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by

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***Developing a Valid and Reliable Measure of Product
Innovativeness for Entrepreneurship Research***

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Dedication

I would like to dedicate this work to my dearly beloved wife and soulmate, Mandakhtsetseg Tsedendamba, who has shown me the true meaning of love and support.

Acknowledgements

As one of the greatest journeys in my life is about to end, I would like to take this opportunity to express my deepest gratitude and appreciation to my supervisors, who have influenced me massively throughout my research and shaped my study in the best possible way.

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Statement of Originality

*This work has not previously been submitted for a degree or diploma in any university. To the best of my knowledge and belief, the thesis "**Developing a Valid and Reliable Measure of Product Innovativeness for Entrepreneurship Research**" contains no material previously published or written by another person except where due reference is made in the thesis itself.*

(Signed)_

Batkhuuag Ganbaatar

Conferences, Poster Presentations and Publications

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- The paper “Developing a Valid and Reliable Measure of Product Innovativeness for Entrepreneurship Research” has been submitted to the *Journal of Small Business Management*, and currently, it is under review.

ABSTRACT

Innovation generates new products and services, introduces new ways of conducting business, and ultimately increases business profits, national income, and consumer wellbeing. Therefore, being innovative is key for any business, because it provides competitive advantages, enables product differentiation, reduces production costs, improves dynamic capabilities, and strengthens absorptive capacities. Moreover, innovation is vital if entrepreneurial new and small firms are to survive and to compete with larger and established firms. Consequently, there is great academic and practical interest in defining and measuring innovation. However, to date, measures of innovation have lacked reliability and consistency across products, across industries, and across time.

In this thesis, a new way of measuring innovativeness through a direct and objective assessment of product innovation is proposed that can be applied to any product in any market. It is especially useful for entrepreneurial new and small firms, because most current measures of product innovativeness have been developed in the context of larger firms and do not apply well to new and small businesses that do not have an explicit R&D department or budget, and few if any patent applications in the early stages of their existence. In any case, firm-level measures tend to focus on antecedent and consequential measures that do not correlate well with innovativeness at the product level, which is of prime importance to entrepreneurs and their investors. Some measures do focus on the product level, but these tend to be subjective (reliant on opinions); may be simplistically categorical (e.g. radical vs. incremental); and may be ordinal (e.g. Likert scales) rather than cardinal objective measures.

To rectify these measurement, reliability, and consistency problems, an authentic measure of product innovativeness is developed that is direct (i.e. measured at the product level); assesses observable innovations in the product (i.e. output driven); objective (i.e.

independent of manager or customer opinion); contemporaneous (i.e. reflective of the specific timing of the innovation) and results in a continuous cardinal measure that can indicate absolute values of product innovativeness.

This new measure ensures validity, as it focuses directly on the product's innovations, and consistency across observations, as it systematically measures observable novel aspects of the product, such that the measure can be verified externally by a third party. For researchers, this new measure will facilitate reliable inter-firm comparisons and enable longitudinal studies of product innovativeness, its causal antecedents, and its consequences. The new measure will also prove useful for entrepreneurs and their investors, as it will provide more reliable and comparative information on the innovativeness of new products relative to others. It is equally applicable to product innovation by larger firms, and in that context could be tested for efficacy against the established measures.

The new measure of product innovativeness integrates multiple gradations of both technical novelty and market novelty using complex algorithms that nonetheless reduce to a simple spreadsheet calculation (or an “app”) that computes the “compound product innovativeness score” effortlessly. Application of the new measure is demonstrated, both cross-sectional and longitudinal studies, in the context of the U.S. smartphone industry.

Keywords: Technical novelty; Market novelty; Product innovation, Product newness; Innovativeness measures;

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ABSTRACT

Innovation generates new products and services, introduces new ways of conducting business, and ultimately increases business profits, national income, and consumer wellbeing. Therefore, being innovative is key for any business, because it provides competitive advantages, enables product differentiation, reduces production costs, improves dynamic capabilities, and strengthens absorptive capacities. Moreover, innovation is vital if entrepreneurial new and small firms are to survive and to compete with larger and established firms. Consequently, there is great academic and practical interest in defining and measuring innovation. However, to date, measures of innovation have lacked reliability and consistency across products, across industries, and across time.

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level); assesses observable innovations in the product (i.e. output driven); highly objective (i.e. independent of manager or customer opinion); contemporaneous (i.e. reflective of the specific timing of the innovation) and results in a continuous cardinal measure that can indicate absolute values of product innovativeness.

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The new measure of product innovativeness integrates multiple gradations of both technical novelty and market novelty using complex algorithms that nonetheless reduce to a simple spreadsheet calculation (or an “app”) that computes the “compound product innovativeness score” effortlessly. Application of the new measure is demonstrated, in both cross-sectional and longitudinal studies, in the context of the U.S. smartphone industry.

Keywords: Technical novelty; Market novelty; Product innovation, Product newness; Innovativeness measures;

CHAPTER 1. INTRODUCTION

Outline of Chapter 1

1.1 Introduction

For the last 60 years, the field of innovation research has grown considerably (Rosenberg, 2009). During this time, the meaning of innovation has evolved with new approaches and new theorising. It is described as the main source of economic prosperity (Schumpeter, 1934), and alternatively, it is represented as the tool through which entrepreneurs exploit the market opportunities (Drucker, 1987). Innovation has been applied at the national level through innovation systems (Lundvall, 2007), and assessed at both firm (Tellis, Prabhu, and Chandy, 2009) and individual levels (Shepherd and DeTienne, 2005).

Current entrepreneurial theories focus on innovation as an essential ingredient to entrepreneurial success. For example, entrepreneurial orientation discusses crucial ingredients that characterise entrepreneurship as proactive, risk-taking, and innovative behaviour (Lumpkin and Dess, 1996). According to this theory, innovation is inherent to entrepreneurship, and thus entrepreneurship generates new innovative products and services, processes and/or business models (e.g., Schumpeter, 1982; Davidsson, 2004; Lumpkin and Dess, 1996).

Moreover, literature (e.g. Kim and Mauborgne, 2005) in entrepreneurship suggests that innovation is the critical solution to survive and thrive in highly competitive global markets. Scholars find that development of product or process innovation is positively correlated with established firms' subsequent business survival (e.g. Cefis and Marsili, 2005, 2006, 2011, 2012; Wagner and Cockburn, 2010). Furthermore, Rosenbusch, Brinckmann, and Bausch (2011) aggregate 42 empirical studies on 21,270 new and small firms in their meta-analysis and find that innovation and firm performance have a positive relationship, which supports empirically that innovation benefits resource-scarce firms. On the other hand, larger organizations are also benefited by innovation, therefore they usually establish Research and Development (R&D) units in their organization, which are specifically responsible for the development of innovation to maintain and improve their competitive advantages. The benefits of R&D have been studied and generally positive relationships have been reported by scholars (e.g. Mansfield, 1980; Griliches, 1986; Penner-Hahn and Shaver, 2005).

However, innovation is a complex phenomenon whose performance effects are directly associated with the degree of novelty of that innovation (Freeman and Soete, 1997; Schumpeter, 1934). Innovative new products can offer a transient competitive advantage that ensures appropriate returns on innovation to companies, including firm

growth and higher sales (Bayus, Erickson, and Jacobson, 2003). This phenomenon is believed to increase with an increase in the degree of innovation (Gatignon and Xuereb, 1997). Because product innovativeness enhances product differentiation relative to its competitors and creates first mover advantages (Lieberman and Montgomery, 1988), the firm may build on these to achieve sustainable competitive advantages and enduring profitability (Barney, 1991). Thus, innovation activities have been assessed as a key driver to ongoing business profitability.

Nevertheless, there have been inconsistencies in the measurement of product innovativeness, which consequently may have led to contradicting results in product innovativeness studies, such as the innovation-profit nexus, the innovation-survival nexus, and the innovation-performance nexus. Thus, in this thesis, various innovativeness measures are examined with a particular focus on product innovation measures. This thesis develops a new measure that has the potential to rectify major deficiencies in the current measures. This new measure is highly objective and direct, and can be applied in various industries and business settings. This new empirical tool offers valuable new insights into how innovation can be measured, and provides further scope for future theorising and research.

1.2 Research Background

Innovation research uses various classifications and types of innovation measures. Becheikh, Landry, and Amara (2006) for example, reviewed innovation studies and classified innovation as product innovation, process innovation, marketing innovation and organisational innovation. These innovation types have their own unique ways of occurring in various industries, therefore it would be an oversimplification if we apply them equally across all contexts. Adding to this complexity are the assessments of the

magnitudes of those innovation types. This study will concentrate on product innovation, which is typically used as a metric that points to the overall innovativeness of the firm. Innovative new products are usually the ultimate reflection and objective indication of the firm's innovation efforts.

How has the degree of innovativeness been determined? The answer depends on what innovation is being evaluated and who created it. For corporations and conventional business organizations, the main indicators that have been used to measure innovativeness in the literature are numbers of patents and citations, R&D budgets, sales of innovative products and other variables (see e.g. Mansfield, 1980; Hall, Hausman, and Griliches, 1986; Jensen, 1987; Bogner and Bansal, 2007; Encaoua, Guellec, and Martínez, 2006; Mann and Sager, 2007; Collewaert and Sapienza, 2016). On the other hand, in entrepreneurial cases, to date, scholars usually have tackled the issue by performing self-reported questionnaires and semi-structured interviews, in which Likert scales have been used to measure the innovation intensity of entrepreneurs (Cooper, 1979; Lawton and Parasuraman, 1980; Kleinschmidt and Cooper, 1991; Freel, 1999; Baron and Tang, 2011; Kollmann and Stöckmann, 2014; Collewaert and Sapienza, 2016). Entrepreneurs, SMEs and start-ups usually do not have explicit R&D budgets, nor enough time or expert teams who only focus on innovations and as a result there is a need to use alternative metrics to more effectively measure innovativeness. Entrepreneurs, SMEs, and start-ups often experience resource constraints (Fisher, 2012) and this has made it even more complicated to measure their innovativeness by current innovation measurements (see Appendix: Table 1 to 5). Consequently, Cozza, Malerba, Mancusi, Perani, and Vezzulli, (2012) note that the reason scholars often use the Community Innovation Survey when they study innovativeness is that it specifically provides a representative sample of small and new firms, which is frequently under-represented or even totally ruled out from the

investigation when other indicators for innovativeness, such as R&D expenditures and patents, are adopted. This highlights the essential need to develop a measure that can reflect the magnitude of innovativeness accurately especially among entrepreneurial new and small firms in practice and for academic research.

