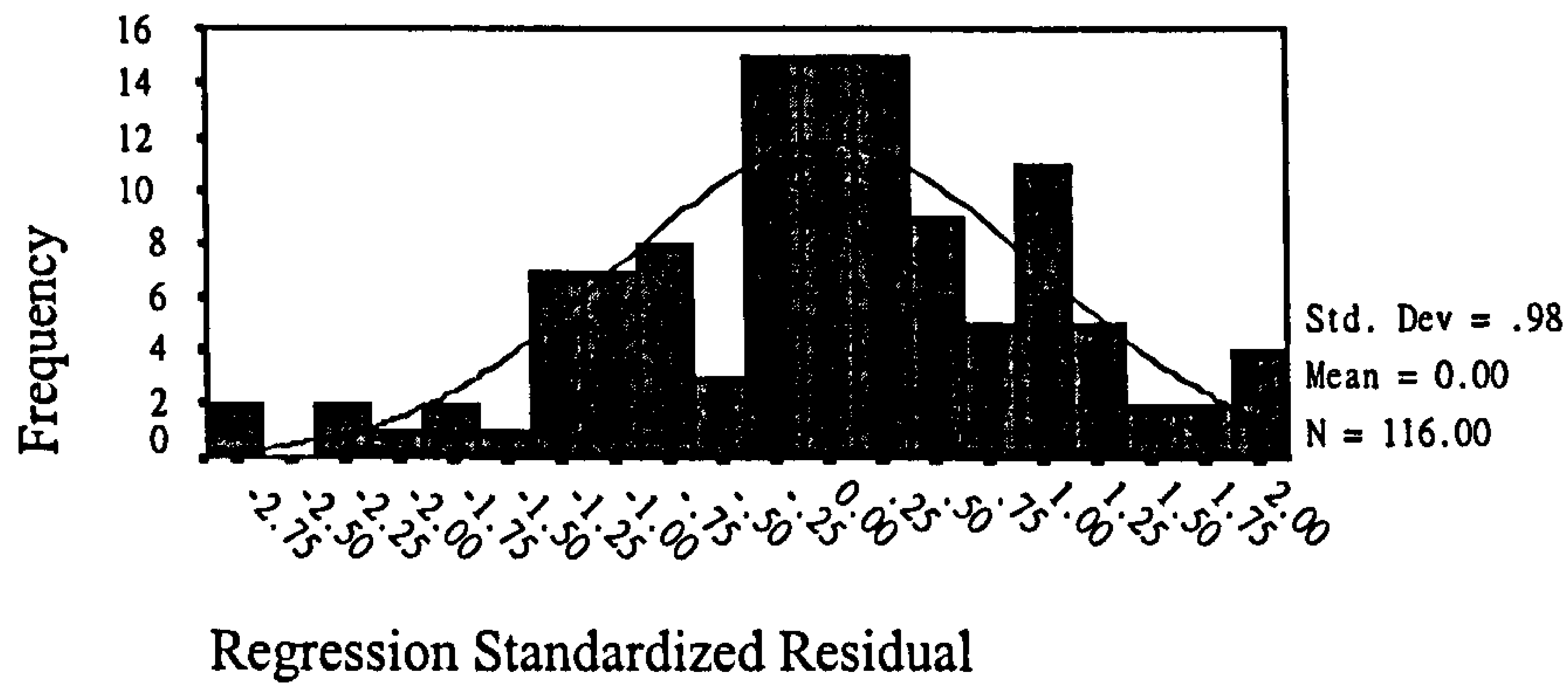


Regression Model 6 of Table 6.5.2.5

Histogram of Residuals

Dependent Variable: Technological Innovativeness

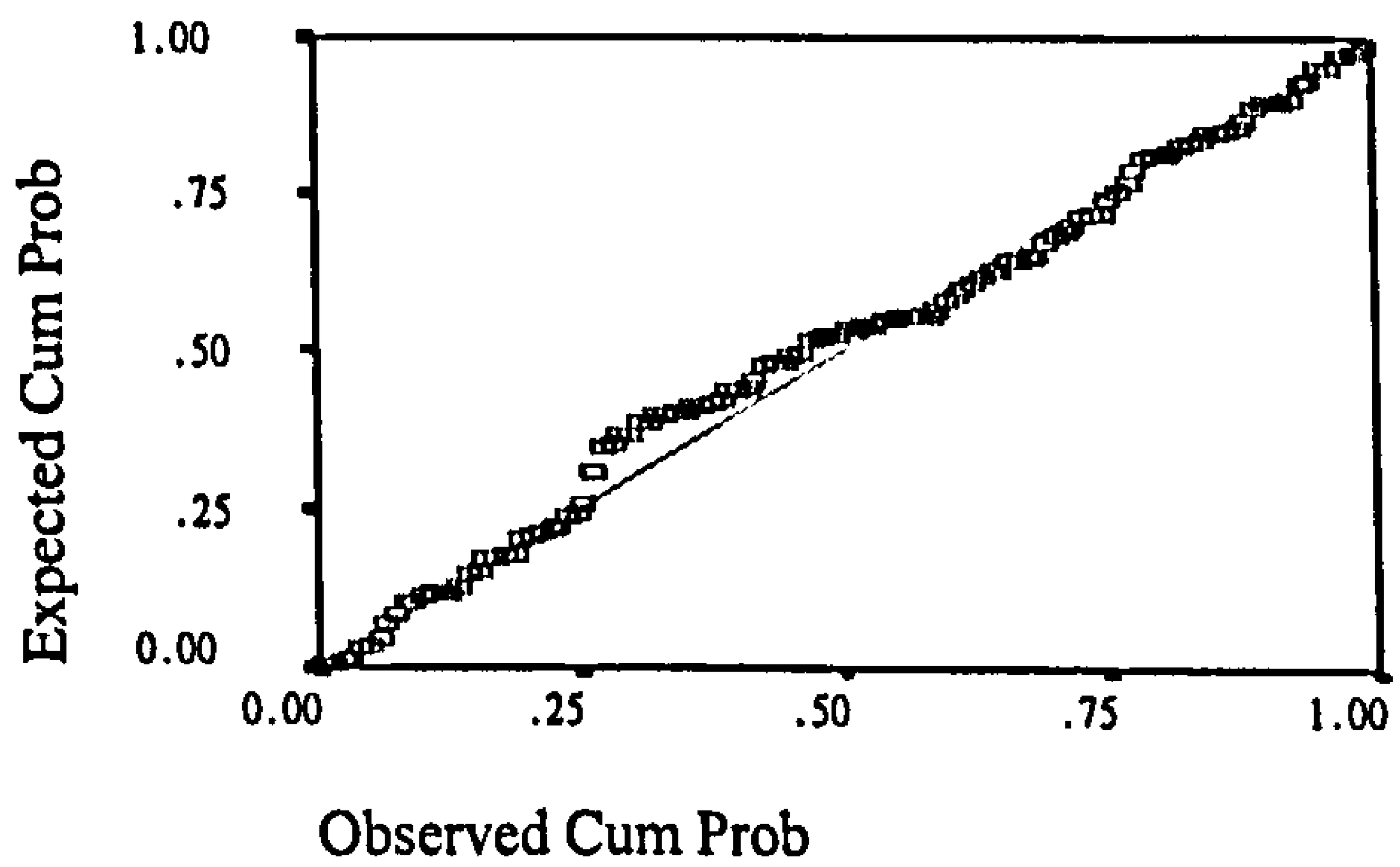
Before the Mediator: R&D Knowledge



Normal P-P Plot of Standardized Residual

Dependent Variable: Technological Innovativeness

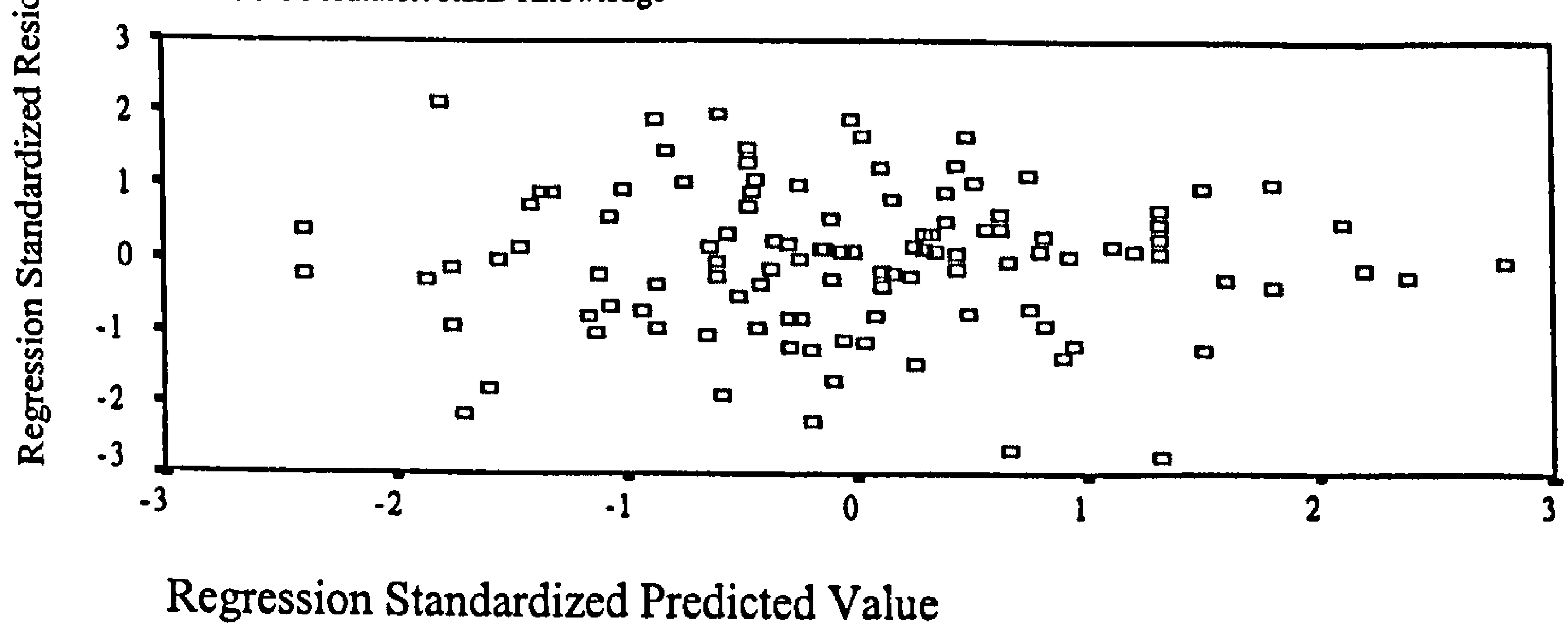
Before the Mediator: R&D Knowledge



Scatterplot

Dependent Variable: Technological Innovativeness

Before the Mediator: R&D Knowledge

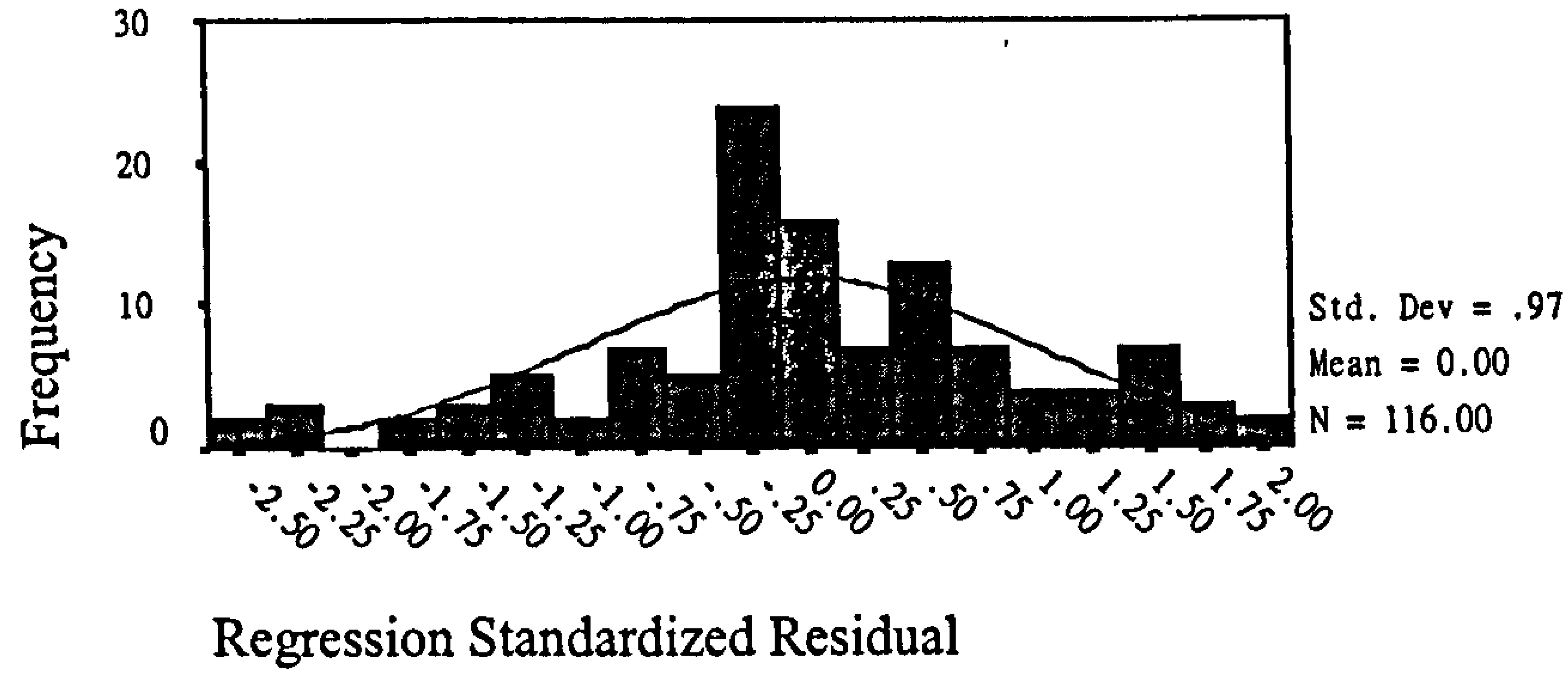


Regression Model 'Before the Mediator – RD' of Table 6.6.1

Histogram of Residuals

Dependent Variable: Technological Innovativeness

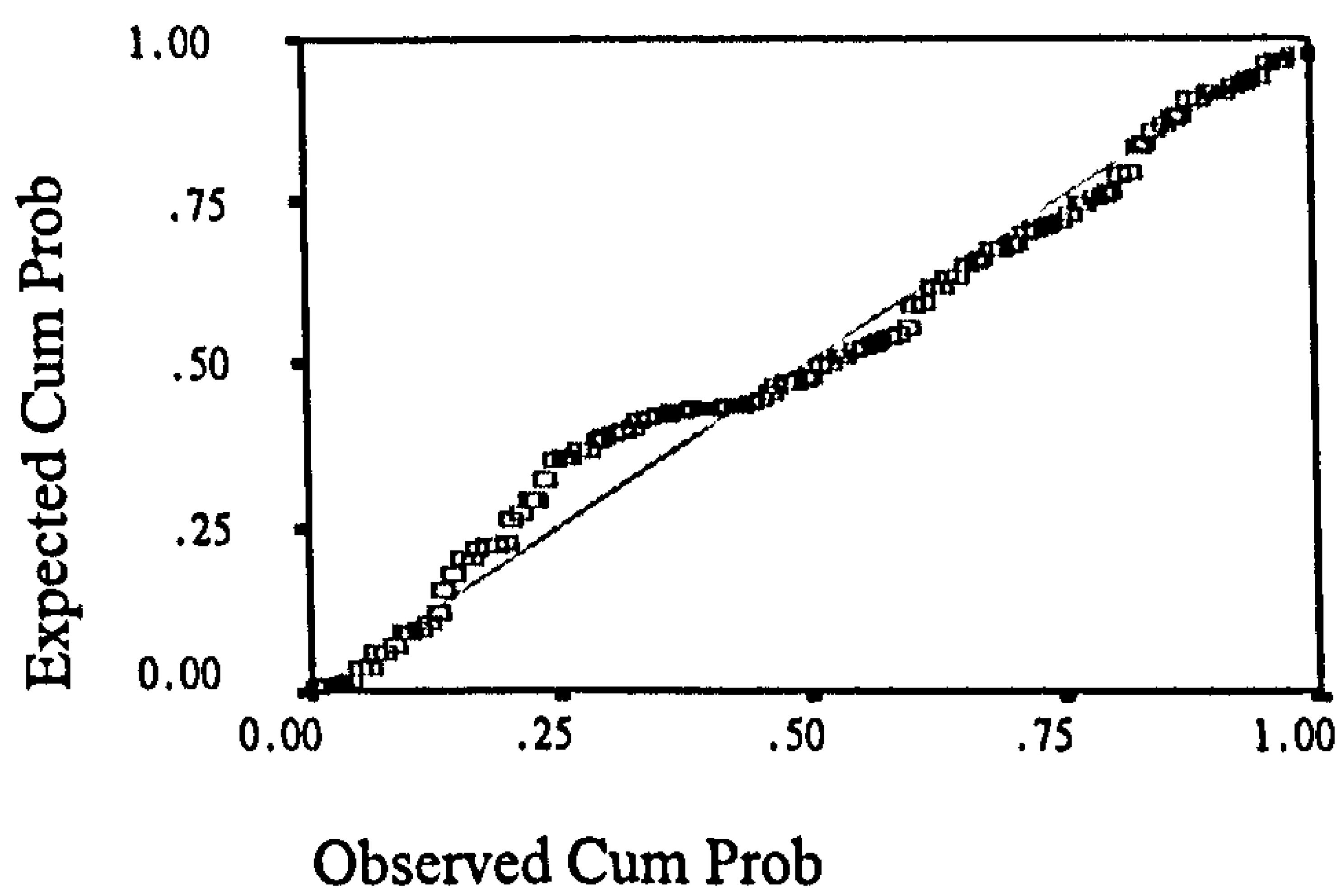
Before the Mediator: Manufacturing Knowledge



Normal P-P Plot of Standardized Residual

Dependent Variable: Technological Innovativeness

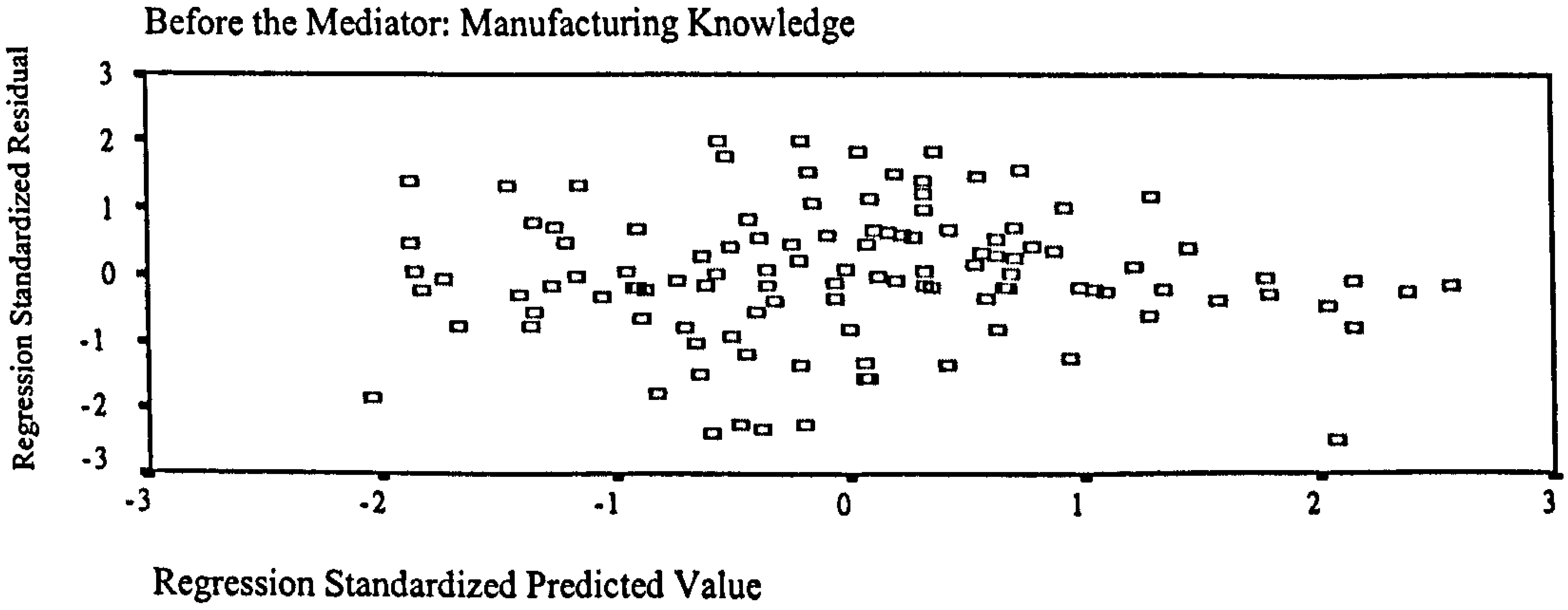
Before the Mediator: Manufacturing Knowledge



