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An Empirical Study of the Entrepreneurial Intentions of Research Scientists and Engineers in South Africa

Janine Chantson

A research report submitted to the Faculty of Commerce, Law and Management, University of the Witwatersrand, in partial fulfilment of the requirements for the degree of Master of Management specialising in Entrepreneurship and New Venture Creation

Parktown, 2015

ABSTRACT

Universities and public research organisations have an important role to play in enhancing regional economic development through the commercialisation of research outputs. In South Africa, little is known about the motivations behind scientists' and engineers' intentions to transition from academic research to entrepreneurship. Drawing on the theory of planned behaviour, this research explores the entrepreneurial intentions of research scientists and engineers and the personal, social and environmental factors influencing these intentions.

Primary data was collected at a university and a science council through an online survey. The theory of planned behaviour model was found to adequately explain the entrepreneurial intentions of the sampled research scientists and engineers. The three antecedents of entrepreneurial intentions in this model are an individual's attitude to the entrepreneurial behaviour, subjective norms and perceived behavioural control. The attitude to entrepreneurial behaviour was found to be the main predictor of entrepreneurial intentions. The indirect effects of the subjective norms and the perceived behavioural control on entrepreneurial intentions were investigated using structural equation modelling.

The research findings suggest that perceived barriers to, and perceived support structures for, entrepreneurship play a marginal role in influencing research scientists' and engineers' intentions to start a new business.

Gender and age are important control variables, as they have an indirect effect on entrepreneurial intention through the three antecedents.

This study is the first of its kind in South Africa where the theory of planned behaviour is used to explain the entrepreneurial intentions of research scientists and engineers. The study advances the knowledge and understanding of academic entrepreneurship in South Africa by accounting for individual attitudes, beliefs and perceptions.

DECLARATION

I, Janine Teresa Chantson, declare that this research report is my own work except as indicated in the references and acknowledgements. It is submitted in partial fulfilment of the requirements for the degree of Master of Management in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in this or any other university.

Janine Teresa Chantson

Signed at ……

On the …….. day of …… 2015

DEDICATION

To my daughter, Tyra Jane.

ACKNOWLEDGEMENTS

To my supervisor, Dr Jose Barreira, for his encouragement and direction.

To the MMENVC lecturers Merle Werbeloff, Dr Robert Venter and Prof Greg Lee, whose valuable teaching and advice on research methodology, decision science, and research theory and design, respectively, contributed greatly to my research.

To Hennie Gerber for his kind assistance and support for the data analyses and interpretation.

To CSIR for its support for my Masters studies and for participating in the research study.

To UWC for participating in the research study.

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CHAPTER 1: INTRODUCTION

1.1 Purpose of the study

The purpose of this research is to provide empirical data on the entrepreneurial intentions of academic research scientists and engineers in South Africa in order to understand what motivates scientists and engineers to pursue an entrepreneurial career.

1.2 Context and background of the study

Commercialisation of academic research through new start-up formation has been a source of wealth and job creation in many developed economies. The emergence of the biotechnology and biomedical industries in the United States of America (USA) was largely due to the commercialisation of research at US universities and National Institutes of Health, NIH (Schacht, 2012). This dramatic increase in the impact of academic technology transfer in the USA is attributed to the promulgation of the University and Small Business Patent Procedures Act of 1980, the so-called Bayh-Dole Act (Loise & Stevens, 2010; McDevitt et al., 2014). The Bayh-Dole Act allowed US universities to own and patent the inventions they made using federal research funding and to license the intellectual property for commercial use. Prior to this legislation, the federal government owned all inventions arising from federally sponsored research and would only make these inventions available to industry under non-exclusive licences. This provided scant incentive for companies to invest in turning these inventions into profitable products, with the result being that a vast proportion of the 28,000 government-owned patents were “left on the shelf” (Markel, 2013). New university start-up companies create high-wage employment and contribute to economic development (McDevitt et al., 2014). Additional benefits accruing to the university as a result of technology transfer include increased opportunities for collaborative research and research funding, the attraction and retention of staff, and an enhancement in the status of the university.

While the licensing of US university-invented technologies to established companies is an important mode of commercialisation; 50% of licenses are to companies with 500 employees or less and 35% is licensed to large companies; a sizeable number of new companies are created to commercialise university technologies (Loise & Stevens, 2010). The 2013 annual survey of technology transfer activity by the Association of University Technology Managers, AUTM, showed that 4,206 start-up companies were still in operation after having been spun out from US universities and research institutions. From the approximately 300 organisations participating in the survey, a total of 818 start-up companies were formed in 2013 alone (AUTM, 2014). In comparison, ten years ago, the average number of start-ups for the period 1998-2004 was 426 (Aldridge & Audretsch, 2011). The success of these university spin-outs is dependent on the role played by the scientist or engineer who created the intellectual property (Wright, Birley, & Mosey, 2004).

In South Africa, despite the research funding allocated to universities and public research organisations or science councils, only a small percentage of research outputs are commercialised (Anastassios Pouris, 2007). Key factors contributing to the low levels of commercialisation include a lack or poor awareness and understanding of the technology innovation process, including the commercialisation of inventions (Anastassios Pouris, 2007). In recognition of the transformative effect of the Bayh-Dole Act, several countries have developed its own guidelines or legislation meant to ensure the commercialisation of publicly funded research (European Commission, 2004; Sampat, 2009). In South Africa, the Intellectual Property Rights from Publicly Financed R&D Act, the “IPR Act”, was effected in August 2010 to facilitate the commercialisation of publicly funded research and development (Republic of South Africa, 2008). The purpose of the IPR Act is to ensure the identification, protection and commercialisation of intellectual property rising from research and development, particularly publicly-financed research and development, through the technology transfer offices at universities and science councils (Republic of South Africa, 2008). While the IPR Act has similarities to the Bayh-Dole Act, it has a much broader definition of intellectual property and it makes

some provision for the potential negative consequences arising from the Bayh-Dole Act's model of proprietary science (Barratt, 2010).

The mode of commercialisation of research worldwide is usually through licensing to an existing company, although academic entrepreneurship is becoming more prevalent (Agarwal & Shah, 2014). With an increasing professionalisation of technology transfer practices in South Africa, there is a growing awareness of academic entrepreneurship (Alessandrini, Klose, & Pepper, 2013).

Along with the increasing importance of research commercialisation and the emergence of the concept of the "entrepreneurial university" (Rothaermel, Agung, & Jiang, 2007), the body of literature dedicated to university spin-outs has grown (Djokovic & Souitaris, 2008). These studies mainly have a contextual perspective, where the role of the university or the local environment is examined, but the role of the academic scientist or researcher as an agent in the entrepreneurial process is often neglected (Rothaermel et al., 2007). Four years on from the IPR Act, it is timely for a study on the entrepreneurial intentions of research scientists and engineers in South Africa.

1.3 Problem definition

1.3.1 *Main problem*

In order for South Africa to increase its levels of commercialisation of research emanating from its universities and public research organisations, it has been recognised that there is a need to encourage technological entrepreneurship. Scientists and engineers are important creators of new knowledge and technological innovation. Entrepreneurship is the mechanism through which knowledge is converted into innovation outcomes (Block, Thurik, & Zhou, 2013) and new businesses in the science and technology sector are created. It is, therefore, important to be able to predict and understand why individual scientists and engineers choose to become entrepreneurs.

The main problem is thus stated as follows: Understand the determinants of individual academic research scientists' and engineers' intentions to commercialise their research through the creation of new ventures.

1.3.2 *Sub-problems*

The first sub-problem is to determine the levels of entrepreneurial intentions of research scientists and engineers in South Africa.

The second sub-problem is to examine the main motivational antecedents of the entrepreneurial intentions of research scientists and engineers in South Africa.

The third sub-problem is to examine the environmental factors influencing the entrepreneurial intentions of research scientists and engineers in South Africa.

1.4 Significance of the study

For the most part, studies of entrepreneurial intentions have focused on individuals, typically students, from a business management or general entrepreneurship background. By providing information on research scientists and engineers this study will add to the existing body of knowledge on entrepreneurial intentions from a technological perspective. Thus, the study will potentially lead to a better insight into the levels of entrepreneurial intention of emerging and nascent technological entrepreneurs within an academic or research setting in South Africa.

Universities and research organisations that strive to contribute to regional economic development need to adapt the traditional academic environment to one that embraces a culture of entrepreneurship. This study may contribute to the development of such a culture through a better understanding of the perceived barriers which research scientists and engineers face and the support systems which they require in transitioning to entrepreneurship. Thus, reliable data from this study will provide guidance to policy makers, research management practitioners, technology transfer professionals, incubators and

the like in developing local, regional and national initiatives for enhancing entrepreneurship.

1.5 Study delimitations

This study is biased towards the fields of science most likely to yield technology-based products and services.

1.6 Definition of terms

Academic entrepreneurship is defined as new venture formation by staff or students who innovate in an academic or non-profit research context, and subsequently found a firm that directly exploits this knowledge (Agarwal & Shah, 2014, p. 1114). This topic is further discussed in Section 2.3

The commercialisation of research is "*the process of moving scientific or technological developments into saleable products*" (Nelson, 2014, p. 1144).

According to the AUTM definition, technology transfer is "*the process of transferring scientific findings from one organisation to another for the purpose of further development and commercialisation*" (McDevitt et al., 2014, p. 75).

Throughout this report, the term "university" is used as shorthand for other publicly financed research institutions or science councils. Similarly, "faculty" is meant to denote staff members of publicly financed research institutions or science councils.

1.7 Assumptions

It is assumed that the respondents are all proficient in English.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This literature review commences with the theoretical framework for this study. The theory of planned behaviour and the use thereof in measuring entrepreneurial intentions for predicting entrepreneurial behaviour is introduced. An analysis of the extant literature pertaining to studies of entrepreneurial intentions is then presented. Particular emphasis is placed on academic entrepreneurship and the entrepreneurial intentions of research scientists and engineers. The exposition then turns to studies of entrepreneurial intentions in the South Africa. A closer examination of the proximal antecedents of entrepreneurial intentions in the theory of planned behaviour is then presented. The final section deals with environmental factors affecting entrepreneurial intentions.

2.2 Definition of EI and models for EI

The theoretical framework of this study is built on the concept of entrepreneurial intentions, hereafter referred to as “EI”. Krueger and Carsrud (1993) described EI as the intention to start a new venture. More specifically, EI has been defined as “*a self-acknowledged conviction by a person that they intend to set up a new business venture and consciously plan to do so at some point in the future*” (Thompson, 2009, p. 676). Thus, the process of discovery, creation and exploitation of opportunities begins with entrepreneurial intentions (Gartner, Shaver, Gatewood, & Katz, 1994). As such, EI is an applicable construct for explaining and predicting why some individuals are more entrepreneurial than others.

The determinants of EI have been the subject of many empirical studies and a wide variety of different determinants has been found to affect EI. Several competing theoretical models and alternative variations thereof have been proposed to explain the EI phenomenon (Schlaegel & Koenig, 2014; Shook,

Priem, & McGee, 2003). The two most widely accepted and tested models (Shook et al., 2003) are: the entrepreneurial event model by Shapero (1982) and the theory of planned behaviour, hereafter “TPB”, by Ajzen (1991). Other models for EI include the model of implementing entrepreneurial ideas (Bird, 1988) and the maximisation of the expected utility approach (Douglas & Shepherd, 2002).

The entrepreneurial event model was one of the first models to be introduced. In this model, EI depend on the perceived desirability, the propensity to act, and the perceived feasibility (Shapero, 1982), Figure 1. A significant event, such as job loss, a midlife crisis or winning the lottery, triggers an individual to overcome his/her inertia and to exercise entrepreneurial intentions and behaviour.

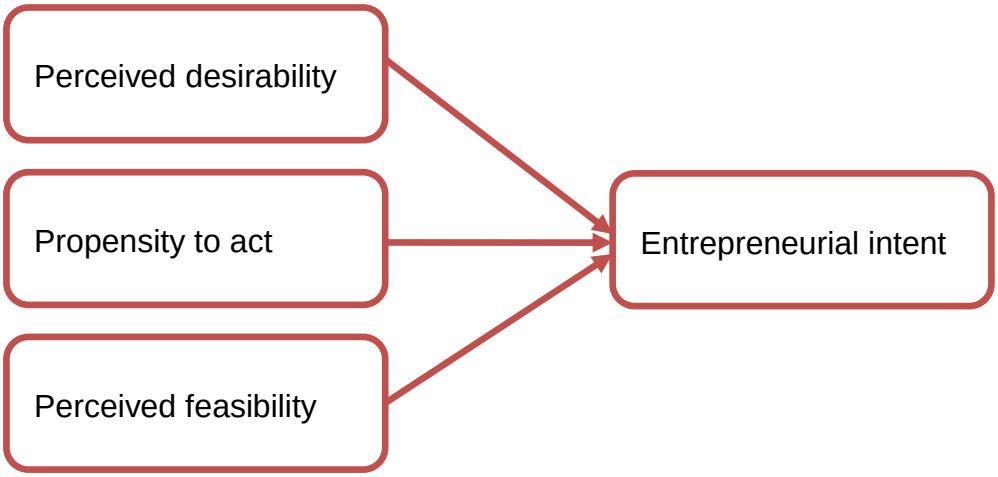


Figure 1. The entrepreneurial event model of EI

In contrast to the entrepreneurial event model, the TPB postulates that intention to act on a particular behaviour depends on the following: the attitude related to the behaviour considered; social standards or the subjective norms and the level of perceived control (Ajzen, 1991). These three determinants of EI are depicted in Figure 2. The TPB has broad applicability in explaining a diversity of behaviours in social psychology (Armitage & Conner, 2001), such as marketing and consumer behaviour (Ajzen, 2008), exercise behaviour (Downs & Hausenblas, 2005), and various health behaviours (McEachan, Conner, Taylor, & Lawton, 2011).

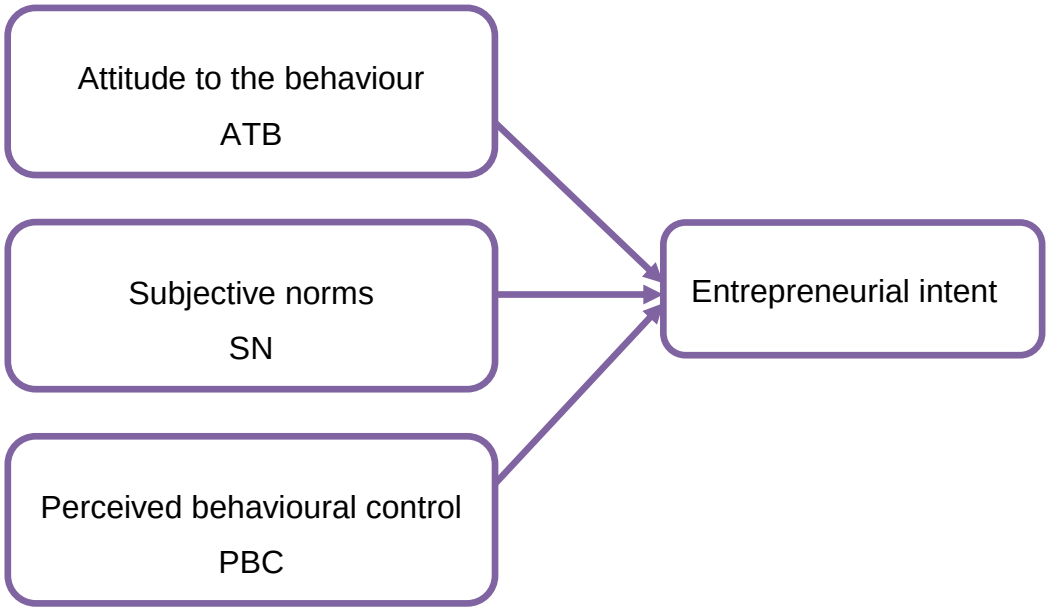


Figure 2. Theory of planned behaviour model of EI

Recognising that starting a venture is a deliberate and planned intentional act (Bird, 1988), and that intentions are a predictor of any planned behaviour, the TPB was first applied to EI by Krueger and Carsrud (1993). The theory was found to be effective for exploring why people opt to become entrepreneurs (Krueger & Carsrud, 1993). Since then, the TPB has been successfully used to describe EI, predominately of student samples in a range of Northern hemisphere countries. A number of studies compare TPB across cultures: A student sample frame in Spain and Taiwan (Liñán & Chen, 2009); a longitudinal survey of the adult populations in Austria and Finland (Kautonen, Van Gelderen, & Fink, 2013); a six-country study of students resident in Germany, India, Iran, Poland, Spain and The Netherlands (Moriano, Gorgievski, Laguna, Stephan, & Zarafshani, 2012); a 14-country study of university business students in Bangladesh, Bulgaria, China, Costa Rica, Egypt, Finland, France, Germany, Ghana, Mexico, Russia, Spain, Sweden and USA (Schlaegel, He, & Engle, 2013); a 13-country study of students in Brazil, Mexico, Romania, Russia, Ukraine, Australia, Canada, Czech Republic, France, Germany, Norway, Spain and The Netherlands (Iakovleva, Kolvereid, & Stephan, 2011).

The predictive power of the entrepreneurial event model and the TPB model, respectively, has been found to be on par and there are certain similarities, if

not overlap, in the two models. Some researchers have interchanged the entrepreneurial event model's perceived desirability with the TPB's attitude to the behaviour, and the entrepreneurial event model's perceived feasibility with the perceived behavioural control from the TPB (Krueger, Reilly, & Carsrud, 2000). Other researchers use various combinations of the three antecedents in the entrepreneurial event model and the three antecedents in the TPB model (Schlaegel & Koenig, 2014). A meta-analytical study undertaken to compare the two models found that larger effect sizes were obtained for the entrepreneurial event model, but that the TPB explained a greater amount of variance, .28 compared to .21. Using the conceptual framework of the model of goal-directed behaviour (Perugini & Bagozzi, 2001; Perugini & Conner, 2000), a proposed integrated TPB- entrepreneurial event model accounted for .31 of the variance in entrepreneurial intentions (Schlaegel & Koenig, 2014).

In this research study, the TPB approach was used for the following reasons: Its dominance in the literature allows for comparison of this study's results with other studies; it accounts for personal as well as social factors; is parsimonious and has been shown to be a valid predictor of entrepreneurial intent and subsequent entrepreneurial behaviour (Kautonen et al., 2013; Kautonen, van Gelderen, & Tornikoski, 2011). The three proximal determinants of EI according to the TPB are discussed in further detail in Section 2.4.

2.3 Academic entrepreneurship

There are various definitions of academic entrepreneurship in the literature (Yusof & Jain, 2010). One view of academic entrepreneurship relates to new venture formation by staff or students who innovate in an academic or non-profit research context, and subsequently found a firm that directly exploits this knowledge (Agarwal & Shah, 2014, p. 1114). This process typically begins with an invention or technology disclosure to the institution's technology transfer office, which will facilitate the licensing of the intellectual property to an entrepreneur willing to establish a new company. The entrepreneur may be the individual scientist or engineer who created the intellectual property in the first place, in other words, faculty or employees affiliated to the parent institution.

Alternatively, surrogate-entrepreneurs are external to the organisation, did not invent the technology, but acquire the rights to commercialise it through a start-up company (Radosevich, 1995). Academic founders may leave the university to join the start-up or remain at the university.

Empirical evidence shows, however, that entrepreneurship within an academic setting may be underestimated when only looking at the formal institutional intellectual property and technology transfer system (Aldridge & Audretsch, 2011; Fini, Lacetera, & Shane, 2010). Consultancy by academics, for example, would not necessarily be counted under academic entrepreneurship. A characterisation of academic entrepreneurship as encompassing all commercial activities outside of the traditional teaching and basic research roles has been proposed by Klofsten and Jones-Evans (2000). These commercial activities were identified as large externally-funded research projects with industry, contract research, consulting, external teaching, patenting/licensing, spin-offs, commercial sales and provision of testing services. In fact, Huyghe and Knockaert (2015) include under the academic entrepreneurship mantle any activity which is innovative, comprises an element of risk and leads to financial rewards for the individual or the institution.

Academic entrepreneurship can also be viewed from a broader corporate entrepreneurship perspective, where the institution embraces corporate venturing, strategic renewal and innovation (Brennan & McGowan, 2006). Corporate venturing includes not only research-based spin-offs, but university technology incubators, for instance. Strategic renewal can be the transformation from a traditional research and higher learning institution into an 'entrepreneurial university' where the so-called third mission of regional socio-economic development is adopted (Nelles & Vorley, 2011). Innovation encompasses new internal methods and practices, and not necessarily only innovations that lead to scientific and technological breakthroughs.

Academic entrepreneurship in the context of this research study means '*the creation of new business ventures by any of the university agents*" (Chrisman, Hynes, & Fraser, 1995), and will be applied to public or non-profit research organisations. The term 'scientist entrepreneurship' has also been used in the

same context as ‘academic entrepreneurship’ (Aldridge, Audretsch, Desai, & Nadella, 2014), although the former also refers to an individual scientist or engineer in an existing corporation who starts a new technology firm (Audretsch & Kayalar-Erdem, 2005). Generally, studies of the entrepreneurial intentions of scientists or academics implicitly assume the commercialisation of research.

Academic entrepreneurship as interpreted in this study should not be confused with the use of the term to describe “the academic field of entrepreneurship” or “entrepreneurship scholarship” (Meyer, 2011).

2.3.1 Empirical studies of academic entrepreneurial intentions

This section provides an analysis of the literature relating to entrepreneurial intentions of nascent technological entrepreneurs from academia.

The psychological factors influencing an individual’s tendency to engage in entrepreneurship have been widely studied (Schlaegel & Koenig, 2014). However, there has been less focus on investigating the intentions of academics and researchers to establish a new venture based on their scientific research. Studies on this topic are generally based on the TPB (Goethner, Obschonka, Silbereisen, & Cantner, 2009; Goethner, Obschonka, Silbereisen, & Cantner, 2012), the entrepreneurial event model (Dutta, Gwebu, & Wang, in press; Parente & Feola, 2013), an entrepreneurial self-efficacy model (Drnovsek & Glas, 2002; Prodan & Drnovsek, 2010), and models based on knowledge spill-over (Guerrero & Urbano, 2014). A number of studies used probit models to investigate factors such as patenting, career experience, educational background in determining scientists’ propensities for academic entrepreneurship (Aldridge & Audretsch, 2011; Fritsch & Krabel, 2010; Goel, Göktepe-Hultén, & Ram, 2015; Goel & Grimpe, 2012; Haeussler & Colyvas, 2011; Huyghe & Knockaert, 2015; Krabel & Mueller, 2009).

Determinants to entrepreneurial intentions in a combined United Kingdom-Slovenia study were found to be entrepreneurial self-efficacy, type of research, perceived role models, number of years spent at an academic institution and number of patents issued (Prodan & Drnovsek, 2010). Research scientists’ and

engineers' intentions to found businesses in their technical fields are influenced by career anchors (S. H. Lee & Wong, 2004). These career anchors are security, autonomy, technical, managerial and creativity anchors (Schein, 1978).

General self-efficacy, along with regretful thinking, was shown to distinguish between inventors who started a business based on their invention, i.e. technology entrepreneurs, and those who did not (Markman, Balkin, & Baron, 2002).

A German research study demonstrated that intentions to start a science-based new venture are shaped by the individual's own attitudes toward the commercialisation of research, his/her entrepreneurial control-beliefs, entrepreneurial self-identity and past involvement in entrepreneurship (Goethner et al., 2009). In another German study, the entrepreneurial activity of scientists, and whether it leads to new venture creation or not, has been found to depend on the rate of patenting and close personal ties to industry (Krabel & Mueller, 2009). This link to industry is a key factor in shaping the attitudes of scientists towards leaving academia for employment in the private sector or to start their own companies (Fritsch & Krabel, 2010). Such findings have been corroborated in a Germany-based study by Goel and Grimpe (2012). They categorised their sample into scientists who based their businesses on their own research, patented or not, and those who started a business due to other reasons, such as family connections or other external opportunities. Consulting with industry and participating in conferences was found to increase the likelihood of research scientists and engineers engaging in research-driven entrepreneurship.

Extant literature in this area is overwhelmingly based on research in developed countries.

2.3.2 Status of entrepreneurship in South Africa

There is ample evidence, accumulated over a number of years, to show that the level of entrepreneurship in South Africa is not commensurate with its state of development. It underperforms in comparison to other developing countries or "efficiency-driven economies" (Amorós & Bosma, 2014; Orford, Herrington, & Wood, 2004). The Global Entrepreneurship Monitor, GEM, is a widely-used indicator of entrepreneurial output (Acs, Autio, & Szerb, 2014), and according to recent GEM data, the total early-stage entrepreneurial activity measure for South Africa is 10.3 of a possible 100 points (Amorós & Bosma, 2014). Of this score, 30.3% is attributed to necessity-driven entrepreneurship while 40.3% is associated with opportunity- or improvement-driven entrepreneurship (Amorós & Bosma, 2014). Furthermore, the GEM entrepreneurial intentions score for South Africa is also very low. It has been recognised by the South Africa Government that entrepreneurship is a possible solution to the twin problems of a high unemployment rate and slow economic growth (National Planning Commission, 2011). This culminated in the establishment of a new ministerial Department for Small Business Development in May 2014 (Republic of South Africa, 2014) – ostensibly to coordinate and expand the different Government-led initiatives to stimulate the development of new micro and small enterprises (Thulo, 2014). Such initiatives encourage and support entrepreneurship in general. However, not all new ventures result in significant job creation. Shane (2009) has suggested that policy makers should rather focus on high quality and high growth companies. Such a notion is controversial in South Africa where there is a strong drive to redress the inequalities of the past and to increase access to the formal economy for the previously disadvantaged majority. The GEM also measures entrepreneurial aspirations in terms of solo and low job expectations and medium to high job expectations, as well as investigating the job or growth orientation, the innovative orientation and the international orientation of early-stage entrepreneurs (Amorós & Bosma, 2014). Despite South Africa's low total entrepreneurial activity score, a positive finding is that a high percentage of early-stage entrepreneurs are innovative-orientated (Bosma, Wennekers, & Amoros, 2012).

Successful businesses need to be innovative at start-up phase and beyond, as innovative businesses are more likely to create jobs and wealth (Shane, 2009). South Africa's latest ranking in the Global Innovativeness Index is 53 of 143 economies and this is largely attributed to its strong institutions and knowledge and technology outputs (Cornell University, INSEAD, & WIPO, 2014). However, South Africa is not a particularly efficient innovator in terms of converting innovation inputs to outputs. The Department of Science and Technology, DST, has fostered a "National System of Innovation, NSI," through a number of policy interventions (DST, 2007), which have recently been reviewed (DST, 2012). Innovation and entrepreneurship are positively related, complementary, and the interaction of the two is vital for ongoing organisational success and sustainability (F. Zhao, 2005). Entrepreneurship can be seen as the mechanism through which knowledge is converted into innovation outcomes (Block et al., 2013). Although much research has been devoted to national systems of innovation (Lundvall, Johnson, Andersen, & Dalum, 2002; Martin, 2012; Uriona-Maldonado, dos Santos, & Varvakis, 2012), the concept of a "National System of Entrepreneurship, NSE," is new to the literature. The NSE is defined as "*the dynamic, institutionally embedded interaction between entrepreneurial attitudes, activities, and aspirations, by individuals, which drives the allocation of resources through the creation and operation of new ventures"* (Acs et al., 2014, p. 479). Acs and co-workers (2014) further provide an index, the Global Entrepreneurship and Development Index, to measure the performance of an NSE. This index is meant to address some of the shortcomings of other country-level entrepreneurship indicators by emphasising the interactions between the system components, making provision for country-specific features and accounting for system bottlenecks. In order to understand the NSE, the study of both individual-level processes and the institutional environments within which these processes operate is required (Acs et al., 2014).

2.3.3 Academic entrepreneurship in South Africa

SA is fairly productive in terms of research output such as publications in journals (Anastassios Pouris, 2012), but produces relatively few academic start-ups. The most recent available aggregated data on start-up formation by South

Africa's publicly-financed research institutions reports that a total of 51 start-up companies were established during the period 2001-2007 (Sibanda, 2009). A study of technology transfer conducted at the University of Cape Town and the University of Stellenbosch reports that the former established 11 spin-off companies, and the latter six spin-offs between 2004 and 2013 (Uctu & Jafta, 2014). The Human Sciences Research Council, HSRC, together with the Southern African Research and Innovation Management Association, SARIMA, and the National Intellectual Property Office, NIPMO, is planning to conduct a survey of South African technology transfer offices in order to gather more recent data on institutional technology transfer performance.

The low rate of start-up formation in South Africa has been attributed to institutions' preference for licensing to established companies, as well as a lack of entrepreneurial researchers prepared to leave academia to start a business based on their research (Sibanda, 2009; Uctu & Jafta, 2014). In recent years, and in response to the IPR Act, more universities have established technology transfer offices for the purposes of increasing the commercialisation of university intellectual property (Alessandrini et al., 2013). The support provided by technology transfer offices is generally concentrated on the identification and protection of new intellectual property, with much less focus on start-up formation (Alessandrini et al., 2013). Technology transfer performance measures tend to be focused on the number of patents granted to an institution and its annual licensing income. Better resourced technology transfer offices are becoming more adept in supporting and assisting their researchers in engaging in entrepreneurial activities and in preparing them for spinning out. A recent case study undertaken at two universities with a strong track record of research commercialisation has shown that the more important reasons for a researcher opting out of creating a spin-off are lack of funding, limited commercialisation skills and distribution-related complexities (Uctu & Jafta, 2014).

2.3.4 Studies of entrepreneurial intentions in South Africa

In light of the role of that entrepreneurship has to play in improving social and economic conditions in South Africa, several studies have been undertaken to elucidate the entrepreneurial intentions and behaviours of South African university students and graduates (Farrington, Venter, & Neethling, 2012; Fatoki, 2010; Gird & Bagraim, 2008; Malebana, 2014; Muofhe & Du Toit, 2011; Urban, 2012; Viviers, Solomon, & Venter, 2013). These studies focus primarily on business administration, management and commerce students, as these students are a primary source of entrepreneurs (Farrington et al., 2012; Gird & Bagraim, 2008; Malebana, 2014; Muofhe & Du Toit, 2011; Urban, 2012). Such studies not only contribute to the academic literature, but provide useful insights for stakeholders, such as policy makers and entrepreneurship education practitioners, on presenting entrepreneurship as a viable career option (Gird & Bagraim, 2008), reducing obstacles to graduate entrepreneurship (Fatoki, 2010) and developing effective entrepreneurship education offerings (Viviers et al., 2013).