1.3 Problem Statement

Entrepreneurship is a process by which individuals and firms convert technical information into new products and services (Shane and Venkataraman, 2000). According to Luecke and Katz (2003, p.2), innovation can generally be understood as the introduction of a new process or thing. Innovation is the synthesis, combination, or embodiment of understanding in unique, appropriate, treasured new services, processes, or products. It can be deduced from these definitions that innovation requires the invention and execution of new knowledge and ideas culminating in new products (including both goods and services) or processes. In the review of a particular company's innovativeness, it is important to examine if the firm adopts innovations, and the extent of uniqueness of such innovations (Bower and Christensen, 1995; Galende and De la Fuente, 2003; Göktan and Miles, 2011; Chang, Hughes, and Hotho, 2011).

Product innovation measures can be objective measures (e.g. R&D budgets, patents, citations, numbers of employees in product development projects, and numbers of new products) and perceived (or subjective) measures (e.g. managers and customers' subjective evaluations on product innovation, assessments of tendency and behaviour toward innovation, and experts' opinions) in terms of origin of the measurement. However, although these types of measures may reveal valuable insights into product innovativeness, they are vulnerable to issues that threaten consistency and validity of the

measures, and as a result the reliability of the measures are questioned. An example of this case is specifically discussed in Chapter 4.

Scholars have developed and utilised innovativeness measures at the firm-level and at the product-level. At the firm-level, there are three main approaches have been discussed that measure product innovation in the literature, which are input, process, and output measurements. They are all indirect (proxy) measures and can be formed from subjective and objective sources. The main issue with the firm-level measurements is a validity issue because these measures do not directly focus on products themselves. Instead, they assess factors that lead to, or are the result of, product innovation. Consequently, it raises a concern whether they really measure what they intend to measure (e.g. validity issue). On the other hand, the product-level measurements previously used are basically perceptual measurements (see Appendix: Table 1 to 5), which utilise surveys and interviews with managers and customers to determine the magnitude of product innovativeness using Likert scales, which raise concerns of reliability, validity, and inconsistency (e.g. Calantone et al., 2006; McNally et al., 2010; Edison, Bin Ali, and Torkar, 2013). The self-reporting questions are usually individual opinions and personal judgements, which are usually affected by biases such as social desirability (Grimm, 2010). Moreover, the product-level innovation measures often use ordinal measures that only indicate positions of innovativeness, which are a refinement of categorical measures yet cannot determine an absolute value of innovativeness. The idiosyncratic nature of such measures means that it is difficult to compare measures reliably as it is influenced by individual perceptions. Because the differences between the ordinal measure's scale values are unknown (Allen and Seaman, 2007), they may be problematic when aggregated, averaged, and compared absolutely. Furthermore, to determine product innovativeness, Oslo Manual (2005) and Community Innovation

Survey (2014) are commonly used, in which participants asked to report on their last three and two year's innovativeness, respectively, but such data is likely to be affected by retrospective and selective memory biases (Pearson and Ross, 1992). However, some scholars use ex-ante measures (e.g. Hyytinen, Pajarinen, and Rouvinen, 2015) that focus on future innovativeness (to avoid ex-post indicators). These however, also are more likely to be biased toward innovations that are more likely to be successful (Buddelmeyer, Jensen, and Webster, 2009). Nevertheless, these ex-ante and ex-post measures do not accurately determine present innovativeness, which is likely to yield more reliable results. Thus, it is hard to accept them as accurate indications of innovativeness. It gets even more complicated in entrepreneurship studies (i.e. cases of small and new ventures) as previously discussed. Adopting firm-level measures are not suitable for entrepreneurship research as these measures are originally designed for larger and conventional organisations, so that they tend to cause validity issues (e.g. Deeds, 2001; Greve, 2003; Parthasarthy and Hammond, 2002).

These challenges with existing measures of innovation constitute an important issue. Firstly, inaccurate product innovation measures could result in false predictions, tests, and inaccurately test theories involving product innovation. This may better explain inconsistent results in innovation-related studies relating to the innovation-profitability, innovation-performance, and innovation-survival nexi (e.g. Geroski, Machin, and Van Reenen, 1993; Roberts, 1999; Cefis and Ciccarelli, 2005; Leiponen, 2000; Coad and Rao, 2008; Buddelmeyer et al., 2009; Boyer and Blazy, 2013). Therefore, research instrument refinements in innovation are essential to capture fully the essence of the phenomenon (Szymanski, Kroff, and Troy, 2007). Secondly, especially in entrepreneurship studies it is critical to develop a measure that is specifically designed for that context, by considering the uniqueness of entrepreneurial new and small ventures, rather than trying

to adopt specific measures that lack compatibility. The entrepreneur's ability to introduce a new innovative product and to identify such potential is of concern not only to the entrepreneur, it is equally important to investors and lenders. In addition, extending current measures to create a more reliable form of innovation measures is crucial for entrepreneurship scholars to enable comparison in results.

This thesis will rectify the lack of a reliable measure of product innovativeness by developing an authentic measure that is (i) direct (i.e. measured at the product level); (ii) assesses observable innovations in the product (i.e. output driven); (iii) highly objective (i.e. independent of management opinion); (iv) contemporaneousness (i.e. indicates the specific time of every measurement) and (v) results in a continuous cardinal measure that can indicate absolute values of product innovativeness. It will be a baseline model of product innovativeness measurement that is capable of being utilised in any business in any industry.

1.4 Research Question and Sub-Questions

The broad aim of the research is to develop a non-proxy measurement for product innovativeness. Consequently, this research's contribution to the theory is to fill the gaps by proposing a direct measurement system that assesses product innovation more objectively and consistently at specific times (i.e. contemporaneously) independent of any assessor's subjectivity. Moreover, unlike subjective measures, the new measurement can be verified externally; thus, it can facilitate a universal consensus on the measurement. Based on the literature review, the identified gaps, and research aim, the broad research question is defined as the following:

'How can a highly objective and direct product innovativeness measure be developed, that is both valid and reliable?'

Therefore, this research will explore the possibilities to create a new measurement for product innovativeness to answer this research question. After developing the new measurement, it will be applied in the smartphone industry in the USA market context to answer the following sub-questions through empirical studies.

1. How innovative have been the products in the U.S. smartphone industry over the past decade?
2. Which firm has typically been the leader/follower in product innovation in the smartphone industry in the US market during the period?
3. Is there any empirical relationship between highly objective product innovativeness and stock price in the Apple Inc. case?

The sub-questions will be answered in Chapter 6 and Chapter 7 by formulating specific research hypothesis and testing them in the empirical case through dynamic analysis and the event study.

1.5 Context of the Study

After the theoretical development of the new measurement, an empirical study will be conducted in the context of the smartphone industry in the US market. This particular context has been chosen for several reasons. First, the smartphone industry in the US market was selected because a large number of innovations are released in this product category. This provides more data to ensure that the measure can capture the ways product innovation evolves over time. Secondly, there is assessable and reliable information regarding product innovation in the smartphone industry. It is easier to generate information over time regarding smartphone innovativeness as all the required data is available publicly. Lastly, for the event study, the author intends to investigate the relationship between Apple's smartphone innovativeness and the company's stock price,

and the US market has a larger share of total sales than any other market in the world (Apple Inc., 2016), and thus dominates the way in which the company's stock prices are determined.

1.6 Research Approach

It is appropriate to approach the problem in a positivist way when the research aim is to develop an objective and cardinal measurement of innovativeness (Creswell, 1996). Positivism can ensure objectivity of the measurement by limiting the subjectivity of the researcher or observer; it values the ability to produce replicable and consistent findings based on external physical evidence; and it prefers quantitative expressions of a phenomenon. Due to the specific aim of the research, it requires a very particular way of conducting the study, applying objective scale development methodology. It consists of specific and sequential steps that ensure the development of a reliable and valid measurement. The product innovativeness concept will be defined firstly, followed by dimensions that are used to determine innovativeness objectively along with sub-criteria in the dimensions. The next step is to build a measurement model based on dimensions and properties of the measurement that reflect logical ways to assess novelties in the product. Finally, the measurement will be used in empirical studies.

The unit of analysis for this research is a product, because the research aim is to develop a direct measurement that is solely focused on products, and an objective measurement that assesses novel elements embedded in products. A sampling frame of the research will consist of the following companies' products during 2008-2017: Apple, Samsung, HTC, Motorola, LG, Sony, OPPO, vivo, Huawei, ZTE, Blackberry, Microsoft Mobile, Google Pixel and Nokia. To collect data, the author will utilise the observation method. Observational techniques are methods by which an individual gathers firsthand

data on programs, processes, or behaviours being studied (Fetterman, 1989). In this case, products will be observed, and information related to their innovativeness will be recorded through a certain procedure. The observational method ensures the collection of information (numbers of new elements) about a product's innovativeness without either internal or external influence. The observational approach allows the evaluator to learn about issues the participants or staff may be unaware of or that they are unwilling or unable to discuss candidly in an interview or focus group (Patton, 1999).

There are two main types of data in research: quantitative and qualitative. If the information is in numerical form, it is quantitative, and otherwise, it is qualitative. This research will be using quantitative data regarding numbers of novel elements in products, which eventually facilitate the overall indication of product innovativeness. Data gathering is crucial in research, as the data is meant to contribute to a better understanding of a theoretical framework (Bernard, 2002). Data will be collected through Purposive Sampling, a type of non-probability sampling to make sure all information regarding the products is reliable (Creswell, 1996). In this study, panel data (also known as a set of longitudinal and cross-sectional data) will be used. Panel data contain observations of multiple phenomena obtained over multiple time periods for the same firms or individuals. In this research, columns represent products of the companies and rows represents times when the products were launched in the market. Therefore, it can be up to 9 (years) x 13 (products) table, which will result in a total number of 117 samples for the dynamic analysis of product innovativeness and the event study.

1.7 The significance and Implications of the Study

Developing a highly objective measurement for product innovation can be significant for both academic research and business practices as it enables more detailed and reliable

assessments on product innovations, which will be useful for both researchers and managers. For example:

- It can be a measure that is reliable, yet simple to use for academic research. The measure does not require any sensitive financial or organizational information as it is based on publicly available and verifiable data. Moreover, the measure is universally applicable, therefore it enables the possibility to conduct inter-industry (comparing different industries) and cross-industry studies without favouring specific firms, which was not possible in previous measurements. Furthermore, it can generate product innovativeness data over time, consequently, it gives an opportunity to conduct longitudinal studies in product innovation. Finally, the objective innovativeness measurement of product innovation can be utilised as independent and dependent variables in other business studies.