Scatterplot

Dependent Variable: Technological Innovativeness

Before the Mediator: Manufacturing Knowledge

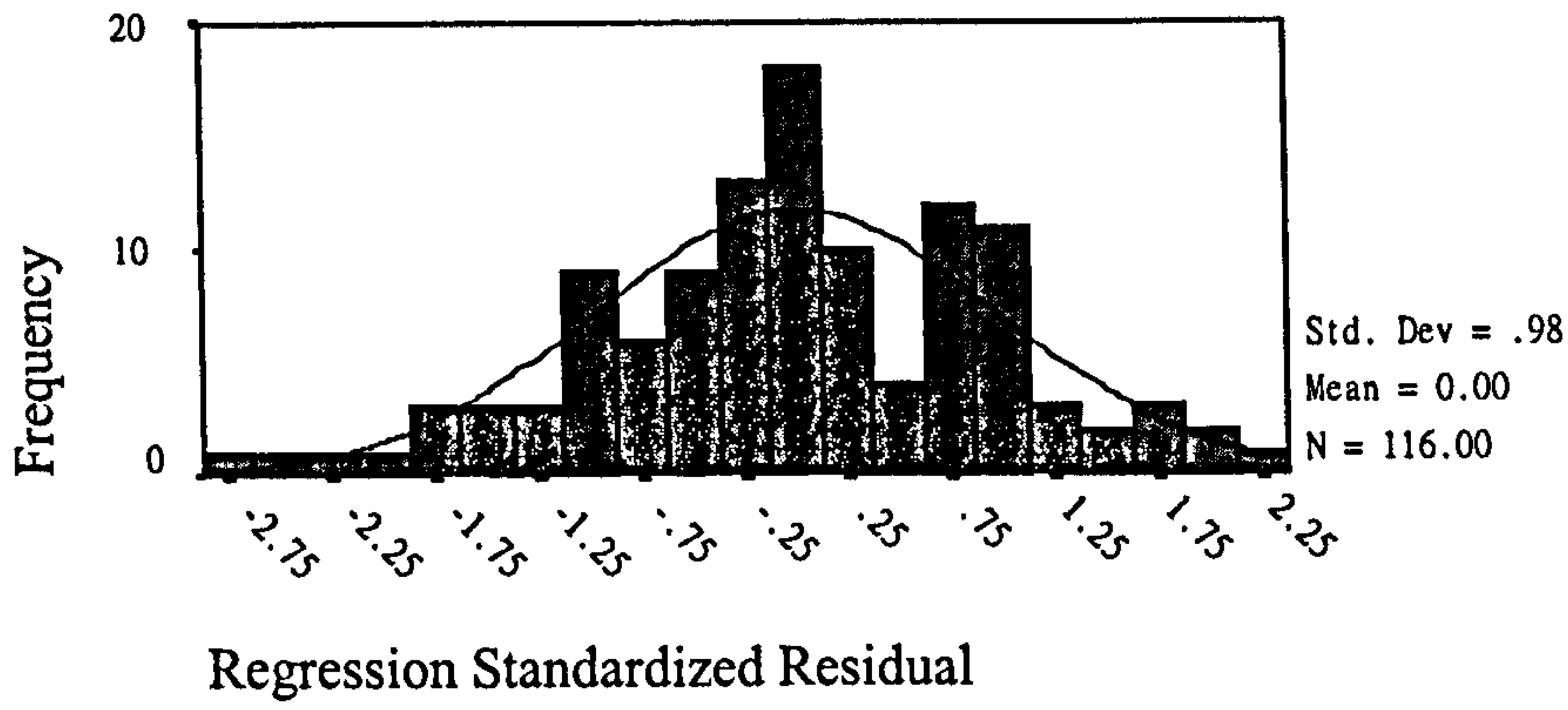


Regression Model 'Before the Mediator: MF' of Table 6.6.1

Histogram of Residuals

Dependent Variable: Technological Innovativeness

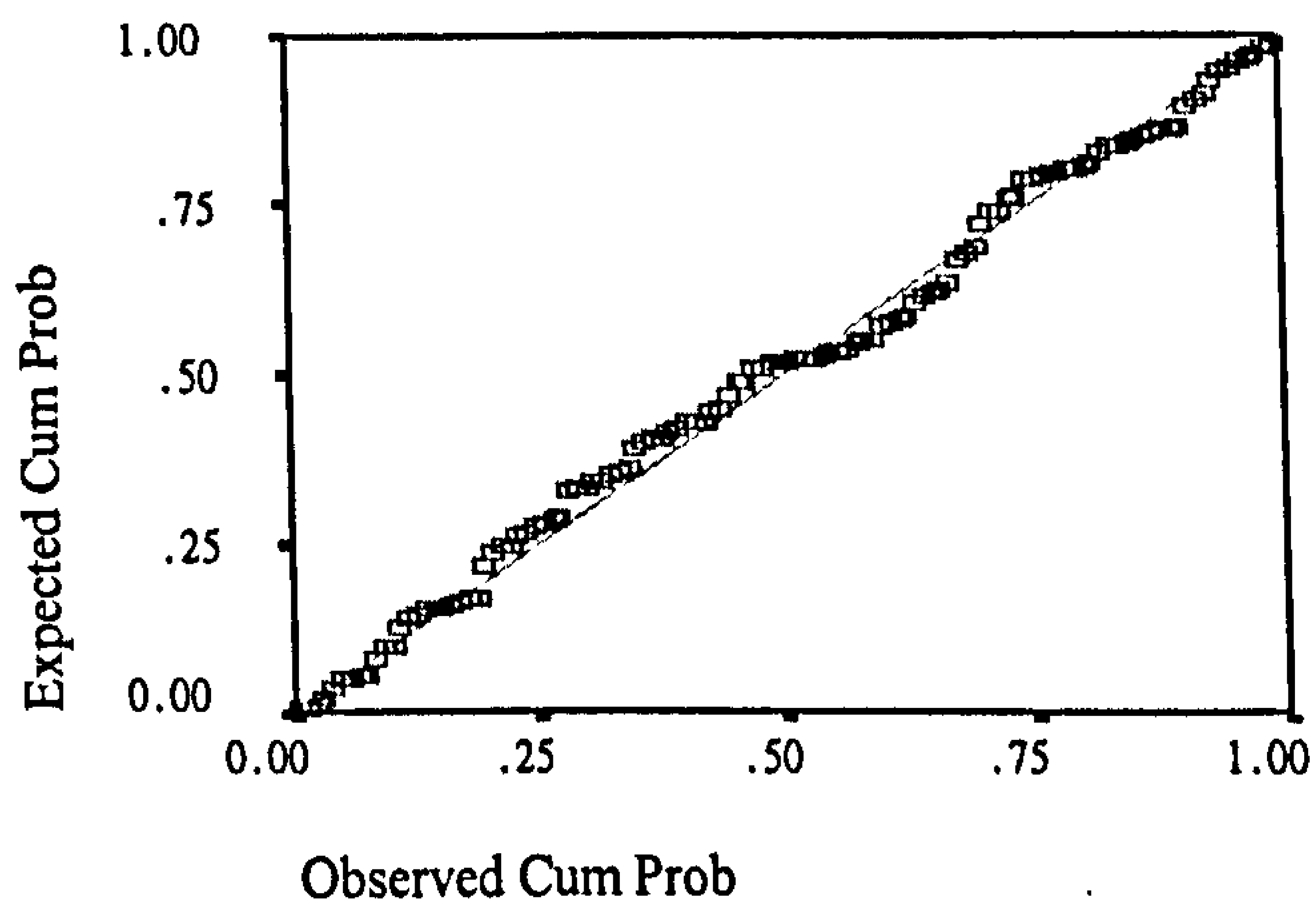
Before the Mediator: Predevelopment Assessment Knowledge



Normal P-P Plot of Standardized Residual

Dependent Variable: Technological Innovativeness

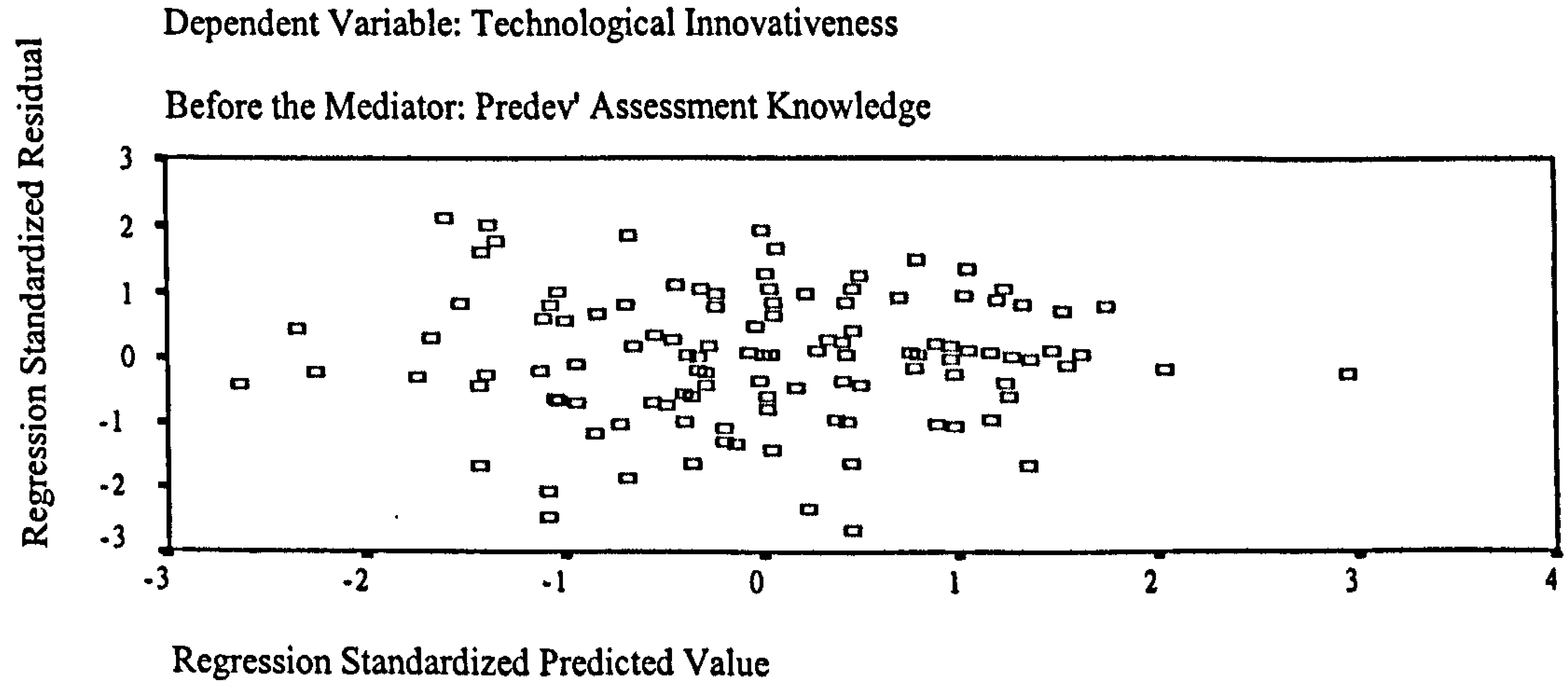
Before the Mediator: Predev' Assessment Knowledge