As part of the Global University Entrepreneurial Spirit Students' Survey across 26 nations, Viviers et al. (2013) investigated a student sample at 15 South African universities. The findings of this particular survey are that the majority of South African students (70%) were interested in establishing his/her own company, unlike their international counterparts where only 42% has entrepreneurial intentions. The main source of the founding idea for the future business was the South African students' hobbies or recreational pastimes and their university studies. A fair proportion of the South African respondents (16%) would start a business based on academic, scientific or applied research.

A number of South African EI studies are based on the TPB (Farrington et al., 2012; Gird & Bagraim, 2008; Malebana, 2014; Muofhe & Du Toit, 2011). An notable exception is Urban (2012) who adopted a metacognitive approach to explaining entrepreneurial intentions of Masters in Business Administration, Masters in Management and Commerce students in the Gauteng province. Studies using the TPB model showed that this theory accounted for 27% of the variance in EI of Western Cape-based final year commerce students (Gird &

Bagraim, 2008); and for 49% of the variance in EI of final year students in Limpopo province (Malebana, 2014). Thus, the TPB has been validated as a predictor of entrepreneurial intentions in the South African context. This is important as national culture has been found to affect entrepreneurial intent both directly and indirectly (Schlaegel et al., 2013).

While the TPB approach has been used on student samples in South Africa, it has not yet been applied to academic scientists and engineers. Goethner et al. (2012), in applying the theory of planned behaviour in longitudinal studies of the entrepreneurial intentions of German-based academic scientists, found that entrepreneurial intentions indeed predicted entrepreneurial behaviour. The TPB should, therefore, be a useful tool for investigating the entrepreneurial intentions of research scientists and engineers, either as postgraduate students or academic personnel at universities and publicly financed research institutions.

2.3.5 Hypothesis 1

In line with the research cited, Hypothesis 1 states that the TPB will significantly predict the EI of research scientists and engineers in South Africa.

2.4 Antecedents of EI in the TPB

The theory of planned behaviour was introduced earlier in this chapter. This section elaborates further on the three conceptually distinct antecedents of EI in the TPB model, namely, attitude towards the behaviour, “ATB”, subjective norms, “SN”, and the perceived behavioural control, “PBC” (Ajzen, 1991).

2.4.1 Attitude to the behaviour, ATB

ATB is the degree to which the implementation of a particular behaviour, such as starting a new business, is favourably or unfavourably valued (Ajzen, 1991). This implies that ATB is formed by the individual’s “*expectations and beliefs about the personal impacts of expected outcomes resulting from the behaviour*” i.e. behavioural beliefs (Krueger et al., 2000, p. 417). Furthermore, the intensity of the belief is weighted by the evaluation of the outcomes (Ajzen, 2001).

Prior behavioural experiences in aspects of entrepreneurship have been identified as an important determinant of behavioural attitudes (Ajzen, 2001). Scientists' participation in commercialisation activities such as patenting, licensing and transferring of university technologies to industry contribute to creating positive attitudes to entrepreneurship.

There is evidence in the literature that ATB is the most important of the three predictors (Ferreira, Raposo, Rodrigues, Dinis, & do Paço, 2012) for secondary students. The dominance of ATB over SN and PBC was also found in a South African study of graduate EI (Gird & Bagraim, 2008; Malebana, 2014).

2.4.2 Subjective norms, SN

SN is the perceived social pressure to perform a particular behaviour, such as creating a business venture (Ajzen, 1991). Thus, SN is underpinned by what the individual perceives are the expectations and beliefs of influential people in his/her life towards creating a start-up, in other word the normative beliefs (Ajzen, 2006). These influential people include the significant other, family, friends, colleagues, mentors or role models (Krueger et al., 2000). A second aspect of SN is the individual's willingness to comply with these normative beliefs.

The effect of the SN on entrepreneurial intentions has varied substantially from one empirical study to another (Heuer & Liñán, 2013). In some EI studies SN was found to be a poor predictor of EI (Krueger et al., 2000; Schlaegel & Koenig, 2014), presumably as a result of the prevalence of student samples where normative beliefs are less relevant (Kautonen et al., 2013). Other studies have shown SN to have a strong effect on EI (Kautonen et al., 2013). Rather than excluding SN from the EI model, as some researchers have opted to do (Peterman & Kennedy, 2003), it has been suggested that the indirect effects of SN on EI through the mediators ATB and/or PBC be considered (Ferreira et al., 2012; Heuer & Liñán, 2013). SN has shown to positively affect ATB and PBC (Liñán, Urbano, & Guerrero, 2011).

Comparisons between analyses are further hampered by the different methods used to measure the SN construct (Ajzen, 2006), but a simple multi-item measure has been found to be superior over the product of normative beliefs and motivation to comply (Armitage & Conner, 2001; Heuer & Liñán, 2013).

2.4.3 Perceived behavioural control, PBC

PBC refers to an individual's perceptions of his/her ability to execute a given behaviour (Ajzen, 1991). It is governed by the beliefs about the perceived factors that facilitate or hinder execution of the behaviour, i.e. control beliefs (Ajzen, 2006). In entrepreneurship, the PBC construct is related to the entrepreneurial self-efficacy construct, and both these constructs are related to the perceived feasibility construct from the entrepreneurial event model for entrepreneurial intentions (Schlaegel & Koenig, 2014). In some studies, PBC has even been replaced by entrepreneurial self-efficacy (Schlaegel et al., 2013; Van Gelderen et al., 2008).

The process of starting a new business involves a number of different types of activities, some of which an individual has little volitional control over. Thus, the PBC is postulated to exercise a larger role in EI and in the decision to embark on an entrepreneurial career, than ATB or SN (Autio, Keeley, Klofsten, Parker, & Hay, 2001). Whereas EI mediates the relationship between ATB, SN, PBC and entrepreneurial behaviour, PBC also directly influences the subsequent entrepreneurial behaviour (Kautonen et al., 2013).

2.4.4 Summary

Although empirical studies of EI have produced different results on the effects of the three determinants of the TPB, the theory is still considered robust (Kautonen et al., 2013; Krueger et al., 2000). One explanation for the disparities in research findings is related to differences in national culture (Schlaegel et al., 2013). Some or all of the three proximal antecedents are important in predicting EI, depending on the characteristics of the population being sampled.

2.4.5 Hypothesis 2

In line with the research cited, Hypothesis 2 states that the EI of research scientists and engineers in South Africa is positively affected by the ATB (*H2a*), the SN (*H2b*) and the PBC (*H2c*). Furthermore, the SN has a positive effect on the EI through the ATB (*H2)* and the PBC (*H2e*).

2.5 Distal antecedents of EI in the TPB

This section deals with the literature relating to contextual or environmental factors which influence the EI of nascent academic entrepreneurs. These variables are termed “distal antecedents” as they are thought to have an indirect effect on EI by influencing attitudes and beliefs (Goethner et al., 2012). A study of engineering students at the Massachusetts Institute of Technology, USA found that perceived barriers and support factors within their immediate surrounds had a direct effect on EI, irrespective of their attitude towards entrepreneurship (Lüthje & Franke, 2003).

The influence of a variety of individual characteristics on EI has been studied, for example, personality (H. Zhao, Seibert, & Lumpkin, 2010), social ties (Sequeira, Mueller, & Mcgee, 2007), human capital and social capital (Aldridge & Audretsch, 2011), learning orientation and passion for work (De Clercq, Honig, & Martin, 2013). Demographic factors such as age and gender have also been investigated. These are discussed in the following section 2.6.

Environmental factors can be categorised into two groups: The micro environment shaped by the university or research organisation to which the scientist or engineer is affiliated; and the macro environment encompassing markets, government institutions, policies and regulations. An individual’s perception of whether his/her environment supports or discourages academic entrepreneurship can affect his/her attitude and, therefore, EI (Nelson, 2014). Furthermore, if individuals are dissatisfied with their jobs, personal abilities such as entrepreneurial self-efficacy may drive them to start their own businesses

(Wong, Lee, & Leung, 2006). "*Scientists' responses to national and local incentives may be mediated by the trade-offs they face in their professions and everyday work*" (Haeussler & Colyvas, 2011).

Organisational characteristics - both climate and culture - within and around the university affect research scientists' and engineers' EI. These include management and peer support, organisational innovation orientation, compatibility of patenting with publishing, incentives for engagement in commercialisation activities, opportunities for networking, and interactions with industry and alliances with established firms.

A significant role identity modification is required for an academic to become involved in a university spin-out that competes with incumbents (Jain, George, & Maltarich, 2009). An academic scientist is more likely to transition to commercial, for-profit science if colleagues in their department have already done so, particularly when prestigious scientists are involved (Stuart & Ding, 2006). Not only does the presence of entrepreneurial role models reinforce the legitimacy of entrepreneurship within the university, it gives research scientists a greater sense of confidence and security to engage in commercialisation activities (Huyghe & Knockaert, 2015).

University policies, and the **incentives** they offer, are important to transform academics' behaviour (Nelles & Vorley, 2011). Such policies have been found to serve as a knowledge filter of academics' start-up intentions indirectly through the motivational factors of ATB and PBC (Guerrero & Urbano, 2014). This effect is more prevalent for technologically entrepreneurial universities than for broad-based universities.

There has been progress in the US towards changing the traditional academic culture, where publication and peer-recognition is paramount, to one which tallies patenting, licensing and commercialisation activities in evaluations towards tenure and career advancement (Sanberg et al., 2014). Some university policies permit faculty to work part time in start-up companies and even allow sabbatical leave for the purposes of transferring technology to start-ups. The increased involvement of faculty in entrepreneurial activities runs the

risk of diverting their time and efforts away from academic knowledge generation and publications. A few studies have been undertaken to measure this effect. One such study involved 150 full-time faculty members who founded firms between 1990 and 1999. The study found that, prior to company formation, academic entrepreneurs published more than their peers. Once the company was formed, their rates of publishing did not decrease and, in some cases, research output even increased (Lowe & Gonzalez-Brambila, 2007). A much larger study of NIH-supported academic entrepreneurs in the life sciences confirmed the finding of higher research productivity prior to commercialisation (Toole & Czarnitzki, 2010). However, the authors observed a significant decrease in research output, except for patenting, by the academic entrepreneurs after they had begun working in for-profit firms, in comparison to the group remaining in academia. This form of academic "brain drain" has social costs which organisations need to offset against the social benefits derived from successful commercialisation (Toole & Czarnitzki, 2010). The link between explicit rewards for academic entrepreneurship and increased levels of spin-offs and licensing has been demonstrated (Huyghe & Knockaert, 2015).

Basic research is directed towards the acquisition of new knowledge without necessarily linking it to a particular practical application. In applied research new knowledge acquisition is driven for a specific goal or use (OECD, 2002, p. 30). The undertaking of applied research by research institutes has been found to mediate the positive relationship between an academic researcher's **cooperation with industry** and his/her entrepreneurial intentions (Prodan & Drnovsek, 2010). The importance of close ties to industry has been emphasised in a number of studies (Karlsson & Wigren, 2012; Krabel & Mueller, 2009).

Kolb and Wagner (2014) found that technological entrepreneurs coming out of universities were '*overly focussed on the scientific aspects of their start-up idea*" which could lead them to pursue their idea in a sub-optimal way, as they are perceived to have limited business knowledge, industrial experience (Djokovic & Souitaris, 2008) and entrepreneurial experience (Goethner et al., 2009; Krabel & Mueller, 2009). The authors provide a number of recommendations for how **technology transfer offices** can support academic entrepreneurs, such as

connecting the university founders to experienced entrepreneurs from outside the university and helping them find suitable team members to join the start-up (Kolb & Wagner, 2014). The Entrepreneur-in-Residence concept has been implemented successfully by a number of US university offices of technology transfer (Herskowitz, Nijhawan, Nisbet, Schrankler, & Shelby, 2014) and has recently been introduced at the Council of Scientific and Industrial Research (CSIR) in South Africa (CSIR, 2012). The technology transfer office needs to be staffed with competent personnel to deal with commercialisation projects. Despite the important role of the technology transfer office, a UK study has shown that technology transfer offices play an indirect role in driving researchers to start new businesses (Clarysse, Tartari, & Salter, 2011), and that individual-level characteristics, notably the capacity to recognise opportunities, are better predictors of academic entrepreneurship.

Academic and research scientists and engineers are perceived to have limited business knowledge, industrial experience (Djokovic & Souitaris, 2008) and entrepreneurial experience (Goethner et al., 2009; Krabel & Mueller, 2009). The entrepreneurial process is inherently complex. It requires skills to develop the business plan, acquire the necessary resources and make effective decisions with limited information (Rasmussen, Mosey, & Wright, 2011). A nascent entrepreneur has to develop or acquire these competencies, for example through **entrepreneurship education and training** programmes. Exposure to an entrepreneurship programme can increase the entrepreneurial intentions and perceptions towards self-employment, and the entrepreneurial self-efficacy of science and engineering students (Bae, Qian, Miao, & Fiet, 2014; Souitaris, Zerbinati, & Al-Laham, 2007; Urban & Barreira, 2006). In fact, EI has been used as a measurable outcome of entrepreneurial education programmes (Franke & Lüthje, 2004).

Network effects are important for facilitating entrepreneurship. The spatial concentration of research organisations, high technology companies, incubators, investors and the like within a science park or in close proximity to each other contribute to a strong regional innovation or entrepreneurial ecosystem. It is no coincidence that pockets of innovation have sprung up

around Silicon Valley and Boston-Cambridge in the US. In South Africa, the Silicon Cape initiative, active venture capital community and the rise of top technology incubators is positioning Cape Town as a start-up hub. Gauteng Province is host to South Africa's first accredited science park, The Innovation Hub.

The macro environment includes markets, capital markets, governmental policy and the national IP regime. Frequently cited barriers to academic entrepreneurship include funding, market knowledge and access to resources (Alessandrini et al., 2013; Djokovic & Souitaris, 2008; Kirby, Urbano, & Guerrero, 2011; O'Gorman, Byrne, & Pandya, 2008; Sibanda, 2009).

Government **regulations** and practices exert an influential role in how potential entrepreneurs perceive "*how new opportunities and market spaces can be created and eventually exploited*" (Griffiths, Kickul, & Carlsrud, 2009). In general, the regulatory environment in South Africa is not conducive to small businesses that have to bear the costs associated with inflexible labour laws, broad-based black economic empowerment and inefficiencies in the South African Revenue Services and municipal departments (Small Business Project, 2014).

The nature of the national **intellectual property rights regime** can have a marked effect on innovation, technology transfer, commercialisation and entrepreneurship. This is best exemplified by the impact of the Bayh-Dole Act, as mentioned in Chapter 1. The IPR Act should have a similar catalysing effect in South Africa. There are, however, two major contextual differences which could potentially the positive consequences of the legislation. Firstly, unlike many countries which have examining patenting systems, South Africa has a deposit or non-examining patent regime in place. This type of intellectual property rights system creates an asymmetry disadvantage for South African inventors, thereby expediting exploitation by foreign interests and leading to increased social costs (Anthipi Pouris & Pouris, 2011). Secondly, certain provisions in the IPR Act have been negatively received by the private sector and such perceptions have not dissipated. Thus, an unintended consequence of the legislation is that it has driven the private sector away from collaborating

with publicly-funded research organisations. The importance of academic researchers' ties to industry in fostering entrepreneurial intentions has already been mentioned. The overall impact of the IPR Act remains to be seen.

South Africa has a relatively small domestic **market**, especially for technology products. Its economy is dominated by large multi-national companies. In countries and regions with a weak industrial base, it has been suggested that greater reliance is placed on creating spin-offs for the commercialisation of research (Rasmussen, 2008).

The venture capital industry in South Africa is small, with Government being the main source of limited seed and early-stage **funding** (KPMG & SAVCA, 2014). A lack of funding is a major reason for deterring South African scientists from transitioning to entrepreneurship (Uctu & Jafta, 2014).

The contextual factors influencing EI described above can be grouped into two categories, those that would-be entrepreneurs view as being supportive of entrepreneurship, and those which are perceived as barriers to entrepreneurship.

2.5.1 Hypothesis 3

In line with the research cited, Hypothesis 3 states that perceived barriers have a negative effect on the EI of research scientists and engineers in South Africa through the PBC (*H3a*) and that perceived support structures have a positive effect on the EI of research scientists and engineers in South Africa through the PBC *(H3b).*

2.6 Influence of demographic factors on entrepreneurial intentions and behaviour

A number of individual-level factors have been shown to affect EI. This section elaborates on a selection of such control variables, namely, gender, age, position, organisation and scientific field.

Gender. Several studies have confirmed the existence of considerable differences in the rate of new business formation between men and women worldwide (Minniti & Nardone, 2007). Such differences also become apparent in university scientists' involvement in technology transfer and entrepreneurial activities (Murray & Graham, 2007; Stephan & El-Ganainy, 2007). For example, the extent of participation of women scientists and engineers in invention or technology disclosures to US technology transfer offices has been shown to be lower than their male counterparts (Thursby & Thursby, 2005). A longitudinal, empirical study of life sciences faculty at US universities showed that considerably fewer women hold patents compared to men (Ding, Murray, & Stuart, 2006). Not all patents are licensed and commercialised, but patents serve as a good proxy for technological innovation and, by extension, start-up opportunities. Ding et al. (2006) attributed the gender differences in patenting to women faculties limited connections to industry and less experience on the academic-industry boundary. Another explanation lies in women's perceptions that patenting could potentially detract from teaching and research, thus hindering their university careers. These traditional views are changing, especially as commercialisation activities are being counted in promotion and tenure evaluations (Sanberg et al., 2014). Another example of gender differences in entrepreneurial activities is the participation of academic scientists on scientific advisory boards, an activity regarded to be closer to commercial engagement. After accounting for professional accomplishments, network ties, university employer characteristics and proxies for interest in commercialising research, women were far less likely to serve as scientific advisory board members of biotechnology companies (Ding, Murray, & Stuart, 2013). This is once again linked to the women's limited direct contact to relevant networks.

The proportion of female founders of academic spinout companies has also been found to be very low; 12% in the case of academic spinouts from 20 leading UK universities (Rosa & Dawson, 2006). This observation is only partially explained by the under-representation of female academics in science research. Similar gender differences in founding a start up company were identified in a study of German and UK life scientists (Haeussler & Colyvas, 2011). In many countries there is considerable importance placed on promoting gender equality in science and technology fields. South Africa is particularly conscientious in encouraging the participation of women across all sectors, not only in science and technology, but in general entrepreneurship as well.

What of entrepreneurial intentions of female scientists and engineers? Using the theory of planned behaviour, Santos and Liñán (2010) report that the entrepreneurial intentions of females are lower than males despite the similarity in the antecedent factors determining these intentions. The results of academic entrepreneurship studies which control for the gender and/or the age of the researcher are mixed. Aldridge et al. (2014) observed a higher propensity to start a company among male scientists and engineers, and the factors affecting propensities towards academic entrepreneurship vary significantly between males and females (Goel et al., 2015). While male scientists have been shown to have higher levels of entrepreneurial intentions than female scientists (Goethner et al., 2009; Goethner et al., 2012), other studies show no significant effect of gender on the propensity to pursue academic entrepreneurship (Aldridge & Audretsch, 2011; Fritsch & Krabel, 2010; Goel & Grimpe, 2012).

Age. In general, younger people are more likely to start a new company than older people (Lévesque & Minniti, 2006). However, this generalisation is not necessarily applicable in academic entrepreneurship. Often the inventor's scientific expertise, tacit knowledge and reputation is built up over time (Aldridge et al., 2014), and in certain scientific fields the development of a commercially-ready technology may take years, even decades. In the US tenured faculty, i.e. more senior staff, are more likely to disclose inventions and engage in commercial activities (Jensen, Thursby, & Thursby, 2003). One study has found that the average career age at which academic entrepreneurs found

a life sciences-based company is 16.6 years after obtaining their advanced degrees (Toole & Czarnitzki, 2010). Another study found that scientists become academic entrepreneurs about 12 years after earning their PhD (Ding & Choi, 2011).

Older PhD students find working in the private sector relatively more attractive than younger PhD students, while this attractiveness decreases with increasing age of PhD holders (Fritsch & Krabel, 2010). Other studies find that age makes no difference to entrepreneurial intentions (Goel & Grimpe, 2012; Goethner et al., 2009; Goethner et al., 2012).

Scientific field. The propensity of scientists and engineers to start a firm has been shown to vary widely from one scientific field to another (Aldridge et al., 2014). The engineering sciences (process, chemical or construction engineering) are more likely to give rise to technology entrepreneurs than the life sciences (medicine, biology, plant sciences) or the natural sciences (chemistry, physics, mathematics); while entrepreneurial intentions are lowest among the social sciences and humanities (Aldridge et al., 2014; Goel & Grimpe, 2012; Krabel, Siegel, & Slavtchev, 2012). This is consistent with the higher rate of patenting in the fields of engineering, information technology and the life sciences or biotechnology (Alessandrini et al., 2013; Krabel et al., 2012; Sibanda, 2009). Furthermore, academic entrepreneurs from engineering fields tend to be much younger than their counterparts in medicine, biology, physics and chemistry (Lowe & Gonzalez-Brambila, 2007). Where the field involves basic research, much more financial, human capital and infrastructure resources may be required to commercialise the research, for example, in drug development. In such instances, licensing the technology to an incumbent firm rather than founding a new company is the preferred option of the technology transfer office.

2.7 Conclusion of the literature review

The relevance and importance of the EI construct was highlighted. Theoretical models for EI were presented, with the focus placed on the TPB. Empirical

studies employing the TPB were discussed. While only a few of these studies were directed towards academic scientists' EI, the topic of academic entrepreneurship was elaborated upon.

The three proximal antecedents of EI in the TPB model were introduced. These are ATB, SN and PBC. Nascent entrepreneurs' perceptions of barriers to, and support systems for, academic entrepreneurship influence their intentions to start a new venture. A number of situational and personal factors known to have an influence on EI, either directly or indirectly, were discussed.

Based on the literature review, a number of hypotheses were formulated. These are summarised below. The proposed research model, Figure 3, displays the inter-relationships among the variables and the hypotheses associated with these relationships.

2.7.1 Hypothesis 1:

Hypothesis 1: The theory of planned behaviour will significantly predict the entrepreneurial intentions of research scientists and engineers in South Africa.

2.7.2 Hypothesis 2:

Hypothesis 2: The entrepreneurial intentions are positively affected by the attitude to the entrepreneurial behaviour (*H2a*), the subjective norm (*H2b*) and the perceived behavioural control (*H2c*). The subjective norm has a positive effect on the entrepreneurial intentions through the attitude to the entrepreneurial behaviour (*H2d*) and the perceived behavioural control (*H2e*).

2.7.3 Hypothesis 3:

Hypothesis 3: Perceived barriers have a negative effect on the entrepreneurial intentions of research scientists and engineers in South Africa through the perceived behavioural control (*H3a*) and perceived support structures have a positive effect on the entrepreneurial intentions of research scientists and engineers in South Africa through the perceived behavioural control *(H3b).*

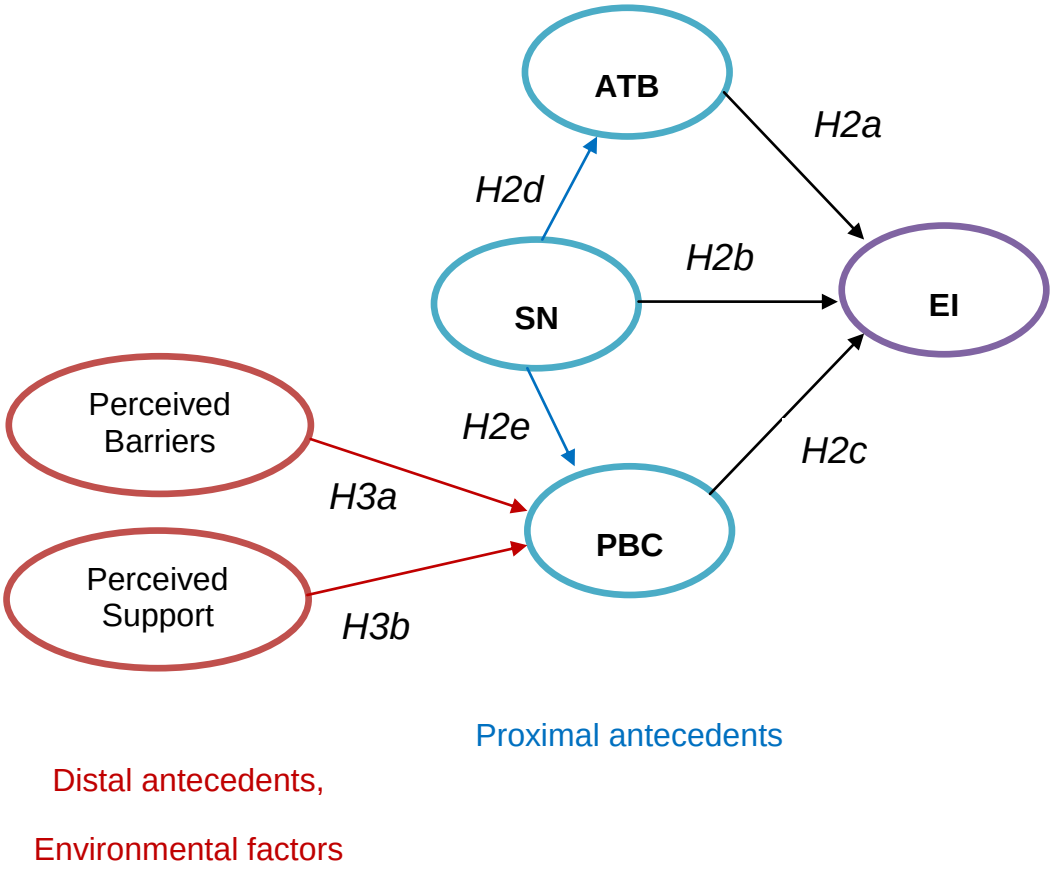


Figure 3. Proposed research model with hypotheses

CHAPTER 3: RESEARCH METHODOLOGY

The nature of this research study is quantitative and a cross-sectional correlational design was adopted. This chapter describes in detail the research approach and design, the population and sample, the research instrument, and data collection and analysis techniques. A consideration of the validity and reliability of the research design is then presented. Lastly, the demographic profile of the study's respondents is discussed.

3.1 Research methodology / paradigm

This study was based on a positivistic paradigm which is consistent with quantitative, objectivist, scientific, experimental or traditional research. A deductive, quantitative research strategy was employed. This type of strategy allows for the testing of relationships between theory and research and it emphasises the quantification of the data collected and analysed (Krüger & Struwig, 2012). Within the positivistic paradigm, the epistemological approach is to view knowledge as objective and to remain at arm's length when collecting data from respondents. A number of hypotheses, based on theory, were presented in the previous chapter. Through the objective, value-neutral collection of data, the presented hypotheses were tested by means of statistical tests. The drawback of collecting numerical rather than descriptive data is that the quantitative approach does not cater for an in-depth exploration or explanation of the relationships between variables.

3.2 Research design

A correlational design was used in order to measure multiple variables for each respondent, to find relationships among these variables and to examine the strengths of such relationships (Gravetter & Forzano, 2012, p. 591). Primary data was collected from individuals via an online survey. Due to time constraints imposed by the short 14-month duration of the Master of Management degree programme, a cross-sectional design was selected for this study. A longitudinal

research design would be required in order to further investigate whether the respondents' self-reported EI endure and result in actual venture creation.

3.3 Population and sample

3.3.1 Population

A population is any complete group of people, companies, organisations, college students or the like that share some set of characteristics (Zikmund & Babin, 2006, p. 369). For the purposes of this research study, the research population comprises of postgraduate students, postdoctoral fellows and academic research scientists and engineers in universities and research organisations in South Africa.

3.3.2 Sample and sampling method

The premise of sampling is that by selecting some of the elements in a population, conclusions can be drawn about the entire population (Zikmund & Babin, 2006, p. 369). A non-probability purposive sampling method was utilised for this study. Purposive sampling is defined as "*the use of judgement and a deliberate effort to obtain representative samples by including presumably typical areas or groups in the sample*" (Kerlinger, 1973, p. 129). The sampling frame is provided in Table 1 and it was drawn from two types of organisations, a science council and a university.

A science council is a statutory research body, of which there are eight in South Africa (Republic of South Africa, 1988). Their central purpose is to conduct directed research and development, and the science councils are largely publicly-funded (Scholes et al., 2008). The science council selected for this study was the Council of Scientific and Industrial Research, CSIR. It is the largest research organisation in South Africa, if not the whole of Africa. The CSIR conducts multidisciplinary, applied research and employs large numbers of research scientists and engineers (CSIR, 2013). The total number of science, engineering and technology staff employed by the CSIR in 2012-2013 was 1578

(CSIR, 2013, p. 111). The CSIR has a long history of commercialisation of research outputs which pre-dates the formal establishment of a technology transfer office in 2002 (Alessandrini et al., 2013).

Three different universities were approached to participate in the research study. These were the University of Pretoria, the University of Witwatersrand and the University of the Western Cape.

The selection of the University of Pretoria and University of the Witwatersrand was based on their standing as pre-eminent South African research institutions. University of Pretoria has the highest weighted research output by South African universities (University of Pretoria, 2012, p. 3). In the 2013/2014 QS World University Rankings, the University of the Witwatersrand was the second highest ranked university after the University of Cape Town; positions 313 and 145 respectively (QS, 2014). Both the University of Pretoria and the University of the Witwatersrand are in the top 100 universities in the BRICS and emerging economies (Macfarlane, 2013).

The selection of the University of the Western Cape, UWC, was largely for the sake of expediency – it was able to provide a timely, positive response to participating in the research study. UWC is a historically disadvantaged university (Grobbelaar, 2004) and its office of technology transfer was only formalised in 2012.

A written request was submitted by email to the relevant university and science council authorities to explore their willingness to have their postgraduate students and research faculty or staff participate in the study and to assist in the dissemination of the survey via email to the sample groups. Approval letters were obtained from the relevant executive at CSIR and the UWC Deputy Vice-chancellor: Academic. While in-principle approval was obtained from the University of the Witwatersrand, it was excluded from the research study due to time constraints. The University of Pretoria declined to participate on the basis of protecting their academic and student community from over-surveying.

Table 1: Profile of respondents

Organisation - faculty/staff and postgraduate students in science and engineering	Approximate Number to be Sampled
CSIR science, engineering and technology , SET, base	1500
UWC Faculty of Natural Sciences; Dentistry; Community and Health Sciences; Arts	1500

According to Floyd and Widaman (1995) the minimum acceptable sample size for the data to be analysed by exploratory factor analysis, EFA, or confirmatory factor analysis, CFA, is five to ten responses per scale item. Since this research study has 27 scale items, a minimum sample size of 135 to 270 would need to be obtained. A total of 252 responses were actually received. Five of these surveys were incomplete and excluded from the study, leaving 247 useable responses.