- For investors, business angels, and venture capitalists, it has always been vital to be aware of and determine businesses that can offer more innovative products, because it gives a chance to avoid market competition and to attract customers through product differentiation (Sood and Tellis, 2008). Due to today's dynamic technological and business environment, being innovative and staying as innovative as possible leads to competitive advantages in modern business. Moreover, investors, business angels, and venture capitalists tend to prefer end-results (actual new products) rather than the performance of antecedent activities (such as how companies prioritise innovation in their strategic plans or how many patents they hold). This is particularly the case for entrepreneurship, as investors are more interested in entrepreneurs' innovative products, and services. Therefore, the product innovation measurement, which is direct and objective, can provide valuable information regarding businesses.

- For entrepreneurs and managers, the novel innovation measurement will assist in more accurate decision-making with respect to their advancement on innovation and direction of product development, which may fuel firm growth and performance. The objective innovativeness measure demonstrates exactly which type of novelties occur and at different levels of analysis (firm, market, the world), and when this occurs. Based on the analysis, firms can allocate their resources more efficiently by focusing on the particular type of technical novelties of their products and develop innovative advantages over their competitors' products. Also, the measurement helps to understand and recognise market situations in terms of product innovativeness. Managers can evaluate products in the current markets and can depict the current positioning of competing products in their markets and to determine where their new products are located relative to other firm's products.

- Finally, for governments, the innovation measurement can be useful to identify more innovative businesses that are likely to generate greater economic and social potential domestically and globally, so that these businesses can be supported. The Australian Government needs to promote entrepreneurial activities with promising innovative capacities as a long-term alternative for the mining industry, which is highly dependent on world economy and political factors, as well as being not environmentally sustainable. Thus the innovativeness measure can have considerable significance in policy-making as well.

1.8 Definitions of Key Terms

To facilitate better understanding of the research, the author provides definitions of key terms that are mentioned in the study in Table 1.

Table 1. Definitions of terminologies

Key terms	Definition
Entrepreneurship	Entrepreneurship is a nexus of two phenomena: the presence of lucrative opportunities and the presence of enterprising individuals (Shane and Venkataraman, 2000).
Innovation	Innovation refers to the process of establishing any new idea, which serves to resolve a problem (Kanter, 1983).
Product innovation	A product innovation is the introduction of a good or service that is new or has significantly improved characteristics or intended uses (Mortensen and Bloch, 2005).
Innovativeness	A measure of the degree of newness of innovation (Garcia and Calantone, 2002).
Novelty	Novelty refers to the extent to which a concept, idea, or object differs from conventional practice within the domain of interest (Sethi, Smith, and Park, 2001).
Technical novelty	A form of newness in a technology of a new product or service (Song and Montoya-Weiss, 1998).
Market novelty	Type of newness that depends on market perspectives such as new to the firm, new to the market, and new to the world (Garcia and Calantone, 2002).
Contemporaneous measure	A measure should be recorded as it was observed, and at the time it was executed (Stevenson, 2010).
Cardinality	The term cardinality refers to the number of cardinal (basic) members in a set (Clapham and Nicholson, 2009).
Highly objective measure	The new measure assesses product innovativeness based on the new features (i.e. style changes, function improvements and additions) that are embedded in the product. Therefore, it measures product innovativeness more objectively than the measures that focus on subjective evaluations of managers and customers. Hence, it is defined as a highly objective measure.

1.9 The Structure of the Thesis (roadmap)

This thesis adopts the structure suggested by Perry (1998), and consists of eight chapters with figures, tables, equations, and references that follow the American Psychological Association (2010) format. Following are brief summaries of the chapters.

Chapter 1. Introduction. In this chapter, the current research background of product innovation measurements, existing problems and gaps in the literature of product innovation measurements, the overall research aim and research questions to fill the gaps, research methodology that has been utilised in the study, significances and implications of the study, and definitions of terminologies in the thesis are summarized.

Chapter 2. Literature review. The author discusses various measurements that have been proposed and utilised in the literature. Two main types of product innovation measures are studied in this chapter, namely the firm-level measurements and the product-level measurements. Moreover, issues that are caused by the current measures and how the commonly used measures are not compatible to be applied in entrepreneurship studies are explained, consequently properties of the new measure that ensures the reliability of the measurement are defined.

Chapter 3. Methodology. This chapter discusses research methodology aspects of the study such as research paradigm, research approach, research methodology, and research methods. It starts with a discussion of ontology and epistemology of the research by examining possible research paradigms that could complement the overall aim and objectives of our research. Then, the ‘scale development’ methodology is explained with a focus on the formative measurement development. In addition, it explains the context and the time frame of the study. Next, the chapter also explains the sampling frame, sampling criteria, and sample size in detail. Finally, the chapter discusses other methods to conduct the longitudinal analysis through utilising the new measurement results.

Chapter 4. In this chapter, the design and propositions of the measurement model are discussed. It explores both reflective and formative measurement model designs. In addition, desired properties of the model are discussed, in which six properties are argued in detail. Moreover, constructs of the technical and market novelty dimensions are described individually and their relationships are considered through a series of propositions, which are essential for the working of the measurement.

Chapter 5. Development of the model. In this chapter, the new measurement model that is designed to capture innovativeness in a product objectively will be developed. The author explains in detail the building blocks of the model; how the model assesses product innovativeness; how it generates measurement results as cardinal numbers. It involves mathematical equations of the model and graphic illustrations of the measurement. Finally, it discusses how to understand and interpret possible results of the measure and meanings of outputs.

Chapter 6. Empirical study of product innovativeness in the US smartphone industry. In this chapter, the results of the empirical study of smartphone industry in the US from 2008 to 2017 are reported in an unprecedented way of analysing the dynamics of an industry that is well known for its product innovation. The dynamic analysis shows which products are dynamically more innovative than others, which firms are leaders and which are followers, what type of novelties are most common in the smartphone, and so forth. This chapter reveals product innovation advancement of two leading products in the US market.

Chapter 7. Longitudinal analysis of the Compound Product Innovation Score (CPIS). One of the classic ways to validate a new measure is to use it to explain another phenomenon that is considered to be highly related to the measured variable. Therefore, in this chapter, a longitudinal analysis is performed using the newly developed CPIS

measures as an independent variable. A model that is analysed in this longitudinal study is $P_t^{stock} = f(CPIS_t^{iPhone}; CPIS_{t-1}^{iPhone})$. That is, the model examines a relationship between stock prices of Apple Inc. and innovativeness of their iPhone products, in which lagging and leading effects will be examined as well.

Chapter 8. Discussion. This chapter discusses the research results including the empirical studies, limitations of the model, and future developments and implementations of the measure.

1.10 Conclusion

This chapter starts with the introduction and discusses the research background of product innovation measurements, existing problems and gaps in the literature of product innovation measurements, the overall research aim and research questions to fill the gaps, the brief introduction of research methodology that has been utilised in the study, significances and implications of the study, definitions of terminologies in the thesis, and lastly, a roadmap of the thesis.

CHAPTER 2. LITERATURE REVIEW

Outline of the Chapter 2

2.1 Introduction

This chapter presents an extended literature review on innovation and innovation measurement, with a focus on product innovation measurement, and its operationalisation in the literature. As a result of this focus, product innovation measures are assessed, highlighting challenges around reliability and effectiveness. It suggests scope for further work in applying and extending product innovation measures in entrepreneurial new and small firms. Research questions are then defined to address the omissions in the current literature and measures. The chapter is divided into seven sections. Following this introduction, Section 2.2 discusses the importance and significance of innovation and entrepreneurship in the modern businesses and economies, and how innovation is intrinsic to entrepreneurship. Section 2.3 focuses on general measurement of innovation, what types of measurement have been studied to evaluate innovation intensity, and how

scholars measure those different types of innovation. Section 2.4 has two sub-sections: Section 2.4.1 focuses on measurements that assess product innovativeness at the firm-level, while Section 2.4.2 examines prior and current product-level measures. Subsequently, issues that are related to the firm-level and the product-level measurements are discussed in Section 2.5, and these serve as a foundation to formulate the research questions outlined in section 2.6. The chapter concludes with Section 2.7 that summarizes the chapter.

2.2 Innovation and Entrepreneurship

One of the enduring topics researched in business, economics and technology is innovation (Rosenberg, 2009). It was shown by a linear concept of innovation as a unidirectional sequence from science to technology to commerce to market (Godin, 2006).

Figure 1. A classic linear model of innovation

However, today, according to Rosenberg, all things are interlinked. Society, economy, technology and science are self-driving composite systems in which innovation is not only endogenous in every entity but also the result of the interface among them.

Figure 2. A modern model of innovation

Having been introduced as a construct more than eight decades ago Schumpeter (1934), the significance of innovation grows by day and it is broadly recognised as an unavoidable

component of the modern world's success. At a micro-level, innovation generates the growth of new products and services, introduces new ways of doing things, creates new markets and gives ventures competitive advantages (Porter, 1998). Schumpeter (1934) established the earliest definition of innovation by stating that innovation is what can be referred to in a non-scientific way as "economic progress." This, in essence, means the application of creative resources in manners not practically proven yet, and the withdrawal of the applications they have had before. Drucker (1987) pointed out, from a market-oriented point of view, that innovation is an instrument by which inventive entrepreneurs take advantage of the adjustment as an opportunity for a new market. On the other hand, Kanter (1983) asserts that innovation is the process of setting up new ideas, which are useful in resolving a problem. A general meaning of innovation is stated by the UK Department of Trade and Industry's (DTI, 1998) as the successful implementation of new ideas. However, it would be considered a one-sided definition if innovation refers only to successful innovation since many innovations are not successful in the marketplace.

Innovation and Economic Growth (Macro Level Impacts)

Schumpeter (1942) argued that innovation and its impacts on industrial revolution have been essential factors to economic growth. Therefore, scholars (Romer, 1986, 1990; Nelson, 1993; Stokey, 1995; Freeman and Soete, 1997) study innovation and its influence on important factors of macroeconomics such as economic growth, and their results verify and support empirically that innovation is one of the crucial factors that fuels the long-term economic growth, yet the variation of economic policies and structures directly influence how innovative processes can be converted into diverse rates of growth (Grossman and Helpman, 1994). Consequently, policy makers specifically focus on developing and nurturing innovation in their areas in order to get benefits from

technological advancement that may lead to improved efficiency, cost reduction, new products and new markets, and one such example is the European Union Innovation Policy (2006). Thus, innovation plays a significant role in the prosperity of modern nations.