Scatterplot

Dependent Variable: Technological Innovativeness

Before the Mediator: Predev' Assessment Knowledge

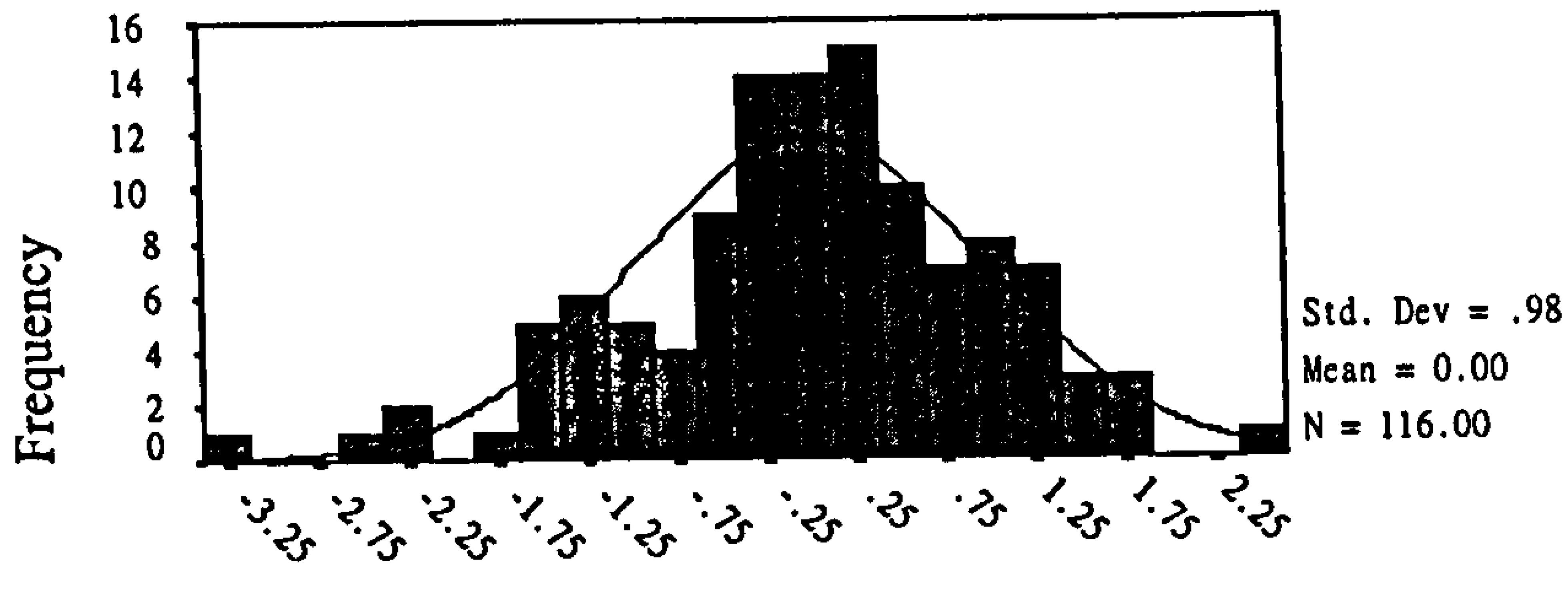


Regression Model 'Before the Mediator- PDA' of Table 6.6.1

Histogram of Residuals

Dependent Variable: Technological Innovativeness

Before the Mediator: Marketing Knowledge

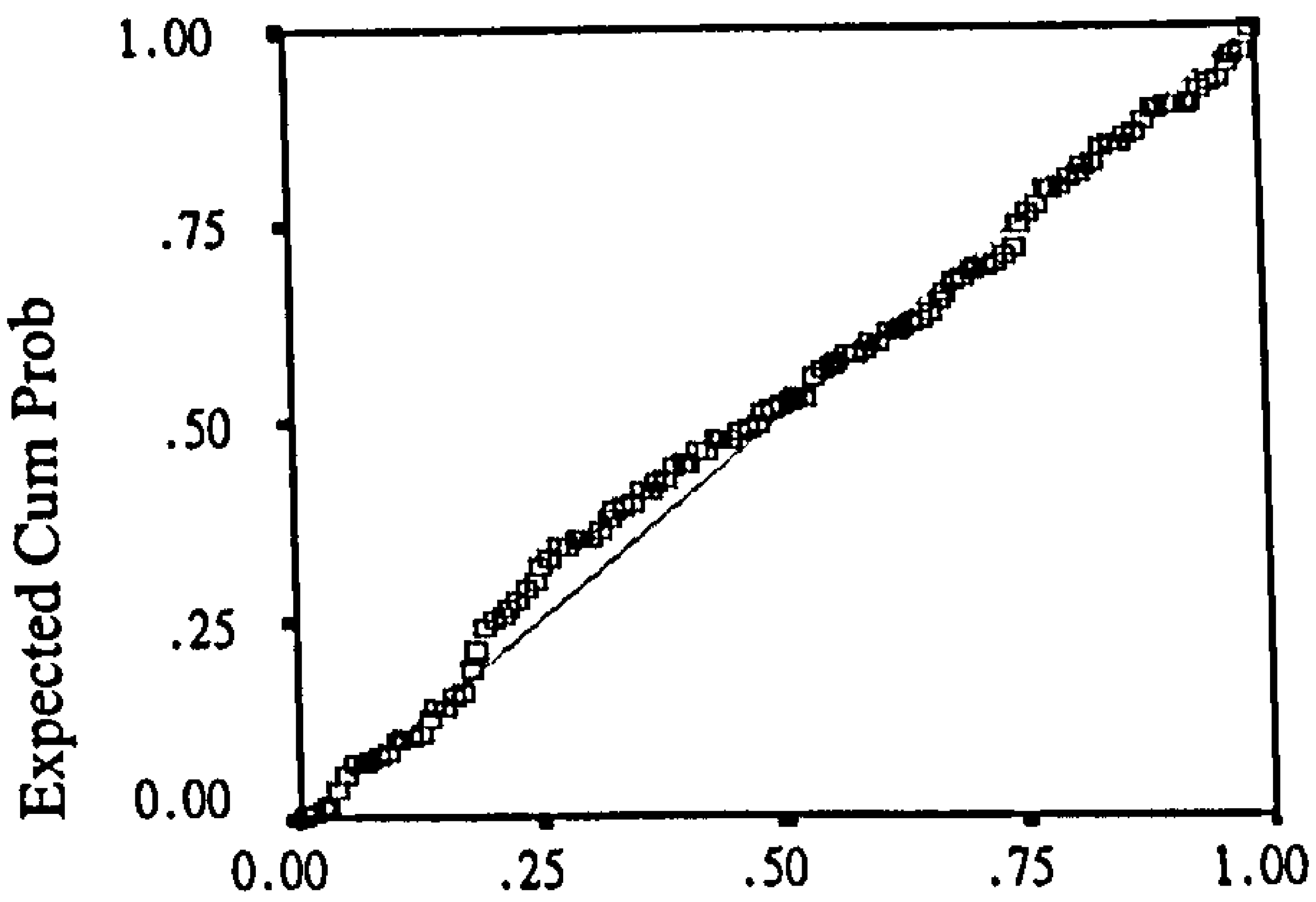


Regression Standardized Residual

Normal P-P Plot of Standardized Residual

Dependent Variable: Technological Innovativeness

Before the Mediator: Marketing Knowledge

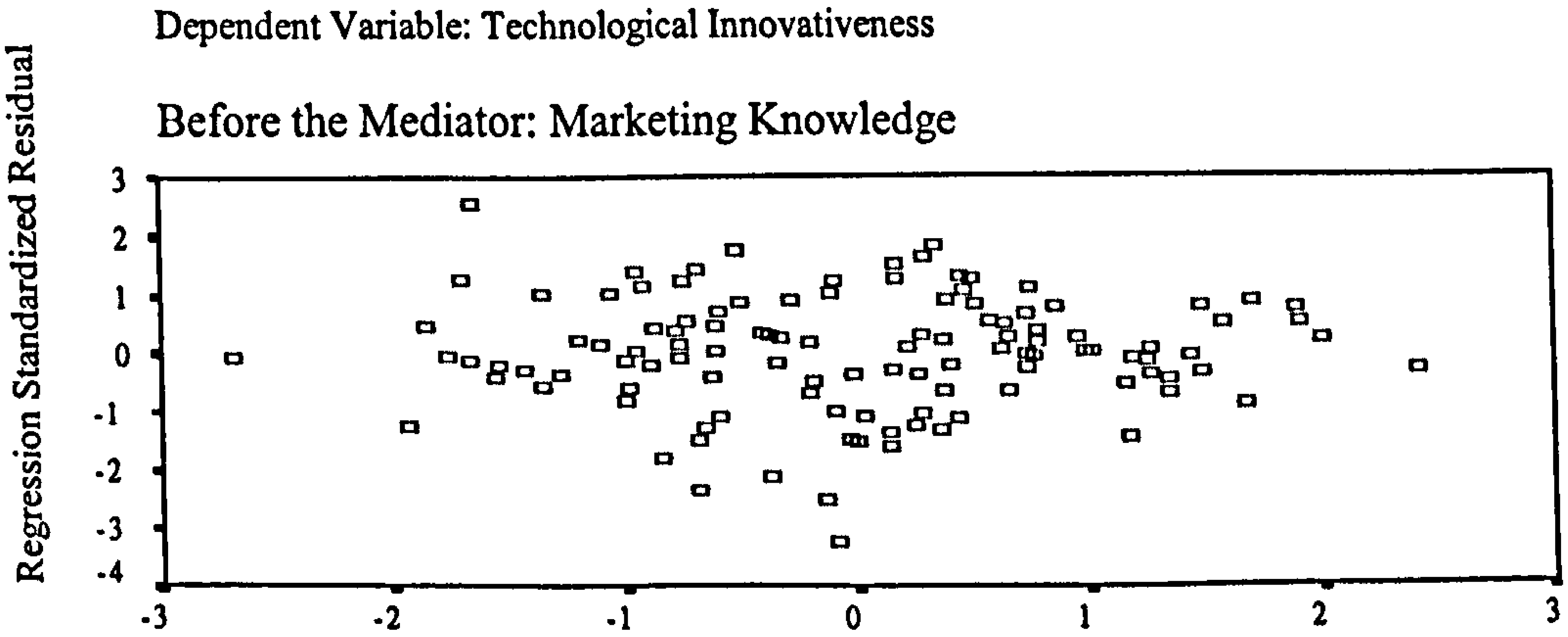


Observed Cum Prob

Scatterplot

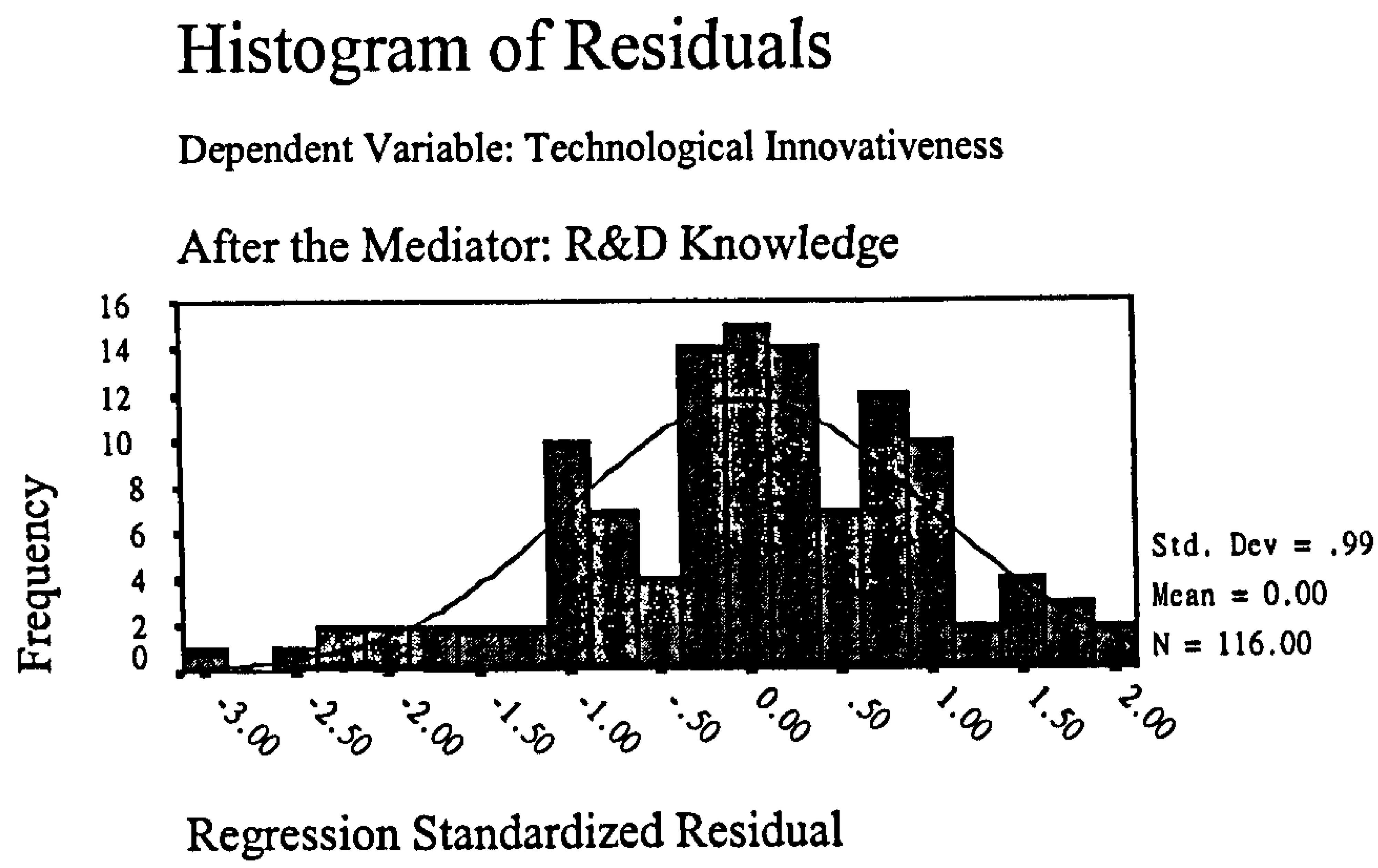
Dependent Variable: Technological Innovativeness

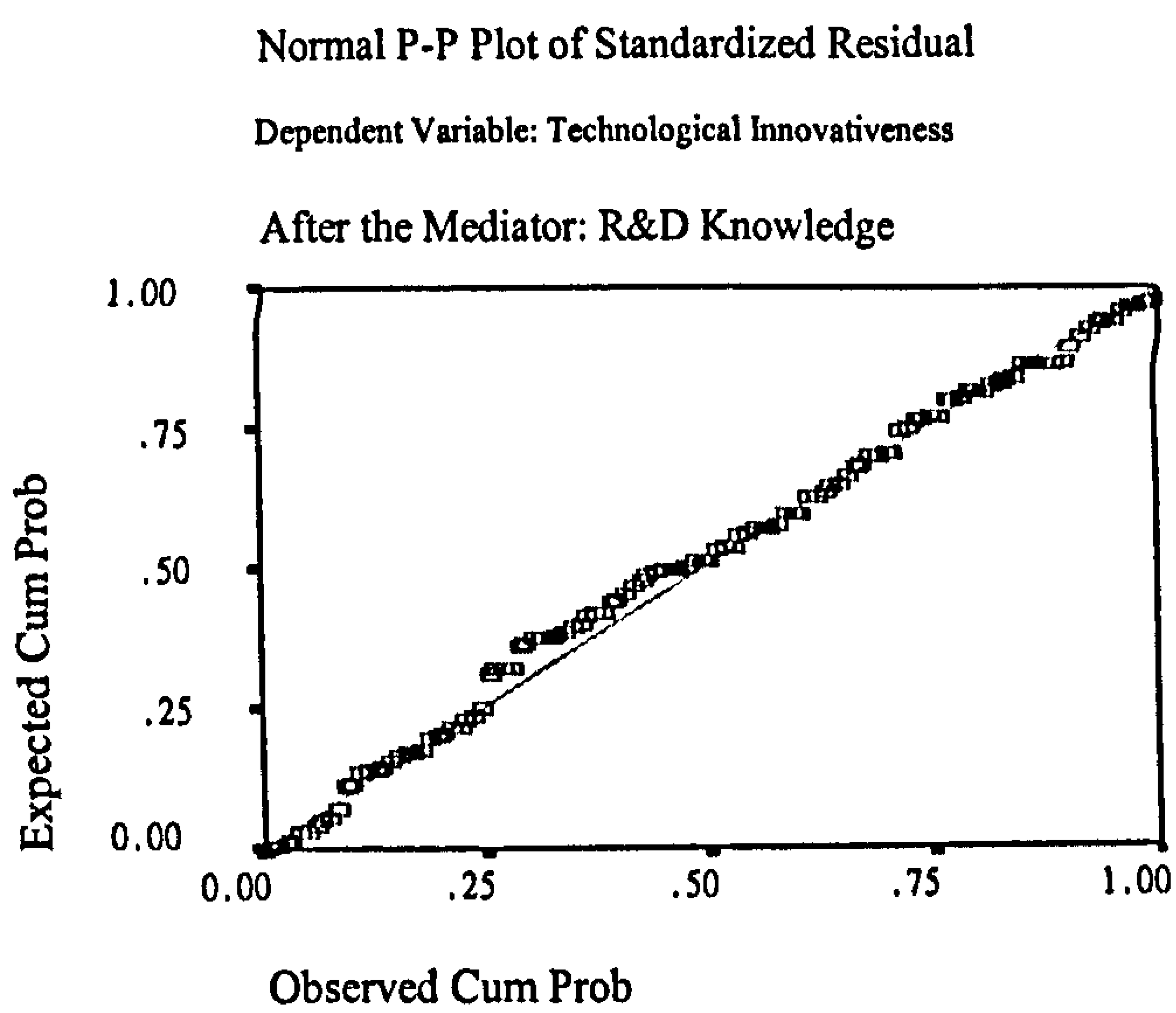
Before the Mediator: Marketing Knowledge

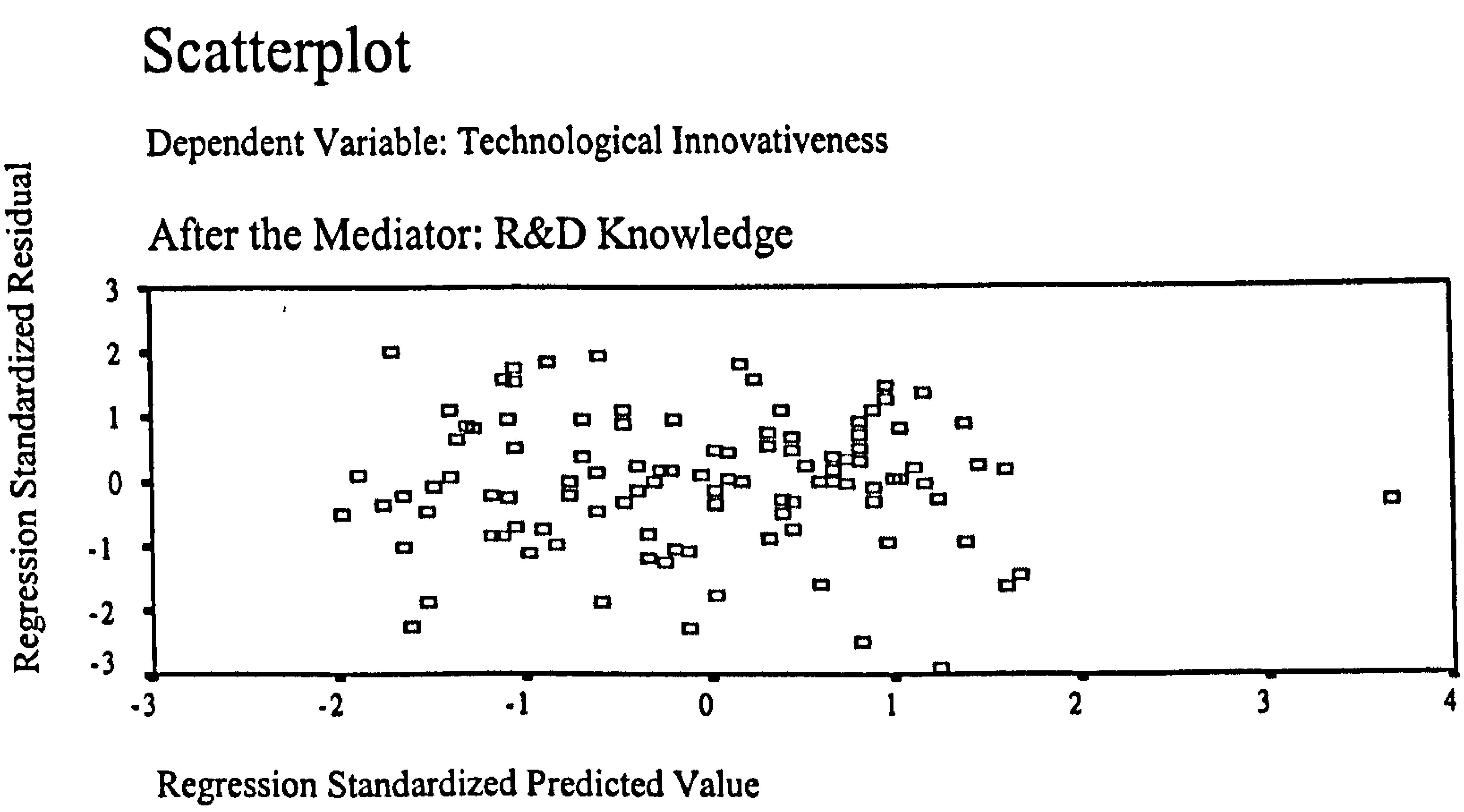


Regression Standardized Predicted Value

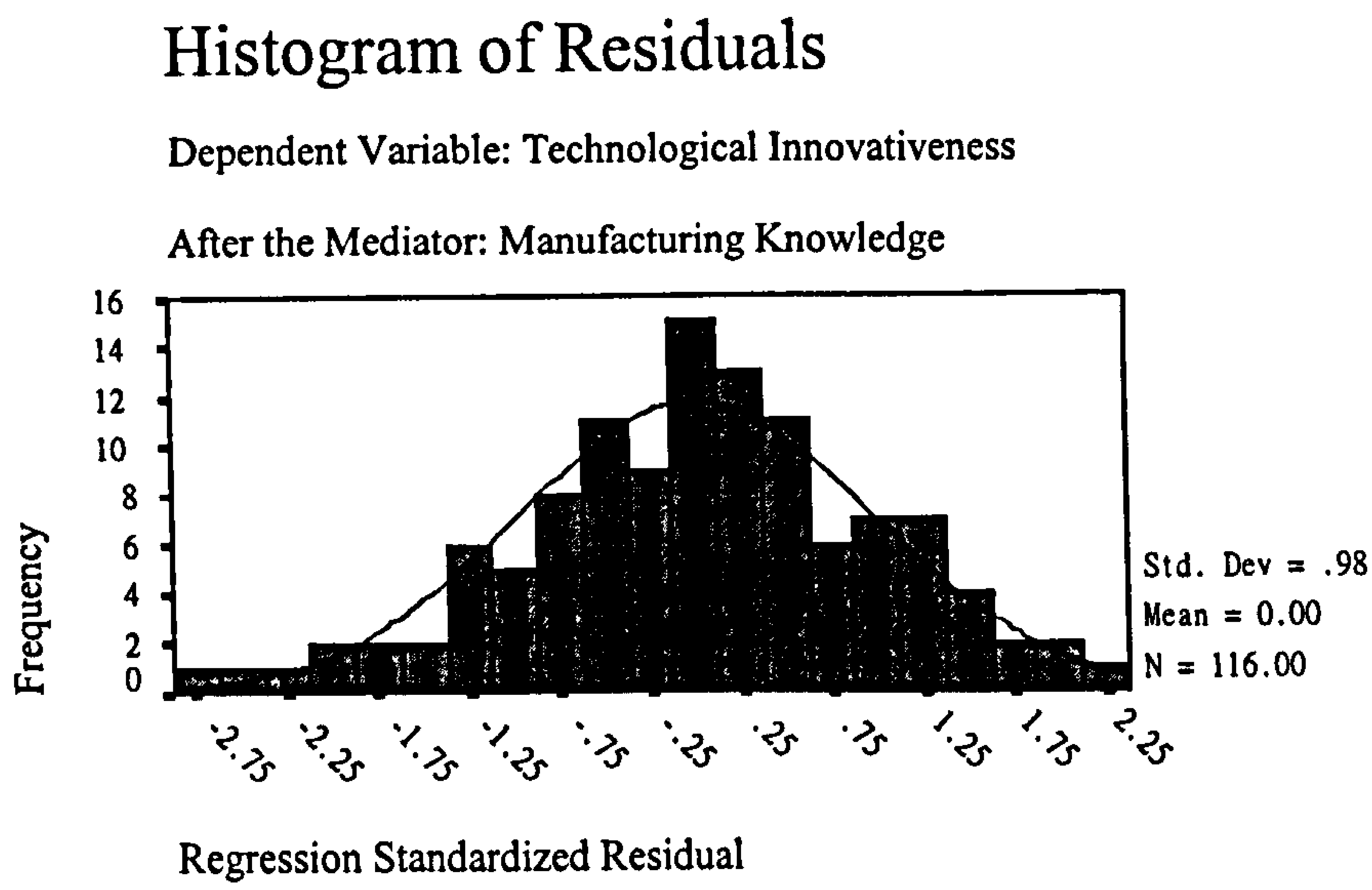
Regression Model 'Before the Mediator-MK' of Table 6.6.1