A response rate of 32% was previously reported for a study of academic entrepreneurial intentions at two universities in two different countries (Prodan & Drnovsek, 2010). Another academic entrepreneurship study reported a response rate of 24% from university and non-university research organisations in Germany (Goethner et al., 2009). A more recent study of EI among research scientists registered a response rate of 11% to an online survey (Huyghe & Knockaert, 2015). Response rates to online surveys tend to be quite poor. Furthermore, it has been shown that the response rates for emailed surveys in health services research decrease significantly over time (Cull, O'Connor, Sharp, & Tang, 2005). The replacement of traditional mail by email and the prevalence of free online survey formats such as SurveyMonkey® and Google Forms have led to a marked increase in the number of survey requests. It was clearly apparent that the organisations approached to participate in this study were wary of their employees and students being bombarded by all manner of

surveys. Survey fatigue resulting from the overuse of online questionnaires may be limiting the effectiveness of this type of sampling method.

This study's actual response rates was 11% from CSIR and <5% from UWC. Nevertheless, a sample size of 247 is reasonable for the use of statistical tests having higher statistical power.

3.4 The research instrument

The research instrument was a self-report online-questionnaire, provided in Appendix A. A survey format permits a convenient, fast and cost effective means of covering large samples with a high level of anonymity. The sample frame used in this study has ready access to computers and the internet in the organisations In which they are based. A major disadvantage of surveys is the low response rate.

The scales used in this study are based on the entrepreneurial intention questionnaire, EIQ, originally developed by Liñán and Chen (2009). The EIQ has been shown to display high internal reliability: Reported Cronbach alpha values ranged from .77 to .94 for the EIQ's four factors, namely, EI, ATB, SN and PBC (Liñán & Chen, 2009). Convergent validity of the EIQ was assessed using factor analysis and a high Kaiser-Meyer-Olkin sample adequacy value of .912 and a highly significant ($p<.001$) Barlett's sphericity test were reported (Liñán & Chen, 2009). The applicability of the EIQ has been empirically tested across cultures (Iakovleva et al., 2011; Liñán et al., 2011).

In the research instrument, six items measure EI (items 4, 6, 9, 13, 17), five measure ATB (items 2, 10, 12, 15, 18), three measure SN (items 3, 8, 11), and six measure PBC (items 1, 5, 7, 14, 20). Five of these 20 items are reverse statements (items 2, 5, 9, 12, 16) (Liñán et al., 2011). The benefits of including reversed items are to control for acquiescence and to disrupt non-substantive patterns of responding (Weijters & Baumgartner, 2012). Furthermore, multi-item variables reduce the measurement error.

The environmental variable “Perceived Barriers” is measured using three items modified from the literature (Krabel & Mueller, 2009; Lüthje & Franke, 2003). Two of these (items 21, 22) are from Lüthje and Franke (2003) and the third (item 23) is from Krabel and Mueller (2009). The environmental variable “Perceived Support” is measured using four items of which two (items 24, 25) are attributed to Lüthje and Franke (2003). The original authors used a 5-item Likert-type scale for these variables where 1 = not at all accurate and 5 = accurate.

The drawback of Likert or Likert-type scales is that they give rise to ordinal data because “*the response categories in Likert scales have a rank order, but the intervals between values cannot be presumed equal*” (Jamieson, 2004, p. 1217). In applying descriptive statistics to ordinal data, the median or mode and the frequencies should be reported (Boone & Boone, 2012). The use of the mean and standard deviation may give misleading results (Allen & Seaman, 2007; Jamieson, 2004). Statistical analysis of ordinal data requires nonparametric tests such as chi-squared statistics and Kruskall-Wallis (Allen & Seaman, 2007). Nonparametric statistics are considered to be less powerful than the parametric statistical tests applied to interval data (Pell, 2005).

The original EIQ was based on a 7-point Likert scale with 1= total disagreement and 7 = total agreement. In this study a continuous rating scale was used in the research instrument in order to overcome the limited resolution of the Likert scale and to unequivocally provide interval data for the use of statistical methods which do not rely on the arithmetic mean (Treiblmaier & Filzmoser, 2011). Qualtrics was the online survey format utilised in this study. It provided respondents the use of a slider to indicate their selected position on a continuous scale of 0 – 100. The slider was initially set at the zero position. The scale was underpinned by a 7-point Likert anchor.

The online survey was tested on a small group of ten individuals in order to confirm whether respondents could understand the instructions and use the slider appropriately. Based on their feedback, a few minor adjustments were made to the layout and wording: The default position of the slider was set at 50, requiring respondents to move the slider to the left or to the right, in accordance

with the extent to which they agreed or disagreed with each of the scale items. Since Qualtics only registers an answer when the slider is moved, the survey settings were adjusted so that respondents could only proceed to the next item once they had moved the slider for the current item. This strategy ensured that all 27 scale items were answered, thus avoiding the problem of missing data.

A number of demographic factors served as control variables in this study. These variables and their coding are as follows: Gender (dummy variables 1 = male, 0 = female), age, position (dummy variables 1 = postgraduate student or postdoctoral fellow, 0 = staff member), type of research organisation (dummy variables 1 = university, 0 = research organisation or science council), scientific field (agricultural sciences; medical and life sciences; natural sciences; engineering and technology; social sciences and humanities; and other).

The research instrument included a question regarding the origin of the respondents' business ideas (Viviers et al., 2013), namely their academic scientific or applied research, hobby or recreational pastime, family or friends, former work activity, their own idea. Respondents were provided with the option of entering any other source of idea not covered by the aforementioned items.

The EI measure in the survey does not explicitly distinguish intentions to create start-ups for the commercialisation of research as opposed to other reasons, i.e. entrepreneurship outside the formal intellectual property system.

3.5 Data collection procedures

The ethical principles guiding data gathering are rooted in two inalienable human rights: Free speech and privacy (Watson, 1997). Watson (1997) further noted that survey and interview professionals must protect each participant's well-being to prevent harm and to get accurate information. In order to ensure that survey participant's well-being is protected, an application for ethics clearance was submitted to the University of Witwatersrand Human Research Ethics Committee: Non-medical. The decision of the committee was to approve

the application unconditionally and an ethics clearance certificate, protocol number H14/10/16, was subsequently issued.

In the pilot phase of this research study, the survey was emailed to a group of 69 CSIR staff members categorised as “science, engineering and technology management”, so as not to dilute the main sample. For the full study the survey was emailed directly to 1496 of CSIR’s “SET base” staff.

At the UWC, the emails were sent out by the human resources department, via the UWC Office for Technology Transfer, to the Faculties of Natural Sciences, Community and Health Sciences, Dentistry, and Arts. I have not been able to confirm the exact number of email recipients.

Individuals in the sample groups received an email covering letter, provided in Appendix B, informing them that their participation in the survey would be anonymous, voluntary and that they could withdraw from the survey at any point.

Those who wanted to participate could then click on a hypertext link to the Qualtrics online survey. The first item on the survey asked respondents whether they consent to participate. If they responded in the negative, Qualtrics re-directed them to the end of the survey. Those that agreed to participate proceeded to the survey proper. The respondents were afforded a period of four weeks to complete the survey. A reminder was emailed to them ten working days after the initial email. Qualtrics has the functionality to automatically save partial responses. Thus, respondents had the option of returning to complete the survey once started should they have been interrupted for whatever reason.

Qualtrics has online security features such as login and password access in order to protect confidentiality of data. The software further provides data back-up to the cloud to prevent loss of data.

3.6 Data analysis and interpretation

Once the survey window period had expired, the survey data were retrieved from Qualtrics. The collected data were analysed by descriptive and inferential

statistical methods using SAS 9.3 software. Inferential statistics is used in correlational, quasi-experimental and experimental studies to identify if a relationship or difference between variables is statistically significant. Quantitative studies usually identify the lowest level of significance as $p < .05$ (Coughlan, Cronin, & Ryan, 2007).

The data was assessed for the amount and nature of missing data; the centrality through means and medians; and the spread including standard deviations, interquartile ranges, minima and maxima. Frequency distributions of the responses to the scale items were assessed for normality, skewness and kurtosis. A number of comparisons of means tests were conducted to investigate differences in EI across categorical variables, namely gender (male – female); position (postgraduate student or postdoctoral fellow – staff); type of organisation (university – science council); and scientific fields.

Cronbach's alpha coefficients were used to test the reliability or internal consistency of the instrument scale (Cronbach, 1951). Pearson correlations were calculated in order to assess the nature of the relationships between the variables. An inter-item correlational analysis (Gulliksen, 1945) assisted with assessing reliability.

Exploratory and confirmatory factor analyses were also undertaken to further test for convergent and discriminant validity, and to confirm whether a set of manifest variables is associated with a particular latent variable (G. J. Lee, in press, p. 97). This is particularly important for the two multi-item sets of environmental factors, namely, Perceived Barriers and Perceived Support, which have not previously been validated for the proposed research model.

Basic linear regression analyses were conducted to test the relationships between the main variables. Inter-relationships among the variables, including mediation, as proposed in the research model, Figure 3, was further evaluated using covariance-based structural equation modelling, SEM. SEM is a powerful tool in "*assessing the main complex path relationships in the presence of latent measurement properties*" (G. J. Lee, 2010) and is used to test, confirm or compare theories (Hair, Ringle, & Sarstedt, 2011). Since the ATB and PBC are

postulated to mediate the relationship between SN and EI, and SEM is able to calculate the effects of both the direct and indirect paths.

3.7 Limitations of the study

- Academic entrepreneurship is typically studied from a Northerncentric perspective. This acontextual slant may complicate the theoretical interpretation of the results.
- While the TPB model is sufficient to explain entrepreneurial intentions (Gird & Bagraim, 2008; Schlaegel & Koenig, 2014), additional situational factors not accounted for in this study may have an indirect effect on the antecedents of entrepreneurial intentions or on entrepreneurial intention itself.
- This study is limited to the generic intention to start a new business and does not distinguish between growth-oriented and independence-oriented ventures (Douglas, 2013). The effects of the antecedents on EI are likely to differ according to the type of venture being considered.
- The three determinants of the TPB are at the generic level of starting a business. New venture creation includes multiple actions such as writing a business plan, raising start-up funding etc. The research instrument was not designed to account for such specificity.
- The cross-sectional nature of the study does not allow for causality inferences to be made. Longitudinal studies are required to test whether entrepreneurial intentions endure and can be positively linked to the actual behaviour of venture creation.
- Social desirability to be an entrepreneur may give rise to response bias (Spector, 2006) where respondents may inflate their scores or provide normative responses. A possible mitigating tactic would be to intersperse the questionnaire with extraneous items unrelated to entrepreneurship. However, this would also increase the length of the survey and this strategy was not deployed.

- Individuals with no interest in entrepreneurship may opt out of participating. This may lead to non-response bias (Berg, 2005) and such respondents would be under-represented in the sample.
- Common method biases resulting from a single method of data collection as well as self-report methods.
- As a consequence of time limitations, only two organisations were included in the study. Care would need to be taken in attempting to generalise the results to other universities and science councils. Furthermore, this study is confined to South Africa and results would not be generalisable to other contexts.
- Endogeneity effects may result from the influence of the dependent variable on the independent variable. Tests for endogeneity involve the use of advanced econometric modelling techniques, which are beyond the scope of this study.

3.8 Validity and reliability of the research study

This section discusses the factors influencing the external validity, internal validity and reliability of this study. External validity refers to the level of confidence in stating whether the study's results are generalisable to other groups (Altermatt, 2013). Internal validity refers to the confidence in concluding that the dependent variable was caused by the independent variable and not extraneous factors (Altermatt, 2010). It is also the extent to which the results can be interpreted accurately. Reliability is the extent to which the study can be replicated to give the same or very similar results.

3.8.1 External validity

A large sample size and a high response rate should increase the level of confidence in stating whether the study's results are generalisable to other groups (Altermatt, 2013). While a high response rate can be encouraged, in part, by having the research study endorsed by the management structure of the participating organisations, only two organisations were included in the study. This limits the degree to which the results can be generalised to other

South African universities and science councils, despite the participation of the largest science council in South Africa.

3.8.2 Internal validity

Internal validity relates to the extent to which what one aims to measure is actually captured in the measurement. Various threats or biases to the internal validity of research studies have been described in the literature (Trochim, 2000). When two constructs are measured by the same method, method bias can arise, which affects item reliability and validity and/or the co-variation between two constructs (Podsakoff, MacKenzie, & Podsakoff, 2012). Attempts to ameliorate method bias through careful survey design were as follows: A consistent scale format was used; scale items that have been tried and tested were incorporated into the survey and the scale included negative and positive statements.

The respondents are highly educated and, from a cognitive ability point of view, should be less susceptible to method bias. However, method bias could be introduced should they not have sufficient motivation to provide accurate answers, and the survey instructions emphasised the need for honesty. Furthermore, to avoid nonresponse bias, the importance of the survey was emphasised in the cover letter, and the length of the survey was kept at a manageable length, requiring about five to ten minutes to complete (Yu & Cooper, 1983).

The data were factor analysed to further assess whether items related to an underlying concept have similar scores for a given observation, i.e. convergent validity, and that they do not have substantially similar scores to those items describing a different concept i.e. divergent validity, in other word the degree to which convergent groups of items ‘overlap’ or not (G. J. Lee, in press).

Two different approaches to factor analysis were adopted in this research study, namely, EFA and CFA.

Table 2. Individual item univariate skewness and kurtosis

Variable	Mean	*SD*	Skewness	Kurtosis
EI1	48.63	28.84	.12	-1.02
EI2	58.98	28.85	-.37	-.86
EI3	60.58	28.84	-.19	-1.13
EI4	62.85	29.62	-.35	-.90
EI5	50.78	30.14	.09	-1.02
EI6	64.15	30.72	-.53	-.84
EI combined	**57.66**	**25.44**	**-.22**	**-.88**
ATB1	62.62	29.72	-.45	-.99
ATB2	75.53	25.21	-1.06	.51
ATB3	61.30	30.42	-.50	-.83
ATB4	70.13	25.72	-.82	.04
ATB5	61.71	25.24	-.29	-.44
ATB combined	**66.26**	**22.07**	**-.67**	**.23**
SN1	70.07	20.20	-.45	.14
SN2	66.50	24.45	-.42	-.51
SN3	63.30	22.95	-.43	-.08
SN combined	**66.62**	**18.37**	**-.23**	**-.20**
PBC1	45.82	25.46	.25	-.97
PBC2	74.95	24.51	-.90	.04
PBC3	58.22	22.75	-.31	-.40
PBC4	67.68	21.06	-.58	.50
PBC5	63.38	25.30	-.38	-.86
PBC6	47.40	26.52	.08	-.94
PBC combined	**59.58**	**17.68**	**-.15**	**-.13**
P_Barrier 1	67.36	23.16	-.61	-.07
P_Barrier 2	60.26	21.63	-.20	-.12
P_Barrier 3	50.60	28.66	-.07	-.98
P_Barriers combined	**59.41**	**16.29**	**-.38**	**.62**
P_Support 1	44.68	25.60	-.08	-.08
P_Support 2	50.36	25.62	-.09	-.68
P_Support 3	49.62	26.31	-.10	-.68
P_Support 4	36.89	24.78	.19	-.59
P_Support combined	**45.39**	**19.24**	**-.11**	**.03**

Prior to carrying out the factor analysis, the data was checked for normality. Firstly, the univariate distribution of each item was analysed. The histograms are presented in Appendix D. A number of them appear to the eye to display non-normal distributions. Individual univariate kurtosis scores were all within the acceptable range of ± 3 as displayed in Table 2. Skewness scores were within the ± 1 range (G. J. Lee, in press). These scores indicate that the departures from normal distributions are not too serious.

Secondly, the multivariate normality of the dataset was assessed through the use of Mardia's coefficient (Mardia, 1970). The normalized Mardia multivariate score was found to be much larger than 3.00, indicating non-normality (Ullman, 2006). Ideally, data should be distributed in a multivariate normal fashion for factor analysis to generate well-defined, more replicable factor patterns (Floyd & Widaman, 1995). The assumption of multivariate normality is more stringent for maximum likelihood estimations, which is used in CFA and SEM, than for principle axes solutions in EFA. One way of mitigating for non-normality of endogenous variables is the use of robust standard error estimates (Hox, Maas, & Brinkhuis, 2010). This is beyond the scope of this study.

EFA is usually used when there is no concrete priori expectation based on theory or prior research of the underlying dimensions of a research instrument (Floyd & Widaman, 1995). Despite the fact that the research instrument and the EIQ on which it is based are predicated on the TPB, an EFA was conducted out of interest to explore what factors exist amongst the measured variables.

In EFA the statistical programme is free to explore whether factors exist in a given dataset. Each manifest variable is correlated with each overall factor. By comparing the relative strengths of factor loadings, convergent and divergent sets of variables can be identified. A principal axis factoring approach was used. A good overall MSA score of .94 was obtained with the no individual score being lower than .89. Based on the Scree plot and proportions of variation explained, a four factor model was retained. Table 3, below, shows the major factor loadings, having values >.40, for the final four factor solution.

Table 3. Varimax rotated factor pattern loadings: EI, ATB, PBC, SN

	Factor 1	Factor 2	Factor 3	Factor 4
EI5	.82			
EI4	.79			
EI2	.75			
EI1	.74			
ATB5	.69			
ATB4	.69			
ATB2	.66			
EI6	.66			
ATB1	.51		*.47*	
PBC3		.67		
PBC1		.64		
PBC4		.59		
PBC6		.54		
PBC5		.46	*.41*	
ATB3			.59	
PBC2			.54	
EI3		*.41*	.52	
SN2				.66
SN1				.62
SN3				.53

Note: Overall MSA = .94

The first factor is a combination of EI and ATB, with one variable (ATB1) cross-loading to another factor. The second factor relates to PBC although one of the variables within this grouping (PBC5) is also cross-loaded to another factor. The

third factor is anomalous as it consists of a mixture of variables, namely, ATB3, PBC2 and EI3. The remaining factor is a combination of SN variables. Thus, SN and, to a large extent, PBC exhibit convergent and divergent validity.

A closer look at the cross-loaded, “misplaced” variables reveals that these are all reverse-coded. This seems to indicate that respondents may have misread or misunderstood the reverse statements when completing the survey. Complex factor structures are one of the measurement problems that can arise from the use of reversed items (Weijters & Baumgartner, 2012). However, none of the loadings were sufficiently low or negative to warrant removal of any of the scale items.

An EFA of the distal variables, Perceived Barriers and Perceived Support, was done separately to the proximal variables. Table 4 shows that the items are grouped into two separate factors, as expected, without any cross-loadings.

Table 4. Harris Kaiser rotated factor pattern: Perceived barriers and support

	Factor 1	Factor 2
Perceived Support4	.72	
Perceived Support1	.72	
Perceived Support2	.59	
Perceived Support3	.44	
Perceived Barriers1		.51
Perceived Barriers2		.37
Perceived Barriers3		.34

Note: Overall MSA = .67

Since a hypothesised theoretical model has already been proposed, the more correct methodological approach to factor analysis is CFA. CFA is used to confirm a priori hypotheses based on theory or previous empirical research. The

expected structure of the manifest variables is programmed into the statistical software which can then test the model for fit.

The final CPA model displayed an acceptable fit and the following indices were obtained: $\chi^2(164) = 454.19$, $p < .0001$, SRMSR = .06, RMSEA = .08 at a 90% confidence interval of .08 to .09, CFI = .91, NNFI = .90.

3.8.3 Reliability

Reliability indicates the internal consistency of measurement. In order to increase the reliability of the study, the research instrument was piloted before being administered to respondents. Firstly, technology transfer professionals from the participating organisations provided input on the wording of the questions and the overall flow and design of the survey. Thereafter, the survey was piloted on a separate sample of 69 individuals from the CSIR. Seven responses were obtained, giving a response rate of 12%. Internal reliabilities of the pilot study and the main study, respectively, were examined using Cronbach alpha coefficients. Cronbach alphas indicate whether survey items in a similar multi-item set can actually be grouped together based on a set of consistent answers. The calculated Cronbach alphas for the pilot and the main study are listed in Table 5.

Table 5. Internal reliability of pilot and main studies

		Pilot study, *N*=7	**Main study, *N*=247**
Variable	**Number of items**	**Cronbach alpha standardised**	**Cronbach alpha standardised**
EI	6	.96	.93
ATB	5	.95	.87
SN	3	.65	.75
PBC	5	.94	.83
Perceived Support	4	.68	.75
Perceived Barriers	3	-.19	.38

Due to the small pilot sample size, any irregular responses would significantly affect the Cronbach alpha values. In the pilot study, the Cronbach alpha coefficients for SN and Perceived Support were below the recommended threshold of .70 (Nunnally, 1978), but still within acceptable range (Streiner, 2003; Tavakol & Dennick, 2011). However, the pilot study's Cronbach alpha for Perceived Barriers was particularly problematic. Despite this concerning result, the main study commenced unchanged due to time pressures to collect the survey data before the end of the academic year.

Aside from the Perceived Barriers variable, the Cronbach alpha coefficients for the main study were all larger than .70. This indicates that there is internal reliability in the measurement. The inter-item correlations for each multi-item variable ranged from moderate to large as tabulated in Table 6.

For the most part, these correlations and the multi-items seem to fit together reliably. Therefore, the multi-items for EI, ATB, SN, PBC and Perceived Support were aggregated by averaging the multi-item scores for each observation into a final variable score. The single final variable scores were used in subsequent descriptive statistics, comparison of means tests and regression analyses. The Cronbach coefficient for Perceived Barriers improved in the main study, but was not sufficiently large to demonstrate internal reliability. Thus, it is likely that the three survey items for Perceived Barriers relate to different sub-dimensions of the Perceived Barriers construct.

Table 6. Inter-item correlations for the multi-item variables

	ATB1	ATB2	ATB3	ATB4	ATB5	
ATB1	1.00					
ATB2	.60***	1.00				
ATB3	.51***	.44***	1.00			
ATB4	.61***	.80***	.49***	1.00		
ATB5	.52***	.70***	.39***	.71***	1.00	

	SN1	SN2	SN3
SN1	1.00		
SN2	.55***	1.00	
SN3	.45***	.49***	1.00

	PBC1	PBC2	PBC3	PBC4	PBC5	PBC6
PBC1	1.00					
PBC2	.49***	1.00				
PBC3	.52***	.47***	1.00			
PBC4	.58***	.46***	.52***	1.00		
PBC5	.43***	.50***	.42***	.40***	1.00	
PBC6	.35***	.26***	.49***	.39***	.33***	1.00

	EI1	EI2	EI3	EI4	EI5	EI6
EI1	1.00					
EI2	.78***	1.00				
EI3	.49***	.55***	1.00			
EI4	.74***	.77***	.57***	1.00		
EI5	.75***	.74***	.51***	.83***	1.00	
EI6	.66***	.75***	.70***	.79***	.74***	1.00

	Perceived support1	Perceived support2	Perceived support3	Perceived support4
P_support1	1.00			
P_support2	.43***	1.00		
P_support3	.29***	.38***	1.00	
P_support4	.57***	.43***	.43***	1.00

	Perceived barriers1	Perceived barriers2	Perceived barriers3
P_barriers1	1.00		
P_barriers2	.33***	1.00	
P_barriers3	.18 **	-.01	1.00

3.9 Demographic profile of respondents

This section summarises the profiles of the respondents by gender, age, the type of organisation they work in, their position and their field of specialisation.

Table 7 shows the breakdown of respondents by gender and organisation. Just over 70% of the responses originated from a science council and almost 30% from a university. About 64% of the respondents were male and 36% were female.

Table 7. Respondents' gender and organisation

Gender	***N***	**%**	**Organisation**	***N***	**%**
Male	158	64	University	70	29
Female	88	36	Science council	175	71
Total	*246*		*Total*	*245*	

A closer look at respondents' position within their organisations, Table 8, revealed that academic or research staff members make up 70% of the respondents, while 30% were postgraduate students. Only five respondents (2%) were postdoctoral fellows.

Table 8. Respondents' position

Position	***N***	**%**
Postgraduate student	68	28
Postdoctoral	5	2
Faculty / staff	167	70
Total	*240*	

With regards to scientific field, Table 9, a little more than half (53%) of the respondents were engineers and technologists and about a quarter (26%) are natural scientists. Almost 11% of respondents operated in the medical and health sciences with relatively few in the agricultural sciences (2%) and social sciences/humanities (13%). A number of respondents selected the category labelled “Other” and provided a description of their actual field of specialisation. After analysing these entries, a few of them could be re-categorised into one of the other five categories.

Table 9. Respondents’ field of specialisation and age

Field of Specialisation	***N***	**%**	**Age in years**	***N***	**%**
Agricultural sciences	5	2	< 21	1	.40
Medical & Health sciences	26	11	21 to 30	107	43
Natural sciences	64	26	31 to 40	57	23
Engineering & Technology	132	53	41 to 50	48	19
Social sciences & Humanities	13	5	51 to 60	32	13
Other	7	3	> 60	2	1
Total	*247*		*Total*	*247*	

Table 9 provides further data on respondents’ ages. Most of the respondents (45%) were in the age group 21-30 years old. About 23% were of age 31 to 40 years, 19% were 41 to 50 years old, and almost 13% were between 51 and 60 years old. Only two respondents were older than 60, i.e. of post-retirement age.

Respondents’ origin of business ideas is presented in Table 10. When asked where their business ideas would originate from should they start a business, respondents’ most frequent answer was “academic, scientific or applied research” (39%). About 27% would start a business based on their own idea, with a further 18% looking to their hobbies or recreational pastimes for inspiration. A small number would base their business on former work activities (9%). Even fewer (5%) would source their business ideas from a combination of

factors. Very few (2%) would look to family members or friends for business ideas.

Table 10. Respondents' origin of business idea

Origin of business idea	***N***	**%**
Academic, scientific or applied research	95	39
Hobby	43	18
Family and friends	5	2
Former work	21	9
Idea from self	67	28
Other	13	5
Total	*244*	

CHAPTER 4: PRESENTATION OF RESULTS

4.1 Introduction

In this section, descriptive statistics are described first, followed by the results of Pearson correlations and the outputs of linear regression. Lastly, the SEM analysis is described. The presented results are used to confirm or refute Hypotheses 1, 2 and 3.

4.2 Descriptive statistics and comparison of means tests

As outlined in Table 11, scientists and engineers reported an overall moderate EI, *M* = 56.60, *SD* = 25.46. The mean scores for the antecedent variables are higher than EI: 66.34 (*SD* = 22.14) for ATB, 65.68 (*SD* = 18.47) for SN, and 59.86 (*SD* = 18.18) for PBC. Respondents perceived there to be more barriers, (*M* = 59.35, *SD* = 16.37) than support structures for entrepreneurship (*M* = 44.75 and *SD* = 19.56).

Table 11. Summary of descriptive statistics for the main variables

Variable	Mean, *M*	Median	*SD*	Skewness	Kurtosis
EI	57.66	57.86	25.44	-.22	-.88
ATB	66.26	69.20	22.07	-.67	.23
SN	66.62	66.67	18.37	-.23	-.20
PBC	59.58	58.33	17.68	-.15	-.13
Perceived Barriers	59.41	60.33	16.29	-.38	.62
Perceived Support	45.39	47.50	19.24	-.11	.03

A number of control variables were included in the study. A comparison of means analyses was carried out in order to determine whether EI and its proximal antecedents differ significantly between organisation type, position, scientific field, gender and age. Since comparison of means tests rely on the assumption of normality of the data, normality of the residuals and/or equal variances, these were both assessed as described below.

Normality of data was assessed visually by inspecting histograms of the data. Figures 4 to 9 show the histograms for the summed variables EI, ATB, SN, PBC, Perceived Barriers and Perceived Support. The skewness and kurtosis indices are tabulated in Table 11. Shapiro-Wilk and Kolmogorov-Smirnov formal statistical tests for normality (Razali & Wah, 2011) were also used, the results of which are presented in Table 12.