Innovation as a Process/Outcome (Micro Level)

At the micro level, it is in their best interest for firms to innovate because innovation creates new products and services, new ways of doing things (i.e. process), or even a new way of marketing (e.g. online) can make market entry for new firms and competition in the market for existing firms relatively easier. Because innovation enhances a product differentiation that leads to advantages in market competition (Porter, 1980) and cost efficiency (Cohen and Klepper, 1996a, 1996b), as a result it will create competitive advantages. Firms pay special attention to innovation by establishing specific units or departments (i.e. R&D departments) that are designed to develop and create innovation to facilitate firms' long-term competitive advantages, in which they usually employ specialist experts and invest substantial amounts of money (Griliches and Mairesse, 1984). This type of model has been applied across different industries and businesses, and its effectiveness has been a subject of many research, where scholars (e.g. Sterlacchini, 1989; Hall and Bagchi-Sen, 2002; Hatzikian, 2015) report positive relationships between R&D activities and business performances.

Innovation is one way entrepreneurial ventures create value to survive and grow. One might say it needs to be “in their DNA”. Entrepreneurial ventures exploit market opportunities through innovation, most of which are risky, yet they prefer to be proactive and go for it (Davidsson, 2004). The largest database of scholarly materials, Google Scholar, produces 1,350,000 results by using ‘entrepreneurship’ as a keyword, 70% of these are associated with innovation when it is introduced as a subject in a joint search.

Entrepreneurship and innovation regularly appear to be essential and integrated components in developing growth and industrial rejuvenation in the society (Braunerhjelm et al, 2009), and the two constructs are commonly used jointly in the designation of forums, research papers and academic courses. Innovation is a frequently studied concept in entrepreneurship. The most prominent of those are innovation-entrepreneurial new venture survival nexus, in which scholars discuss and test correlations of the concepts (e.g. Audretsch and Mahmood, 1995; Cefis and Marsili, 2005, 2006, 2011, 2012; Boyer and Blazy, 2013); the innovation-profitability/performance nexus, where some studies confirm the general positive relationship between innovation and profitability (e.g. Geroski et al., 1993; Roberts, 1999; Cefis and Ciccarelli, 2005), while others find ambiguous or negative relationships (e.g. for product innovation: Leiponen, 2000; Coad and Rao, 2008). Moreover, innovation-longevity studies examine consistent innovation's impact on a firm's achievement of long-term sustainability and viability (e.g. Taneja, Pryor, and Hayek, 2016).

To study the effect of innovation in the entrepreneurial context, it is paramount to understand and apply appropriate measures that can represent all activities that are related to innovation. Therefore, in the following sections, measurements of innovation and associated issues are discussed in detail.

2.3 Innovation Measurement

To understand previous product innovation measurements and identify possible gaps in innovation measurement studies, the following two objectives have been set in this literature review. The objectives are (i) to study how product innovation has been approached and assessed by scholars, and (ii) to analyse what constructs and criteria have

been utilised in the measurement frameworks. Research papers that focus on innovation measurement, specifically product innovativeness, were studied regardless of whether they were empirical studies or conceptual frameworks. When selecting the articles, the focus was mainly on papers that published in peer-reviewed and high-impact academic journals (i.e. A*, A, and B ranked) in innovation and entrepreneurship, while excluding other sources (i.e. the internet, dissertations, and most books). According to McKinsey Global Survey (2010), more than 70% of corporate leaders tout innovation as a 'Top Three business priority, yet only 22% set their version of innovation metrics. It gets even vaguer in entrepreneurship, where innovation plays a significant part in firm survival, yet the existing novelty measures are various and fractured. If we cannot effectively measure the phenomenon of innovation, it will be hard to facilitate, monitor, and evaluate it. Therefore, measuring innovation is as critical as innovation itself for both academic research and for business practice.

Innovation is a comprehensive concept, which can be conceived in various ways. Scholars' efforts to determine what really constitutes the term of innovation have resulted in vastly varying conceptualisations. Four types of innovations were introduced by Mortensen and Bloch (2005) in their OECD Oslo Manual (2005), which is the key global foundation of guidelines not only for assessing and defining innovation processes, but also for collection and application of relevant data. It has been adopted as the primary reference resource for describing, identifying and classifying innovations at the company level (Gunday, Ulusoy, Kilic, and Alpan, 2011), namely product, process, marketing, and organisational innovation. Depending on the types, innovation measurements are generally diverse in their approach as to what and how they capture as indications of innovativeness. The idea of technological development is directly linked to the process and product innovations. A product innovation is the introduction of a good or service

that is significantly improved or new in relation to its qualities or anticipated uses, comprising user friendliness, integrated software, components and materials, considerable improvements in technical requirements or other functional properties (OECD Oslo Manual, 2005).

Product innovation entails putting into practice the new technologies and skills, or can be influenced by new applications or both of existing technologies and skills. The word product refers to both services and goods. Product innovation is a complex practice impelled by growing global competition, shrinking product life cycles, evolving customer needs and progressive technologies. To ensure financial success, there must be a strong contact between divisions within the company and also between the company and its suppliers and customers (Akova, Ulusoy, Payzın, and Kaylan, 1998).

Process innovation refers to the achievement of significantly improved or a new production or organisational structure or delivery. This involves tremendous improvements in software, equipment and techniques. The focus of process innovations is to reduce costs of production or delivery, to boost quality, and to produce and deliver notably improved or new products (OECD Oslo Manual, 2005). As stressed by Fagerberg, Mowery, and Nelson (2004), process innovation often exhibits mixed results owing to its cost-cutting nature, although the invention of new products is frequently believed to have a comprehensible, positive impact on the increase in employment and income.

Marketing innovation implies the adoption of a new marketing technique such as major modifications in product pricing, product promotion, product placement, packaging or product design (OECD Oslo Manual, 2005). Marketing innovations aspire to better address customer needs, launch new markets, or re-position the corporate's product on the market so as to increase corporate sales. It is also closely related to promotion

activities, product placement, product package and design properties, and pricing strategies, which constitute the four P's of marketing (Kotler, 1991).

Lastly, an organisational innovation is the realization of an innovative organisational method in the firm's external relations, or internal workplace set up or operational system. Organisational innovations are capable of increasing firm performance by cutting transaction and administrative costs, enhancing work-place contentment (and therefore labour efficiency), accessing non-tradable items (for instance non-codified external skills) or condensing the costs of supplies (OECD Oslo Manual, 2005).

Therefore, depending on what type of innovation is being measured, the constructs, criteria, characteristics and focuses are inevitably different from each other. This requires scholars to look for different ways to evaluate innovations in relation to these contexts.

Several literatures have discussed the idea of innovation, its meanings and associated contradictions. Over the recent years, considerable advances have emerged regarding the measurement of innovation even though there is no specific agreement. Such instances include Adams et al. (2006), whose presentation concentrates on the depiction of a holistic outline covering significant factors throughout the years of innovation quantification. Crossan and Apaydin (2010) also performed profound research on innovation, strengthening primary theories related to innovation and academic approaches. The empirical studies of Edison et al., (2013) describe a particular (though scalable) industry guideline, while Nilsson, Hillman, and Magnusson (2012) and Jensen and Webster (2009) describe the assessment of dichotomies and conventional practices.

Crossan and Apaydin (2010) conducted a systematic analysis of peer-reviewed papers published in academic journals between 1981 and 2008. In the analysis, a

methodical review of 367 highly-cited works (at least 5 citations per annum with 2009 as reference year) were arranged according to levels (multilevel, macro, organization, individual), after that they considered fundamental theories on innovation, its standards and concepts that can be viewed comprising the latest developments on innovation measurement. Based on their findings, most of the innovation measurement papers relate to multi-level, macro, and organisation level. This reveals a lack of innovation measurement at the micro level, especially measurements that are focused on product innovation.

Additionally, those authors amalgamate a range of research standpoints into a complete multi-dimensional structure of organisational innovation, connecting innovation and leadership as a process, and innovation as a product. They also propose actions to determine organisational innovation, and describe repercussions for both managerial practice and research. Upon the review of various elements of innovation in books, they classified the dimensions into two major categories, these being those relating to innovation as a process and those pertaining to innovation as a product.

As no perfect theory or model exists to deal with innovation measurement, researchers have opted to come up with specific frameworks representing the actual focus areas under investigation. Among the approaches developed by Adams et al. (2006), work was based on analysis of six innovation studies (Cooper and Kleinschmidt, 1995; Chiesa, Coughlan, and Voss, 1996; Goffin and Pfeiffer, 1999; Verhaeghet and Kfir, 2002; Burgelman, Verschraegen, Degraeve, and Nollet, 2004; Cormican and Sullivan, 2004) that suggests a seven-factor structure of categories described based on the required structural elements in a firm to create and handle a change (see Table 2). This wholesome structure allows for multiple perceptions such as Cooper and Kleinschmidt (1995) whose presentations aims at the production of five techno-centric features for new product

quality, nonetheless ignoring the non-technical background of innovation. Chiesa et al. (1996)'s scientific innovation inspection tool accesses a range of indicators that are aimed at evaluating the efficiency of systems and tools held by managers so as to facilitate hard innovations. Cornican and Sullivan (2004) investigate the constant and cross-functional connections necessary within an organisation to ensure successful product innovations.

Table 2. Innovation measurement framework areas

Framework Category	Measurement Areas
Inputs	People Physical and financial resources Tools
Knowledge management	Idea generation Knowledge repository Information flows
Innovation strategy	Strategic orientation Strategic leadership
Organization and culture	Culture Structure
Portfolio management	Risk/return balance Optimization tool use
Project management	Project efficiency Tools Communications Collaboration
Commercialization	Market research Market testing Marketing and sales

Source: retrieved from Adams et al., (2006)

2.4 Product Innovation Measurements

Product innovation measurements can be generally categorized as firm-level and product-level measurements in relation to what is the unit of analysis. Both types of measures can reveal important detail regarding product innovation activities. However, there are certain aspects that make some measures more appropriate in some specific contexts or cases. In other words, these measures tend to be context-dependent and method-oriented, which

could result in issues with the measurements. To review prior measures more systematically, the measurements are discussed separately in the next two sections.