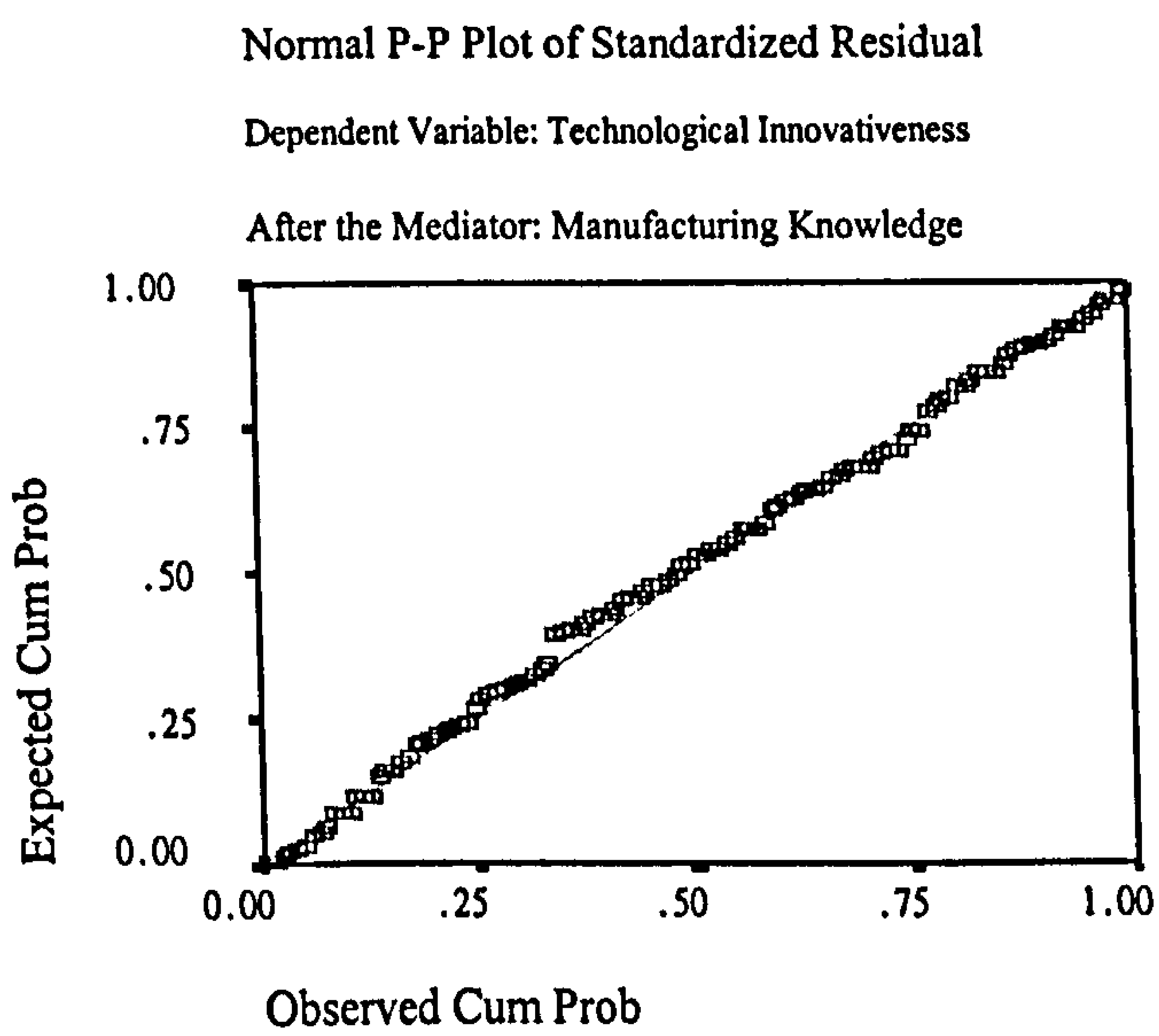


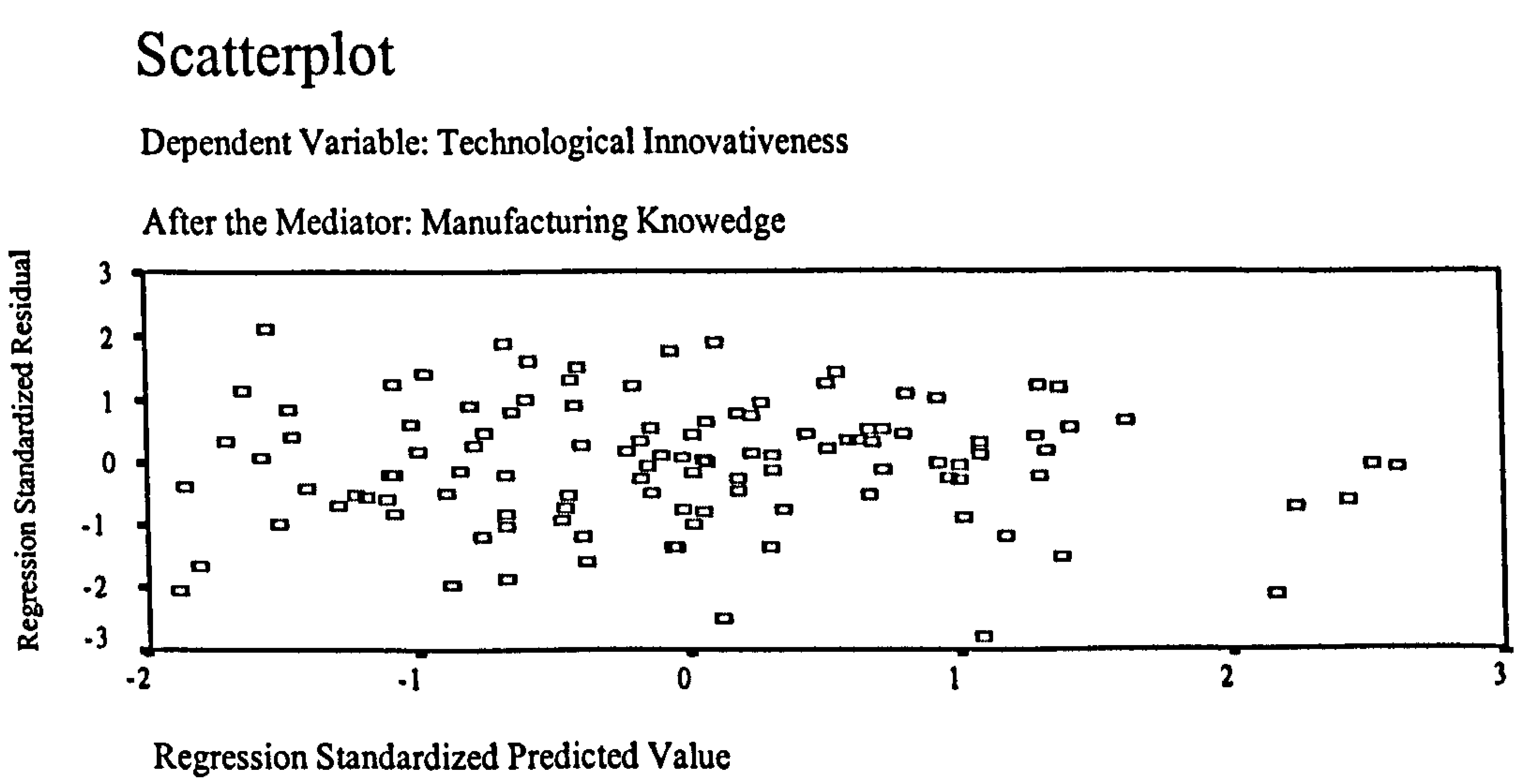




Regression Model 'After the Mediator- RD' of Table 6.6.1





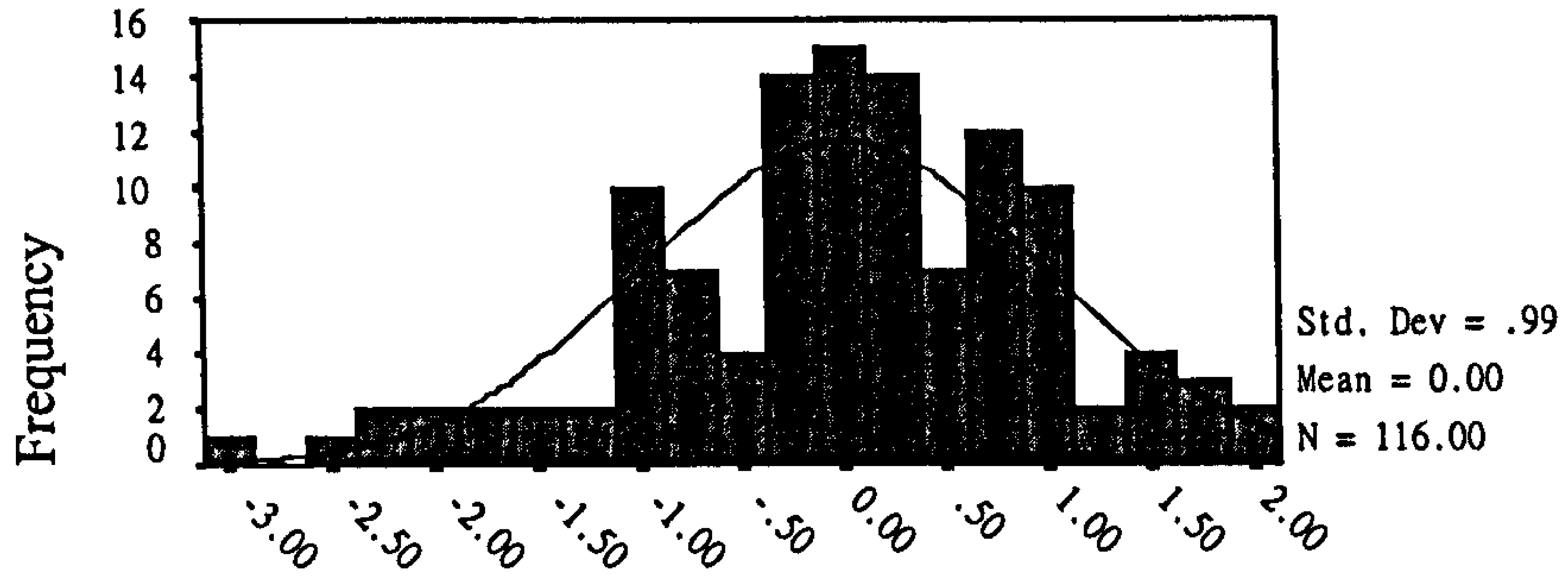


Regression Model 'After the Mediator-MF' of Table 6.6.1

Histogram of Residuals

Dependent Variable: Technological Innovativeness

After the Mediator: Predeve Assessment Knowledge

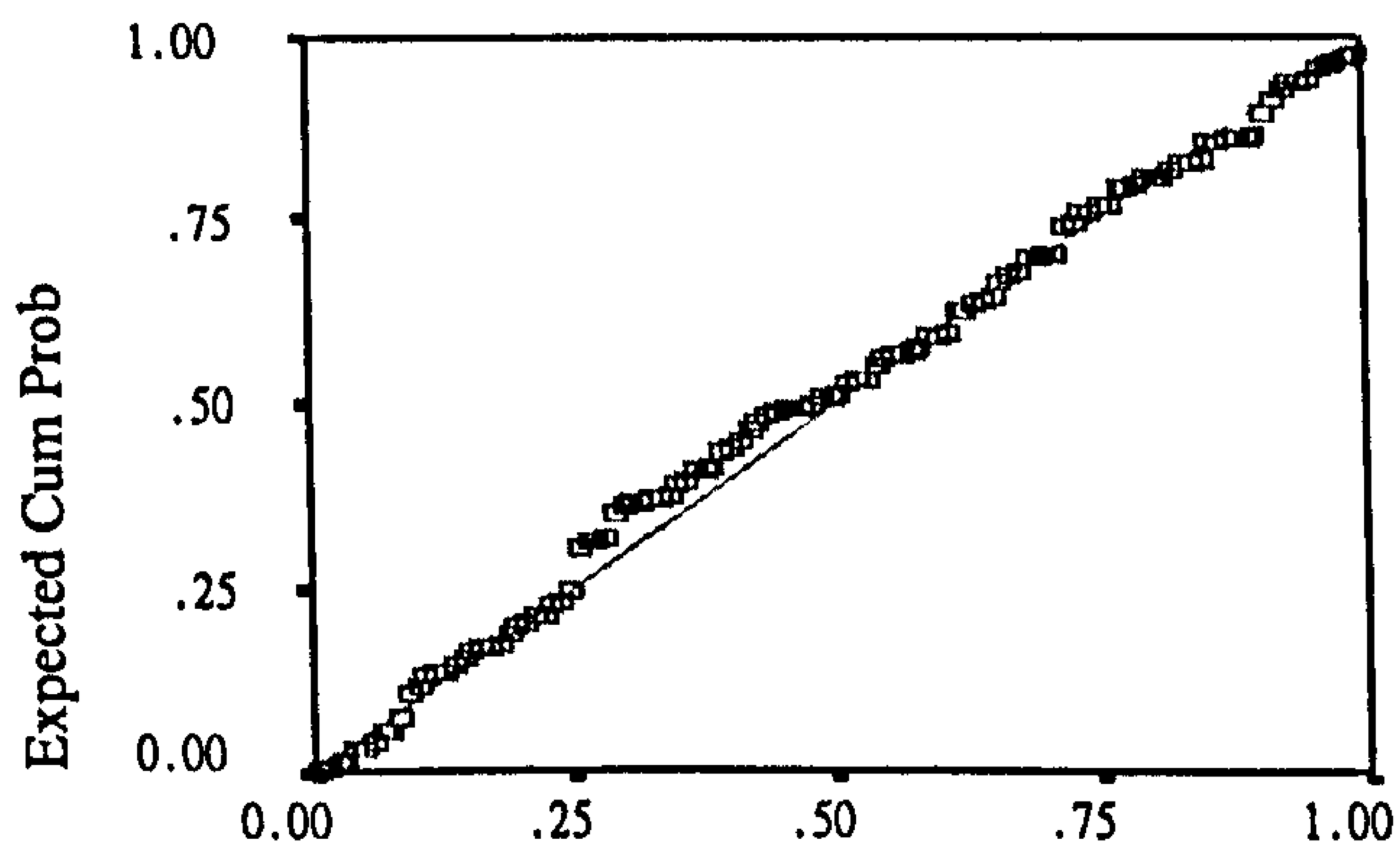


Regression Standardized Residual

Normal P-P Plot of Standardized Residual

Dependent Variable: Technological Innovativeness

After the Mediator: Predeve Assessment Knowledge

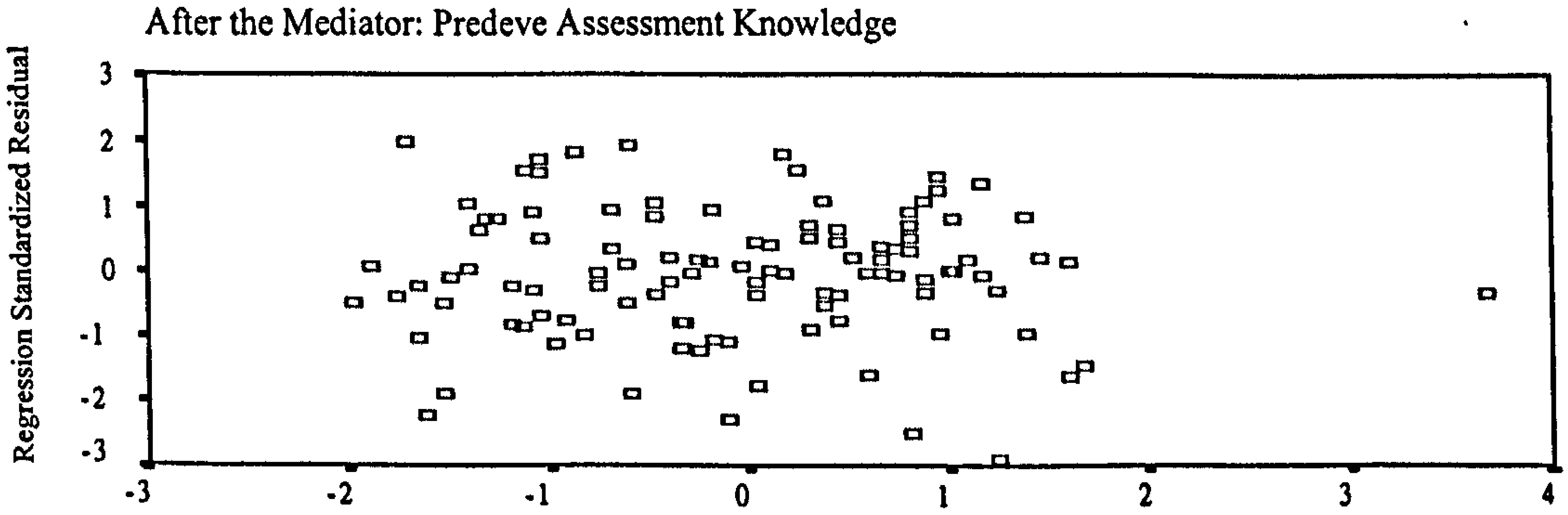


Observed Cum Prob

Scatterplot

Dependent Variable: Technological Innovativeness

After the Mediator: Predeve Assessment Knowledge



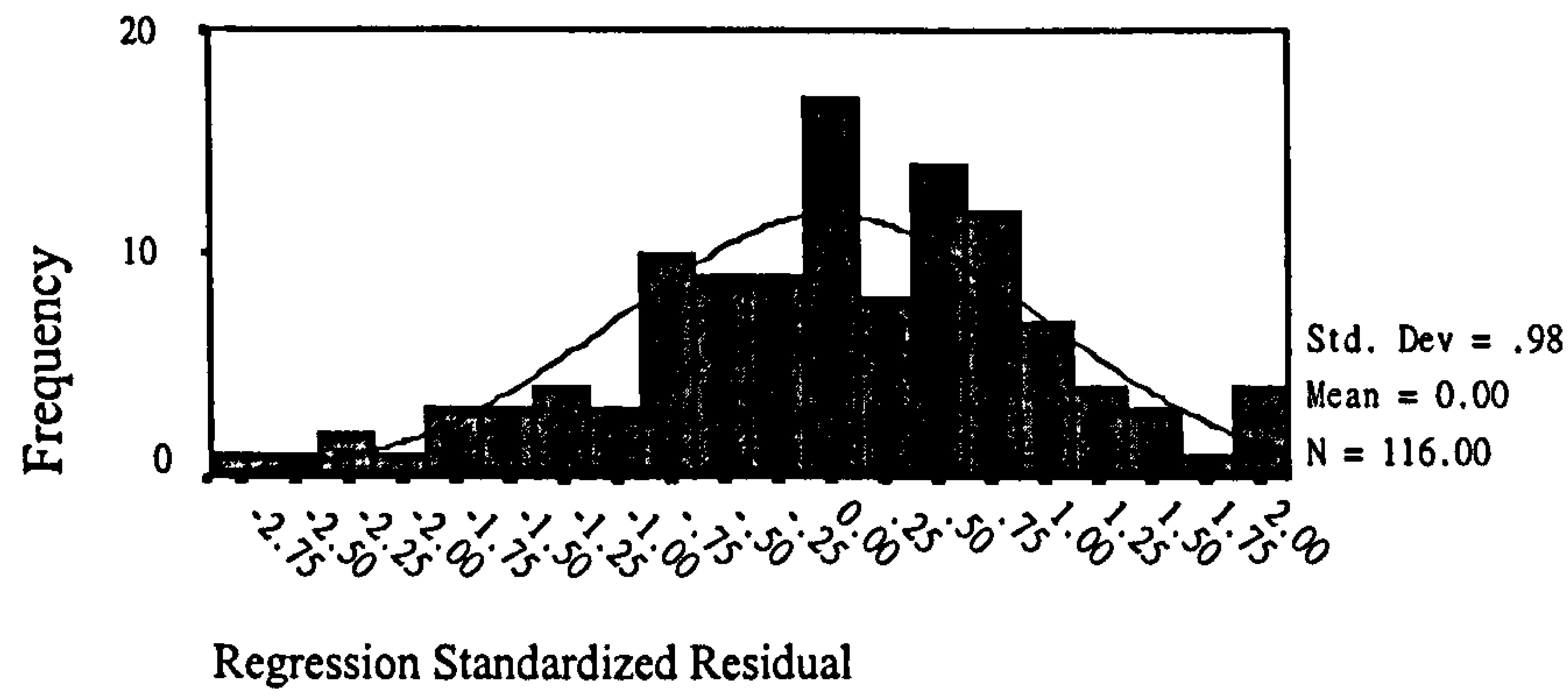
Regression Standardized Predicted Value

Regression Model 'After the Mediator-PDA' of Table 6.6.1

Histogram of Residuals

Dependent Variable: Technological Innovativeness

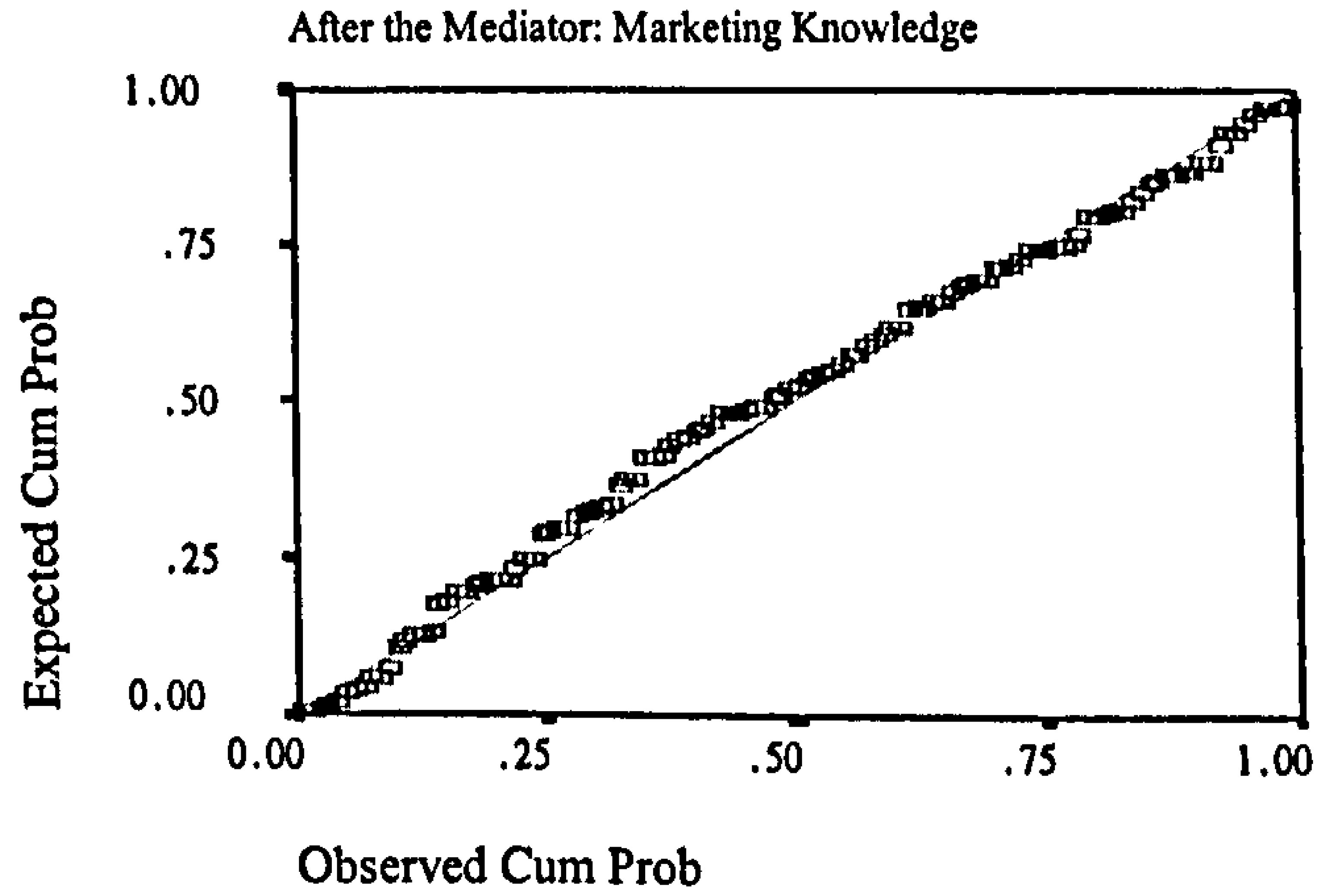
After the Mediator: Marketing Knowledge



Normal P-P Plot of Standardized Residual

Dependent Variable: Technological Innovativeness