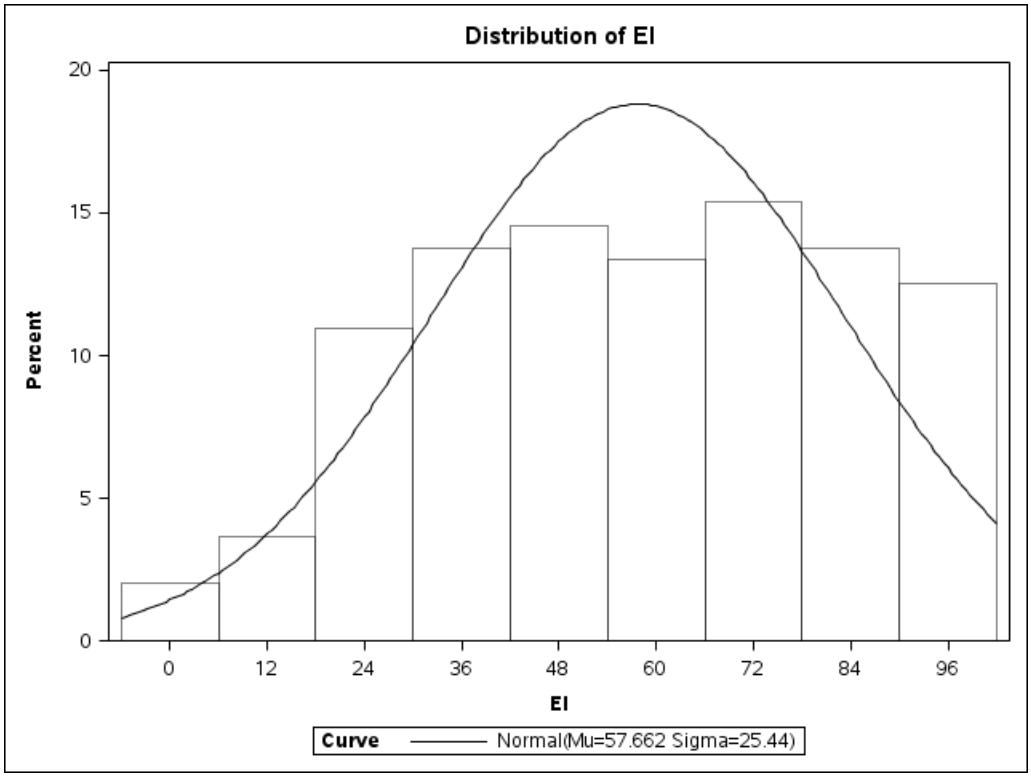


Figure 4. Histogram for EI

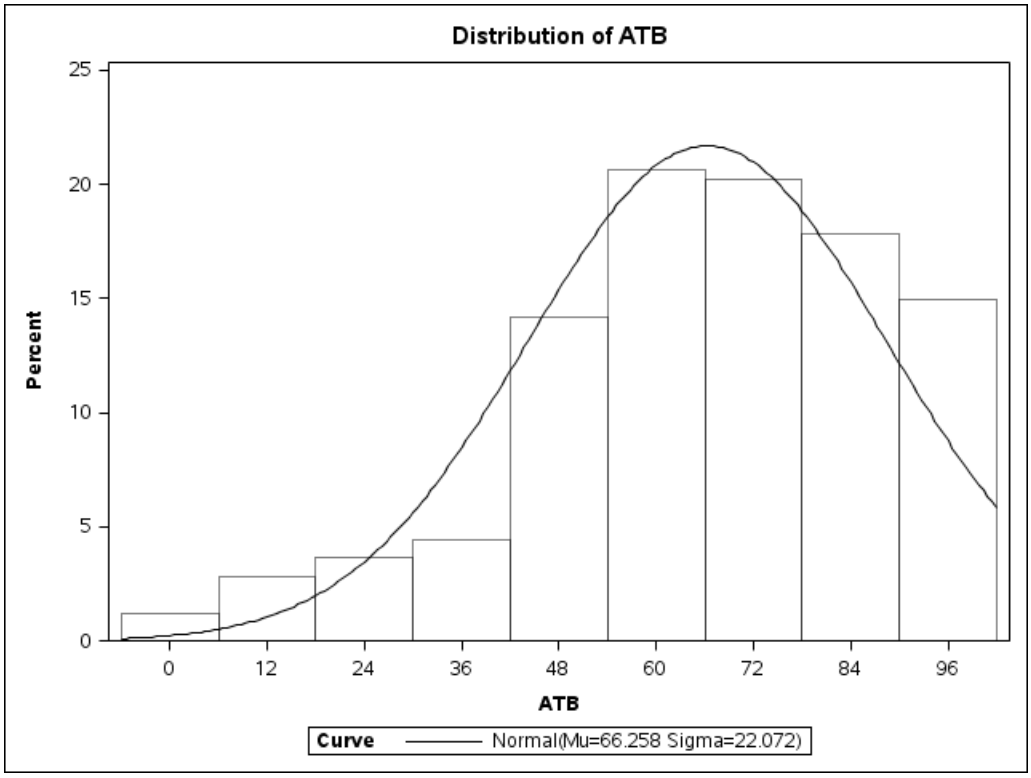


Figure 5. Histogram for Attitude to The Behaviour

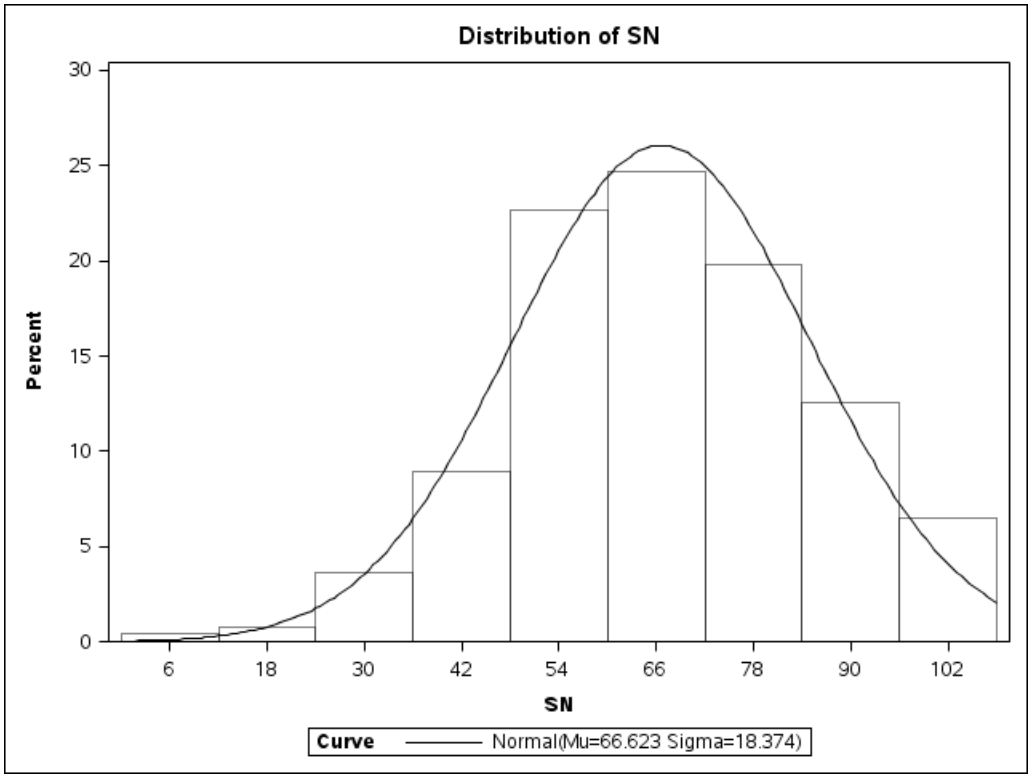


Figure 6. Histogram for Subjective Norms

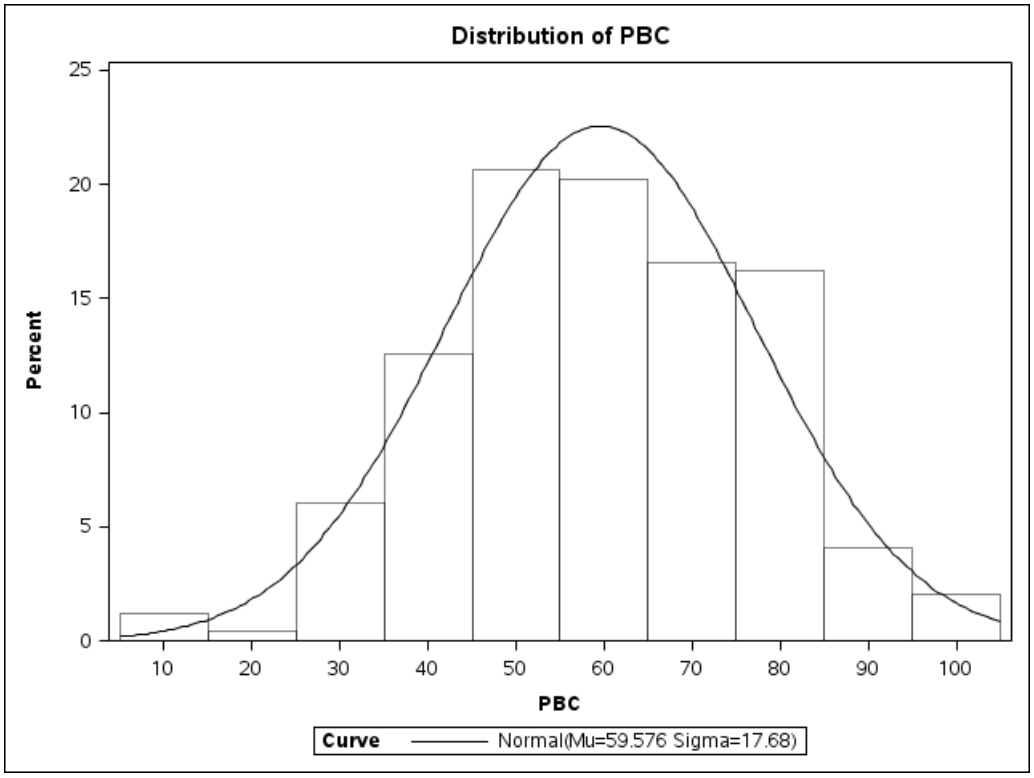


Figure 7. Histogram for Perceived Behavioural Control

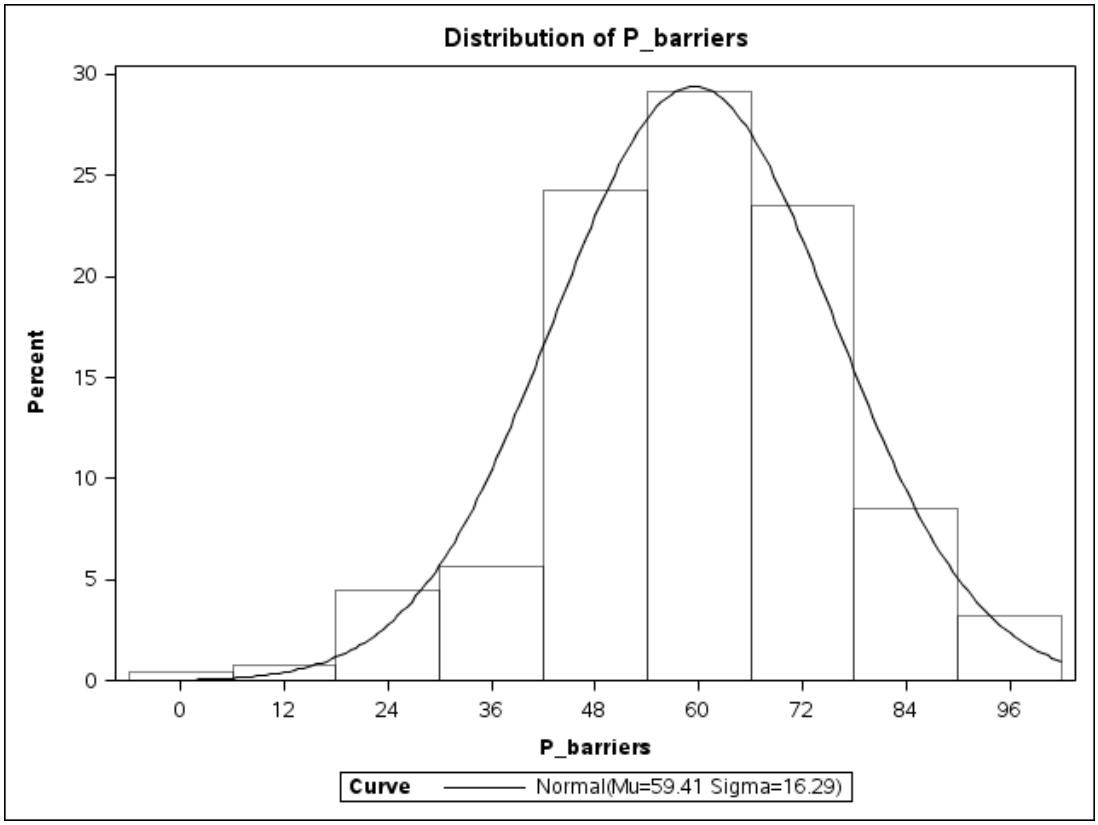


Figure 8. Histogram for Perceived Barriers

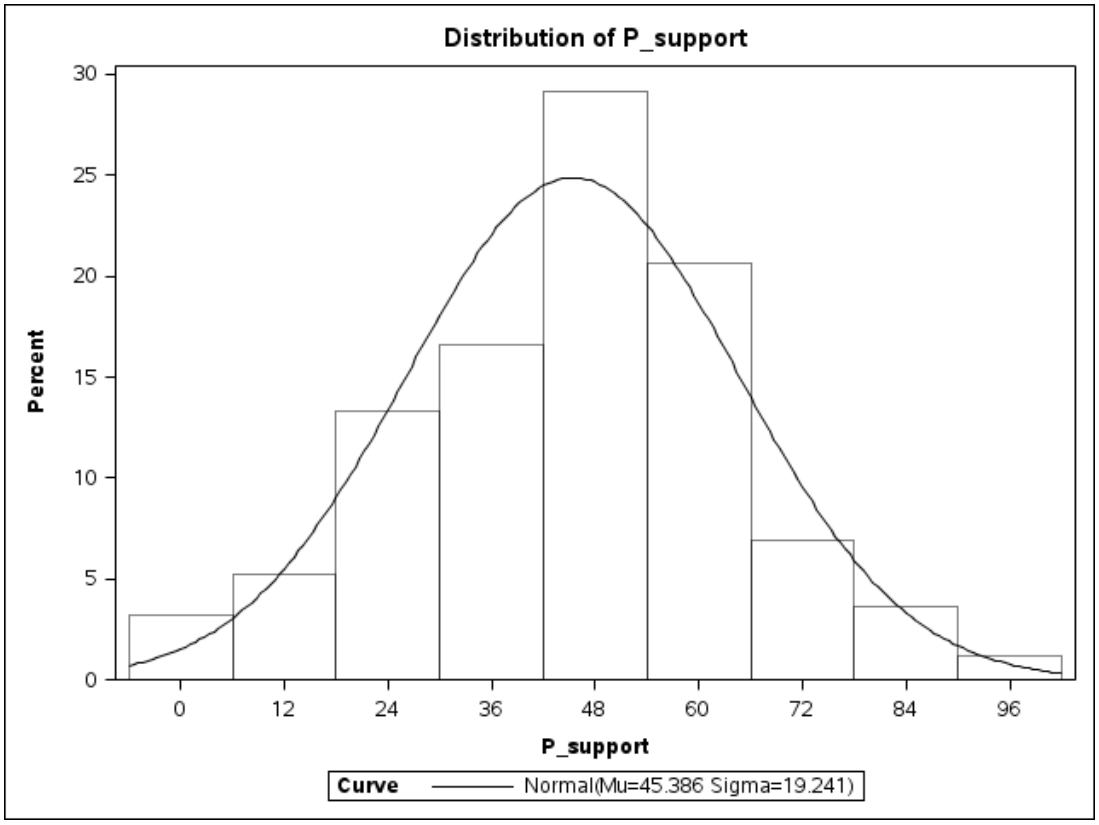


Figure 9. Histogram for Perceived Support

Table 12. Test for normality: Shapiro-Wilk and Kolmogorov-Smirnov

Variable	W	*p*	D	*p*
EI	.97	<.0001	.062	.021
ATB	.96	<.0001	.063	.017
SN	.99	.012	.046	>.15
PBC	.99	.29	.041	>.15
Perceived Barriers	.99	.026	.056	.056
Perceived Support	.99	.057	.067	<.01

While there are mild violations to the assumption of normality of data, the comparisons of means tests employed were considered to be sufficiently robust

for the data to be used without transforming it in some way. Neither was it deemed necessary to utilise bootstrapping techniques.

The Levene's test (Gastwirth, Gel, & Miao, 2009) was used to assess whether the variances of the groups were statistically equivalent. Results for gender and age are provided in Table 13. The assumption of homogeneity of variance was not violated.

Table 13. Levene's test for equality of variance: Age and gender

Group	F	*p*
Age	2.36	.12
Gender	.90	.46

Initially, comparison of means tests were conducted to evaluate the effects of single control variables on EI in isolation to other control variables. A *t*-test for organisational type showed that the difference in means between EI levels at the university (M = 64.98, SD = 24.30) and at the science council (M = 54.91, SD= 25.22) is statistically significant at the 95% confidence interval, $t(243) = 2.85$, $p = .0047$. A separate *t*-test indicated that males have higher EI scores (M = 60.81, SD = 23.80) than females (M = 51.87, SD = 27.46), $t(244) = 2.67$, p = .0081. Thus, in isolation from other control variables, EI differs significantly by gender and type of organisation. Similarly individual one-way ANOVA tests did not find any statistical differences in EI between the positions held by respondents nor in their field of specialisations. However, a significant difference in EI by age grouping was found, $F(5, 241) = 2.97$, $p = 0.0127$.

However, the comparison of means needs to be interpreted in the correct context where other control variables which could also influence EI are included. With the control variables accounted for, the effect of the type of organisation on EI diminishes. However, the results of inclusive one-way ANOVA and *t*-tests showed that there are indeed significant differences in levels of EI based on gender and age, $F(6, 239) = 4.59$, $p = 0.0002$.

The control variable age has a number of sub-groupings. Two of these sub-groupings have a much lower number of observations than the other sub-groupings: one observation for the sub-group younger than 21 years and two observations for the older than 60 sub-group. Since exceptionally small cells should be avoided in ANOVA (G. J. Lee, in press), these two sub-groups were explicitly excluded from the dataset before repeating the ANOVA tests. The new results confirmed that EI differs significantly between gender and amongst age, $F(4, 238) = 6.37$, $p < 0.0001$. The mean scores by gender and age are provided in Table 14.

Male respondents reported higher EI scores, (M = 60.81, SD = 23.80) than females (M = 51.87, SD = 27.46) $F(1, 238) = 11.50$, $p = .0008$. Similarly, male scores are significantly higher than female scores in ATB, $F(1, 238) = 11.58$, $p = .0008$, in SN, $F(1, 238) = 4.49$, $p = .035$, and in PBC $F(1, 238) = 2.65$, $p = .049$.

Post hoc comparisons using the Tukey test indicated that the mean EI score for respondents aged 21 to 30 years (M = 63.22, SD= 24.93) was significantly larger than that of the age group 41 to 50 years (M = 49.18, SD= 24.74) and the age group 51 to 60 years (M = 47.02, SD= 22.63), $F(3, 238) = 6.22$, $p = .0004$.

The age group 21 to 30 years has significantly larger SN scores than those of age 41 to 60 years, $F(3, 238) = 6.67$, $p = .0002$. For ATB, the age group 21 to 30 years is only significantly different to age group 51 to 60 years, $F(3, 238) = 4.39$, $p = .005$. PBC does not differ significantly by age.

Taken together, these results strongly suggest that age and gender have an effect on EI. In particular, males in the age group 21-30 years are expected to have higher levels of EI.

Table 14. Mean scores by age and gender: EI, ATB, SN, PBC

		EI		ATB		SN		PBC	
Gender	***N***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***
Male	158	60.81	23.80	69.25	19.74	67.88	17.27	61.12	16.98
Female	88	51.87	27.46	60.83	25.06	64.12	20.06	56.60	18.62
Effect test F(1, 238)		11.50		11.58		4.49		3.93	
p		.0008		.0008		.035		.049	
Age									
< 21	1	28.83		41.00		29.67			
21 to 30	107	63.22	24.93	69.94	21.60	71.21	20.14		
31 to 40	57	57.99	26.47	67.11	22.36	66.26	16.85		
41 to 50	48	49.18	24.74	58.94	22.81	59.42	13.60		
51 to 60	32	51.29	22.63	63.63	20.07	63.42	16.95		
> 60	2	70.83	15.08	75.40	19.23	74.33	4.71		
Effect test F(3, 238)		6.22		4.39		6.67			
P		.0004		.0050		.0002			
ANOVA *F*(4, 238)		6.37		5.30		5.48		2.76[#]	
p		<.0001		.0004		.0003		.013	

[#] *ANOVA F(6,236)*

4.3 Results pertaining to Hypotheses 1 and 2

Correlation and linear regression tests were used to examine the relationships between the proximal antecedents and EI. Firstly, the correlation results are presented. This is followed by the linear regression results.

The Pearson correlation coefficients for the main variables are presented in Table 15, below.

Table 15. Pearson correlations matrix: summary variables

	1	2	3	4	5	6
1. EI	1.00					
2. ATB	.87***	1.00				
3. SN	.57***	.55***	1.00			
4. PBC	.65***	.64***	.46***	1.00		
5. P.Barriers	-.02	.03	.07	-.10	1.00	
6. P.Support	.14*	.10	.23***	.24***	-.11	1.00

Note: * = $p < .05$; ** = $p < .01$; *** = $p < .001$

The three proximal antecedents of EI showed statistically significant, strong, positive correlations with EI. The strongest association was between EI and ATB (.87, p <.001), followed by PBC (.65, p <.001) and SN (.57, p <.001). Furthermore, the antecedent variables also strongly correlated with each other. In contrast, the environmental variable Perceived Barriers showed very weak, non-significant correlations with EI and its antecedents. Evidence for a significant, moderate correlation between Perceived Support and PBC and SN, respectively, was found.

A linear regression analysis was undertaken in order to explain the statistical variance of the dependent variable EI based on the recorded levels of the independent variables. The analysis was done in a stepwise manner in order to

identify the most parsimonious subset of independent variables having the strongest relationship to EI.

In the first step, the linear regression focused on the effect of the proximal antecedent variables, ATB, SN and PBC, on EI (G. J. Lee, in press, p. 104). Table 16 gives the regression results. The overall model fit is good, with R^2 = .77, adjusted R^2 = .78 and F is significant at < .0001. An analysis of the variance inflation scores and the condition indices confirmed the absence of multi-collinearity: Highest VIF = 2.00; highest condition index = 11.53. The Durban Watson statistic of 2.06 and accompanying *p* values of .63 and .36 indicated low to zero autocorrelation. Residual plots were normal and homoscedastic.

Table 16. Linear regression: Effect of proximal antecedent variables on EI

	Effect on EI		
	B	**95% confidence interval**	**β**
Intercept	-19.16***	-25.64 to -12.69	.00
ATB	.83***	.73 to .92	.72
SN	.15**	.05 to .25	.11
PBC	.20**	.09 to .32	.14
R^2		.77	
R^2 adjusted		.77	
F		276.42***	

Note: *N*= 247, B = unstandardized effect, β = standardized effect,* = $p < .05$; ** = $p < .01$;

In the next step of the multiple regression analysis, the distal antecedent variables, Perceived Barriers and Perceived Support, were included with the three proximal variables. These additional variables did not result in an improvement in R^2, as shown in Table 17.

Table 17. Effect of distal and proximal antecedent variables on EI

	B	95% confidence interval	β
Intercept	-16.00***	-25.03 to -6.97	.05
ATB	.83***	.73 to .93	.72
SN	.16**	.05 to .26	.11
PBC	.19**	.07 to .31	.13
Perceived Barriers	-.05	-.15 to .04	-.03
Perceived Support	.00	-.08 to .09	.00
R^2		.77	
R^2 adjusted		.77	
F		165.57***	

Note: *N*= 247, B = unstandardized effect, β = standardized effect, * = $p < .05$; ** = $p < .01$; *** = $p < .001$***

In the third step of the stepwise regression, the control variables were factored in with the distal and proximal antecedents. The regression results are presented in Table 18. The control variables have weak, non-significant effects on EI, and adjusted R^2 is .76.

From the stepwise regression results presented here, it can be concluded that the TPB explains 77% of the variance in EI. Thus, Hypothesis 1 is supported.

The regression results further confirmed that ATB is the most important predictor of EI, indicating support for Hypothesis 2a. Contrastingly, the SN and PBC appear to have only a small effect on EI, suggesting little support for Hypotheses 2b and 2c. The effect of ATB, SN and PBC on EI, and on each other, was tested using SEM. The SEM results are presented in Section 4.5.

Table 18. Linear regression: Effect of control variables, and distal and proximal antecedent variables on EI

	Effect on EI		
	B	**95% confidence interval**	**β**
Intercept	-17.00*	-30.35 to -3.86	.00
ATB	.81***	.70 to .92	.72
SN	.14*	.02 to .25	.10
PBC	.20**	.07 to .34	.14
Perceived Barriers	-.07	-.18 to .03	-.05
Perceived Support	-.01	-.11 to .08	-.01
Organisation, *dummy = science council*	-.02	-4.32 to 4.29	-.00
Position, *dummy = faculty/staff*	-1.87	-6.22 to 2.48	-.03
Gender, *dummy = female*	1.26	-2.39 to 4.91	.02
Age, *dummy = >50*			
<30	7.19*	1.66 to 12.72	.14
31 to 40	3.81	-1.66 to 9.28	.06
41 to 50	2.14	-3.65 to 7.93	.03
Field, dummy = *Agricultural sciences science and Other*			
Med. & health sciences	.29	-8.81 to 9.39	.00
Natural sciences	-.70	-8.88 to 7.49	-.01
Engineering & technology	.59	-7.46 to 8.64	.01
Social sciences	2.50	-7.78 to 12.79	.02
R^2		.78	
R^2 adjusted		.76	
F		51.16***	

Note: *N*= 247, B = unstandardized effect, β = standardized effect, * = $p < .05$; ** = $p < .01$; *** = $p < .001$***

4.4 Results pertaining to Hypothesis 3

It was previously pointed out in Section 4.2 that a positive correlation between PBC and Perceived Support had been observed. This association was further investigated by examining the Pearson correlation coefficients between PBC and the individual items for Perceived Support, displayed in Table 19.

Table 19. Pearson correlation matrix: EI, ATB, SN, PBC & individual Perceived Support items

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1. EI	1.00							
2. ATB		1.00						
2. SN			1.00					
3. PBC				1.00				
5. P_Support1	.00	-.03	.10	.07	1.00			
6. P_Support2	.**33*****	**.29*****	**.32*****	**.25*****	.43***	1.00		
7. P_Support3	.02	.02	**.23*****	**.25*****	.29***	.38***	1.00	
8. P_Support4	.05	.03	.04	**.17****	.57***	.43***	.34***	1.00

Note: * = p < .05; ** = p < .01; *** = p < .001***

Three of the four Perceived Support items are significantly correlated to PBC. These are: Item 2, “the creative organisational atmosphere inspires met to develop ideas for new businesses”; item 3, “I can easily access entrepreneurship courses for postgraduate student and academic researchers”; and item 4, “my organisation has appropriate reward systems for researchers to be entrepreneurial”. The correlations are moderate in size for items 2 and 3, but weak for item 4. One of the items, item 1, “my organisation provides access to qualified consultant and service support for new companies”, was not correlated to any other item.

A stepwise linear regression analysis was used to develop a model for predicting PBC, with Perceived Support, Perceived Barriers and all the control predictors as independent variables. The stepwise selection of predictors was as follows: Perceived Support, social sciences, male, Perceived Barriers and university. No other variable met the .15 significant level for entry into the model. The results of the stepwise linear regression is summarised in Table 20.

Table 20. Stepwise linear regression: PBC

	Effect on PBC		
	B	**95% confidence interval**	**β**
Intercept	50.48***	39.33 to 61.63	.00
Perceived Barriers	-.11#	-.25 to .03	-.10
Perceived Support	.23***	.11 to .35	.25
University	4.01#	-1.01 to 9.05	.10
Gender: Male	4.91*	.46 to 9.35	.13
Field: Social sciences	12.06*	2.21 to 21.90	.16
R^2		.13	
R^2 adjusted		.11	
F		7.02***	

Note: *N*= 238, B = unstandardized effect, β = standardized effect, # *p* < *.15;** = *p* < .05; ** = *p* < .01; *** = *p* < .001*** , *"Female" is the reference variable for the "Gender" dummy variable; Agricultural Sciences & Other" is the reference variable for the "Field" dummy variable*

The model explains 13% of the variance in EI, R^2 = .13, adjusted R^2 = .11 and *F* = 7.02 is significant at < .0001. An analysis of the variance inflation scores and the condition indices confirmed the absence of multi-collinearity: highest VIF = 1.11; highest condition index = 12.89. The Durban Watson statistic of 2.04 and accompanying *p* values of .60 and .40 indicated low to zero autocorrelation. Residual plots appeared normal and homoscedastic.

These results indicate a positive relationship between Perceived Support structures and PBC, thus providing partial support for Hypothesis H3b. There is no evidence to support Hypothesis H3a.

The slopes of the dummy variables indicate that males' PBC score is 4.91% higher than females' PBC levels. PBC scores for respondents in the social sciences exceed those of respondents from the group of agricultural science and other fields by 12%.

4.5 SEM: Results pertaining to Hypothesis 2 and 3

Data were analysed using the CALIS programme in SAS 9.3. Model parameters were estimated using the maximum likelihood estimation method for analysing covariance structure models, with at least three manifest indicators for each of the latent variables. For the sake of simplicity, control variables were not factored into the SEM analysis. SEM analyses were carried out in a stepwise fashion in order to identify parameters which could be dropped from the model without negatively affecting the model's fit. Based on the results obtained at each stage, the path model was trimmed by eliminating non-significant causal paths and variables. The reduced model was subsequently used in the next stage of the SEM analysis. The different stages are described below.

4.5.1 Environmental variables, proximal antecedents and EI

The initial theoretical model is depicted in Figure 10. This model consisted of six latent variables corresponding to the four TPB constructs and two distal variables, namely, Perceived Barriers and Perceived Support. The initial SEM output highlighted a problem with the covariance matrix: Estimates were not full ranked. The error in variance of one of the manifest variables for Perceived Barriers was particularly problematic. As reported in Section 3.8.3, the Cronbach alpha for the Perceived Barriers construct indicated reliability problems in the scale items. Furthermore, in the previous section, correlation and linear regression analyses showed that Perceived Barriers has a minimal

effect on PBC. These were sufficient reasons to exclude Perceived Barriers from the path model, and the measurement model was re-estimated.