2.4.1 Firm-level product innovation measurement

In business practice, using an accurate measure of product innovation is vital as it reveals the true nature of their product development from an innovation perspective. Numerous measures have been introduced in the literature, and these can generally be categorised as input, process, or output measures. The previous research and their findings in every category will be outlined to demonstrate how the literature in innovation measurement has evolved to date. Consequently, key omissions will be identified to make a contribution to the existing knowledge in innovation measurement study. Innovation lacks a single universally accepted definition, as does innovation measurement. Various measurements have been proposed and discussed from different ontological and epistemological perspectives. Innovation measurements can be divided into the following categories based on how it measures, what it measures, and sources of variables.

Source: Developed for this work

2.4.1.1 Input measurements

The measurement of inputs pertains to sourcing innovation processes and comprises aspects which include physical and human resources, generation of new ideas, and finance (Adams et al., 2006). The construct R&D (research and development) intensity has often been applied as an international input measurement. Classically, it is defined as a ratio of numbers used in R&D duties (Kivimäki, Lämsä, Elovainio, Heikkilä, Lindström, Harisalo, and Puolimatka, 2000), or expenditure (e.g. Parthasarthy and Hammond, 2002) to some terms of output. The relationship between innovation or firm performance and R&D intensity has been practically shown in numerous studies (such as Deeds, 2001; Greve, 2003; Parthasarthy and Hammond, 2002).

Moreover, although R&D is among many inputs to the innovation development, it cannot be an important process for SMEs (small and medium-sized enterprises), which are without proper R&D processes or may not proof them (Kleinknecht, 1987), and, definitely, for service sectors, which seem to have low R&D power (Hipp and Grupp, 2005). Higher degrees of R&D intensity are thus not necessarily indicative of good innovation practice, but may merely cover process ineffectiveness (Cebon and Newton, 1999; Dodgson and Hinze, 2000). Nevertheless, sufficient financial support is evidently a significant input into the innovation activities. Since they are readily available, expenditure data have often been a popular alternative measure of innovation input.

A range of approaches, qualitative as well as quantitative, to determining funding can be acknowledged to include expenditure by item, expenditure illustrated as a percentage of revenues or sales and total expenditure (scientist, innovation, patent or organisational department) (Geisler, 1995; Oliver, Dewberry, and Dostaler, 1999). In addition, a chain of permanent measures exist that endeavor to establish the sufficiency of funding (Atuahene-Gima, 1995).

People factors can be measured in terms of the number of people devoted to the innovation role (total numbers and relative to total workers), based on the mix of classes of people in terms of cosmopolitanism and tendency to innovate and in terms of education, experience and skills. Damanpour (1991) posits that an assortment of experience and skills facilitates more diversified components from which mutual correlations can come out and introduce great value to outcomes of innovation. Although it is hard to measure, the tendency of a person to innovate has gained great attention. Kirton (1976) designed a 32-item survey intended to build an individual's stand on an 'adaptor-innovator' scale. Scott and Bruce (1994) operationalised an 'innovative behaviour measure' consisting of six items against which subordinates are measured by hierarchical superiors.

Lastly, Patterson (2003) stated that the "Innovation Potential Indicator" offers a guideline for exploring individual behaviours likely to support or hinder innovation in the place of work. This measure is built on four measurements, which include an individual's drive to transform; tricky behaviour; an ideal approach to work; and an inclination for attempted and reliable techniques of work, rather than doing things uniquely.

Tellis, Prabhu, and Chandy (2009) noted the following measures of innovativeness at the firm level: *labour* – i.e. numbers employed in R&D roles (e.g. Zucker, Darby, and Armstrong 2002; Parthasarthy and Hammond, 2002); *capital* – i.e. financial resources such as R&D budgets (e.g. Sorescu, Chandy, and Prabhu 2003); and *corporate culture* as a driver of innovation, in which category they identified three firm attitudes and three firm practices that may drive innovation (e.g. Chandy and Tellis 1998; Olson, Walker, and Ruekert 1995). Rubera and Kirca (2012) used three types of variables to measure innovativeness in their meta-analysis. First, they considered innovativeness *inputs*, which are efforts made toward innovation (Geroski, 1994), such as R&D

intensity/expenditures (e.g., McAlister, Srinivasan, and Kim, 2007) and/or a number of patents (e.g., Tellis et al., 2009). Second, they considered innovativeness *processes*, which can be an openness to new ideas as an aspect of firms' organisational culture (Hurley and Hult, 1998). Finally, they considered innovativeness *outputs*, which are consequences of innovation activities visible to consumers (Geroski, 1994), such as a number of new products or service introductions (see Zhou, Yim, and Tse 2005). Recently Story, Boso, and Cadogan (2015) identified three key factors that have been used to determine innovativeness at the firm level, these being spending on R&D (Özçelik and Taymaz, 2004); innovation capabilities (Hult and Ketchen, 2001); and internal and external firm-level environmental and institutional factors (Deshpandé and Farley, 2004; Kyrgidou and Spyropoulou, 2013).

2.4.1.2 Process measurements

Measurements related to innovation as a process must give an answer to the question 'how' (Crossan and Apaydin, 2010). The process of innovation is complex, as it comprises innumerable activities and events some of which can be considered as a series while others occur concurrently. It is very likely that the processes of innovation will vary to some extent, throughout organisations as well as inside organisations on a project-by-project basis. Critical to innovation, and universally accepted, is the introduction of an efficient process that is capable of managing the uncertainty of the innovation (Globe, Levy, and Schwartz, 1973).

Different techniques have been adopted in modelling innovation processes. These include processes of communication (Farrukh, Phaal, Probert, Gregory, and Wright 2000); a series of transactions (Nelson and Winter, 1982); social interactions (Voss, Chase, and Roth, 1999); and a series of events (Zaltman, Duncan, and Holbek, 1973).

Project management is responsible for the processes that transform the efforts into a viable innovation. Some studies have attempted to determine the project management efficiency, generally in terms of comparing the budget with actual (revenue forecasting, project duration and project costs).

Speed is another dimension of project management efficiency. Innovation speed can surely be linked to product quality or the extents to which it meets customer needs. Its dimensions consist of duration of the process (Cebon and Newton, 1999); performance against schedule (Chiesa and Masella, 1994); and speed (Hauser and Zettelmeyer, 1997).

Communications, as a factor of innovation, is important in project management. Damanpour (1991) revealed the presence of an optimistic connection between innovation and internal communication. Internal communication makes possible the passage of ideas in an organisation, enhances the diversity and also contributes to the teamwork environment. The measurement of communication can be made through different combination mechanisms, such as contacts, numbers of meetings and committees (Damanpour, 1991). Dimensions for external communications also exist, which are based on whether communication is happening, the degree at which it happens and the person involved (Cebon and Newton, 1999; Lee, 1996; Rothwell 1992; Souitaris, 2002). Such dimensions of external and internal communication in the literature depend on objective frequency counts as well as subjective evaluations. Subjective evaluations entail the level of conformity with phrases such as “we constantly consult suppliers/consumers on new product designs” (Parthasarthy and Hammond 2002) as well as “level of organisation of members involved in extra-organisational specialized duties” (Damanpour, 1991). Objective counts comprise (Damanpour, 1991) the degree of communication among organisational departments or groups determined by different integrating methods including number of committees and regularity of meetings, occurrence of official

meetings relating to new ideas (Anderson and West, 1998), and the technical aspects encouraging people to communicate with each another (Souitaris, 2002; Szakonyi, 1994).

It is well known that collaboration with customers (von Hippel, 1986) and suppliers (Bessant, 2003) may make a considerable input to the innovation process. Collaborative operation may be proxied by the degree to which decision-making is described by cross-functional debates (Miller and Friesen, 1982); the fraction of projects in collaboration with intermediaries (Kerssens-van, Drongelen and Bilderbeek, 1999); and the utilization of company engineers (Maylor, 2001). Additionally, Jassawalla and Sashittal (1999) identified a number of features of internal collaboration whereby teams are typified by their attentiveness, transparency, synergy, and levels of “at-stakeness”.

2.4.1.3 Output measurements

Innovation output measurement usually focuses on commercialisation results of new products, as well as that of other technological advancement achievements such as the number of patents, and as a lagging indicator, metrics that consider the amount of revenue generated by innovative products and market shares. Adams, Bessant, and Phelps (2006) established that commercialization is a less developed section of innovation management since it is frequently believed to be the realm of other professionals, mostly marketers. Commercialization consists of adherence to schedule (Griffin and Page, 1993); post-launch reviews (Atuahene-Gima, 1995); personnel expertise; launch know-how (Song and Parry, 1996); marketing ability like the number of products launched (Yoon and Lilien, 1985); financial plan for market testing (Balachandra and Brockhoff, 1995); and market research (Verhaeghe and Kfir, 2002).

Although we can see some consistencies among the measurements at the firm level, the majority of them cannot be applied directly in the entrepreneurship context,

where many new and small ventures usually do not have the track records, organizational structure, expert teams, prior market involvement, and adequate budgets for R&D units which are essential for the above measures to be used as proxies for the innovativeness of the firm.

Furthermore, the firm-level measures are diverse, using different constructs that examine subjective or objective values to measure the same concept. For instance, in terms of the value, the R&D budget is a hard and objective measure, while a cultural propensity to innovate (see, e.g. Deshpandé and Farley, 2004; Kyrgidou and Spyropoulou, 2013) is a subjective and perceptual measure. Therefore, the diverse results of these measures consequently lead to (validity) concerns whether they really measure what they intend to measure.

Moreover, variations in innovativeness measurements at the firm level may reflect the firms' different methods of innovating. For instance, suppose one firm can afford to commit to R&D projects that last longer and require highly skilled experts and other resources, while another may licence external innovation sources, including open innovation (Chesbrough, 2003; Tranekjer and Knudsen, 2012). If we compare them using R&D intensity measures (e.g. Özçelik and Taymaz, 2004), the first firm will be categorized as more innovative than the second. On the other hand, if they both had been measured by collaboration-oriented measures (Cheng and Huizingh, 2014; Wirsich, Kock, Strumann, and Schultz, 2016) the ranking is likely to be reversed. Thus, at the firm level, innovativeness measures may have been built differently based on what aspect of innovativeness they intend to measure. In other words, input measures focus on *how* firms innovate, rather than *what* they innovate, which may be measured by outcomes of the innovation process. Innovativeness should be seen and measured by common criteria that is evident throughout firms and markets.

Therefore, it can be argued that, especially in the context of entrepreneurship, the measurement of innovativeness should concentrate on the outcome of the innovation process (i.e. product innovativeness) to facilitate unification of mensurandum (i.e. property of the concrete system we wish to measure) and directness of assessment by focusing on the product that the firm offers.