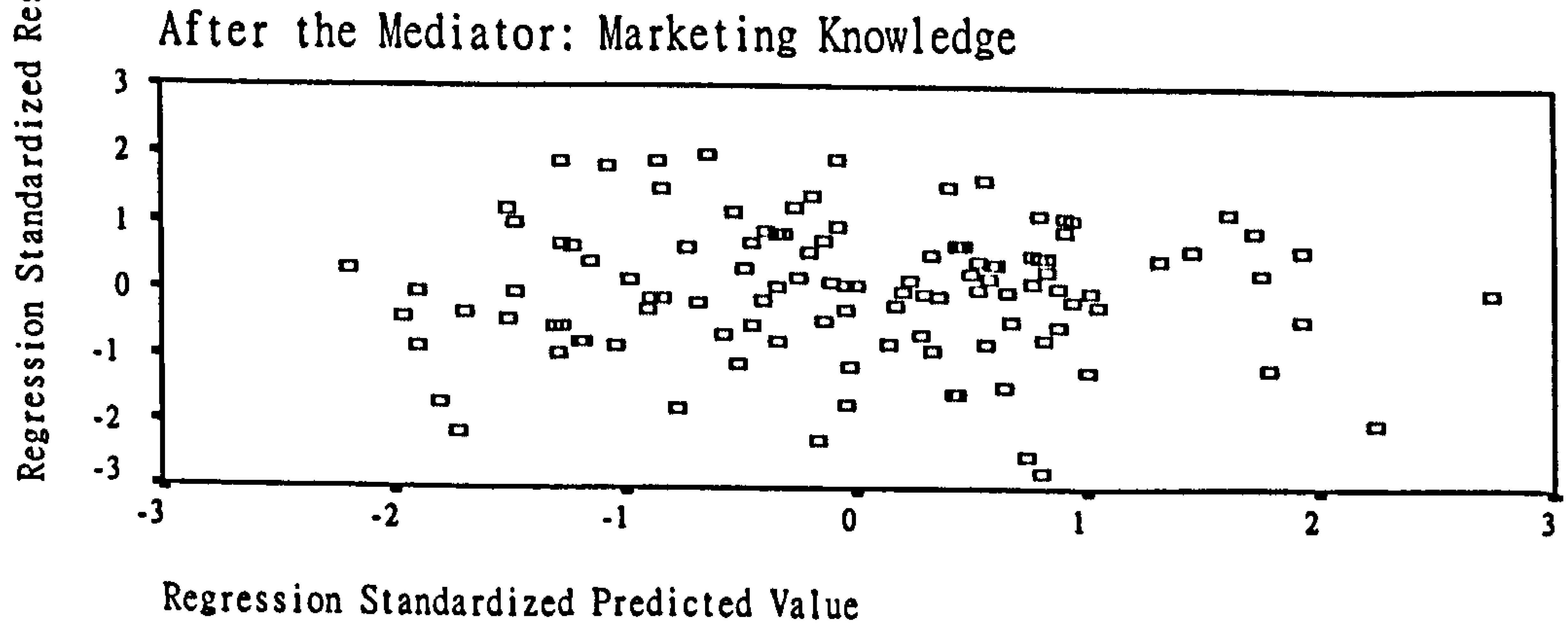
After the Mediator: Marketing Knowledge



Scatterplot

Dependent Variable: Technological Innovativeness

After the Mediator: Marketing Knowledge

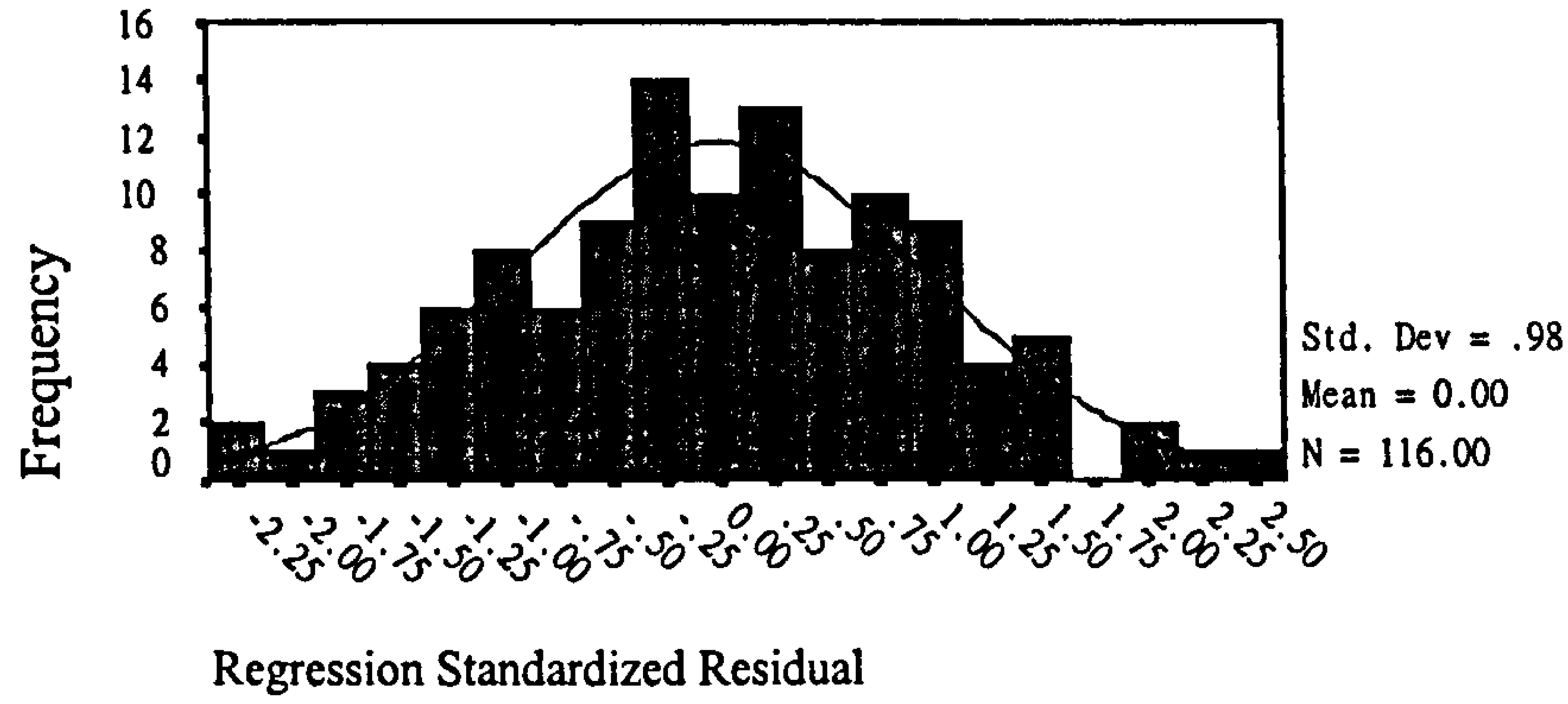


Regression Model 'After the Mediator- MK' of Table 6.6.1

Histogram of Residuals

Dependent Variable: Market Innovativeness

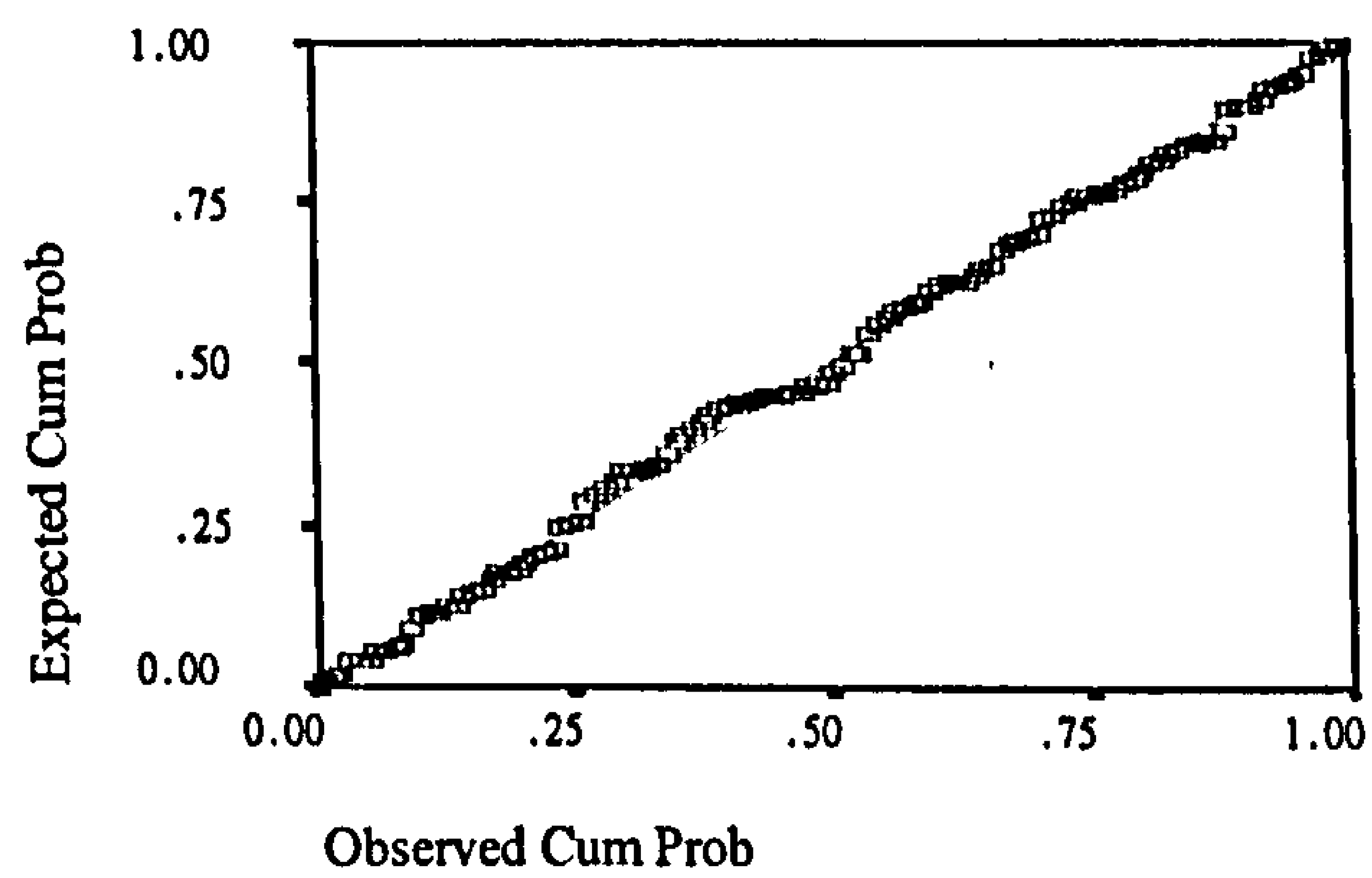
Before the Mediator: R&D Knowledge



Normal P-P Plot of Standardized Residual

Dependent Variable: Market Innovativeness

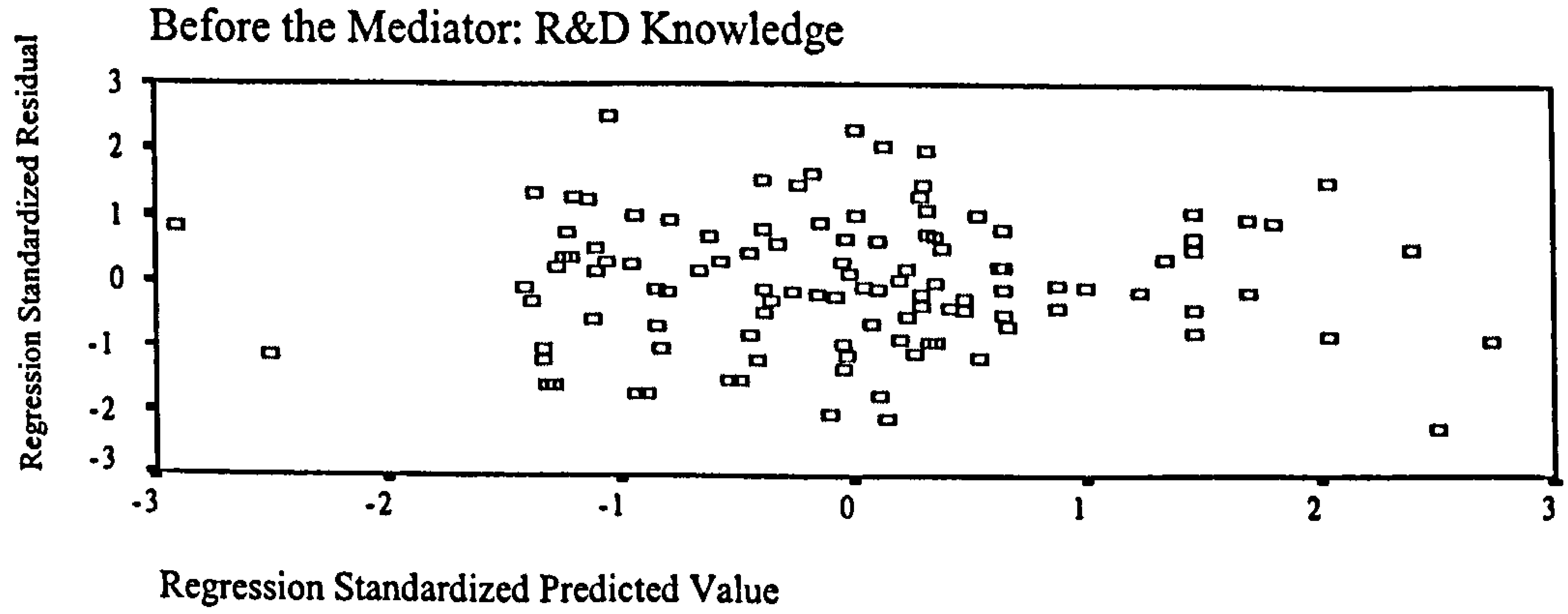
Before the Mediator: R&D Knowledge



Scatterplot

Dependent Variable: Market Innovativeness

Before the Mediator: R&D Knowledge

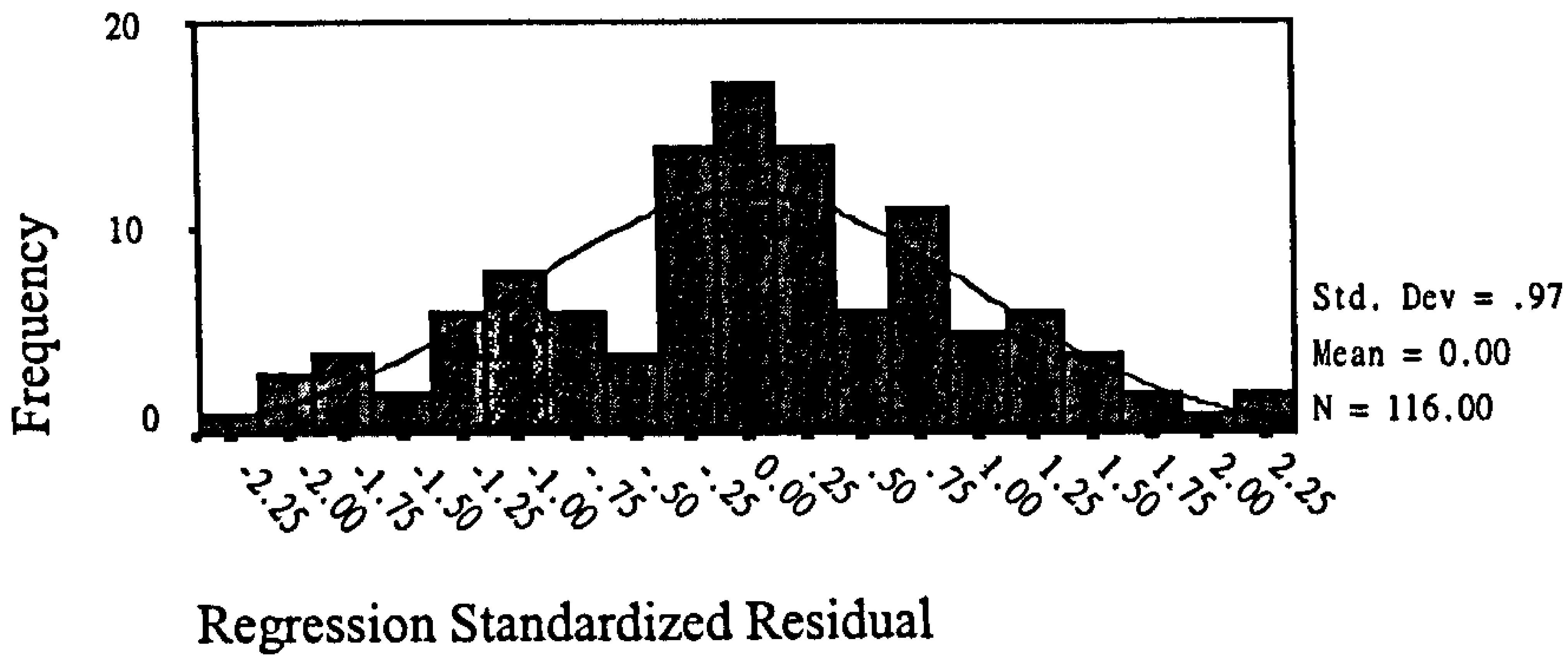


Regression Model 'Before the Mediator- R&D' of Table 6.6.2

Histogram of Residuals

Dependent Variable: Market Innovativeness

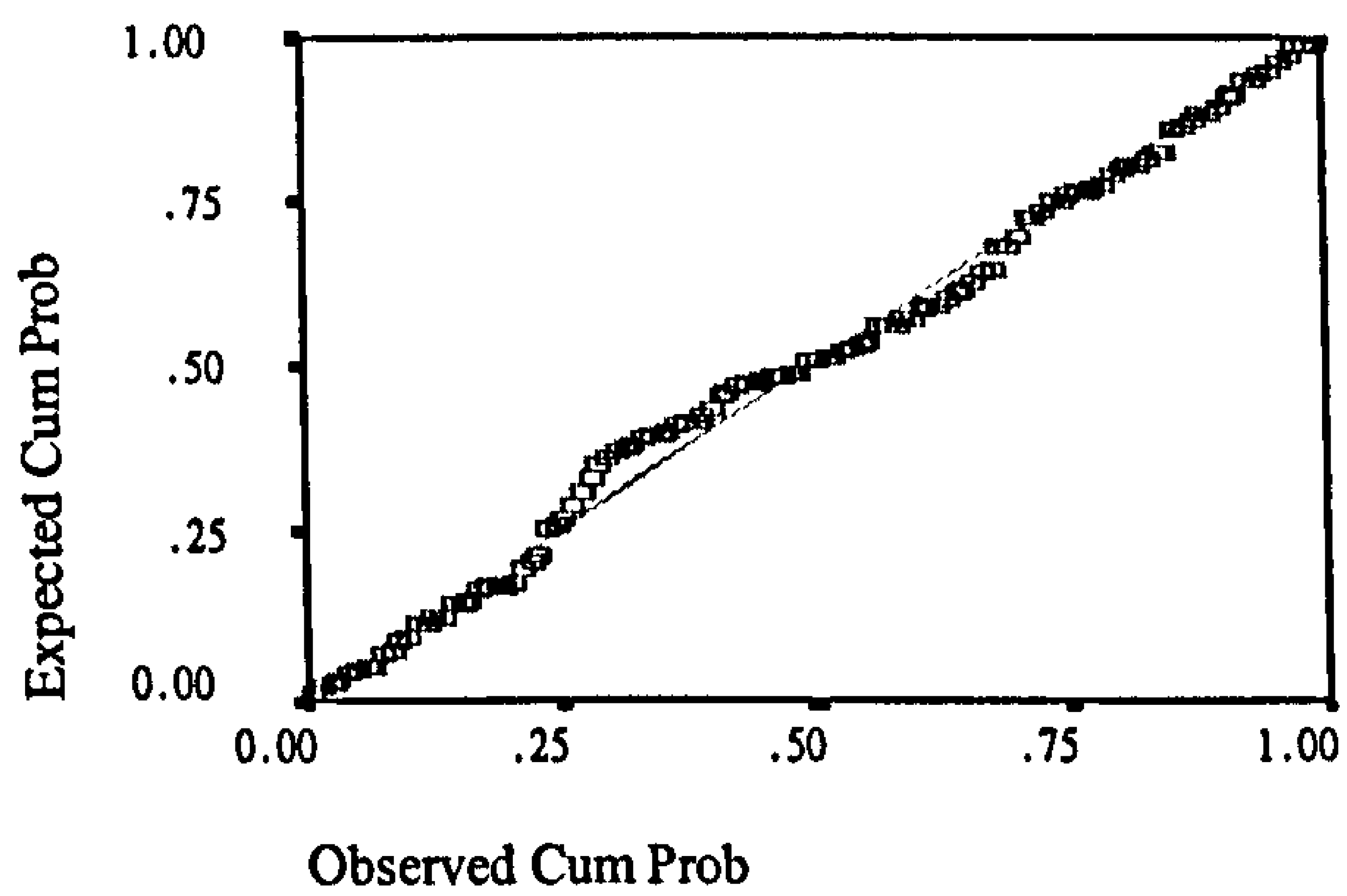
Before the Mediator: Manufacturing Knowledge



Normal P-P Plot of Standardized Residual

Dependent Variable: Market Innovativeness

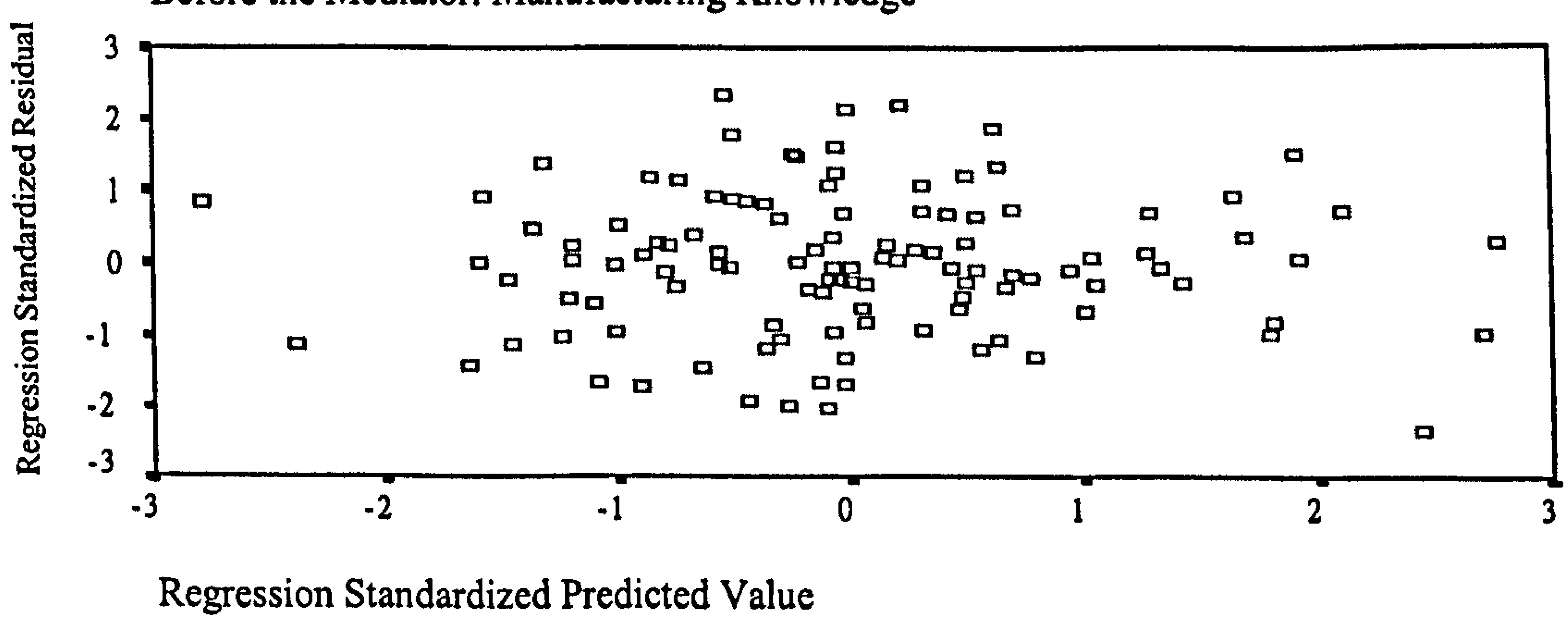
Before the Mediator: Manufacturing Knowledge