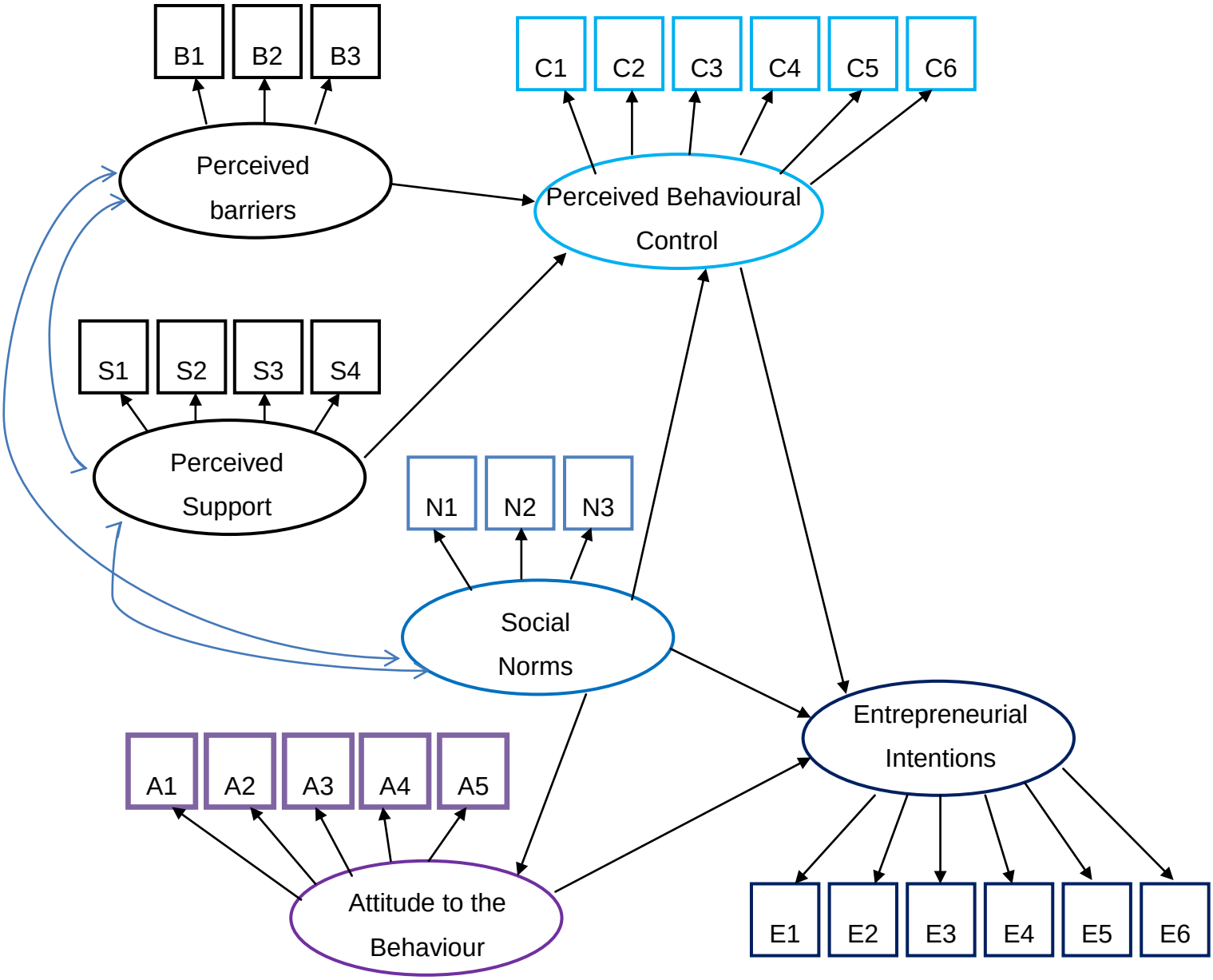


Figure 10. Theoretical model

The standardised and unstandardised path coefficients for revised model 1 are provided in Table 21, along with goodness of fit indices, which indicate an acceptable fit.

A number of paths linking two latent constructs proved to be non-significant: The direct effect of Perceived Support on PBC and its indirect effect on EI were small and non-significant; and similar conclusions could be drawn for the direct relationships between SN and EI and between PBC and EI.

Highly non-significant Wald statistics suggested that the removal of causal paths from SN to EI, PBC to EI and Perceived Support to PBC would not harm the overall model fit. In line with a stepwise reduction in causal paths, the second environmental variable, Perceived Support, was dropped from the SEM model. The resulting model, revised model 2, was then estimated.

4.5.2 Proximal antecedents and EI

Revised model 2 consisted of the three proximal antecedents and EI. The standardised parameter estimates for this model are shown in Figure 11 and the direct and indirect path coefficients are tabulated in Table 21. A full list of measurement model estimates is provided in Table 24, Appendix C. The overall goodness of fit improved: SRMR = .071; RMSEA = .090; CFI = .90; NFI = .89. This model accounts for 91% of the variance in EI. The ATB emerges as the most important antecedent of EI. It has a very strong and highly significant effect on EI, $\beta = .95$, $p < .0001$. Thus, this result confirms Hypothesis 2a. The direct path coefficients for SN-EI and PBC-EI, respectively, are small and non-significant. Thus, Hypotheses 2b and 2c are not supported. However, SN has an indirect effect on EI, mediated by ATB, ($.81 \times .95 = .77$). This confirms Hypothesis 2d. Mediation of the SN-EI relationship by PBC is much weaker, ($.75 \times .09 = .07$), causing us to reject Hypothesis 2e.

Table 21. Path estimates: Revised models 1, 2 and 3

Causal path	Revised model 1		Revised model 2		Revised model 3	
	B (SE_B)	**β ($SE_β$)**	**B (SE_B)**	**β ($SE_β$)**	**B ($SE_β$)**	**β ($SE_β$)**
ATB to EI						
Direct effect	1.06***(.12)	.95***(.07)	1.06***(.12)	.95***(.07)	1.08***(.09)	.95***(.01)
SN to EI						
Direct effect	-.11 (.20)	-.06 (.11)	-.11 (.20)	-.06 (.11)	-	-
Indirect effect	1.49***(.23)	.83***(.10)	1.50***(.24)	.84***(.10)	1.43***(.17)	.79***(.03)
Total effect	1.38***(.16)	.77***(.04)	1.39***(.16)	.78***(.04)	1.43***(.17)	.79***(.03)
PBC to EI						
Direct effect	.12 (.08)	.09 (.06)	.12 (.08)	.09	-	-
P_support to EI						
Indirect effect	.01 (.01)	.01 (.00)	-	-	-	-
SN to ATB						
Direct effect	1.29***(.16)	.81***(.04)	1.30***(.16)	.81***(.04)	1.33***(.16)	.82***(.04)
SN to PBC						
Direct effect	1.01***(.14)	.73***(.05)	1.04***(.14)	.75***(.04)	1.08***(.14)	.77***(.04)
P_Support to E						
Indirect effect	.11 (.07)	.11 (.07)	-	-	-	-
EI R^2	.91		.92		.92	
ATB R^2	.65		.66		.68	
PBC R^2	.57		.56		.59	
X^2(DF), $p < .0001$	$X^2(245) = 666.98$		$X^2(165) = 490.94$		$X^2(167) = 493.20$	
SRMR	.084		.071		.072	
RMSEA	.084		.090		.080	
CFI	.88		.90		.90	
NNFI	.87		.89		.89	

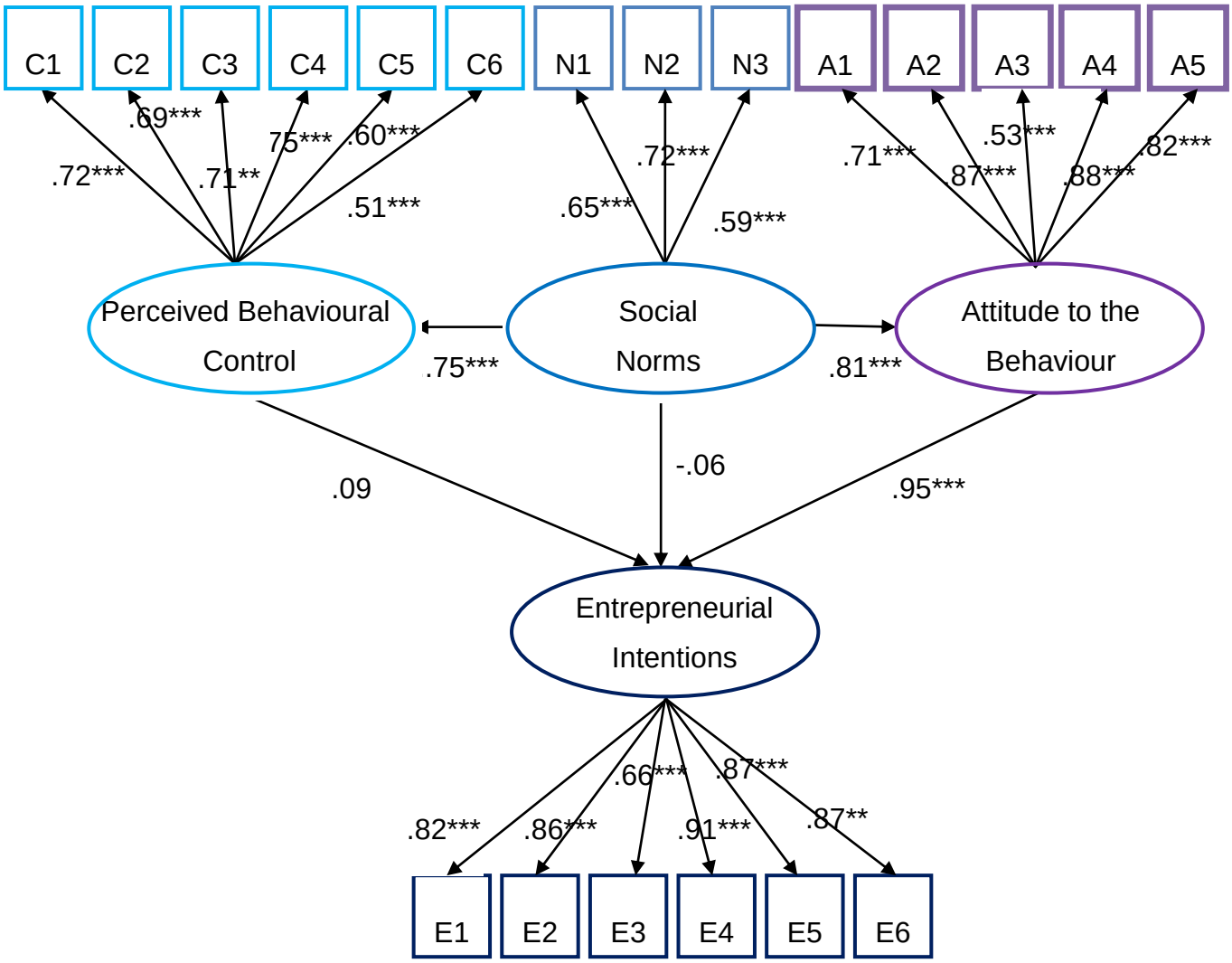


Figure 11. Measurement and path model (standardised estimates): revised model 2

Wald tests conducted in the course of analysing revised model 2 once again indicated that the model's fit would not be detrimentally affected by the removal of causal paths SN to EI and PBC to EI. When these two paths are deleted and re-estimated, the model, revised model 3, is left with three causal paths: SN to ATB, PBC to ATB and ATB to EI. The path coefficients and overall goodness of fit for revised models 2 and 3 are compared in Table 21. Differences between the two models' parameters are negligible.

4.5.3 Final model

Lagrange multiplier tests for the revised model 3, or for that matter revised model 2, suggested the addition of a causal path from PBC to ATB. Adding such a path would account for an indirect effect of PBC on EI. Given the strong effect of ATB on EI, it is entirely plausible that both SN and PBC, and not SN alone, exert their influence on EI through the mediation effect of ATB. The fit indices of this final mode, as presented in Table 22, are better than those of the original theoretical model and the two revised models. The standardised and unstandardised path coefficients are all significant. Full details of the final model's parameter estimates are provided in Table 25 in Appendix C.

Table 22. Path estimates: Final model

Causal path	B (SE_B)	β ($SE_β$)
ATB to EI		
Direct effect	1.08***(.09)	.96***(.01)
SN to EI		
Indirect effect	1.11***(.14)	.66***(.05)
PBC to EI		
Indirect effect	.65***(.10)	.49***(.06)
SN to ATB		
Direct effect	.57***(.12)	.38***(.07)
Indirect effect	.46***(.09)	.31***(.05)
PBC to ATB		
Direct effect	.60***(.10)	.52***(.07)
SN to PBC		
Direct effect	.77***(.12)	.61***(.06)
EI R^2	.92	
ATB R^2	.65	
PBC R^2	.37	
$X^2(166)$, $p < .0001$	454.25	
SRMR	.056	
RMSEA	.084	
CFI	.91	
NNFI	.90	

In the final model ATB, SN and PBC account for 92% of the variance in EI. SN and PBC account for 65% of the variance in ATB, and SN accounts for 37% of the variance in PBC.

This final model is based on post hoc data-driven modifications. It must, therefore, be regarded as tentative. Further studies should be undertaken to cross-validate whether the results can be replicated for other samples.

4.5.4 Possible alternative or equivalent models

Since it is not possible to know for certain whether the modified model is closer to the “true” model, equivalent models should at least be explored. From the linear regression results, ATB was shown to have a strong effect on E. Thus, a plausible alternative model could centre on the ATB to EI path, with SN and PBC affecting EI indirectly through ATB. Thus, in this alternative model, SN and PBC are exogenous variables, and ATB and EI are endogenous variables.

Path estimates model for this alternative model are tabulated in Table 23. The overall global fit is almost identical to the final model described in Section 4.5.3, and the direct path coefficients are the same. The indirect influence of SN on EI, mediated by ATB is lower, .37 vs .66. Model trimming the original theoretical model, and taking an alternative model approach essentially leads to the same result.

Other equivalent models were derived by changing the directions of causal paths or including additional paths between variables. However, such modifications either do not have a strong theoretical foundation, or did not provide an improved goodness of fit.

Table 23. Path estimates: Possible alternative model

Causal variable	Endogenous variable EI (R^2 = .92)			
	B	**SE_B**	**β**	**$SE_β$**
ATB				
Direct effect	1.06***	.11	.96***	.01
Indirect effect	-	-	-	-
Total effect	1.08***	.09	.96***	.01
SN				
Indirect effect	.61***	.13	.37***	.07
PBC				
Indirect effect	.65***	.10	.49***	.06
	Endogenous variable ATB (R^2 = .65)			
	B	SE_B	**β**	$SE_β$
SN				
Direct effect	.57***	.12	.38***	.07
PBC				
Direct effect	.60***	.10	.52***	.07

Note: N = 247; $X^2(164)$ = 454.19, p < .0001; SRMR = .056; RMSEA = .085; CFI = .91; NNFI = .90

4.6 Summary of the results

Descriptive statistics for the main variables were provided. Comparison of means tests indicated that the levels of the main variables differed significantly by gender and age, but not by any other demographic variable. The three proximal antecedents of EI were strongly correlated with EI and with each other. The environmental variable Perceived Barriers was not associated with any of the other main variables. Evidence for significant, but weak associations between Perceived Support and PBC and Perceived Support and SN were found.

Linear regression analyses confirmed that the dominant predictor of EI was ATB, whereas the effect of PBC and SN on EI was quite weak. The TPB model explained 77% of the variance in EI. Perceived Support was a predictor of PBC.

Three of the seven initial casual paths in the theoretical research model were statistically significant. Of the three proximal antecedents, only ATB had a direct effect on EI. SN had an indirect effect on EI through the ATB. While SN and PBC are associated, PBC did not mediate the SN-EI relationship. An additional path from PBC to ATB was added to the final model. Equivalent structural models were considered before settling on the final model.

CHAPTER 5: DISCUSSION OF THE RESULTS

5.1 Introduction

The discussion of results begins with the demographic profile of the respondents before delving into the findings pertaining to levels of observed EI. The differences in the observed levels of the main variables by demographic profile are then discussed. The exposition then turns to the use of the theory of planned behaviour in predicting EI and the relationships of the main variables with EI and each other. The role of the distal variables is then described. The discussion concludes with the presentation of the final structural model.

5.2 Demographic profile of respondents

The research sample consisted of research scientists and engineers, as postgraduate students or faculty/staff members, at a science council and a university. The proportion of responses received by organisational type is 71% from the science council and 29% from the university. The response rates were 11%, from the science council and less than 5% from the university. This is a good response rate since researchers are generally reluctant to participate in surveys (Uctu & Jafta, 2014). The lower response from the university was to be expected as the survey period coincided with the academic end-of-year examination period, a very busy time for university faculty. Sample groups are more likely to respond to a researcher whom they know or at least whose name they recognise. The fact that the researcher is a science council employee and was able to distribute the survey directly to the sample group may have also contributed to a higher level of participation from the science council than the university.

More responses were received from males (64%) than females (36%). Generally, men outnumber women in the field of engineering and technology, while relatively higher proportions of women are active in the life sciences and

social sciences. Given that 53% of the respondents belong to engineering and technology, it is not surprising that 64% of all respondents were male.

5.3 EI of respondents

The main variables were measured on a sliding scale of 0 to 100. Overall, the level of EI amongst research scientists and engineers was found to be moderate (*M* = 57.66, *SD* = 25.44). This is a better than expected score. From the low levels of spin-out activity in South Africa, as well as the low levels of entrepreneurship in general, it could have been expected that entrepreneurial intentions would be correspondingly low.

The levels of EI between the two participating **organisations** were compared. A university typically undertakes more basic research, while science councils are engaged in applied research. Since applied research is closer to commercialisation readiness, it would be logical to assume that the entrepreneurial intentions to start a new business based on one's research ideas would be higher at a science council than a university. However, the data analysis showed no statistically significant differences in EI between the researcher scientists based at the university and those based at the science council. There are two possible explanations for this. Firstly, the study's EI measure does not differentiate between the sources of the business idea. Only 39% of all respondents indicated that they would pursue a business based on his/her academic, scientific or applied research. A fair proportion would start a business that is based on his/her own ideas (27%) or hobbies (18%). Secondly, the levels of job or career dissatisfaction that contribute to "pushing" individuals from a fixed job to self-employment (Wong et al., 2006) are likely to be quite different for the two types of organisations. For example, competitive salaries and good research infrastructure serve to retain scientists and engineers in employment, while heavy teaching loads and a shortage of research funding may tip the balance in the favour of self-employment.

Scientists' **fields** of expertise and their position within their organisation did not lead to significant differences in EI. While research in the fields of engineering and technology, the physical sciences and life sciences are more likely to lead to patentable and commercialisable technologies (Alessandrini et al., 2013; Krabel et al., 2012), the research study encompasses general entrepreneurial intentions. Scientists in the social sciences may, for example, start businesses offering consulting services (language editing, translation), freelance writing, or sale of artwork.

The **age** group 21 to 30 years was found to have higher levels of EI, ATB and SN than either or both of the age groups 41 to 50 and 51 to 60 years. The levels of each of these variables decrease from age 21 to 50 and increase slightly from age 51 to 60. High levels of EI in younger respondents are to be expected, as empirical evidences supports the view of entrepreneurship as a young person's game (Lévesque & Minniti, 2006). Older researchers have a more established career in research and have built up an academic reputation over time. For these reasons they could be less motivated than their younger colleagues to compromise their research by re-directing their focus to commercialisation (Prodan & Drnovsek, 2010). As they approach retirement age, entrepreneurship becomes relatively more attractive.

5.4 Gender differences

The role of gender in entrepreneurship has been well documented. However, the results of academic entrepreneurship studies controlling for gender are mixed. Of previous EI studies conducted in South Africa, only one controlled for gender (and age). Regression results reported by Malebana (2014) indicated that gender was not significant in accounting for the variance in EI. This is not dissimilar from the findings of this research study when all variables are regressed on EI. However, demographic factors are known to exert an influence on EI indirectly through one or more of the three antecedents of EI (Goethner et al., 2012). Although not hypothesised, this study investigated the effect of gender effects in more detail. Firstly, for each of the main variables, males reported significantly higher levels of EI, ATB, SN and PBC than females.

Secondly, when the control variables were regressed onto each of the three antecedents, gender was found to be statistically significant in each case. The regression results for PBC only were reported in Chapter 4, as it relates to Hypothesis 3. These findings are further corroboration for the mediating role of gender in the PBC – EI relationship as previously proposed by Goethner et al. (2009).

The observed gender differences in EI and its antecedents in this study provide further evidence that academic entrepreneurship is not gender-neutral. This has importance implications for practitioners and policy makers.

5.5 The TPB in explaining EI: Discussion pertaining to Hypothesis 1

This study set out to explain how well the TPB explains the entrepreneurial intentions of research scientists and engineers in South Africa. Using linear regression methods, the three antecedents of EI in the TPB were found to account for 77% of the variance in EI. Demographic variables did not help predict EI, neither did external environmental variables exert a direct effect on EI.

There is a high degree of variability in the literature regarding the amount of variance in EI which is explained by the three proximal predictors. According to Liñán and Chen (2009, p. 607) "*linear models typically explain less than 40%*". A South African study involving final-year university students of commerce showed that the TPB explained 27% of the variance in EI (Gird & Bagraim, 2008). In a previous academic entrepreneurship study, the TPB accounted for 33% of the variance in EI for a sample of German research scientists (Goethner et al., 2009). Malebana (2014) found that the TPB accounted for 49.2% of variance in EI for a South African sample of rural students. Gird and Bagraim (2008) have previously attributed the highest proportion of explained variance that they had found in the literature to a study by Tkachev and Kolvereid (1999), where the TPB was said to account for 67% of the variance in EI for a Russian

student sample. On closer inspection, however, the reported R^2 of 67% included additional predictors to the three proximal antecedents in the TPB. When adjusted for the number of predictors, Tkachev and Kolvereid (1999) reported an adjusted R^2 of 45%. In comparison to the cited literature, this study provides a far greater proportion of explained variance. Clearly, the population being studied (e.g. whether commerce students or research scientists) and contextual factors (e.g. culture or nationality) influence the degree to which the TPB predicts EI.

In summary, the TPB model was shown to be applicable for predicting the EI of research scientists and engineers in South Africa, and Hypothesis 1 is supported. These findings further demonstrate the generalisability of the TPB.

5.6 Relationships between proximal antecedents and EI. Discussion pertaining to Hypothesis 2

This section elaborates on the relationships between the proximal antecedents and EI and identifies the relative importance of the three motivational antecedents ATB, PBC and SN.

In this study ATB was considerably more influential in predicting EI ($\beta = .72$, $p < .001$) than either PBC or SN. The predictive power of PBC ($\beta = .14$, $p < .01$) was slightly higher than that of SN ($\beta = .10$, $p < .05$), although both exert very weak influences on EI. This sequence of the relative contributions of ATB, PBC and SN corroborates the findings of previous studies (Moriano et al., 2012), including those conducted in South Africa (Gird & Bagraim, 2008; Malebana, 2014).

What sets the present results apart, however, is the dominance of the ATB over both PBC and SN. This is not completely unprecedented, as Ferreira et al. (2012) have previously presented a structural model where ATB has a direct effect on EI, SN only has an indirect effect on EI, and PBC has no effect on EI.

The sample consisted of 14-15 year old students. Unfortunately, no explanations for their findings were provided.

In the paragraphs that follow, an attempt will be made to identify characteristics of scientists and engineers which could explain why the proximal antecedents contribute to EI in the manner observed.

Awareness of, and exposure to, different aspects of entrepreneurship are likely to play an important role in shaping attitudes towards entrepreneurship. Technology transfer offices that provide entrepreneurship training (UWC) or run entrepreneur-in-residence programmes (CSIR) make entrepreneurship more visible to their staff and students. Furthermore, prior behavioural experiences through scientists' participation in patenting and collaborating with industry contribute to creating positive attitudes to entrepreneurship. A combination of such factors may explain the important role of ATB in this study.

The nature of research and development confers a certain degree of freedom and independence to research scientists and engineers. This may moderate the importance they place on the perceived expectations of their workplace peers. Where scientists more strongly identify with their peers, SN is expected to play a bigger role in determining EI (Goethner et al., 2012). In the South African research context, few of their colleagues would have transitioned to entrepreneurship, in other words, there are few role models to look up to.

Several other studies suggest that SN plays a lesser role than ATB and PBC in determining EI (Krueger et al., 2000; Schlaegel & Koenig, 2014). The relatively weak influence of PBC on EI, however, was surprising. Some researchers consider PBC to be main determinant of EI, with ATB and SN playing supporting roles (Autio et al., 2001). Douglas (2013) found that entrepreneurial self-efficacy, a construct closely related to PBC, was more strongly related to EI for growth-oriented businesses than to EI for independence-orientated businesses. A possible explanation for the weaker effect of PBC is that scientists and engineers, strong in human capital, have the belief that they will be able to acquire or access the skills necessary to start and run a business at the time it is required. In other words, PBC becomes important when engaging

in the behaviour and not when entrepreneurial intentions are formed. While PBC does not have a direct effect on EI in this study, further research is required to determine whether its importance manifests as a direct effect on eventual entrepreneurial behaviour.

In summary, ATB has a strong positive effect on EI and Hypothesis 2a is supported. In contrast, SN and PBC only have a very weak positive direct effect on EI. Thus, Hypotheses 2c is not supported. As will be shown below, SN has a positive indirect effect on EI, providing partial support for Hypothesis 2b.

5.6.1 Original theoretical path model and final model

Only three of the original seven paths hypothesized in the original theoretical model were found to be statistically significant. These are displayed in Figure 12. SEM analyses confirmed that SN influences ATB, which in turn influences EI, i.e. ATB mediates the relationship between SN and EI. SN also has an effect on PBC, but this is not "passed on" into an effect on EI. Thus, PBC does not mediate the relationship between SN and EI as originally proposed.

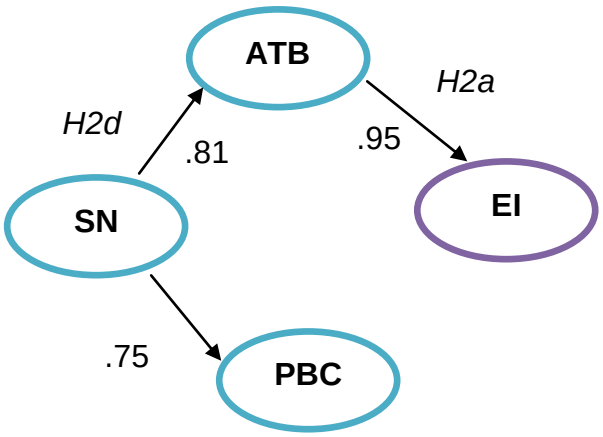


Figure 12. Revised model 3 (only significant path coefficients are shown)

An additional causal path, shown in red on Figure 13, was added in the final model.

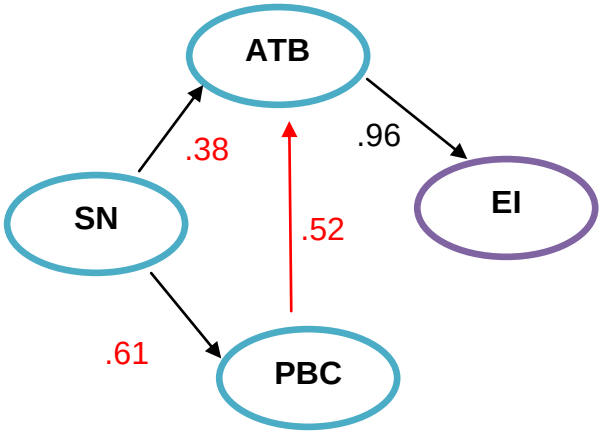


Figure 13. Final model (additional path shown in red)

This final model is based on post hoc data-driven modifications. It must, therefore, be regarded as tentative. Further studies should be undertaken to cross-validate whether the results can be replicated for other samples.

Conclusion: Hypothesis *2a*, which states that entrepreneurial intentions are positively affected by the attitude to the entrepreneurial behaviour, is supported. Hypothesis *2b* is partially supported as the subjective norm has a positive effect on entrepreneurial intentions, albeit indirectly. No support was given for Hypothesis *2c* as no significant positive relationship between perceived behavioural control and entrepreneurial intentions were found. The subjective norm has a positive effect on the entrepreneurial intentions through the attitude to the entrepreneurial behaviour, but not through the perceived behavioural control. Thus, Hypothesis *2d* is supported while Hypothesis *2e* is not.

5.6.2 Possible alternative path models

Seeing that ATB is the main predictor of EI, it is plausible that ATB not only mediates the SN → EI relationship, but that it mediates the PBC → EI relationship as well. Thus, the research model was adjusted accordingly and is shown in Figure 14. The significant path coefficients corroborate those obtained through the post-hoc model trimming exercise leading to the final model.

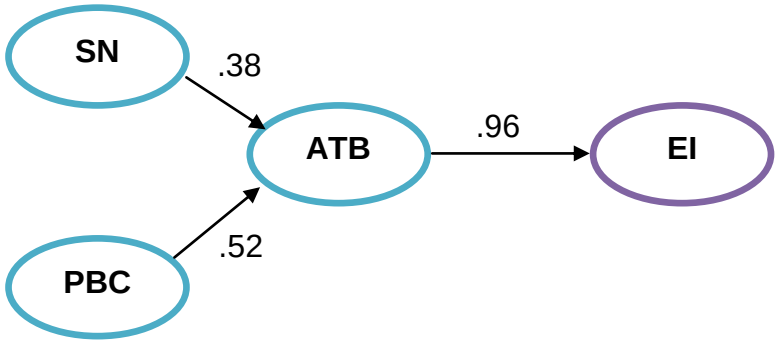


Figure 14. Alternative path model

5.7 Distal variables and EI Discussion pertaining to Hypothesis 3

The effect of Perceived Barriers and Perceived Support on PBC is discussed in this section. Perceived Barriers were expected to negatively influence PBC. However, the results show that Perceived Barriers do not have any significant effect in this study. It may be that respondents are simply resigned to the existence of barriers, such as onerous government regulations, and are resilient in overcoming these barriers. From the organisation's point of view, barriers such as access to start-up finance and government regulations are outside of its control and it would be a positive finding for them if such barriers do not inhibit spin-out formation. The internal consistency of the multi-item Perceived Barriers variable was problematic in this study, so conclusions on the role of Perceived Barriers on PBC in the hypothesized model are strictly tentative.

Unlike Perceived Barriers, Perceived Support was a weak-to-moderate predictor of PBC ($\beta = .25$, $p < .001$). While this suggests that the efforts of organisational support initiatives positively influence PBC, in the structural model, the perceived support was insufficiently strong to reinforce EI indirectly through PBC.

From these results, Hypothesis 3c, which states that perceived barriers have a negative effect on the perceived behavioural control, is not supported. Hypothesis 3b is also not supported as support structures do not have a

positive effect on the entrepreneurial intentions through the perceived behavioural control.

5.8 Conclusion

The TPB was found to significantly predict the EI of research scientists and engineers in a South African sample. The average levels of EI are moderate and statistically different between genders and among age groups. EI was shown to be positively affected by the ATB, with SN and PTB having a minimal positive effect. Perceived barriers have no effect on PBC, while there is a moderate to weak association between perceived support structures and PBC. A final structural model for the study's data was presented. The following conclusions regarding the hypotheses were drawn:

Hypothesis 1: supported

Hypothesis 2a: supported

Hypothesis 2b: partially supported

Hypothesis 2c: not supported

Hypothesis 2d: supported

Hypothesis 2e: not supported

Hypothesis 3a: not supported

Hypothesis 3b: not supported

CHAPTER 6: CONCLUSIONS, IMPLICATIONS AND RECOMMENDATIONS

6.1 Introduction

This chapter draws together the conclusions of the study, the implications of the findings for practitioners and lastly, makes suggestions for further research.

6.2 Conclusions of the study

Overall the respondents were fairly ambivalent towards to starting a new business, with average EI scores of 55%. While there is much room to increase the EI scores, the scores are higher than can be expected from a country with very low levels of entrepreneurship. This can be taken as an encouraging sign that there is good potential for academic entrepreneurship to increase and flourish.

The EI were not statistically different for university based research scientists and engineers than those based as a science council. Neither did EI differ by scientific field nor position within the organisation. However, gender and age are significant contributors to the levels of EI and to the levels of the proximal antecedents.