2.4.2 Product-level product innovation measurement

At the product level, scholars defined various new product design measurements ranging from single item (Landwehr, Wentzel, and Herrmann 2012, 2013); double dimensions, such as the hedonic and utilitarian dimensions (e.g., Chitturi, Raghunathan, and Mahajan 2008; Dhar and Wertenbroch, 2000); and a three-dimensional concept (e.g., Bloch 2011; Homburg, Schwemmler, and Kuehnl, 2015) in relation to their definitions of product design, which are quite diverse and inconsistent (Luchs and Swan, 2011). In the new product development (NPD) literature, the broad intention of the product design scholars is to evaluate a new product design when developing new products to assure possible commercial success and market appreciation for them through considering different critical dimensions such as Ergonomics (Antioco, Moenaert, and Lindgren, 2008); Kinesthetic (Noble and Kumar, 2010); Functionalities (Creusen, 2011); Properties of the form/ aesthetics (Luchs and Swan, 2011); Emotional appeal and Humanistic value (Moon, Miller, and Kim, 2013); Cuteness (Nenkov and Scott, 2014), and so on. Even though those are for new products, they are not designed for measuring innovativeness, thus they may not be used directly to measure product innovativeness. An innovativeness measure should be focused on relative differences/upgrades between the current and previous offers by the firm, and by other offers in the markets, rather than a static characteristics of a product, which is usually the concern of product design.

Figure 3. Literature review map

Source: Developed for this work

However, to measure the innovativeness at the product level scholars used different dimensions such as technological newness and market newness (Sethi, Iqbal, Sethi, 2012) by utilising a three-item, seven-point Likert-type scale for each dimension, while Chandy and Tellis (2000) used technology and customer benefits as dimensions through measuring them on a scale that is ranging from 1 to 9, in which the 1 indicates no difference at all (technology dimension) and no benefits at all (customer benefits dimension) and the 9 indicates substantial technology difference/higher customer benefits. Generally, scholars utilised questionnaires and semi-structured interviews that were designed to capture feelings and personal judgements of managers responsible for innovation processes, and the customers who are targeted for the innovation (e.g. McNally, Cavusgil and Calantone, 2010; Schultz, Salomo and Talke, 2013). They have used single (e.g. Calantone, Chan and Cui, 2006) and multi-item scales (e.g. Schultz et al., 2013). To operationalize the items to measure product innovativeness intensity, scholars used either categorical (e.g. Athuahene-Gima, 1995; Song and Montoya-Weiss, 1998) or continuous measures (e.g. Chandy and Tellis, 2001; Calantone et al., 2006; Schultz et al., 2013). Continuous measures tend to dominate recent product innovation research and capture more sensitively the phenomenon (Szymanski et al., 2007).

As categorical measurements, scholars have utilised the following constructs: high/moderate/low innovativeness; incremental/radical innovativeness; new/not new; and routine/radical (Garcia and Calantone, 2002). When using the quasi-continuous measurement categories, scales of the measurements are usually 1-5, 1-7, and 1-10 Likert scales (e.g. McNally et al., 2010; Schultz et al., 2013). But especially at the product level, various items that are designed to determine product innovativeness tend to utilize subjective or perceptual measures such as customer discontinuity items (Atuahene-Gima, 1995), product advantage scale and project protocol scale (Cooper and Kleinschmidt,

1987), marketing discontinuity scale and technological discontinuity scale (Danneels and Kleinschmidt, 2001), and product innovativeness scale (Tellis et al., 2009; Wang and Ahmed, 2004).

Moreover, these subjective measures are often expressed in ordinal scales making it difficult to aggregate and compare their values (Rose-Ackerman, 1999). Although, subjective measures are effective to capture information about innovation, especially where other objective measures are impossible, yet there are issues that threaten their reliability such as self-reporting bias, selective memory bias, and social desirability bias. Therefore it is argued here that there is a need for an objective and direct measure of product innovativeness in both academic research and business practice.

Figure 4. Overview of product innovation measurements

	Innovation measurements		
How it measures:	Direct		Indirect
What it measures:	Input	Process	Output
Source of variables:	Objective		Subjective

Source: Developed for this work

In summary of the literature review, scholars have proposed various dimensions and many constructs to determine product innovativeness. These measures range from the size of R&D budgets, numbers of new products and patents, to perceptions of entrepreneurs and consumers of the new product innovativeness. It has been evident that the studies have concentrated on aspects that lead to, go along with, and/or are the results of product innovation, rather than the actual product itself (see Figure 4). Therefore, it is clear that the inconsistencies in innovation measurement literature are due to the fact that scholars are studying different aspects of innovation by firms/entrepreneurs. Some

measure innovation through collaborations or their innovation policies, others relied on their own experts and huge budgets, while most of them follow the industry leader. Thus, previous measurements vary in relation to firms' (entrepreneurs') different ways of innovate. It is almost inevitable to see inconsistency if we use a collaboration-oriented measurement on a firm that relies on their R&D units, or vice-versa. Therefore, to unify the understanding of product innovativeness the focal issue should be a product, the ultimate end-result of the firm's innovativeness.

2.5 Research Gaps

After reviewing the literature related to product innovation, the following gaps have been identified that exist throughout the literature from the view of the positivist paradigm.

Firstly, various measures have been developed to date for product innovation, and all of these are proxy measures that relate to input, process and outputs measurements. The majority of them relied on subjective data (see Appendix: Table 1 to 5) and consequently raises concerns of validity, consistency and reliability issues. The rest are objective data such as sales of innovative products, of market shares, and numbers of new product launches, which basically deal with post-launch activities that hugely depend on marketing and other operational aspects. Surprisingly, none of these measurements is directly focused on real products that are being measured for their innovativeness.

Secondly, scholars have determined product innovation measurement as a stable indicator that does not change over time. However, nowadays innovativeness is a constantly changing variable, whose result depends on current market offerings and their current activities. Thus, it will vary over time regardless of a firm's non-commitment due to other players' nonstop activities in the field. Therefore, to fill this gap, the new

measurement must indicate product innovativeness at any given point in time. Thus, time will be considered as an essential factor to determine product innovativeness.

Finally, the measurements that have been introduced in the literature are ordinal measurements, which ultimately indicate the position or rank order of innovativeness. In this study the possibility of developing a cardinal measurement for product innovativeness is examined. Only a cardinal measurement can answer the question ‘how many’ as revealing the absolute value of innovativeness.

Even though scholars have conducted research on the relationship between innovation and financial value of the firm (Belenzon, 2012; Blundell, Griffith, and Van Reenen, 1999), they used the output measurements (such as R&D cost, patents, etc.) as the independent variable to explain the changes of the market value over time when they operationalize the innovativeness. The measurement proposed here for innovativeness is not a proxy measurement: it directly originates from the product itself. Therefore, it might have greater potential to yield more explanatory power on the innovation created, and as a result generate more accurate result on the relationship between innovativeness and financial market value of the firm.

2.6 Research Question Formulation

The broad aim of the research is developing a non-proxy measurement for product innovativeness. Consequently, this research’s contribution to the theory is to fill the gaps by proposing a direct measurement system that assesses product innovation objectively and consistently at given times regardless of the subjects who perform the assessment. Moreover, unlike subjective measures, the new measurement can be verified externally; thus, it can facilitate a universal consensus on the measurement. Based on the literature

review, the identified gaps, and research aim, the broad research question was defined as the following:

‘How can an objective and direct product innovativeness measurement be developed that is valid and reliable?’

This research will explore the creation of a new measure of product innovativeness by answering this research question.

2.7 Research Objectives

To fulfil the broad aim of the research as answering the research question, the following objectives have been set, which are the summarization of what is to be achieved by this particular study:

- To develop a highly objective product innovativeness measurement, which will consist of two dimensions: technical novelty and market novelty. As a result, the Compound Product Innovativeness Score (CPIS) and Compound Innovativeness Index (CII) will be determined, which are relative measures that indicate how innovative a certain product is compared to other products at a given time and how novel the new product is compared to its predecessor products.
- To perform dynamic analysis of product innovativeness in the smartphone industry in the US, which is the first attempt to study the whole industry’s intensity of innovativeness longitudinally based on products themselves that have been introduced to the market.
- Investigate a relationship between product innovativeness and the market value of the firm. This kind of research has been done before (Belenzon, 2012; Blundell et al., 1999), yet when operationalising the innovation, scholars used the output

measurements as an independent variable due to their objectivity, such as R&D cost, number of patents, etc. In this research, the newly constructed measures, the CPIS and CII, will be applied as the independent variable that represents innovativeness when operationalizing the innovation. As the CPIS and CII are directly estimated from an actual product itself, they are likely to have greater potential to yield more explanatory power in the relationship between the two variables.

2.8 Conclusion of Chapter 2.

This chapter provides an overview of the significance of innovation in economics and business, especially in entrepreneurship; a review of innovation measurements with a special attention on product innovation measurements, in which is discussed the firm-level and product-level measures in detail, followed by the identification of gaps that are based on the review and the formulation of research questions. Finally, the research objectives of the study were stated.

CHAPTER 3. RESEARCH METHODOLOGY

Outline of Chapter 3

3.1 Introduction

This chapter will outline the research methodology aspects of the study, including the research paradigm, research approach, research methodology, and research methods. In Section 3.2, the philosophy of the research, including the ontology and epistemology of the research, is examined via consideration of possible research paradigms that could complement the overall aim and objectives of our research. In the following section, Section 3.3, the research methodology is considered. As the development of a measurement model is intended, it is necessary to discuss the “scale development” methodology. This process differs from traditional psychological construct development activities. Formative measurement is used to develop an objective measurement system that assesses observable novel features in a new product. In section 3.4, the research methods are discussed, in which the observation method is emphasised. This method was

chosen as the most appropriate way to collect data because it intends to evaluate the objective innovation of a product. Finally, the chapter is concluded by Section 3.5, which summarizes the chapter.

3.2 Research Paradigm

The overall aim of the research is to develop a highly objective measurement system of product innovativeness, which assesses innovativeness objectively and directly, and can be verified externally.