Scatterplot

Dependent Variable: Market Innovativeness

Before the Mediator: Manufacturing Knowledge

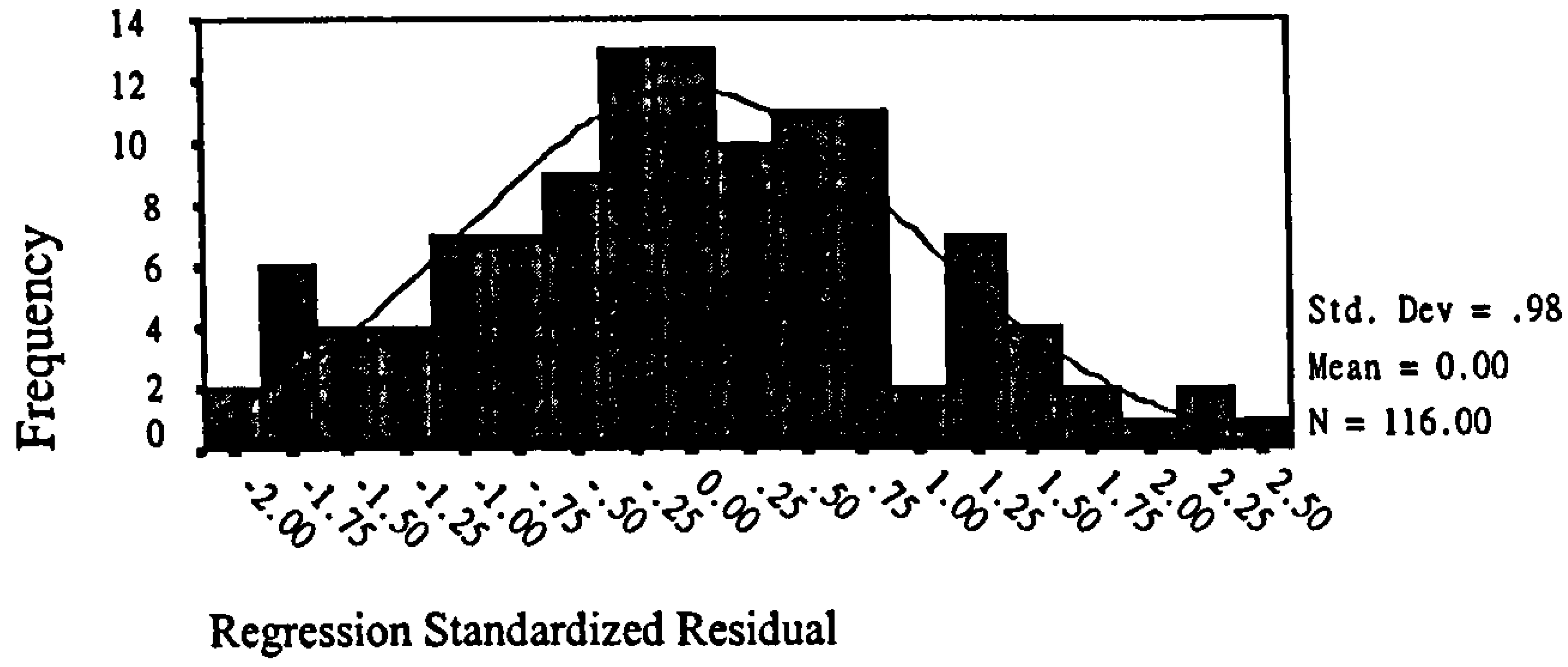


Regression Model 'Before the Mediator: MF' of Table 6.6.2

Histogram of Residuals

Dependent Variable: Market Innovativeness

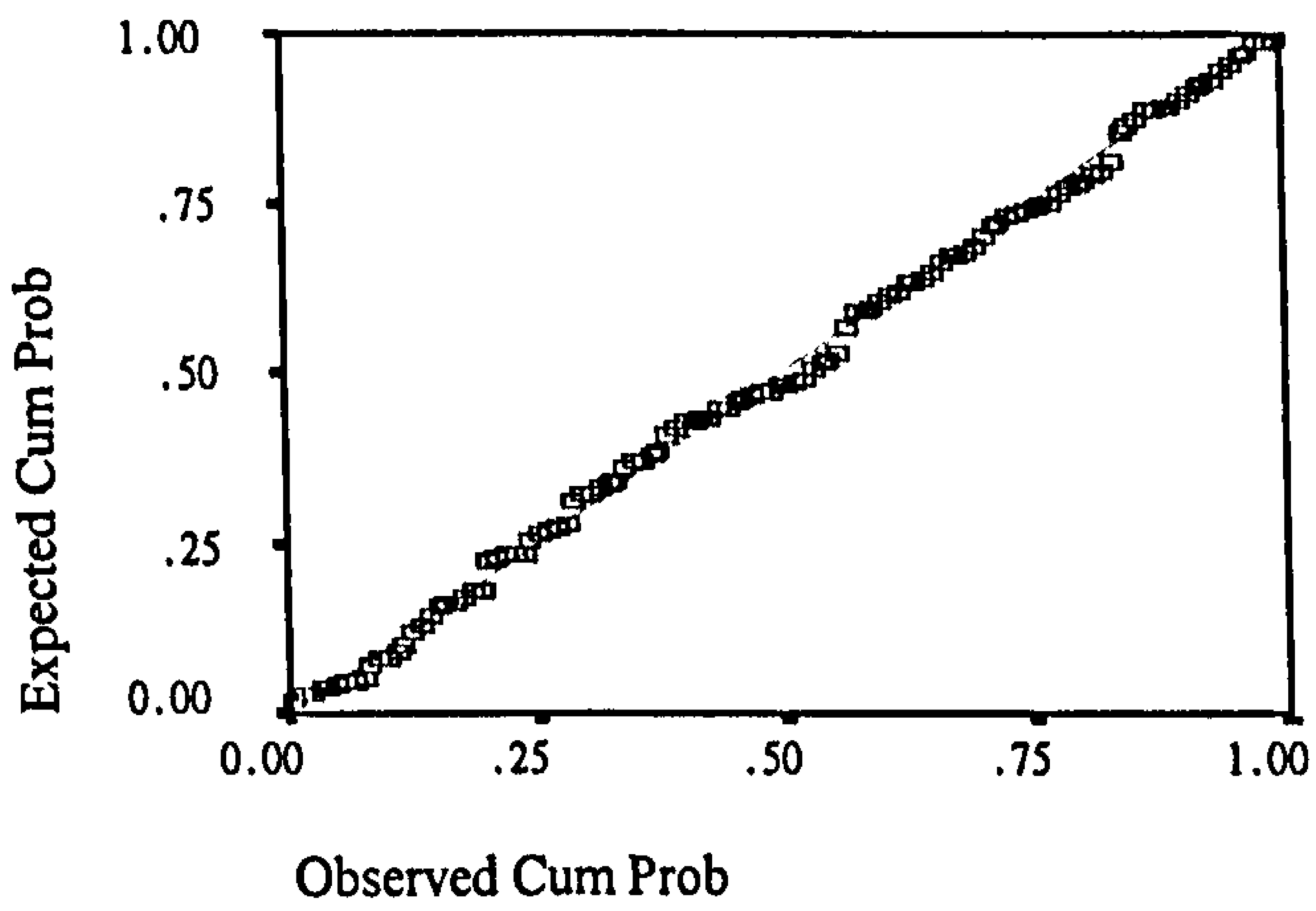
Before the Mediator: Predeve Assessment Knowledge



Normal P-P Plot of Standardized Residual

Dependent Variable: Market Innovativeness

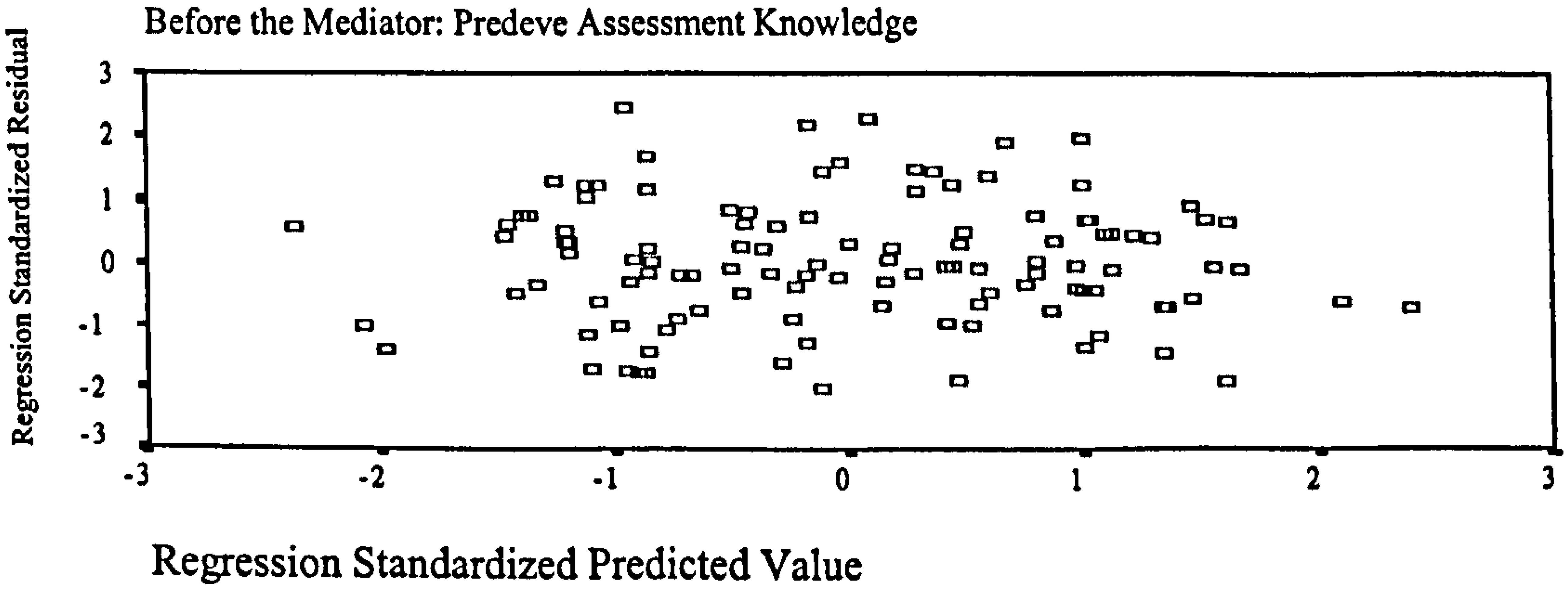
Before the Mediator: Predeve Assessment Knowledge



Scatterplot

Dependent Variable: Market Innovativeness

Before the Mediator: Predeve Assessment Knowledge

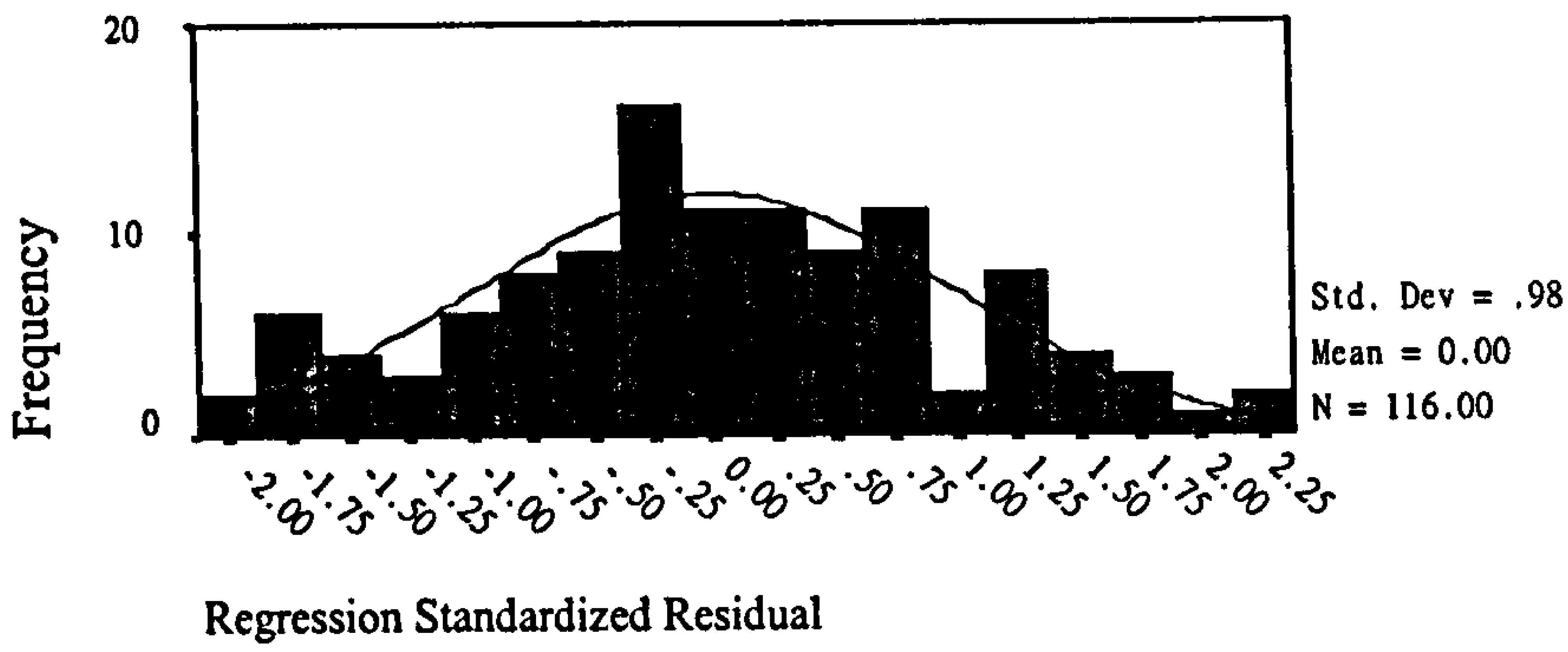


Regression Model 'Before the Mediator-PDA' of Table 6.6.2

Histogram of Residuals

Dependent Variable: Market Innovativeness

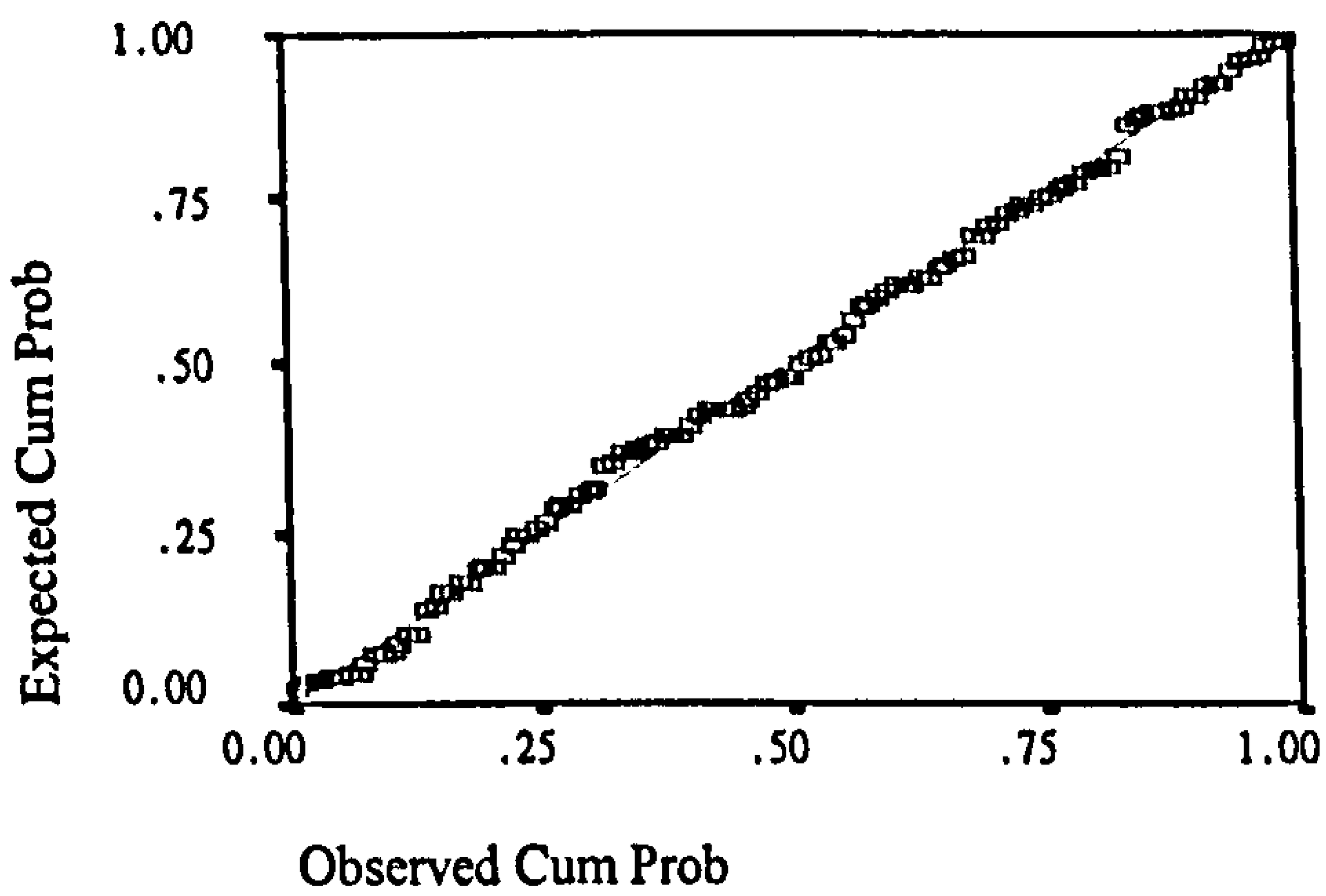
Before the Mediator: Marketing Knowledge



Normal P-P Plot of Standardized Residual

Dependent Variable: Market Innovativeness

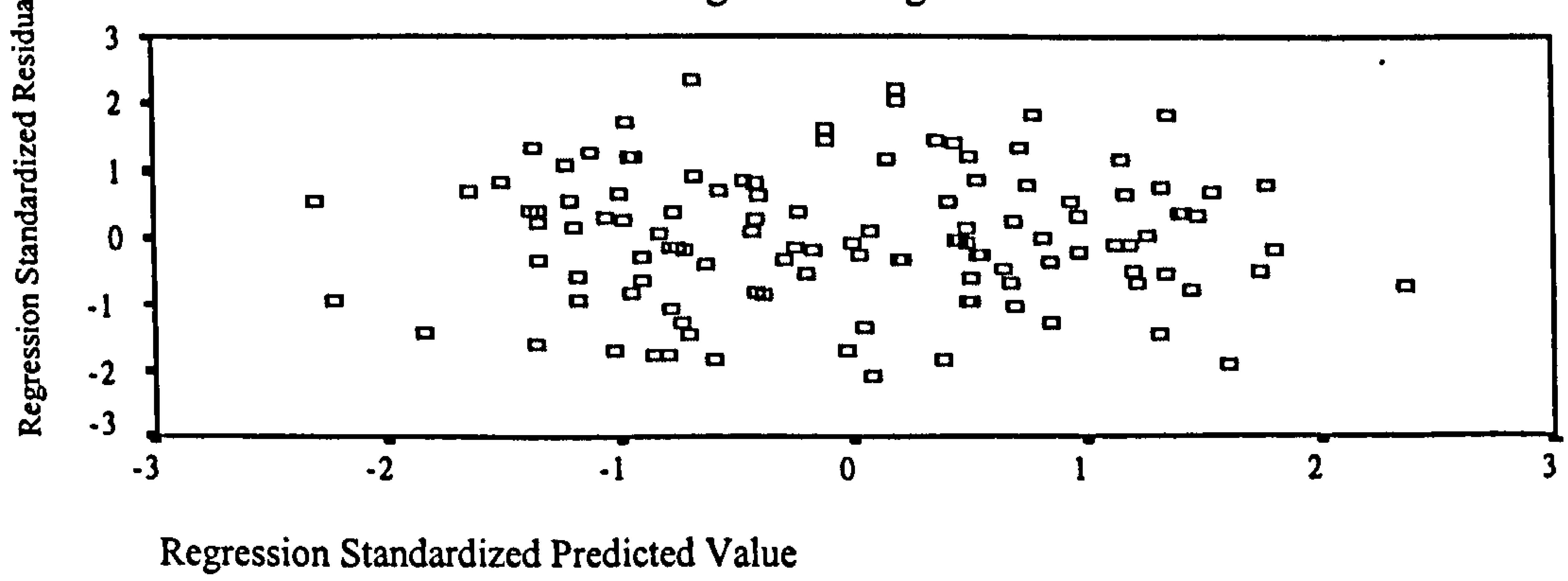
Before the Mediator: Marketing Knowledge