The applicability of the theory of planned behaviour model for explaining the entrepreneurial intentions of research scientists and engineers in South Africa was successfully demonstrated. While intention models typically explain between 40% and 60% of the variance in EI, the explanatory capacity of this study was much higher at 77%. In order of increasing importance, the influence of the proximal motivational antecedents was SN, PBC and ATB. ATB was the most important factor in determining EI, thereby corroborating results found in other research.

Environmental factors in the form of perceived barriers and perceived support did not have an effect on EI.

6.3 Implications and recommendations

This study extends prior entrepreneurial intentions research in South Africa beyond commerce student samples. It is the first study of this kind to provide empirical data on the entrepreneurial intentions of academic research scientists and engineers in South Africa. As such, it makes an important foray into the field of academic entrepreneurship in South Africa. As research in this domain advances, the similarities and differences with more general entrepreneurship models will begin to emerge.

The unit of analysis for this study was the individual research scientist and engineer. Integration of this research with previous research focusing on technology transfer offices (Alessandrini et al., 2013; Uctu & Jafta, 2014) will provide a better understanding of the individual-institutional nexus driving the creation of spin-offs from research organisations.

The research sample represents a small fraction of the total research population in South Africa and was only drawn from one university and one science council. Therefore, the research results cannot be generalised. Furthermore, the correlational design of the study does not allow for strict causal interpretations. Replication of this study at other universities and research organisations may or may not corroborate the findings. A wider study may be able to detect differences in the relative importance of the antecedents of EI between different types of organisations, which this study was unable to ascertain.

University managers and technology transfer offices have an important role to play in developing both formal and informal institutional frameworks that foster a culture and climate for entrepreneurship. By providing support for academic entrepreneurship in the form of a creative organisational atmosphere, entrepreneurship training and incentives for commercialisation, universities and research organisations can increase the perceived behavioural control of their research scientists and engineers. Institutions should consider how to improve their support offerings for entrepreneurship, so that the institution plays a bigger role in influencing behavioural control, and, in turn, entrepreneurial intentions.

Entrepreneurship education programmes are known to increase the entrepreneurial intentions of the participants. These programmes are becoming increasingly prevalent outside of the business school setting and targeted towards technology entrepreneurship. Empirical evidence suggests that entrepreneurship education has a greater effect on EI for students from technological majors than from other majors (Zhang, Duysters, & Cloodt, 2014), so programmes designed to cater for scientists and engineers are likely to be effective in facilitating EI. These programmes would require differentiated content, for example patenting and regulatory approvals relevant to a specialised technical area, in order to promote the commercialisation of scientific research over independence or lifestyle entrepreneurship. The use of pre- and post- measurement of EI is one of the ways in which the impact of entrepreneurship education programmes can be assessed (Fayolle, Gailly, & Lassas-Clerc, 2006; Souitaris et al., 2007). Stricter course evaluation methods, which go beyond simply measuring participants' satisfaction with the training course, are recommended.

Recognising that attitudes towards entrepreneurship is the main determinant in shaping entrepreneurial intentions in this study, and in other EI studies in South Africa (Gird & Bagraim, 2008; Malebana, 2014), in the absence of initiatives to simultaneously improve attitudes, support measures for entrepreneurship may have limited impact. One way of improving attitudes is by providing inspiration through role models. However, the scarcity of female entrepreneurial role models remains a widespread problem globally. South Africa has made great strides in encouraging the participation of women at all levels of society, for example, the Minister of Science and Technology and the Minister of Small Business Development are both women. However, successful entrepreneurs whether technology, academic or general entrepreneurs are still predominantly men, and targeted efforts will be required to overcome gender-stereotypes in entrepreneurship.

Practitioners need to address potential brain drain from their organisations should their initiatives to encourage academic entrepreneurship be successful. Policies need to be developed that allow for dual university and private business

roles and effective management of potential conflicts of interest. Greater commitment to succession planning would also be required. The alternative is to build up a cadre of suitable surrogate entrepreneurs to whom university technologies can be transferred for commercialisation.

Entrepreneurship is seen as a solution to the high unemployment rate in South Africa, especially among the youth. However, in tackling this huge problem, the distinction between different types of entrepreneurship is often ignored, resulting in one-size-fits-all solutions that lead to less than optimal outcomes. A specific type of entrepreneurship is most likely to lead to high-growth businesses that are able to compete in new markets, namely, technology entrepreneurship or academic entrepreneurship. Policy- and other decision-makers need to devise differentiated support initiatives and incentives for academic entrepreneurship. As the commercialisation of research increases, more specialised technology incubators will need to be established.

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6.4 Suggestions for further research

This study was empirical in nature and its positivistic approach leaves little room for a humanistic view. In order to gain a better understanding of the complex psychosocial and country-specific cultural factors underpinning the formation of entrepreneurial intentions, the study should be followed up by qualitative research that holistically examines the reasons behind research scientists' and engineers' entrepreneurial intentions.

Another area for further research is the contextual factors affecting entrepreneurial intentions. By investigating the role of the institution, its policies and practices, at a more granular level than the approach used in this study, differences in EI between types of institutions may be unearthed, which this study was not able to detect. Certainly, the limited number of generic perceived barriers and perceived support structures that were selected for analysis in this study leaves scope for research on a more inclusive list of barriers and support.

In order to test the link between entrepreneurial intentions and actual entrepreneurial behaviour, respondents would need to be tracked over time. Longitudinal studies, therefore, would be able to determine whether EI endures and converts to new venture creation and to elucidate a mechanism of how this occurs.

Lastly, more research into the design of the entrepreneurial intentions questionnaire is required, as some issues with respondents' handling of reverse items was observed.

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APPENDIX A: ACTUAL RESEARCH INSTRUMENT

Questions relating to: Age, Sex, Position [postgraduate student, postdoctoral fellow, faculty/staff], Type of Organisation [university or science council[, Scientific field [agricultural sciences, medical and health sciences, natural sciences, engineering and technology, social sciences and humanities; other]; Source of business idea [academic scientific or applied research; hobby or recreational pastime; family or friends; former work activity; own idea; other].

Instructions: Complete the questionnaire as **honestly** as possible

Indicate the scale to which you agree/disagree with items below:		Totally disagree / Disagree / Disgaree somewhat / Neither disagree nor agree / Agree somewhat / Agree / Totally agree
		0 — 100
EIQ (Liñán et al., 2011)		
1. To start a business and keep it working would be easy for me.	PBC1	0 — 100
2. A career as an entrepreneur is unattractive for me. [R]	ATB1	0 — 100
3. My friends would approve of my decision to start a business.	SN1	0 — 100
4. I am ready to do anything to be an entrepreneur.	EI1	0 — 100
5. I believe I will be completely unable to start a business. [R]	PBC2	0 — 100
6. I will make every effort to start and run my own business.	EI2	0 — 100
7. I am able to control the creation process of a new business.	PBC3	0 — 100
8. My immediate family would approve of my decision to start a business.	SN2	0 — 100
9. I have serious doubts about ever starting my own business. [R]	EI3	0 — 100
10. If I had the opportunity and resources, I'd like to start a business.	ATB2	0 — 100
11. My colleagues would approve of my decision to start a business.	SN3	0 — 100
12. Amongst various options, I would rather be anything but an entrepreneur. [R]	ATB3	0 — 100
13. I am determined to create a business venture in the future.	EI4	0 — 100
14. If I tried to start a business I would have a high chance of being successful.	PBC4	0 — 100
15. Being an entrepreneur would give me great satisfaction.	ATB4	0 — 100
16. It would be very difficult for me to develop a business idea. [R]	PBC5	0 — 100

17. My professional goal is to be an entrepreneur.	EI5	0 100
18. Being an entrepreneur implies more advantages than disadvantages for me.	ATB5	0 100
19. I have a very low intention of ever starting a business. [R]	EI6	0 100
20. I know all about the practical details needed to start a business.	PBC6	0 100
21. It is *difficult to find finance* for a start-up company (Lüthje & Franke, 2003)	Bar1	0 100
22. *Government regulations* are adverse to running a company (Lüthje & Franke, 2003)	Bar2	0 100
23. I have very *few business contacts or contacts with research partners in industry* (Krabel & Mueller, 2009)	Bar3	0 100
24. My organisation provides access to qualified consultant and service support for new companies. (Lüthje & Franke, 2003)	Sup1	0 100
25. The creative *organisational* atmosphere inspires met to develop ideas for new businesses. (Lüthje & Franke, 2003)	Sup2	0 100
26. I can easily access entrepreneurship courses for postgraduate student and academic researchers	Sup3	0 100
27. My organisation has appropriate reward systems for researchers to be entrepreneurial.	Sup4	0 100

[R] indicates reverse statements

PB = Perceived barriers

PS = Perceived support

APPENDIX B: EMAIL COVER LETTER

Dear Research Scientist or Engineer / Postgraduate student

As a busy researcher you are no doubt aware of the importance of your research outputs both to your personal career as well as to the organisation you work for. Research scientists and engineers are a critical source of new knowledge that leads to technological innovation. It is through entrepreneurship that these new-to-market research outputs are commercialised. The commercialisation of research outputs through new start-up companies has been quite successful in the USA and other countries. Studies of these phenomena tend to focus on the role of the university, the technology transfer offices or the local environment. The role of the individual scientist/engineer is often neglected. We are, therefore, undertaking a study entitled "*An empirical study of the entrepreneurial intentions of research scientists and engineers in South Africa*". We ask that you answer a short survey on this topic.

Your participation will contribute to a better understanding of the factors influencing research commercialisation and entrepreneurship. Your participation in this survey is anonymous and no personal identification information will be requested or collected. Your data is analysed as part of a whole sample - and not as an individual. The on-line questionnaire will take you between 5 and 10 minutes to complete. Please note that you are free to opt out of undertaking this survey for any reason. However, you can return to finish the survey as partial responses are automatically saved. The survey will remain open for the next *four* weeks.

Click on the survey link to begin:

https://wits.eu.qualtrics.com/SE/?SID=SV_3Vqv3CYQ8A4d2ER

This study is being conducted for a Master of Management: Entrepreneurship and New Venture Creation degree at Wits Business School, and has been endorsed by CSIR at executive level. You are welcome to contact me should you have any questions about the study. I would be happy to share the outcomes of the completed study with you.

Thank you in advance for your time and assistance.

Dr Janine Chantson

Email address: jchantson@csir.co.za

and

Dr Jose Barreira

Research Supervisor

Email address: jose.barreira@wits.ac.za

APPENDIX C: ADDITIONAL SEM RESULTS

Table 24. Parameter estimates: Revised model 2

Model Parameter: Loadings	B (SE_B)	β ($SE_β$)	*t*-value	Parameter Estimate: Residual	β ($SE_β$)	*t*-value
PBC → C1	1.00	.72 (.04)	19.04	Error in C1	.49 (.05)	9.06
PBC → C2	.92 (.09)	.69 (.04)	17.16	Error in C2	.53 (.06)	9.64
PBC → C3	.89 (.09)	.71 (.04)	18.74	Error in C3	.49 (.05)	9.14
PBC → C4	.87 (.08)	.75 (.03)	21.49	Error in C4	.44 (.05)	8.39
PBC → C5	.83 (.10)	.60 (.05)	12.94	Error in C5	.64 (.06)	11.43
PBC → C6	.75 (.10)	.51 (.05)	9.82	Error in C6	.74 (.05)	13.65
SN → N1	1.00	.65 (.04)	14.51	Error in N1	.58 (.06)	9.94
SN → N2	1.34 (.15)	.72 (.04)	18.23	Error in N2	.48 (.06)	8.38
SN → N3	1.03 (.13)	.59 (.05)	12.07	Error in N3	.65 (.06)	11.27
ATB → A1	1.00	.71 (.03)	20.67	Error in A1	.50 (.05)	10.46
ATB → A2	1.05 (.08)	.87 (.02)	48.51	Error in A2	.24 (.03)	7.72
ATB → A3	.77 (.10)	.53 (.05)	11.09	Error in A3	.72 (.05)	14.21
ATB → A4	1.08 (.08)	.88 (.02)	52.20	Error in A4	.22 (.03)	7.49
ATB → A5	.99 (.08)	.82 (.02)	35.72	Error in A5	.33 (.04)	8.61
EI → E1	1.00	.82 (.02)	35.89	Error in E1	.33 (.04)	8.91
EI → E2	1.05 (.06)	.86 (.02)	46.62	Error in E2	.26 (.03)	8.27
EI → E3	.80 (.07)	.66 (.04)	17.29	Error in E3	.57 (.05)	11.50
EI → E4	1.14 (.06)	.91 (.01)	71.41	Error in E4	.17 (.02)	7.24
EI → E5	1.12 (.07)	.87 (.02)	51.70	Error in E5	.24 (.03)	8.04
EI → E6	1.13 (.07)	.87 (.02)	49.68	Error in E6	.25 (.03)	8.13
ATB → EI	1.06 (.12)	.95 (.07)	12.83	Exogenous SN	1.00	
SN → EI	-.11 (.20)	-.06	-.56	Error in EI	.09 (.02)	3.76
SN → ATB	1.30 (.16)	.81 (.04)	22.15	Error in ATB	.34 (.06)	5.69
SN → PBC	1.04 (.14)	.75 (.04)	17.06	Error in PBC	.44 (.07)	6.58
PBC → EI	.12 (.08)	.09 (.06)	1.46			

Table 25. Parameter estimates: Revised model 3

Parameter Estimate	B (SE_B)	β ($SE_β$)	*t*-value	Parameter Estimate	β ($SE_β$)	*t*-value
PBC → C1	1.00	.71 (.04)	18.89	Error in C1	.49 (.05)	9.24
PBC → C2	.95 (.10)	.70 (.04)	18.11	Error in C2	.51 (.05)	9.47
PBC → C3	.89 (.09)	.71 (.04)	18.58	Error in C3	.50 (.05)	9.33
PBC → C4	.87 (.08)	.75 (.03)	21.80	Error in C4	.44 (.05)	8.47
PBC → C5	.84 (.10)	.60 (.05)	13.10	Error in C5	.64 (.06)	11.45
PBC → C6	.74 (.10)	.50 (.05)	9.48	Error in C6	.75 (.05)	14.10
SN → N1	1.00	.70 (.04)	16.13	Error in N1	.51 (.06)	8.35
SN → N2	1.35 (.14)	.78 (.04)	20.04	Error in N2	.39 (.06)	6.31
SN → N3	1.02 (.12)	.63 (.05)	13.13	Error in N3	.60 (.06)	9.98
ATB → A1	1.00	.71 (.03)	20.95	Error in A1	.50 (.05)	10.45
ATB → A2	.77 (.08)	.87 (.02)	47.62	Error in A2	.25 (.03)	7.89
ATB → A3	1.04 (.10)	.54 (.05)	11.32	Error in A3	.71 (.05)	14.08
ATB → A4	1.08 (.08)	.88 (.02)	52.27	Error in A4	.23 (.03)	7.62
ATB → A5	.99 (.08)	.82 (.02)	36.16	Error in A5	.32 (.04)	8.64
EI → E1	1.00	.82 (.02)	36.27	Error in E1	.33 (.04)	8.89
EI → E2	1.05 (.06)	.86 (.02)	47.08	Error in E2	.26 (.03)	8.27
EI → E3	.80 (.07)	.66 (.04)	17.42	Error in E3	.57 (.05)	11.47
EI → E4	1.14 (.06)	.91 (.01)	72.24	Error in E4	.17 (.02)	7.24
EI → E5	1.12 (.06)	.87 (.02)	52.40	Error in E5	.23 (.03)	8.02
EI → E6	1.13 (.07)	.87 (.02)	50.25	Error in E6	.24 (.03)	8.12
ATB → EI	1.08 (.09)	.96 (.01)	85.23	Exogenous: SN	1.00	
PBC→ ATB	.60 (.10)	.52 (.07)	7.88	Error in EI	.08 (.02)	3.85
SN → ATB	.57 (.12)	.38 (.07)	5.45	Error in ATB	.35 (.05)	7.33
SN → PBC		.61 (.06)	10.48	Error in PBC	.63 (.07)	9.06

Table 26. Parameter estimates: Possible alternative model

Parameter Estimate	B (SE_B)	β ($SE_β$)	*t*-value	Parameter Estimate	β ($SE_β$)	*t*-value
PBC → C1	1.00	.71 (.04)	18.89	Error in C1	.49 (.05)	9.24
PBC → C2	.95 (.10)	.70 (.04)	18.11	Error in C2	.51 (.05)	9.47
PBC → C3	.89 (.09)	.71 (.04)	18.58	Error in C3	.50 (.05)	9.33
PBC → C4	.87 (.08)	.75 (.03)	21.80	Error in C4	.44 (.05)	8.47
PBC → C5	.84 (.10)	.60 (.05)	13.10	Error in C5	.64 (.06)	11.45
PBC → C6	.74 (.10)	.50 (.05)	9.48	Error in C6	.75 (.05)	14.10
SN → N1	1.00	.70 (.04)	16.13	Error in N1	.51 (.06)	8.35
SN → N2	1.35 (.14)	.78 (.04)	20.04	Error in N2	.39 (.06)	6.31
SN → N3	1.02 (.12)	.63 (.05)	13.13	Error in N3	.60 (.06)	9.98
ATB → A1	1.00	.71 (.03)	20.95	Error in A1	.50 (.05)	10.45
ATB → A2	.77 (.08)	.87 (.02)	47.62	Error in A2	.25 (.03)	7.89
ATB → A3	1.04 (.10)	.54 (.05)	11.31	Error in A3	.71 (.05)	14.08
ATB → A4	1.08 (.08)	.88 (.02)	52.27	Error in A4	.22 (.03)	7.62
ATB → A5	.99 (.08)	.82 (.02)	36.16	Error in A5	.32 (.04)	8.64
EI → E1	1.00	.82 (.023)	36.27	Error in E1	.33 (.04)	8.89
EI → E2	1.05 (.06)	.86 (.02)	47.08	Error in E2	.26 (.03)	8.27
EI → E3	.80 (.07)	.66 (.04)	17.42	Error in E3	.57 (.05)	11.47
EI → E4	1.14 (.06)	.91 (.01)	72.24	Error in E4	.17 (.02)	7.24
EI → E5	1.12 (.06)	.87 (.02)	52.40	Error in E5	.23 (.03)	8.02
EI → E6	1.13 (.07)	.87 (.02)	50.25	Error in E6	.24 (.03)	8.12
ATB → EI	1.08 (.09)	.96 (.01)	85.22	Exogenous: SN	1.00	
PBC→ ATB	.60 (.10)	.51 (.07)	7.88	Exogenous: PBC	1.00	
SN → ATB	.57 (.12)	.38 (.07)	5.45	Error in EI	.08 (.02)	3.85
				Error in ATB	.35 (.05)	7.33
				Covariances among exogenous variables PBC,SN	.61 (.06)	10.48