From a philosophical point of view, there is no ultimate truth or single universal reality of product innovativeness. In fact, the nature of reality of product innovativeness can be viewed from different perspective depending upon researchers' preferred worldviews, also known as a paradigm. A paradigm is a set of basic beliefs (or metaphysics) that deals with ultimates or first principles (Creswell, 1996). All research is guided by a set of beliefs and feelings about the world and how it should be understood. It represents a worldview that defines, for its holder, the nature of the world, the individual's place in it, and the range of possible relationships to that world and its parts. These are basic beliefs in the sense that they must be taken on faith; there is no way to establish their ultimate truthfulness (Guba and Lincoln, 1994). Especially when studying a complex concept as innovation, paradigms may be one reason why innovation definitions and measures are inconsistent and face challenges in their operationalization; scholars have held various ontological assumptions in their studies as discussed in the literature review chapter.

The research aim is to overcome the inconsistency or reliability issues resulting from subjective measurements (e.g. Calantone et al., 2006; McNally et al., 2010; Edison et al., 2013) and validity issues as consequences of objective yet indirect or proxy

measurements (e.g. Deeds, 2001; Greve, 2003; Parthasarthy and Hammond, 2002) of product innovativeness. Thus, the research problem should be approached in a way that ensures independence or objectivity of the measurement; values ability to produce replicable and consistent findings based on external physical evidence; and utilises quantitative expressions of a phenomenon. A paradigm whose underlying assumptions are fit to address the above problems is positivism, for this particular paradigm assumes the existence of an objective external reality upon which inquiry can converge (Guba and Lincoln, 1994).

Product innovativeness can exist independently from perceptions, yet its true nature is not free of context and time. Therefore, the preferred ontology is empirical realism (positivist paradigm), which concerns a single concrete reality that exists independently and can be seen or measured objectively, yet the author agrees to a certain extent that there can be a very limited subjective influence to the measurement model. Hence, it can be argued that the paradigm should lean toward postpositivism (critical realism) that accepts imperfect, yet apprehendable reality by acknowledging the limited influence of subjectivity. Kwan and Tsang (2001) maintained that although realism and critical realism are very different, they have a common hypothesis that reality, such as social reality, occurs quite apart from the perceptions and thoughts of individuals and therefore can be researched by means of scientific method.

Critical realism is mindful of the significance of investigators and human structures. Reality, according to critical realism, is believed to be present though it not clearly understandable due to fundamentally imperfect human intellectual potentials and the basically stubborn behaviour of the event. The ontology was branded by Cook and Campbell (1979) as critical realism owing to the position of supporters that advocates for subjection of reality to the broadest possible critical test to enable apprehending reality as

directly as possible (although not perfect). However, the ultimate goal of the research is to measure product innovativeness objectively. Therefore, the research focus will be on developing objective and independent measurement that can indicate innovativeness quantitatively rather than exploring qualitative aspects of the phenomenon.

It can be considered that there are certain factors that make the reality of the product innovativeness value cognizant observation; as a result, product innovativeness does not totally exist independently as a certain phenomenon in physics (e.g. the speed of light). These factors are; (1) the researcher's argument (i.e. judgement), which has a substantial base in literature, on measurement constructs; and (2) fundamental factors (context and time) that influence product innovativeness. The nature of product innovativeness is a relative concept, as varies in relation to the context (e.g. different geographical markets) and the time. That is, how innovative a certain product is depends on comparisons to its predecessor and competitor products, and the time when the comparison takes place. Something can be considered as very innovative today, but next week it may be less so due to new offers from other competing firms, which is especially the case in today's fast-paced technological world.

Likewise, a product can be very novel to and never before produced by a particular firm, but it might not be novel when it is compared to other products in the market or the world. With consideration of the above circumstance, the ontological assumption, which is going to be the base and the general guidance of the research and its design, can hold the post-positivist view as well (see Figure 5).

Figure 5. Development of the product innovativeness measure

Source: Developed for this work

Product innovativeness can be viewed as a relative concept, yet it is measurable objectively and quantitatively such that the measurement result can reveal how innovative the new product is.

Epistemology refers to the study of the manner in which people or groups of people understand things and the manner in which they believe to comprehend things (Keeney, 1983). It is therefore related to what constitutes valid understanding, the nature of understanding, who can understand and what can be understood.

Any scientific contributions to knowledge can be the result of reasoning through two main approaches: inductive and deductive. Inductive reasoning is a process, wherein initially, all types of data will be collected by qualified research methods to formulate theories or find generalisations regarding the issues under investigation. Therefore, induction is a process of going from specifics to generalisations and drawing conclusions from evidence. Interpretivism and constructivism are paradigms that usually apply to this approach as they operate on assumptions that the reality is multiple and relative (Hudson and Ozanne, 1988). They usually avoid rigid structural frameworks such as in positivist research and adopt a more personal and flexible research structure (Carson, Flores, and Meade, 2001), which are receptive to capturing meanings in human interaction (Black, 2006), and make sense of what is perceived as reality (Carson et al., 2001).

Deductive reasoning, on the other hand, is a process, which starts with valid premises or general statements, then draws conclusions from them on specific cases. Thus, it is the reverse process of induction, going from the general to the specific. This particular approach is mainly applied by positivists and post-positivists, who operate on ontological assumptions that there is a “real” reality that exists regardless of human perception, and it can be captured. Positivism predominates in science and assumes that science quantitatively measures independent facts about a single apprehensible reality

(Healy and Perry, 2000). According to the positivist epistemology, science is seen as the way to get to the truth, and to understand the world well enough so that it might be predicted and controlled (Krauss, 2005). Thus, deductive reasoning is mainly used to verify and test theories. Which approach researchers should follow depends on the purpose of their studies, whether their aim is to test certain hypotheses to answer specific research questions or to explore the possibilities of new theories in particular situations.

One of the examples of qualitative methodologies that uses inductive reasoning can be an exploration of ‘fear of failure among new entrepreneurs’, which is a psychological phenomenon that can play a substantial role in entrepreneurs’ decision-making as scholars agree that entrepreneurs are individuals who are innovative and risk-taking. The overarching research question can be stated as the following: How do nascent entrepreneurs deal with the fear of failure? This particular study might be more effective to be approached by the interpretivist paradigm, which ensures adequate dialog between a researcher and entrepreneurs to construct a meaningful reality (Angen, 2000) collaboratively. The researcher can use in-depth interview methodology to generate data, which must represent all possible views toward the fear of failure by reaching the saturation level. However, apart from sufficient data collection, to ensure that this qualitative research is a rigorous study, the researcher can perform a method triangulation (Denzin, 1978; Patton, 1999) by utilising case-study methodology concurrently.

A classic example of a quantitative methodology that uses deductive reasoning can be an empirical study of Okun’s law, which states that a 1% increase in the unemployment rate causes a 2.4% decrease in potential GDP (Okun, 1962), in a certain country’s case. In this case, a researcher tests the theory that has already been formulated through stating a research question about whether Okun’s law is accurate in a different country’s case. From the research question, specific and testable hypotheses are

formulated, which are tested by statistical analysis including regression analysis and other specified tests that ensure the Best Linear Unbiased Estimation (BLUE) for this ‘ordinary least square’ (OLS) estimation.

Finally, the main difference in the goals of the two types of research is that qualitative research aims to generate meanings from data that are usually formed by non-quantitative elements, while quantitative research mostly intends to focus on relationships among variables by posing testable hypotheses. Therefore, the author approaches this current research from the deductive perspective, in which we test theoretical proposals through the new measurement of product innovativeness.

3.3 Research Methodology

According to Dobson (2002), the researcher’s theoretical lens is also suggested as playing an important role in the choice of the methodology because the underlying belief system of the researcher (ontological assumptions) largely defines the selection of method (methodology). In order to answer the research question, under the empiricist realism umbrella, the most effective methodology that ensures a reliable and valid measurement is scale development methodology due to a very specific aim of the research. Nevertheless, as an alternative paradigm, the development of innovation measurement can be approached by the realist paradigm as accepting the main underlying assumption that there are multiple perceptions about a single reality (Healy and Perry, 2000). Realism posits that there is a "real" world to discover even though it is only imperfectly apprehensible (Godfrey and Hill, 1995; Guba and Lincoln, 1994; Merriam, 1988; Tsoukas, 1989). In view of realism, an individual’s discernment for realism is a channel to reality which allows for triangulation of an idea of reality with other perceptions. Such manifold observations entail triangulation of numerous data sources, and of numerous

peer researchers' explanations of particular triangulations. Therefore, methodologies such as case studies and unstructured or semi-structured interviews are commonly used, if necessary quantitative methodologies (i.e. structural equation modelling) can be applied concurrently.

3.3.1 Formative and Objective Scale Development Methodology

Due to the specific aim of the research, a scale development methodology is used. A primary goal of scale development is to create a valid measure of an underlying construct (Clark and Watson, 1995). Thus, the scale development methodology is arguably the only way to carry out this research effectively. It consists of specific and sequential steps (methods) that ensure the development of reliable and valid measurement. Deductive scale development uses a theoretical definition of a construct which is then used as a guide for the creation of items (Schwab, 1980). This approach requires an understanding of the relevant literature and the phenomenon to be investigated and helps to ensure content adequacy in the final scales. In most situations where some theory exists, the deductive approach would be most appropriate.

There are two main types of measurement models, which each require a specific procedure and assessments to ensure the validity and reliability of the measurement, namely, reflective and formative models. The reflective measurement model has a long tradition in social sciences and is directly based on classical test theory (Lord and Novick, 1968). Another measurement perception entails the development of an index instead of a scale (Bollen and Lennox, 1991) and is anchored in the application of formative (causal, cause) indicators (Diamantopoulos and Winklhofer, 2001). In such a case, formative indicators are noted parameters that seem to bring out a latent variable. The details of the two approaches will be discussed further in the next chapter, which evaluates the measurement model development.

Figure 6. Formative Product Innovativeness Measurement Model

In this particular study, the product innovativeness measurement can be treated as a formative measurement model with observable variables. Because the direction of causality between the concept and items is from the items to the concept (see Figure 6). In other words, a variation in item measures causes a change in the concept. Moreover, the nature of the measurement model does not require an internal relationship between items (Cronbach, 1951) as it typically does in a reflective measurement model.

The methods for evaluating a newly developed scale have been widely discussed in the literature (Anderson and Gerbing, 1988; Bagozzi, 1980; Bagozzi and Phillips, 1991; Bollen, 1989; Fornell and Larcker, 1981; Gefen, 2003; MacCallum and Austin, 2000; Segars, 1997; Spector, 1992). However, the majority of the research has focused much more on the criteria for evaluating reflective indicator measurement models than on formative indicator measurement models. Frameworks for building indexes according to formative indicators are very hard to discover, unlike for scale development in which thorough step-by-step directions are available for item selection and purification, construct specification, and scale validation (such as Churchill, 1979; DeVellis, 1991; Spector, 1992). However, Diamantopoulos and Winklhofer (2001) established criteria for the evaluation of formative measures: content specification, indicator specification, indicator collinearity, and external validity. To ensure the validity and reliability of this second-degree formative measurement model, the above four analyses will be carried out, which have been used by scholars (e.g. Diamantopoulos and Winklhofer, 2001; Diamantopoulos, Riefler, and Roth, 2008) to assess the reliability of formative models (see Figure 7).