Scatterplot

Dependent Variable: Market Innovativeness

Before the Mediator: Marketing Knowledge

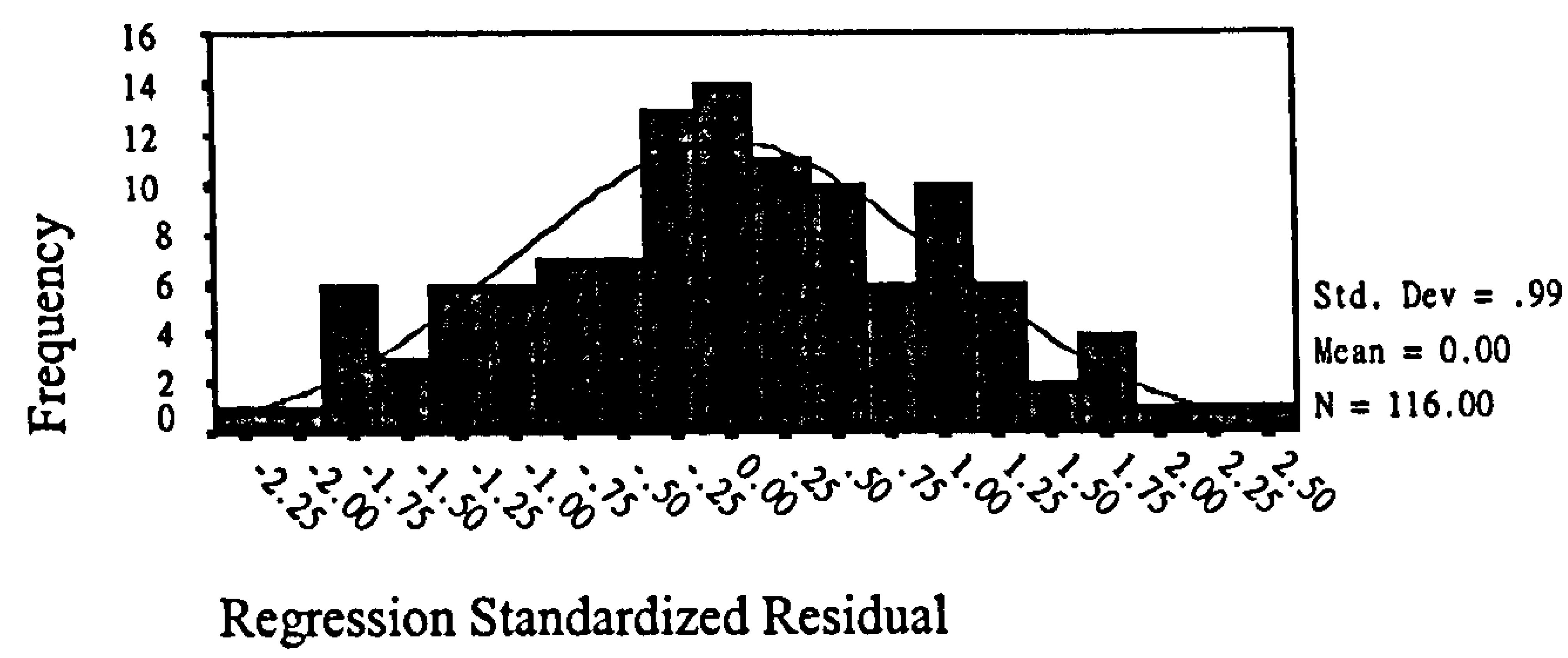


Regression Model 'Before the Mediator-MK' of Table 6.6.2

Histogram of Residuals

Dependent Variable: Market Innovativeness

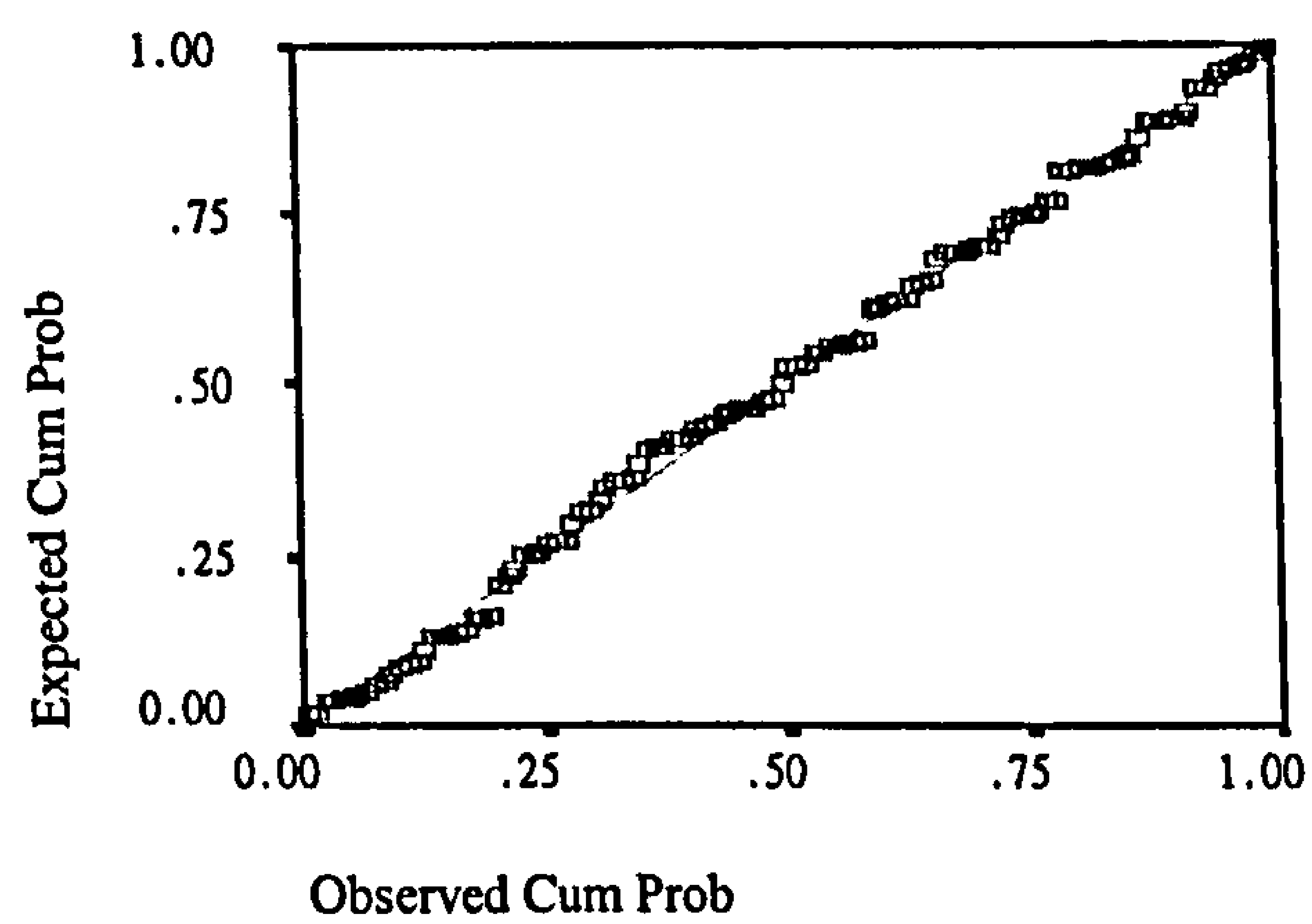
After the Mediator: R&D Knowledge



Normal P-P Plot of Standardized Residual

Dependent Variable: Market Innovativeness

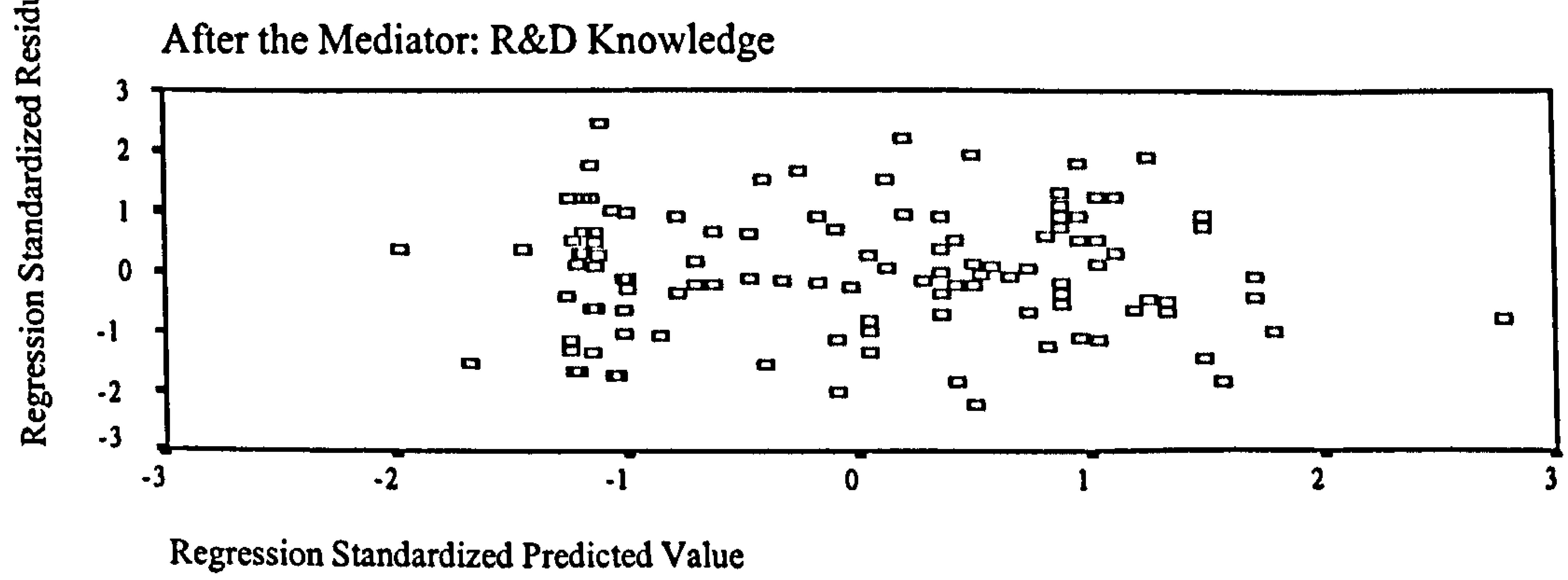
After the Mediator: R&D Knowledge



Scatterplot of Residuals

Dependent Variable: Market Innovativeness

After the Mediator: R&D Knowledge

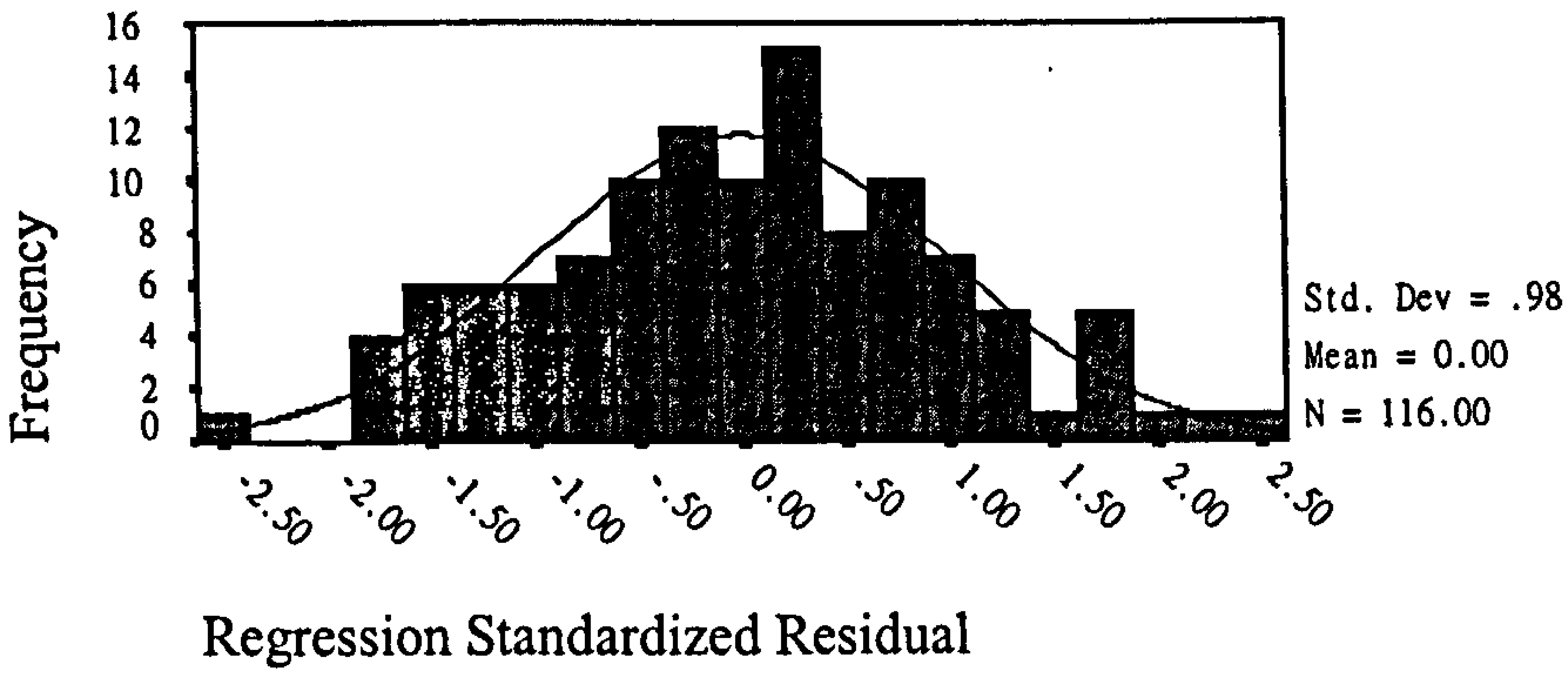


Regression Model 'After the Mediator-RD' of Table 6.6.2

Histogram of Residuals

Dependent Variable: Market Innovativeness

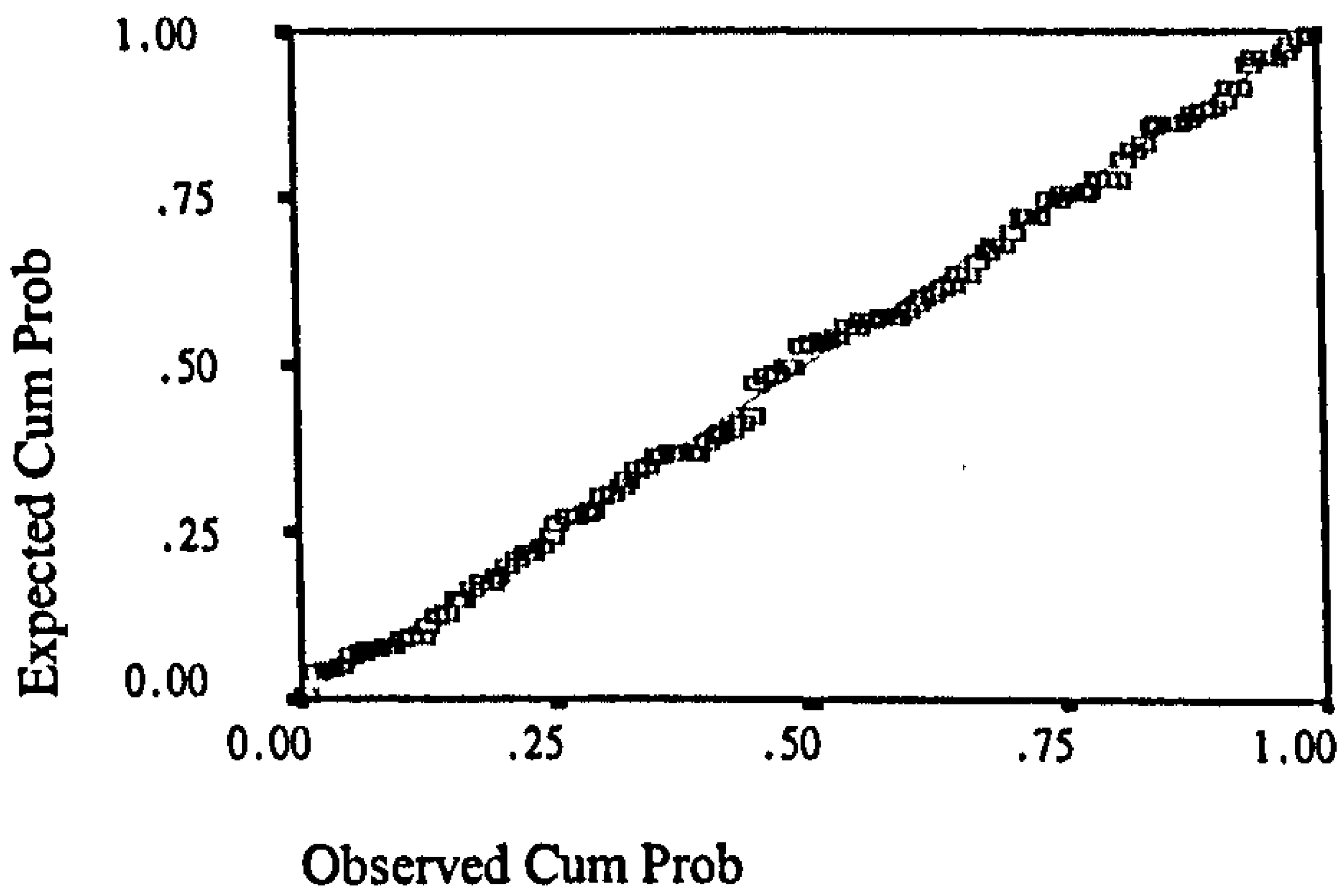
After the Mediator: Manufacturing Knowledge



Normal P-P Plot of Standardized Residual

Dependent Variable: Market Innovativeness

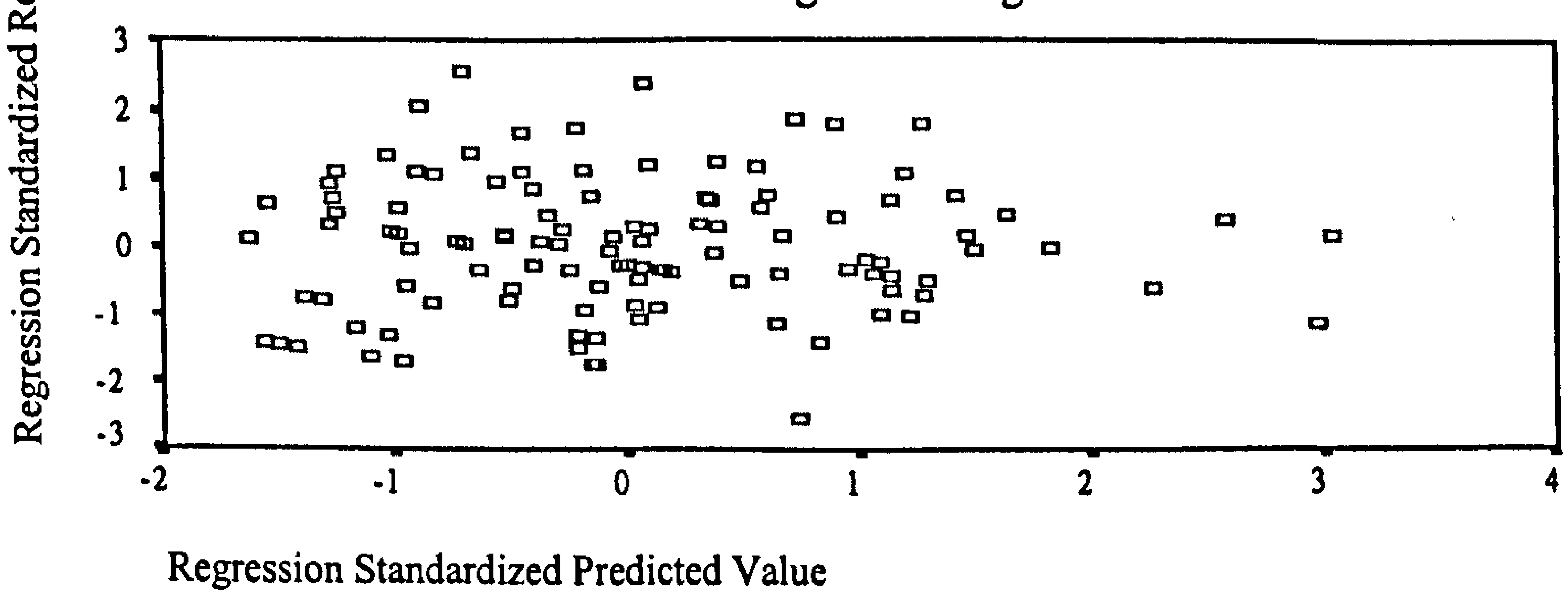
After the Mediator: Manufacturing Knowledge