APPENDIX D: UNIVARIATE HISTOGRAMS

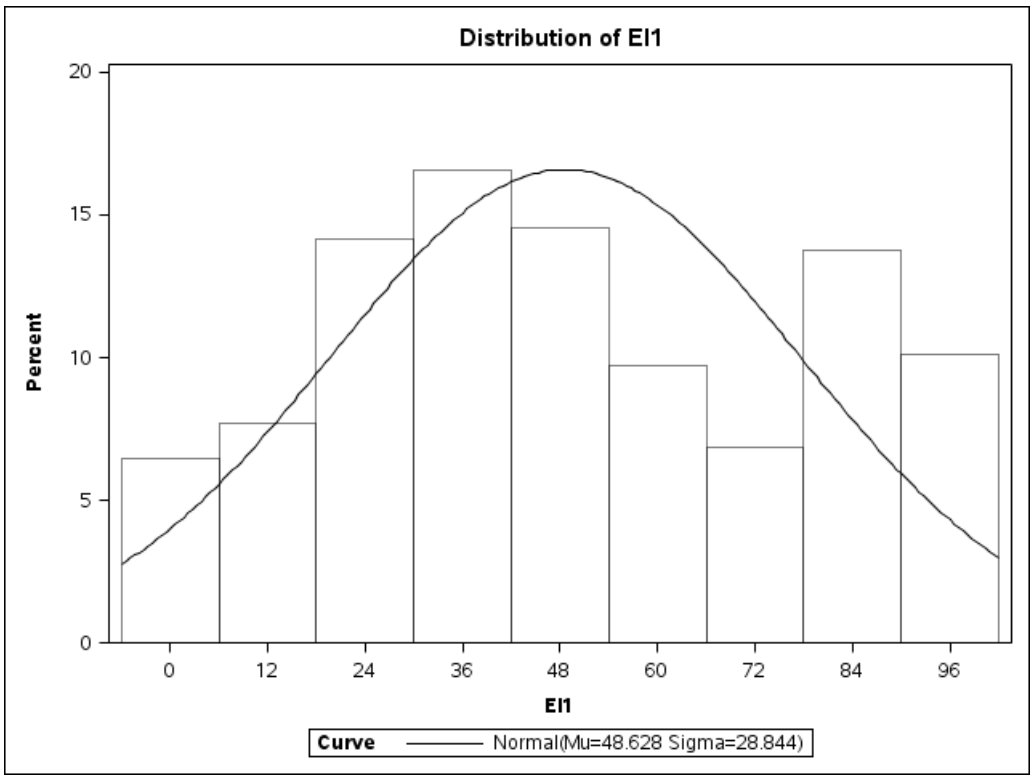


Figure 15. Histogram EI1

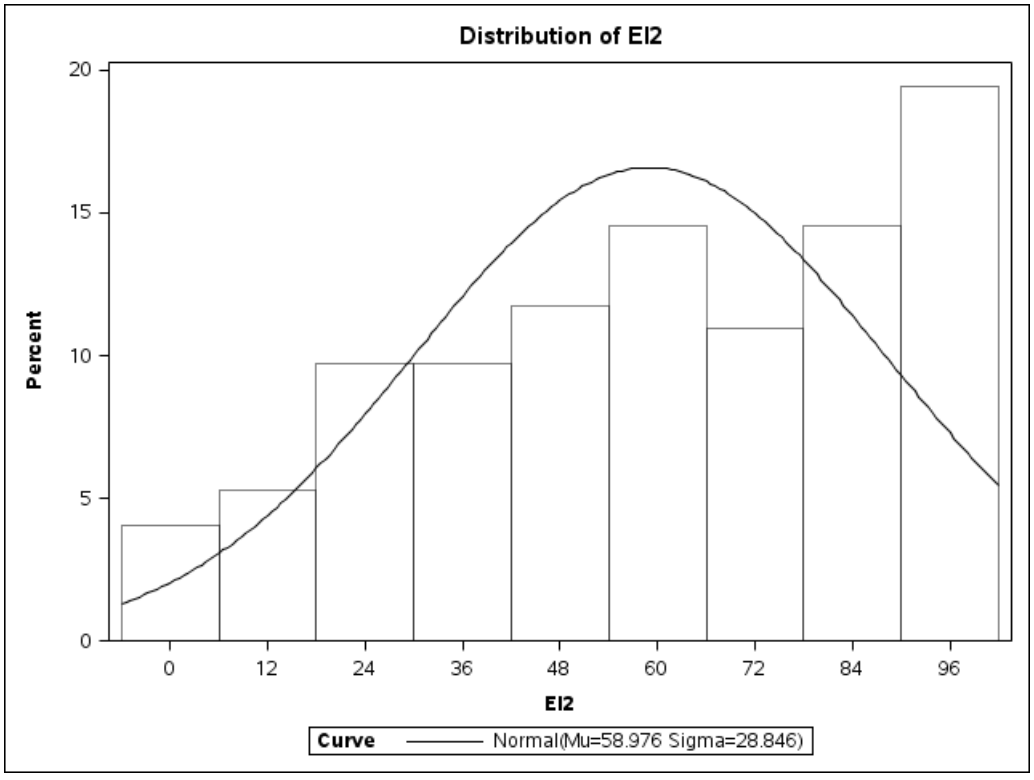


Figure 16. Histogram EI2

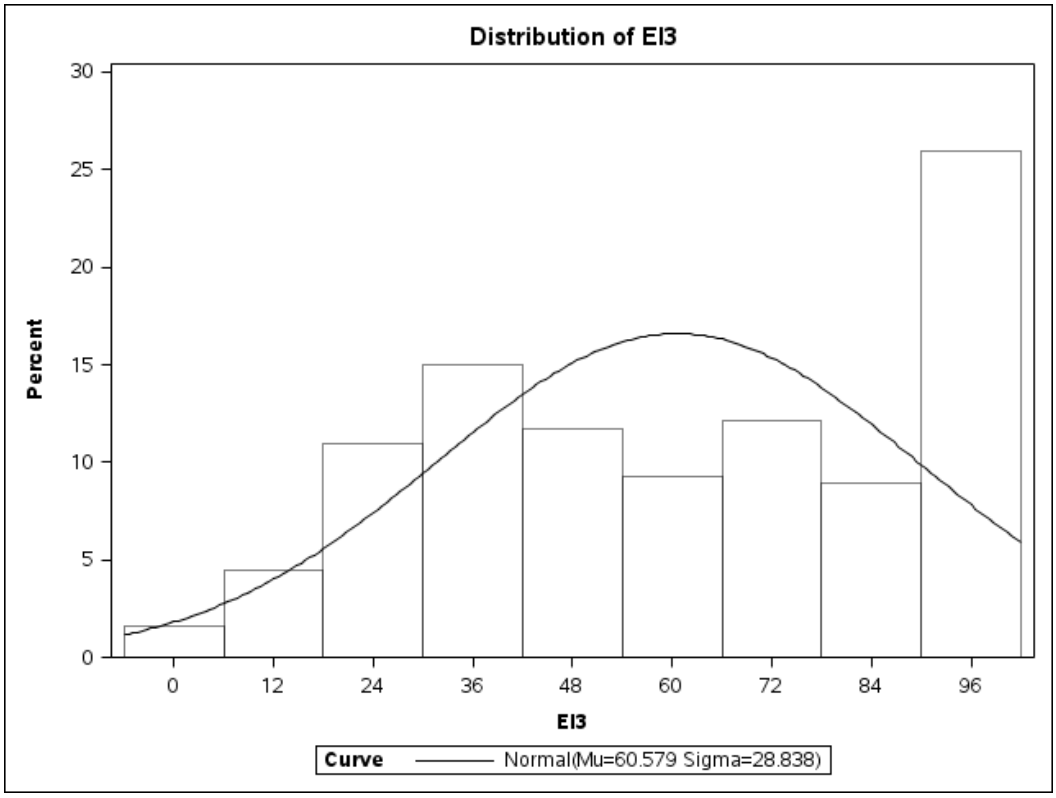


Figure 17. Histogram EI3

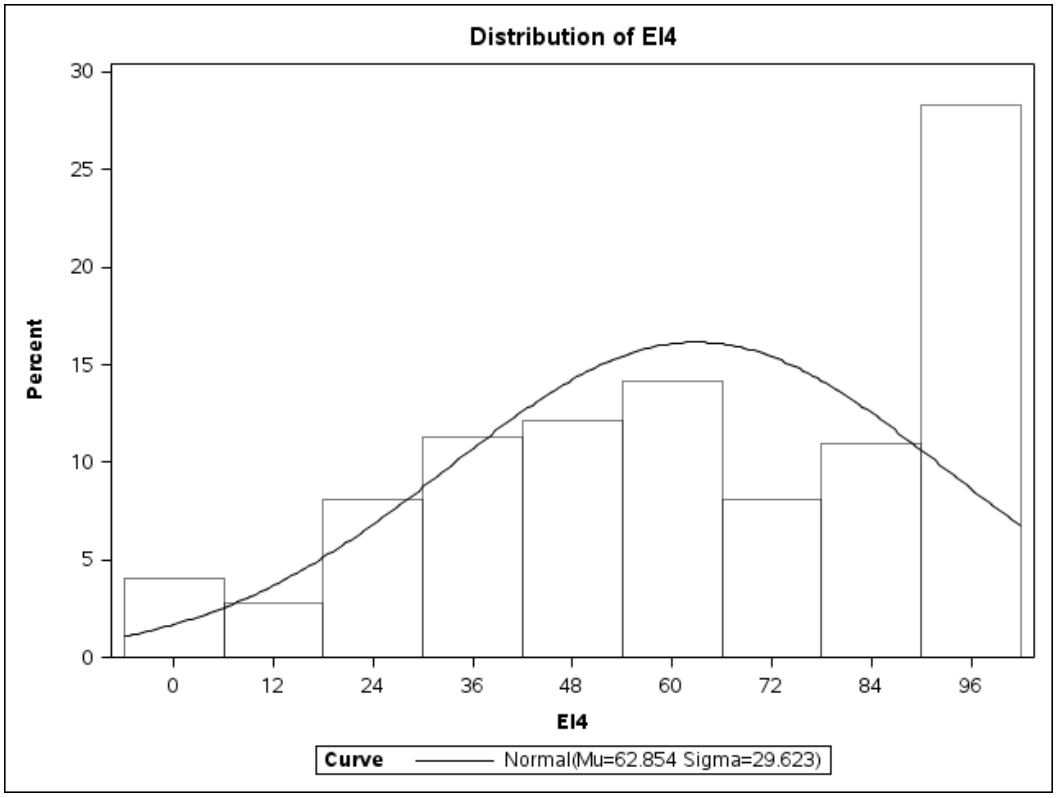


Figure 18. Histogram EI4

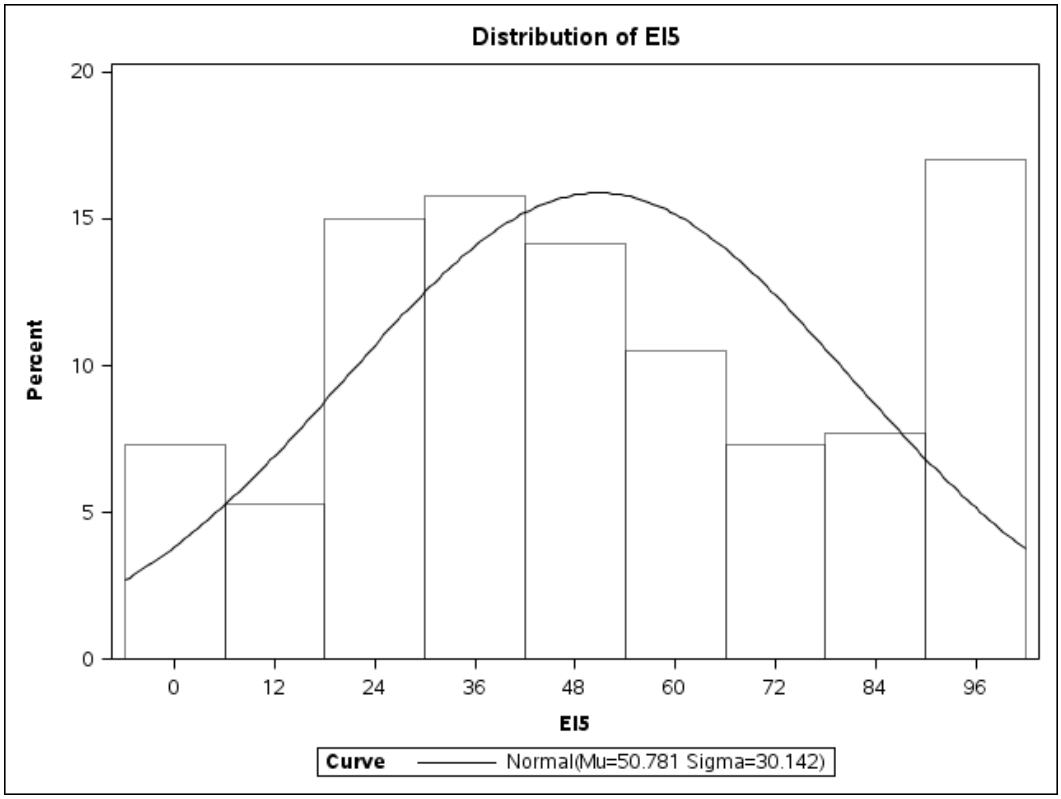


Figure 19. Histogram EI5

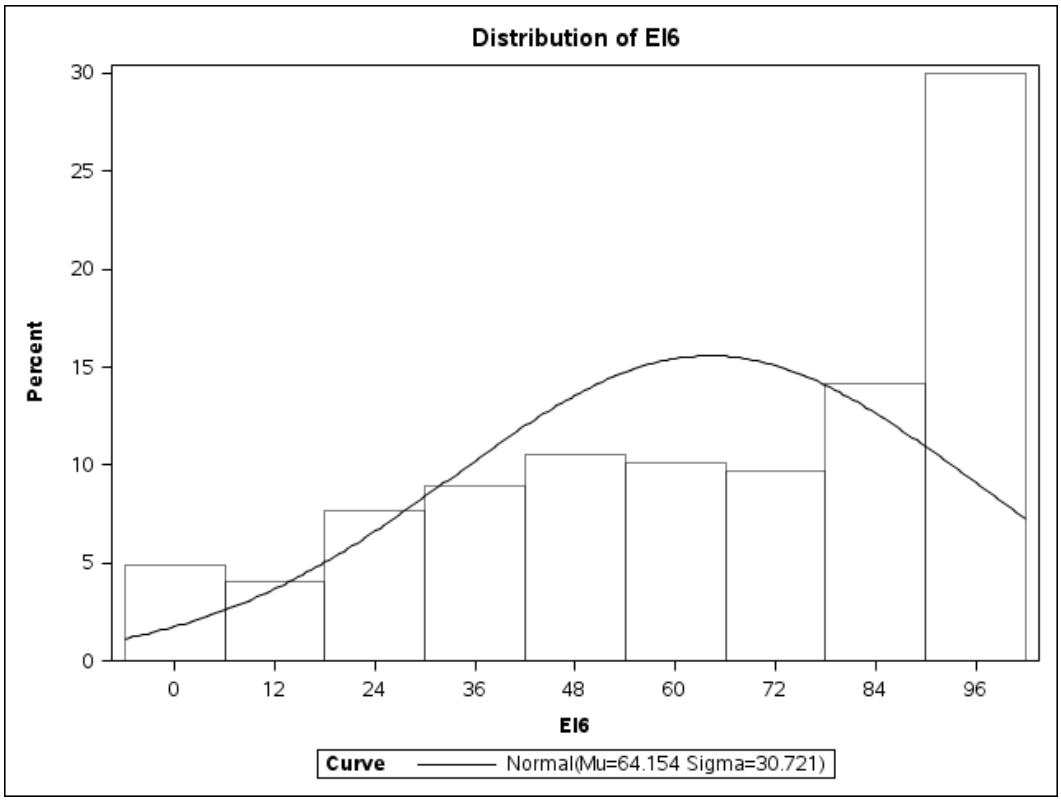


Figure 20. Histogram EI6

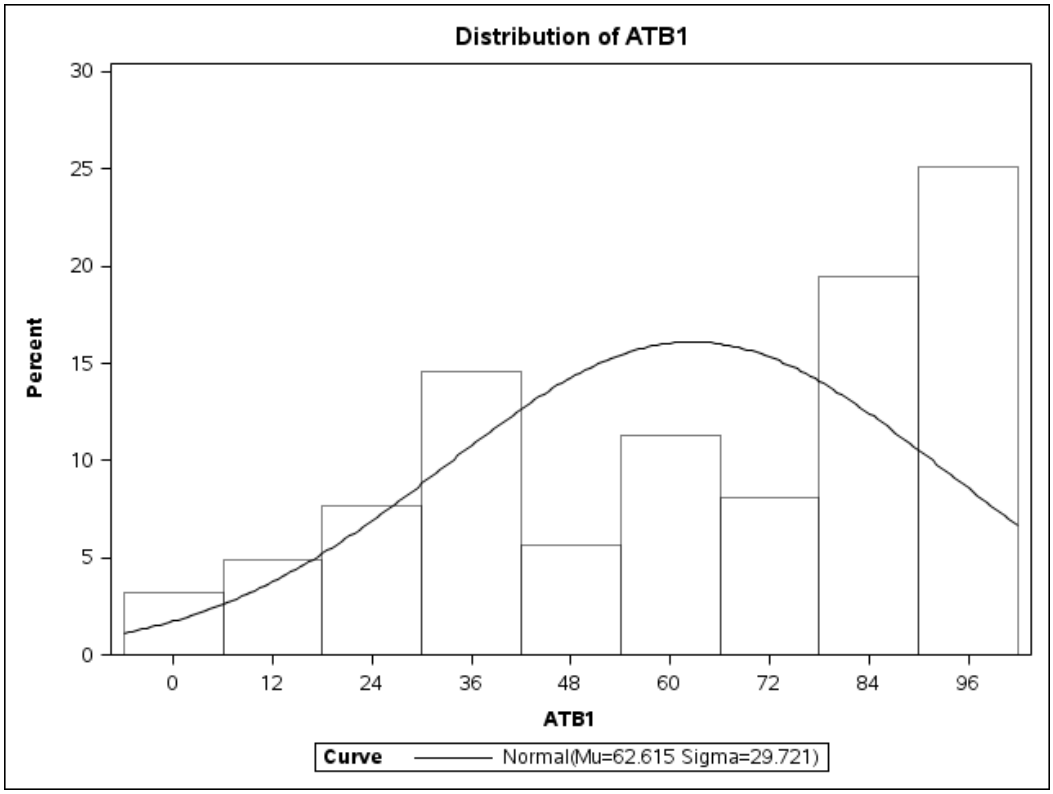


Figure 21. Histogram ATB1

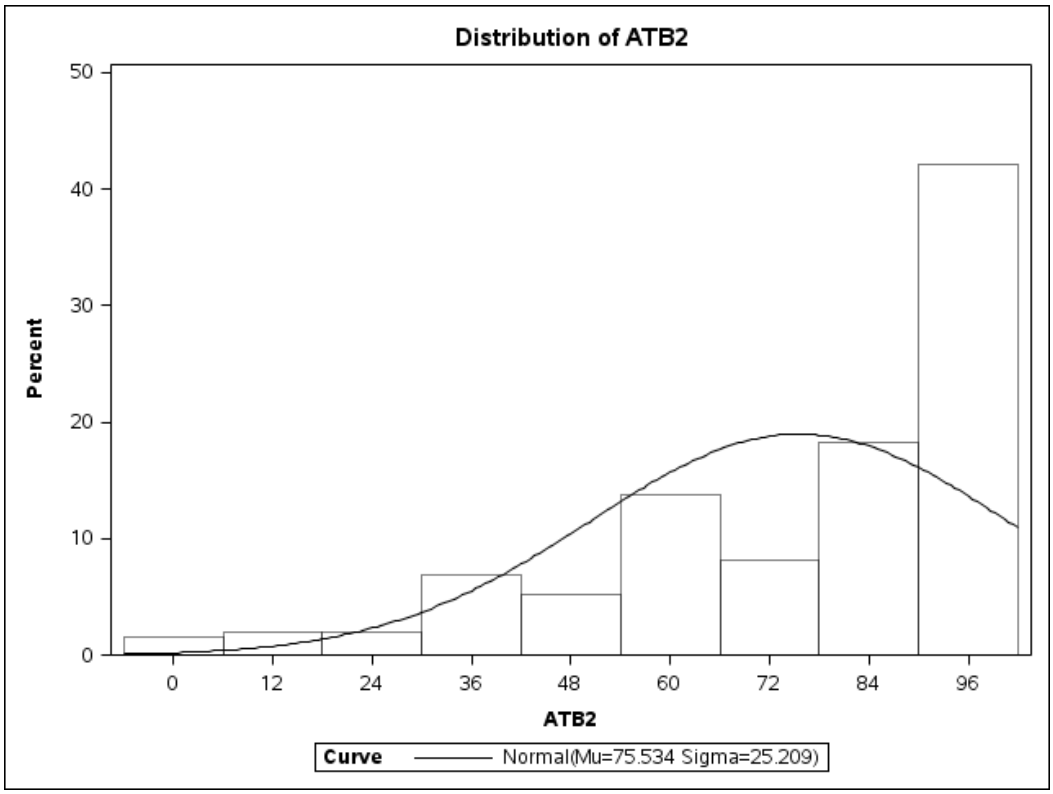


Figure 22. Histogram ATB2

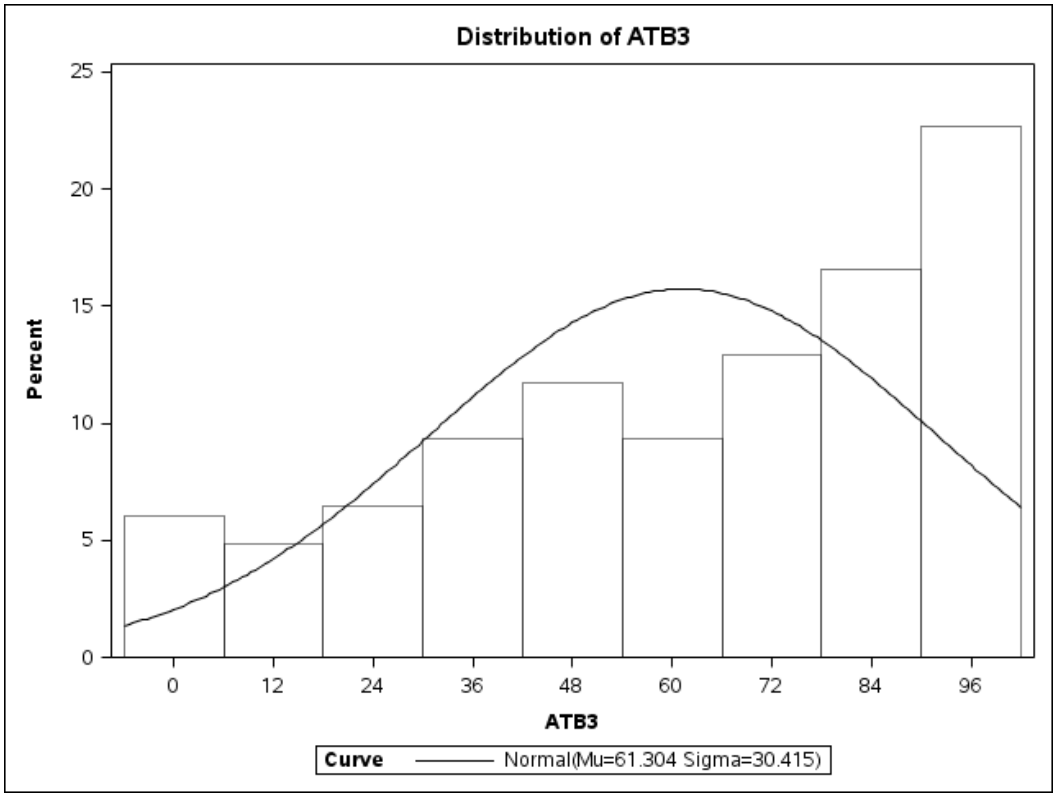


Figure 23. Histogram ATB3

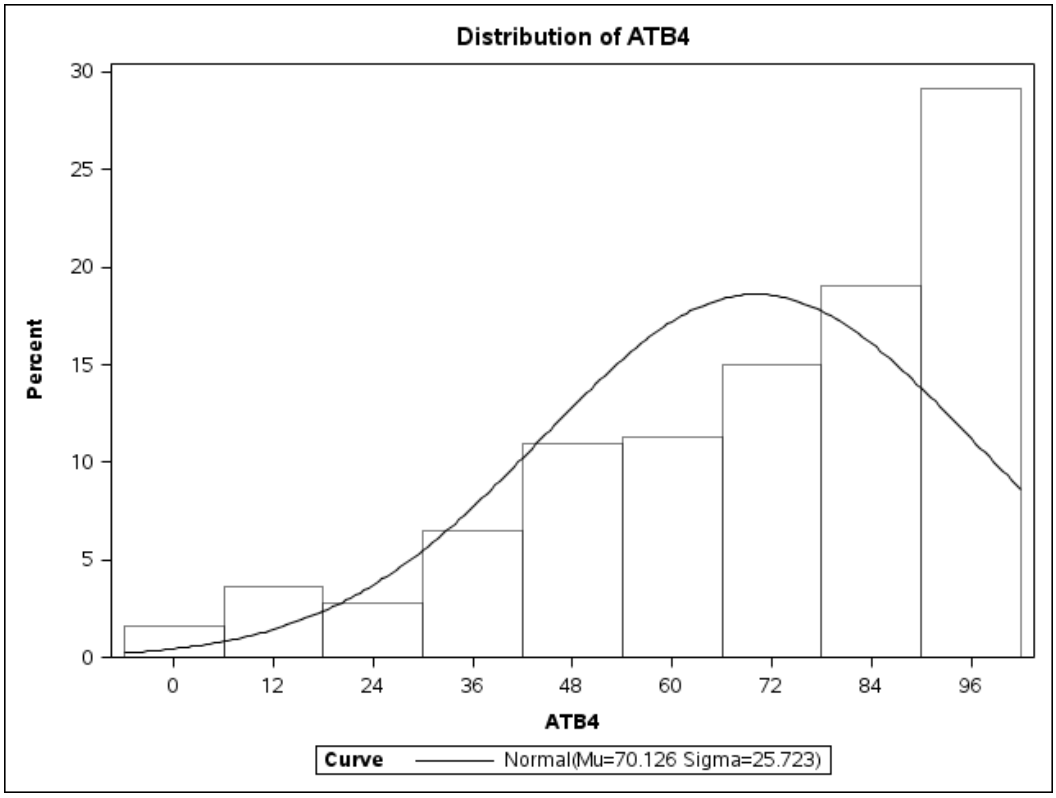


Figure 24. Histogram ATB4

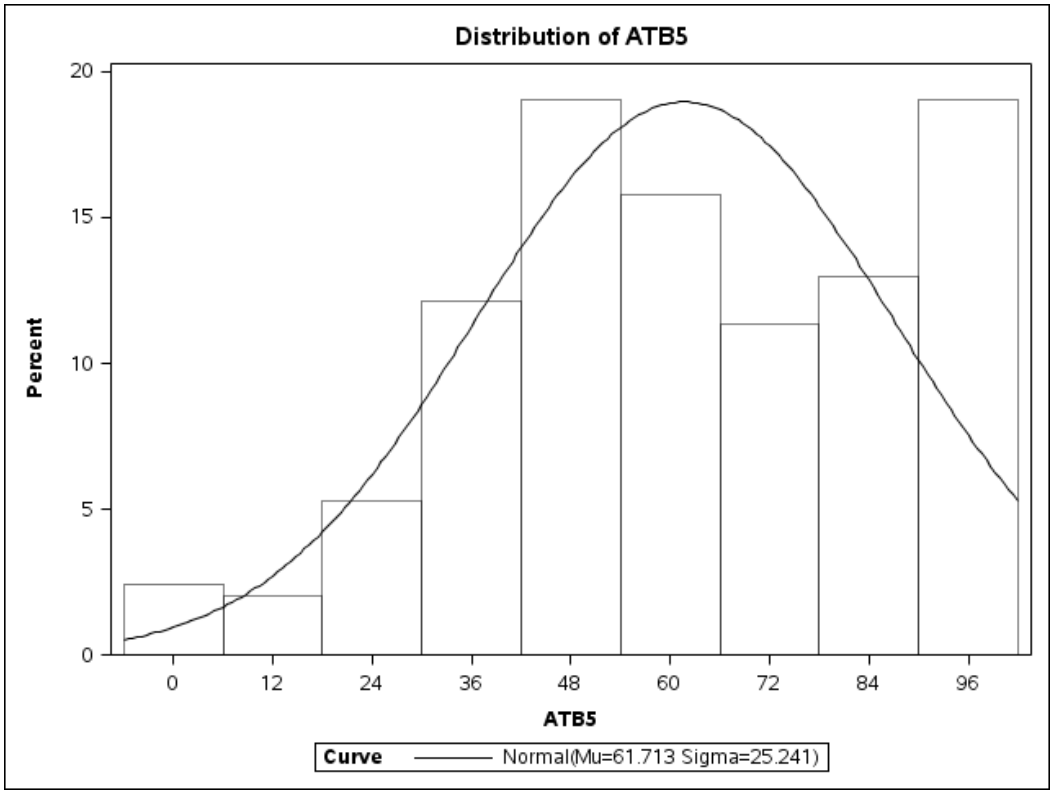


Figure 25. Histogram ATB5

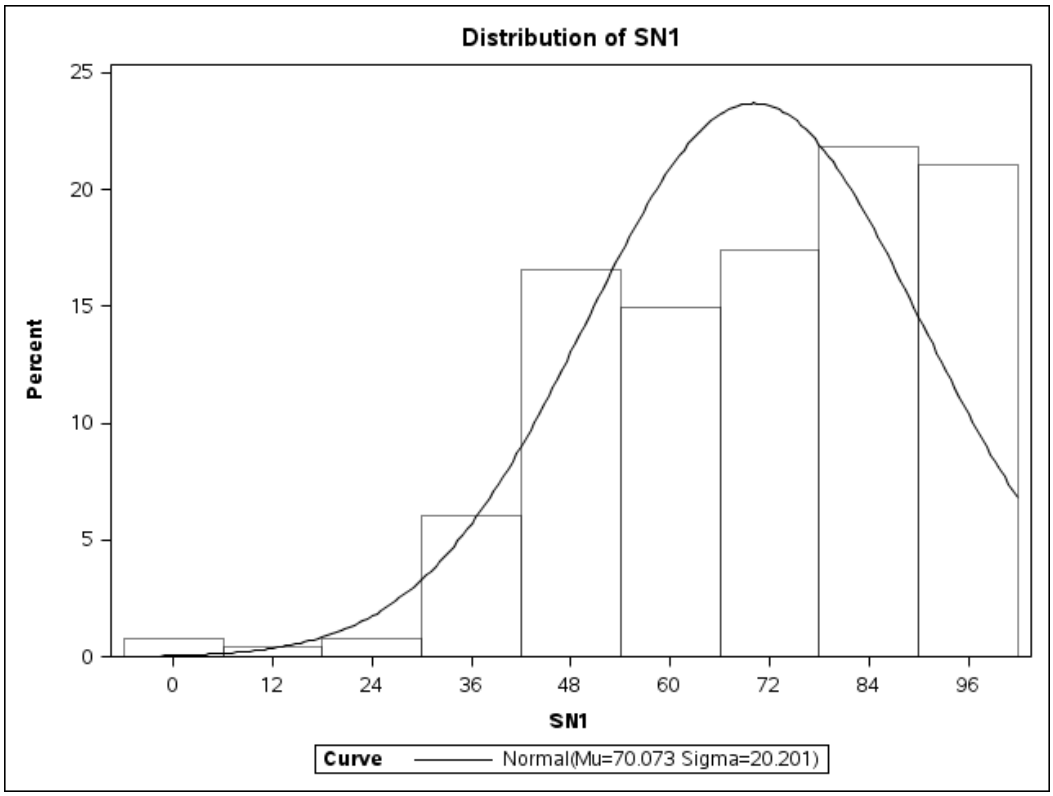


Figure 26. Histogram SN1

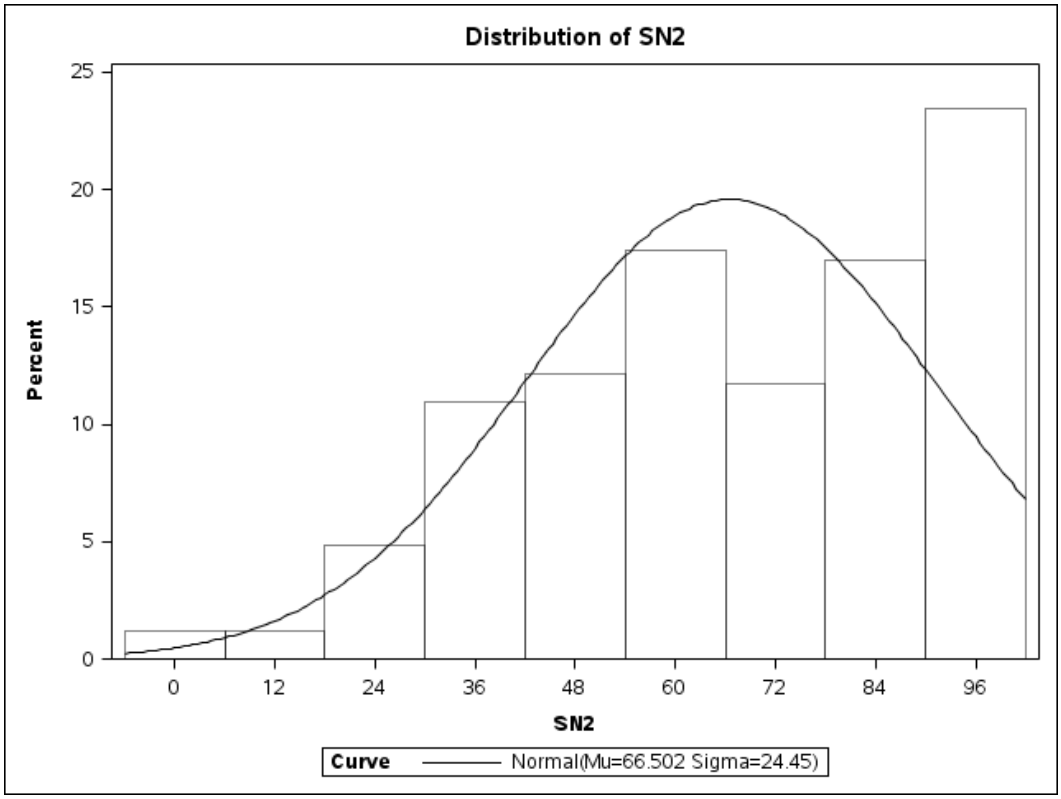


Figure 27. Histogram SN2

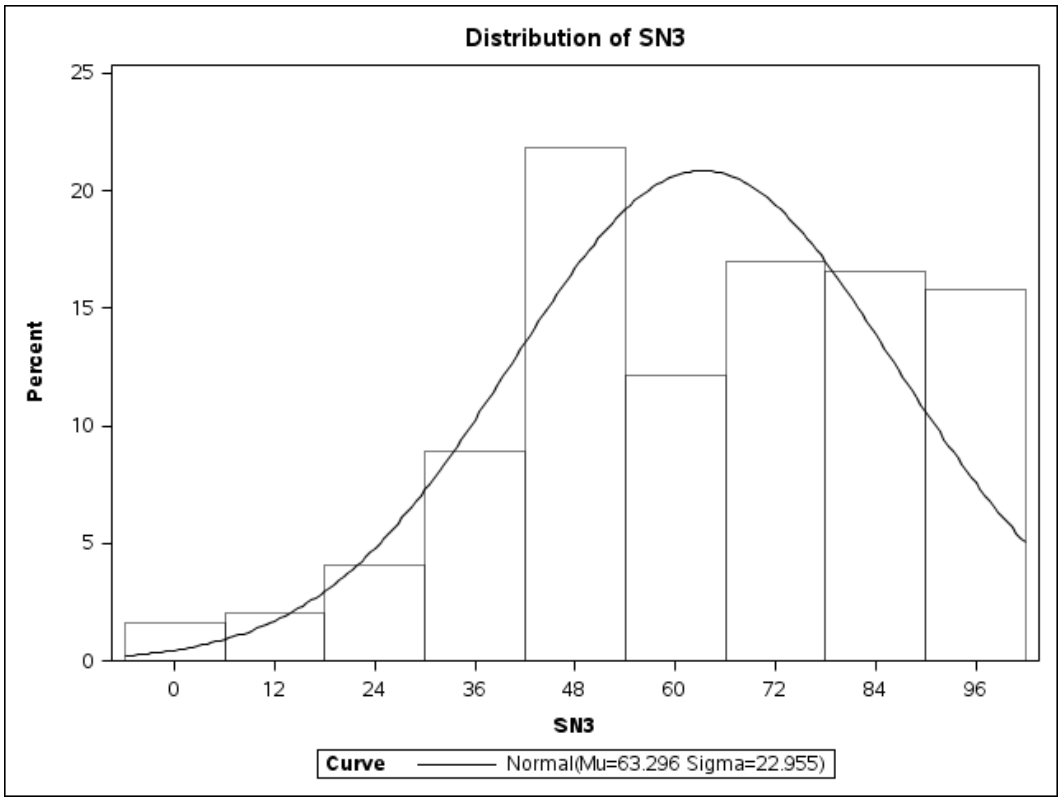