Scatterplot

Dependent Variable: Market Innovativeness

After the Mediator: Manufacturing Knowledge

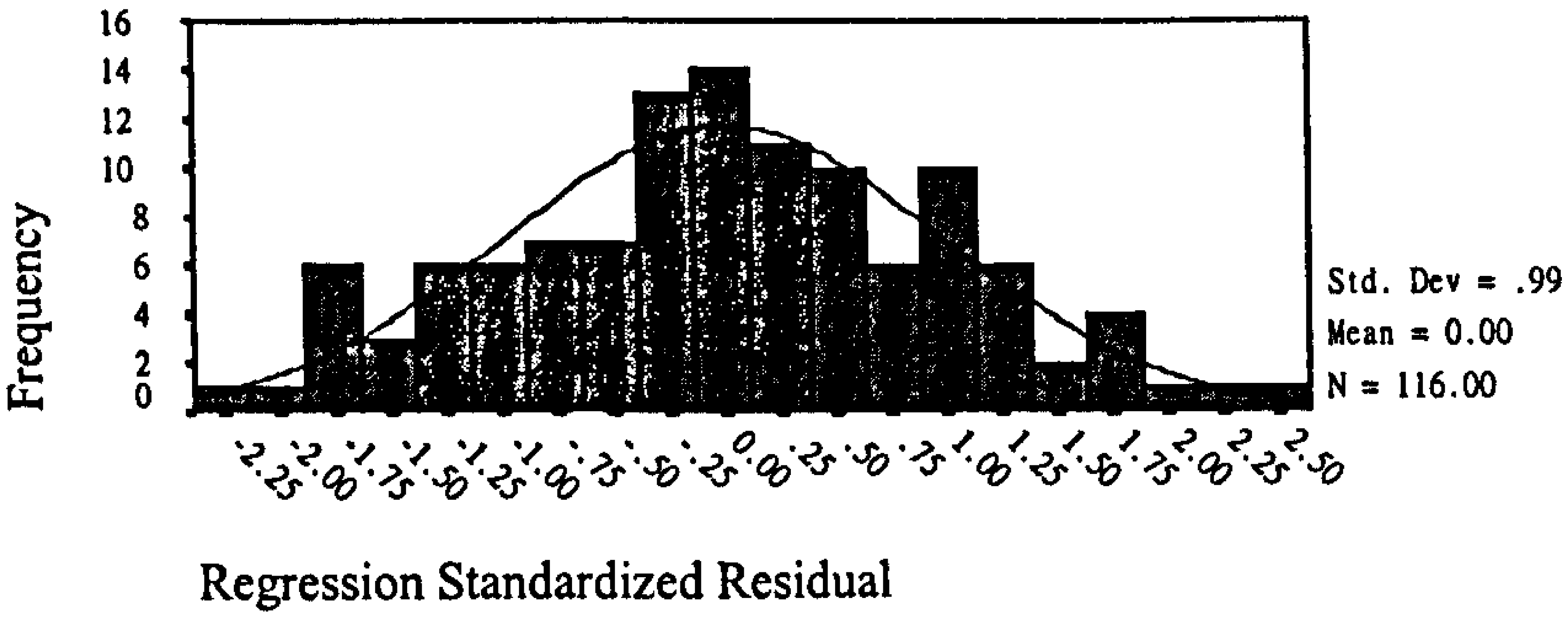


Regression Model 'After the Mediator- MF' of Table 6.6.2

Histogram of Residuals

Dependent Variable: Market Innovativeness

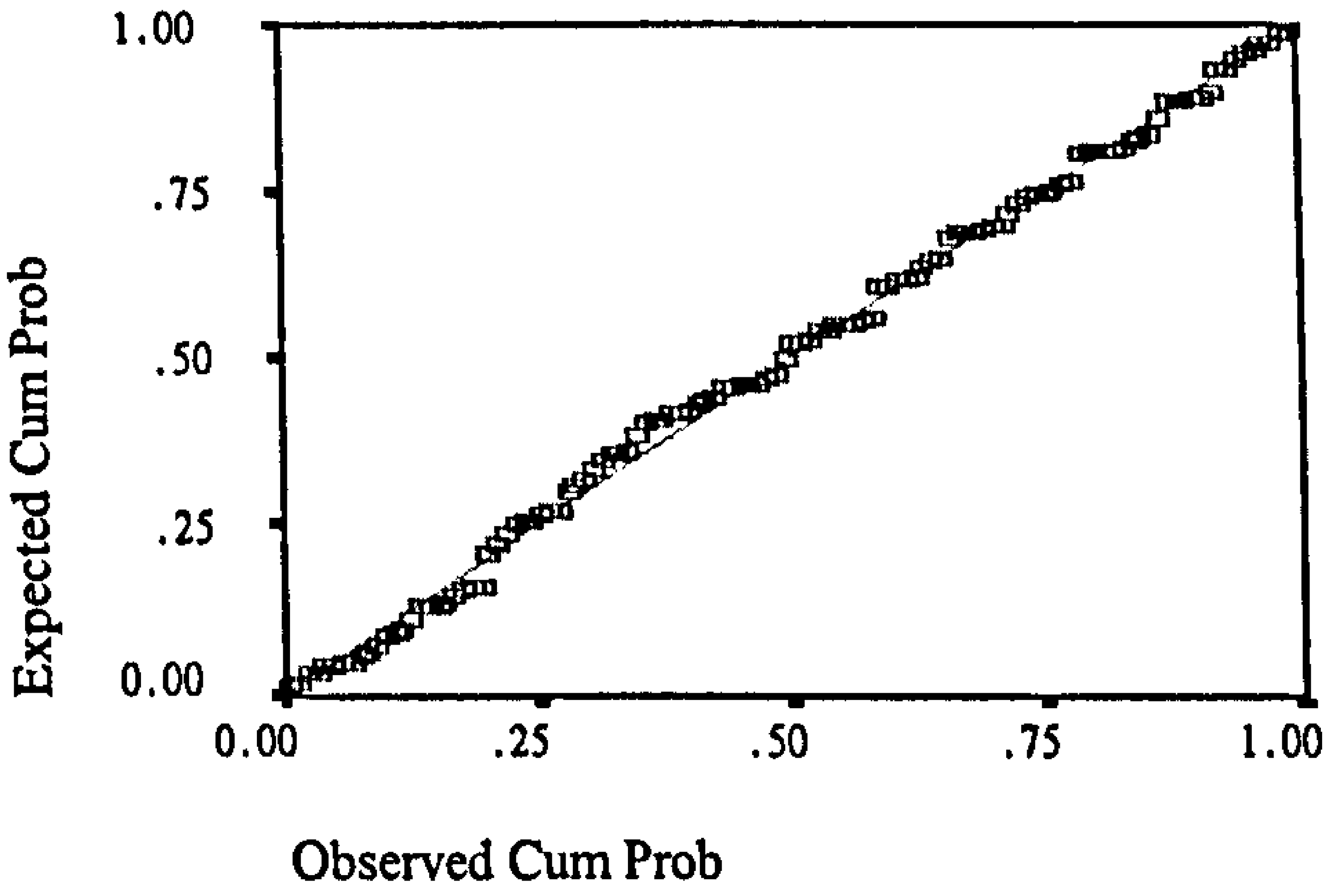
After the Mediator: Predeve Assessment Knowledge



Normal P-P Plot of Standardized Residual

Dependent Variable: Market Innovativeness

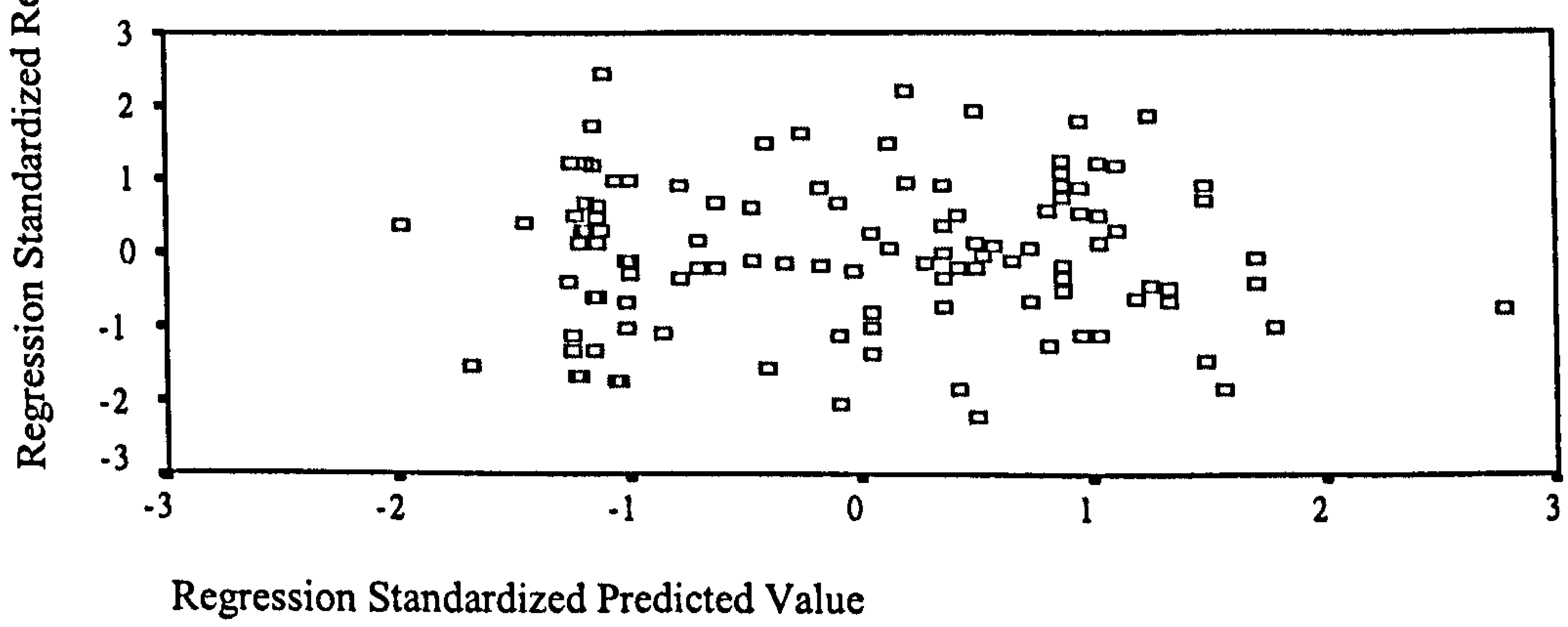
After the Mediator: Predeve Assessment Knowledge



Scatterplot

Dependent Variable: Market Innovativeness

After the Mediator: Predeve Assessment Knowledge

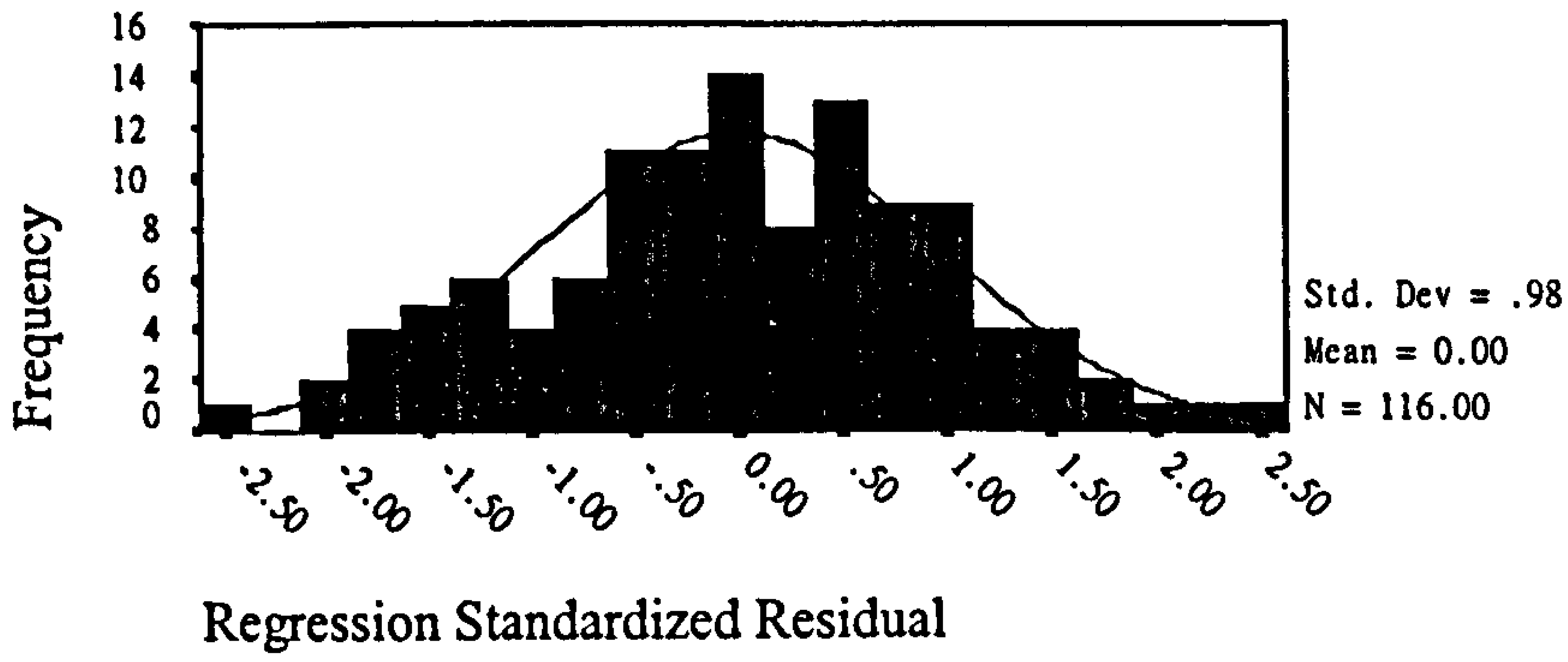


Regression Model 'After the Mediator- PDA' of Table 6.6.2

Histogram of Residuals

Dependent Variable: Market Innovativeness

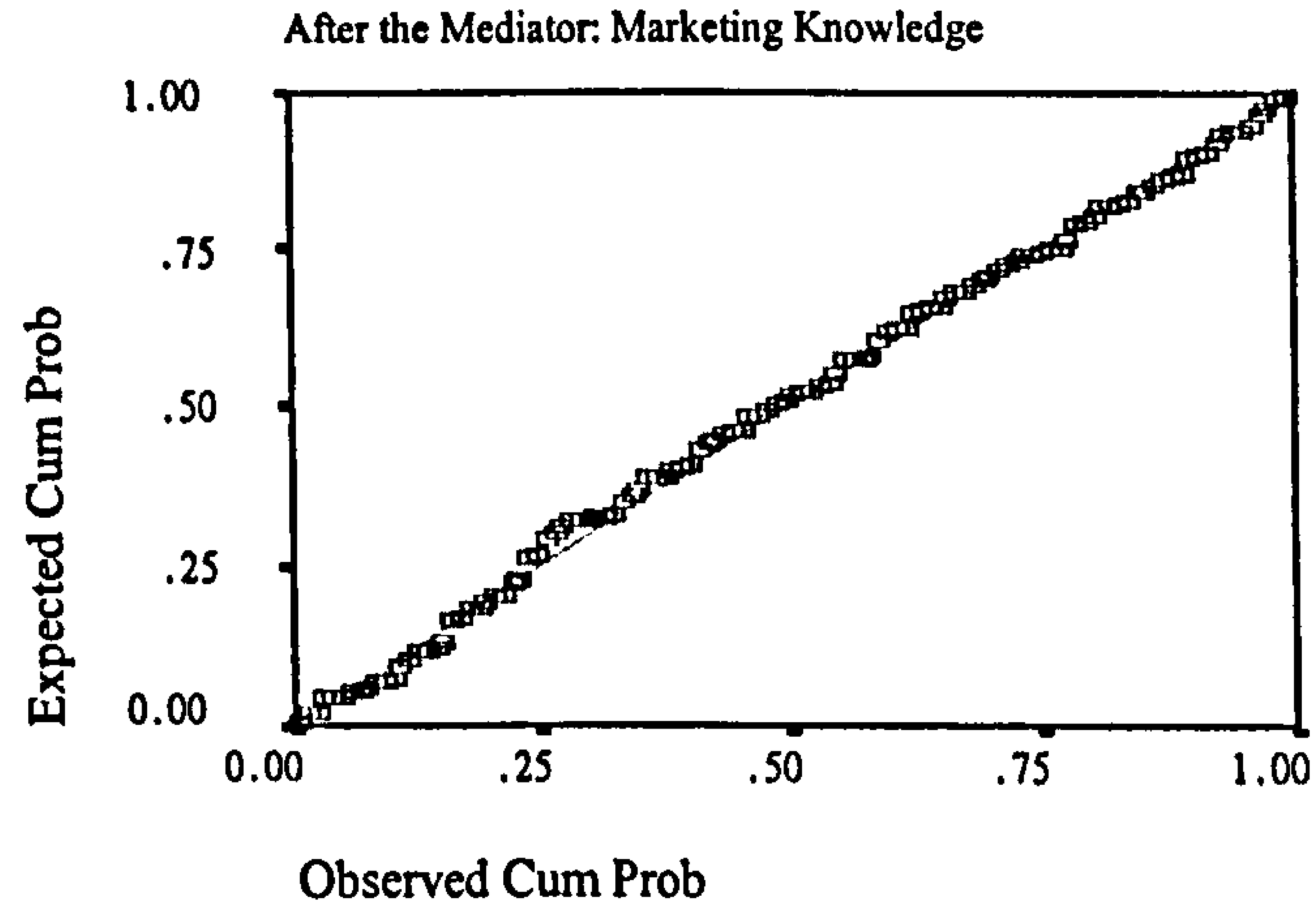
After the Mediator: Marketing Knowledge



Normal P-P Plot of Standardized Residual

Dependent Variable: Market Innovativeness

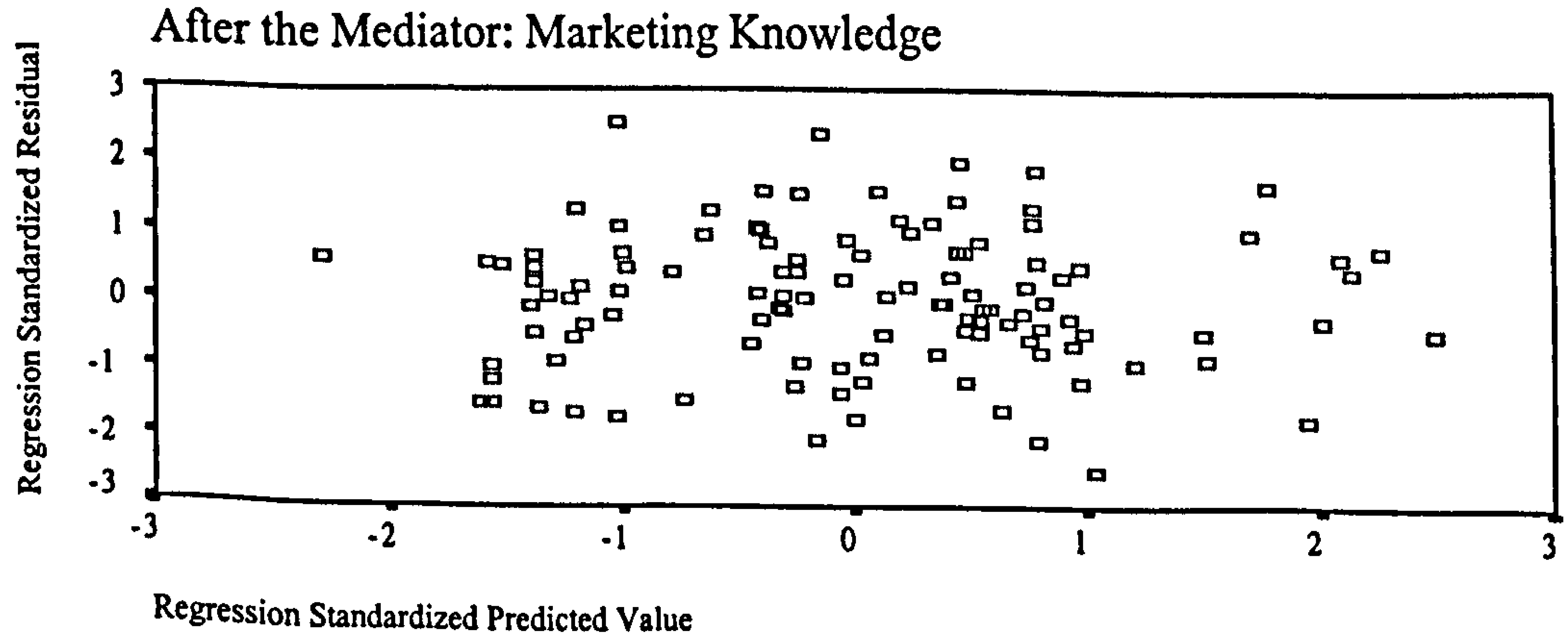
After the Mediator: Marketing Knowledge



Scatterplot

Dependent Variable: Market Innovativeness

After the Mediator: Marketing Knowledge



Regression Model 'After the Mediator-MK' of Table 6.6.2