Figure 28. Histogram SN3

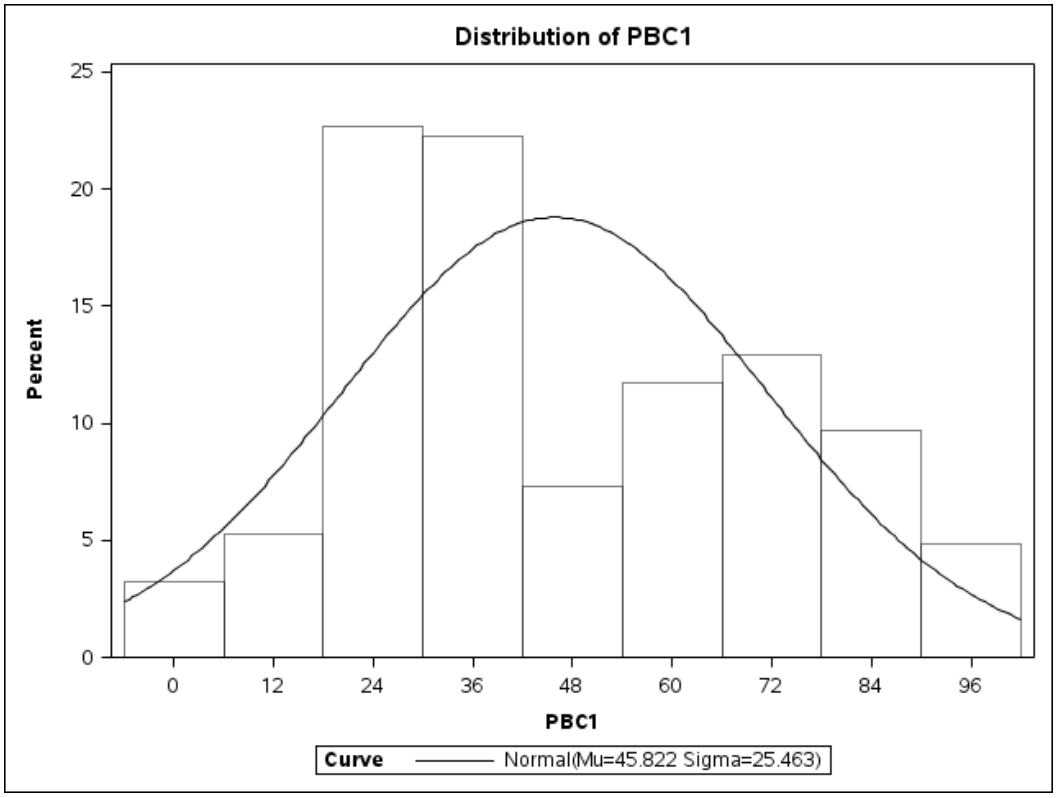


Figure 29. Histogram PBC1

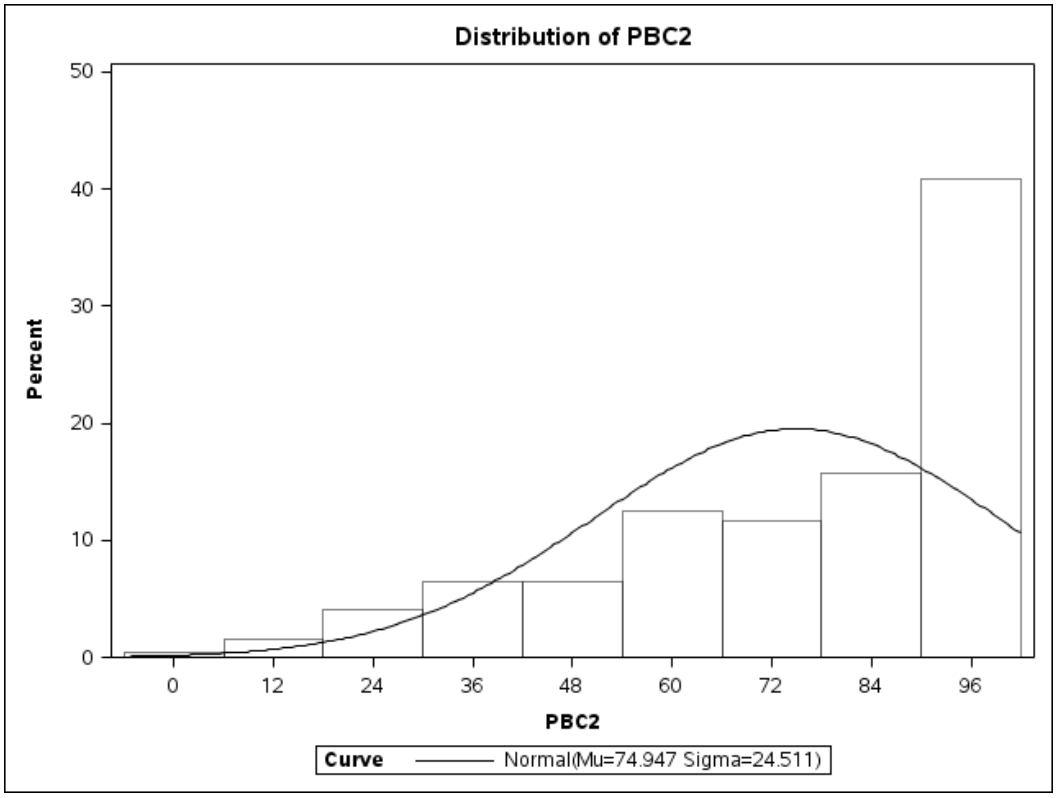


Figure 30. Histogram PBC2

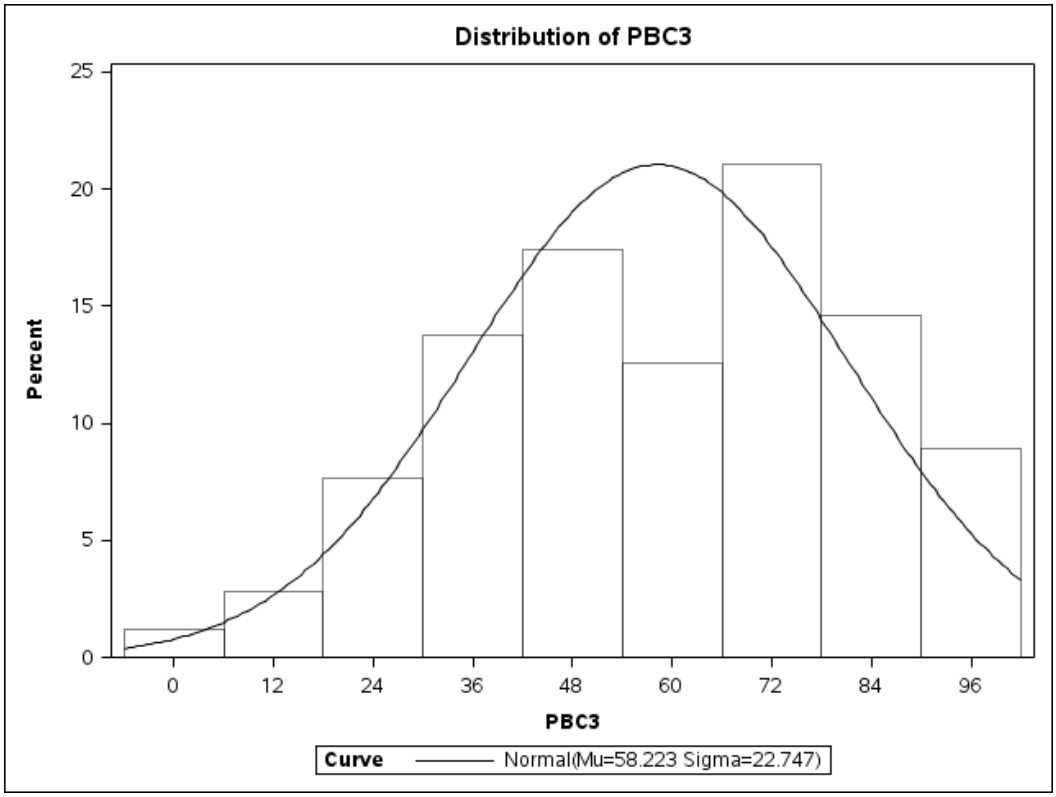


Figure 31. Histogram PBC3

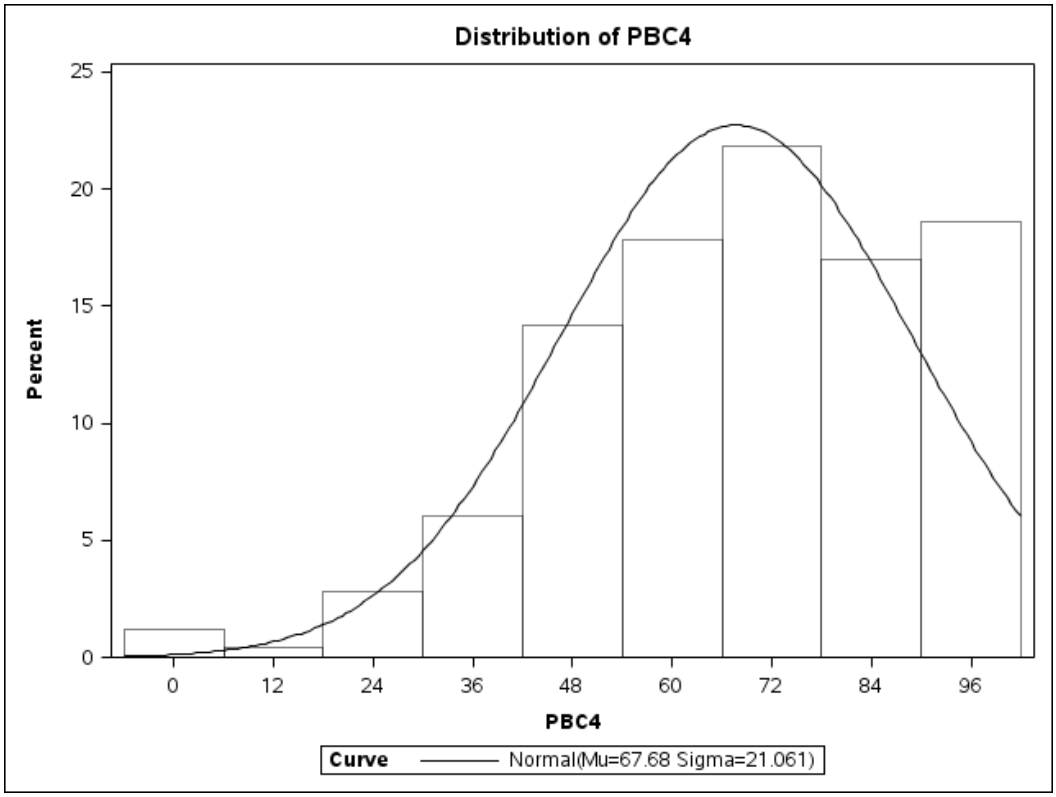


Figure 32. Histogram PBC4

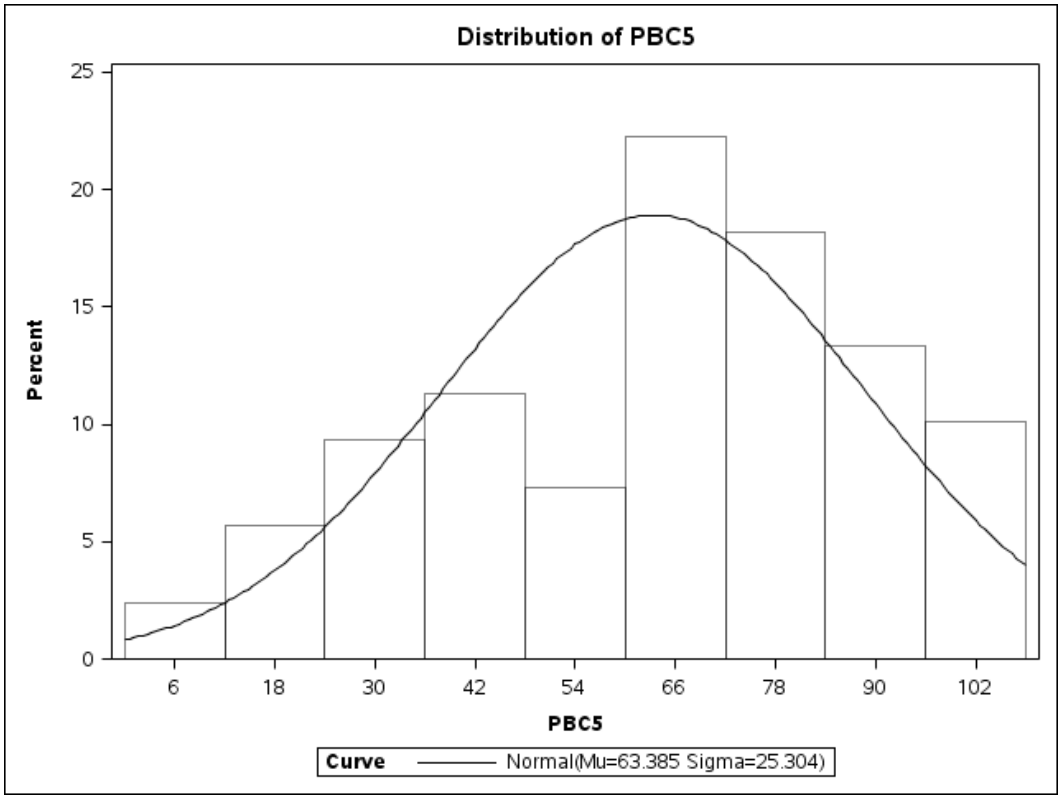


Figure 33. Histogram PBC5

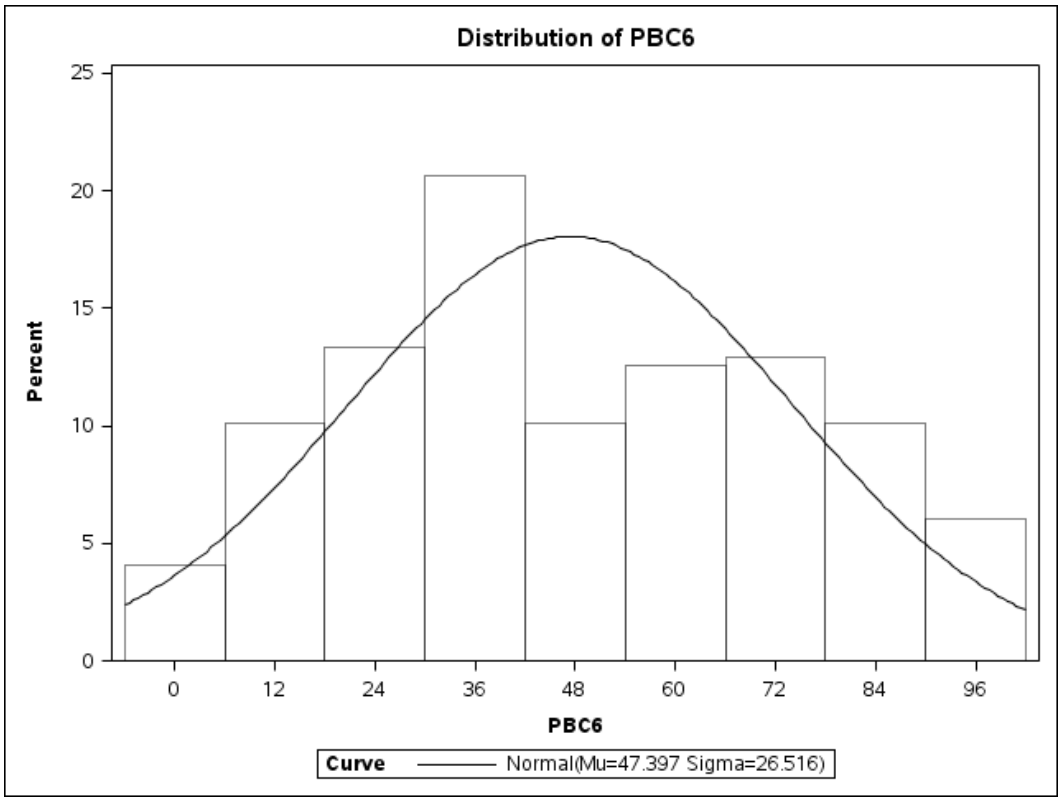


Figure 34. Histogram PBC6

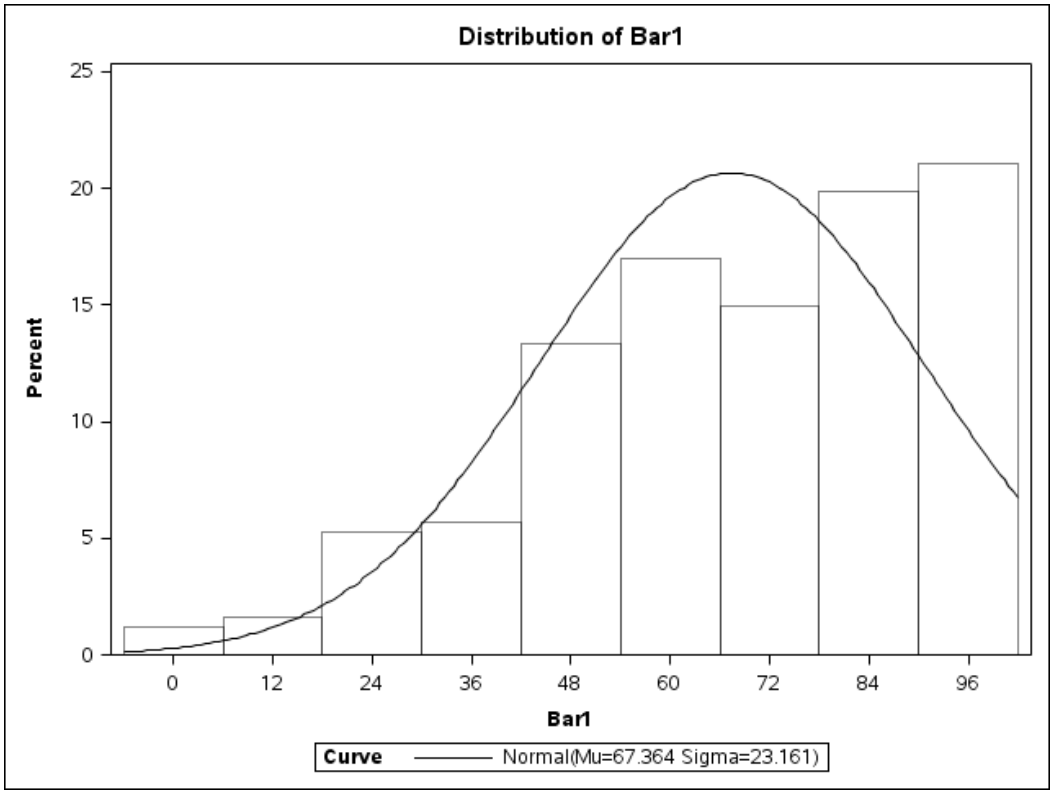


Figure 35. Histogram Barrier1

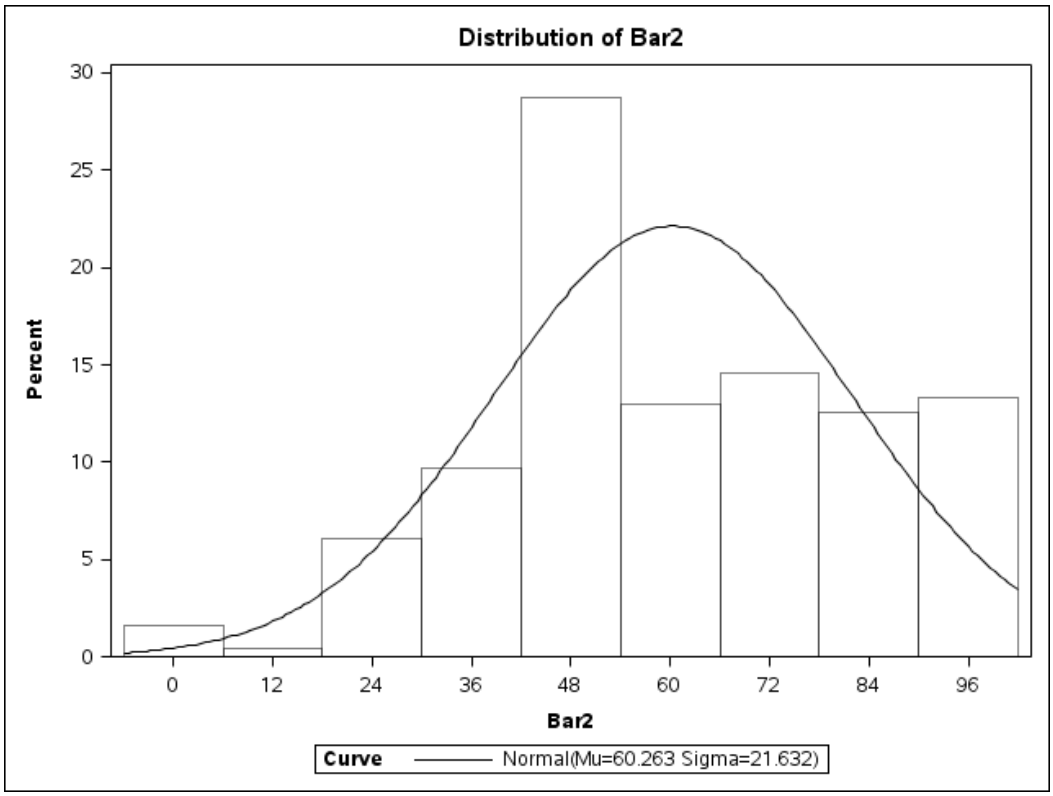


Figure 36. Histogram Barrier2

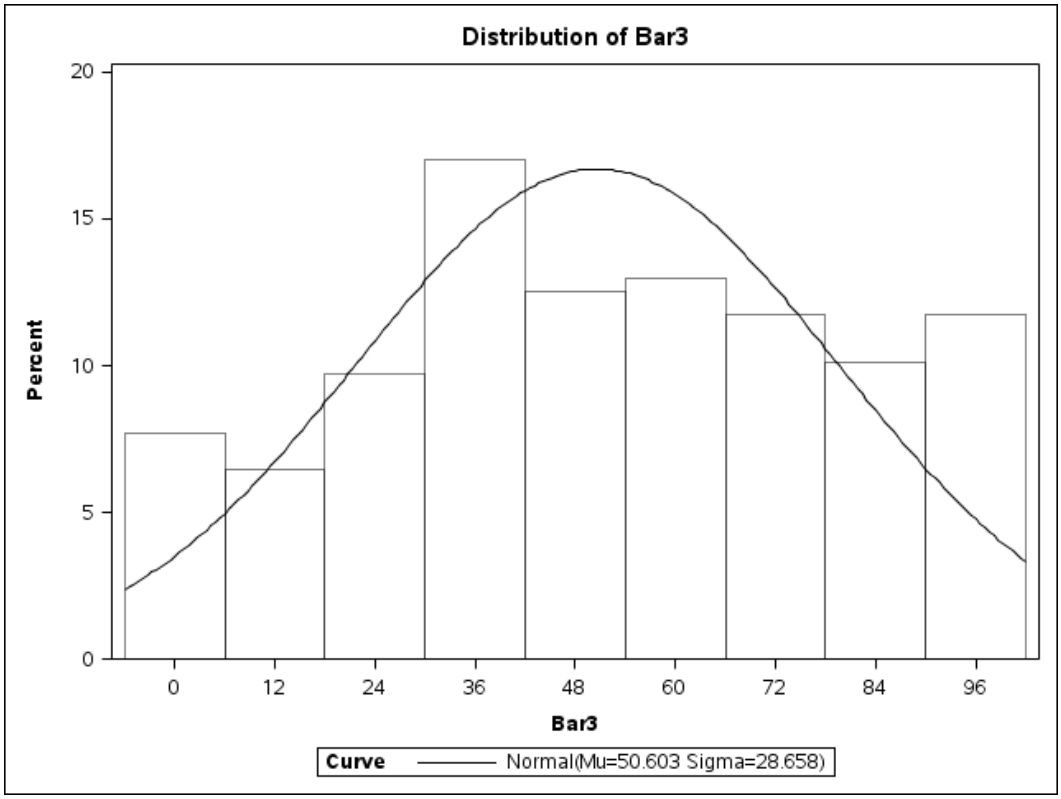


Figure 37. Histogram Barrier3

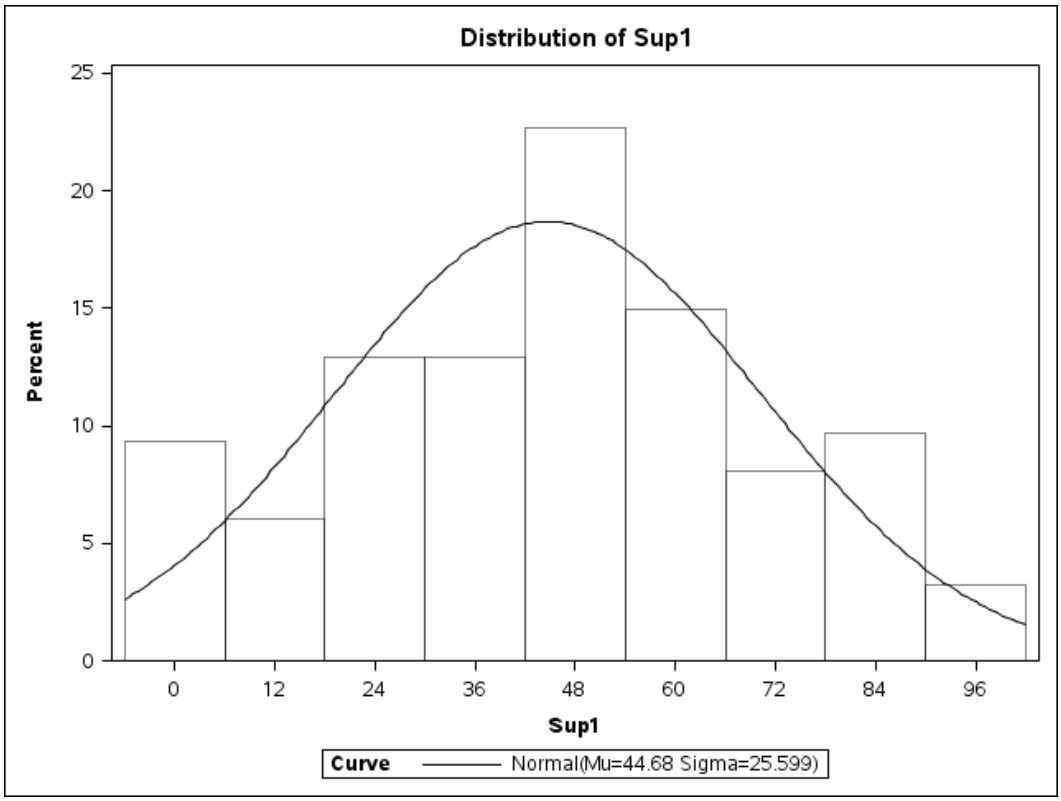


Figure 38. Histogram Support1

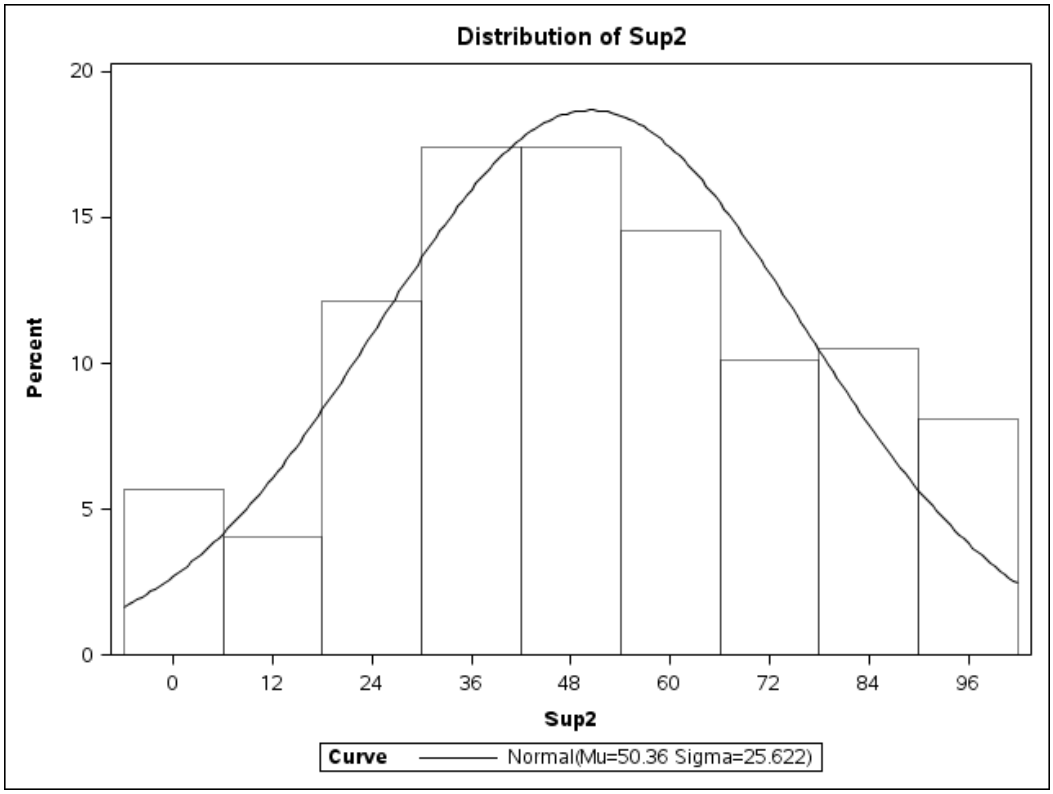


Figure 39. Histogram Support2

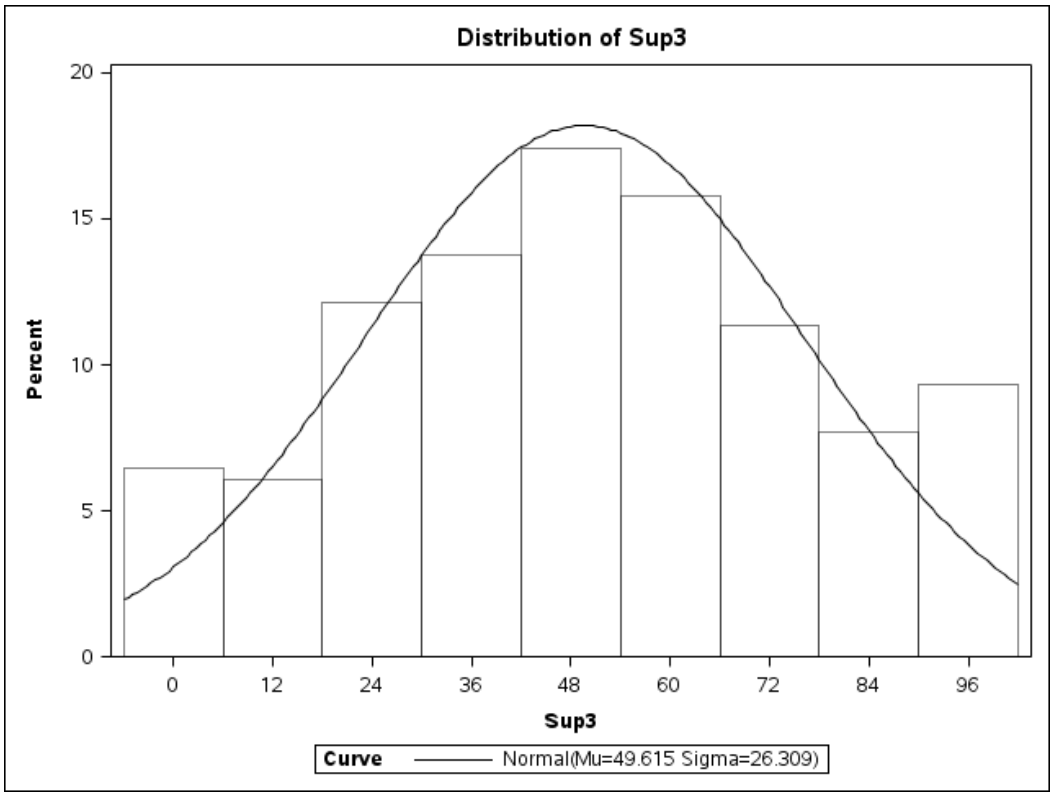


Figure 40. Histogram Support3

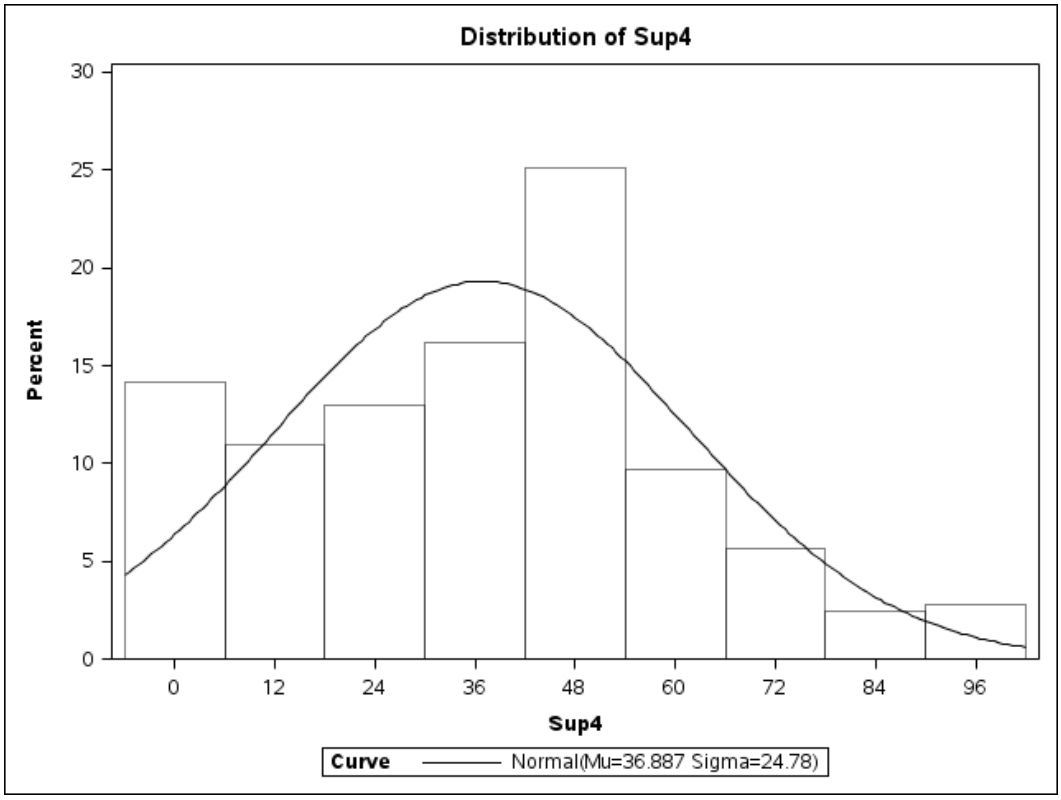


Figure 41. Histogram Support4