Figure 7. Procedure of developing the new measurement model

Where:

Yes – represents a case that the assessment result is positive.

No – represents a negative assessment result, thus it needs modification.

3.3.2 Longitudinal research methodology

After the measure has been developed using the scale development methodology, the next stage of this thesis is to conduct a longitudinal research utilising the new product innovativeness measurement as an independent variable. In longitudinal research, data is collected on one or more variables for two or more time periods, thus allowing at least measure of change and possibly explanation of change (Menard, 2008). There are commonly used four basic designs for longitudinal research (see Figure 8).

Figure 8. Longitudinal Research Designs

Source: Adapted from Menard (2008)

In this research, the total population design will be utilized because the total population is surveyed or measured in each period of the study. The research object is smartphones and they were introduced in 2008 for the first time, thus the time period is 2008 to 2017. Also, this research studies the total population because the nature of the product innovativeness measure requires assessment of the whole population (as noted previously around innovation being context specific and relative to prior offerings) as it

is only possible to truly determine which product is more innovative after measuring all the products in the market.

Figure 9. Total population design in the smartphone industry

In Figure 9, at the beginning the population (the green bars) was relatively small as there were not many firms that offered smartphones in 2008 but it eventually increases as the demand for the smartphone grows, and as others firms recognize the growing demand and potential of the market, new players enter (the yellow bar) the market. As a consequence of the intense competition, it may cause some firms to fail and exit the market (the orange bar). The horizontal axis represents period (i.e. year) for which data are collected and the vertical axis represents total population of the study (i.e. all the smartphone brands in the market).

Moreover, while the orange bars show a market exit of a smartphone, which has happened during our study period, the yellow bars exhibit an entrance of new players in the market, which has also happened. However, the majority of the population tends to stay as the same. Therefore, the total whole population has been changing over time and

it shapes the size of the population. In the graph, the green area represents the size of overall population and its changes over time rather than a specific number of samples.

3.4 Research Methods

3.4.1 Target population

Units of the analysis for this research are products because the research aim is to develop a direct measurement that is solely focused on products, and a highly objective measurement that assesses novel elements embedded in products. Once the measurement is developed, it will be used in the smartphone industry case. It is preferable to target a product that typically introduces new designs annually to the market, which has been done by manufacturers in the smartphone industry as strategy to retain and grow their market shares and to increase profitability (Jean, 2017). Also, its innovativeness-related information (i.e. detailed specifications of a product's new functions and features) is reliable and accessible. Consequently, the smartphone industry has been considered as the target population due to the availability and accessibility of reliable and detailed cross-industry information (data) of products, as well as the possibility of generating longitudinal data of the industry as the smartphone industry's product related data points in time are mostly available publicly. Therefore, for the longitudinal analysis, the author collects data regarding the products in the industry from 2008 to 2017, which is a ten-year period.

3.4.2 Sampling Frame (Listing of the products)

Sampling frame is a listing of possible population elements, from which a sample is drawn. However, in this research we are not going to sample because the overall aim of the research is to determine product innovativeness in the smartphone industry. As discussed earlier, product innovativeness is naturally context dependent variable, therefore it will not be reliable if certain products or specific years are excluded. Because

product innovativeness is determined through comparison among all products in the market. By using the smartphone industry, the sampling frame in this research is the whole sample phone products. However, there are certain basic criteria that make elements in the sampling frame qualify for the sample (see Figure 10). The criteria to qualify for the analysis, which is the objective measurement of product innovativeness, are the following:

i) Products must be launched in the market (versus a conceptual product and design) during the research period 2008-2017, because innovation is commercialised invention (Savona and Steinmueller, 2013).

ii) Products must have assessable and reliable information regarding their technical specifications. The innovativeness measurement model developed in this thesis processes technical specifications of a product, making correct and valid technical specifications necessary to run the assessment.

iii) Products should be leading products in their innovation. There are many products that employ “me-too” strategy by following the leaders. Therefore, to focus on the innovators, the third requirement is that a product must be highly innovative. If not, it should have more than 10% of the market share. However, in our case the two conditions are met simultaneously, in which more than 70% of the share belongs to the most innovative two main players and the rest is shared by more than ten other players.

iv) Smartphone producers offer different products for different target markets such as high-end flagship models (e.g. iPhone X, Samsung Note series) for tech-enthusiastic and wealthy customers, middle range products (e.g. iPhone SE, Samsung Galaxy series) for ‘ordinary’ customers, and ‘budget’ type of products (e.g. iPhone 5C, Samsung Galaxy J series) for lower income segments in the market. Therefore, in this research, we will only focus on high-end flagship models, which are usually expensive

compared to other models, to measure their product innovativeness as they push the boundaries of existing technology and are typically packed with innovative high-tech features and functions which later diffuse through the ‘ordinary’ and ‘budget’ product lines.

Figure 10. Sampling requirements

Source: Developed for this work

The smartphone industry is one of the most rapidly growing industries over the last decade as the number of smartphone users reached 2 billion in 2016 (Statista 2016). This particular industry heavily relies on innovation and its nature of fierce competition has resulted in some well-known companies to exit from the market, for instance, Nokia and Blackberry, which were once named in the Fortune Global 500 companies.

Figure 11. Trend analysis of smartphone sales

Source: Stata 2017

In the sampling frame of the study, the following companies' products during 2008-2017 have been listed:

Table 3. Sampling frame

#	Brand	Model	Introduced from
1	iPhone	iPhone (1 to X)	2008
2	Samsung	Samsung Galaxy S (1 to 8+)	2010
3	LG	LG (V, Q, G, X series)	2008
4	Motorola	Moto (z, x, e, g series)	2008
5	HTC	HTC U series	2008
6	OPPO	OPPO A, R, F, N series	2014
7	Sony	Sony Xperia series	2008
8	Huawei	Mate series	2016
9	Vivo	V, Y series	2012
10	Google	Pixel (1 to 2)	2016

3.4.3 Data-Collection Method

To collect data, the author utilises the observation method. Observational techniques are methods by which individual gathers firsthand data on programs, processes, or behaviours being studied (Fetterman, 1989). Observation ensures validity as it deals not with what people say they do but their actual behaviour (Gillham, 2008). In this case, products will be observed, and information related to their innovativeness will be recorded through a certain procedure.

Table 4 Characteristics of Structured and unstructured observation

Structured Observation	Unstructured Observation
<ul style="list-style-type: none"> ▪ Relatively economical on time ▪ Data largely quantitative in character ▪ Detached non-participant observation ▪ Data easily summarized ▪ Data essentially superficial ▪ Limited linkage to social context ▪ Not suited to the study of extended and elaborate sequences of behaviour 	<ul style="list-style-type: none"> ▪ Very expensive on time ▪ Data largely qualitative ▪ Participant observation ▪ Data require extended presentation ▪ Capable of analysis of meaning in depth ▪ Embedded in social context ▪ Behaviour viewed as part of a complex social interaction

Source: Adapted from Gillham (2008)

Therefore this particular technique is more effective as the observational method ensures the collection of information (numbers of new elements) about a product's innovativeness without either internal or external influence (Gillham, 2008). Scholars use two main types of observation: structured and unstructured.

In this research, the structured observation method is used to collect data for the analysis because it is a systematic way of collecting data without interfering with the phenomenon and it generates quantitative data of the phenomenon.

3.4.4 Data type

Quantitative and qualitative data provide a trade-off between breadth and depth as well as between generalizability and targeting to specific (sometimes very limited) populations (Kidder and Fine, 1987). The research will be using quantitative data regarding numbers of novel elements in products.

3.4.5 Sampling Method

Data will be collected through Time sampling, a type of structured observation sampling method. This is also known as interval sampling because a researcher observes the phenomenon at specified intervals, in our case 2008 to 2017. The reason for this particular interval is the frequency of the event, as new flagship smartphone introduction to the market usually occurs once a year (Apple.com; Samsung.com), therefore in order to obtain as much data as possible the author sets the interval as annually. If the frequency of the event was higher, the interval can be shorter.

Figure 12. Sampling type of structured observation

Source: Adapted from Gillham (2008)

3.4.6 Sample Size

In this study, panel data (also known as a set of longitudinal and cross-sectional data) will be used. Panel data contain observations of multiple phenomena obtained over multiple time periods for the same firms or individuals. In this research, columns represent

products of the companies and rows represents times when the products were launched in the market. Therefore, it can be up to 10 (years) x 2 (products) table, which will result in a total number of 20 samples.

According to the sampling requirement 3, only products that have more than 10% of the US smartphone market share are sampled for the further analysis (see Figure 13). Therefore, we should look at the US market shares of the smartphones, and then identify potential candidates for the next level analysis.

Figure 13. US Smartphone market shares

Source: comScore MobiLens (2017)

After the three requirements, which ensure reliable and efficient analysis of the measurement, our sample size is less than the original sampling frame, which is two main players in the market: iPhone and Samsung Note. The samples represent highly innovative products in their platforms as iPhone is for the iOS and Samsung Note is for the Android and together Android and iOS are the main operating systems in the market.

3.5 Analysing methods

3.5.1 Product innovativeness measurement - CPIS

After collecting the data, the main analysis is to measure the Compound Product Innovativeness Score (CPIS) of the products through the newly developed measurement model. The new model estimates magnitudes of product innovativeness objectively and directly by assessing the novelties in the products through two dimensions, namely technical novelty and market novelty. The CPIS can provide unprecedented and highly detailed information regarding every product's innovativeness in the market.

3.5.2 Descriptive analysis in longitudinal research

Analysis of longitudinal data starts with an examination of descriptive statistics to reveal some insights about patterns of change in response over time (Fitzmaurice, Davidian, Verbeke, and Molenberghs, 2008). The descriptive statistics analysis can be presented both as a table and graphically. However, the graphical display is more effective and revealing than the tables for conveying information about the most salient features of the longitudinal data (Fitzmaurice *et al.*, 2008). To perform the graphical exploration of the data, a scatter-plot method is used, in which the CIS of products are represented on the vertical axis, while the measurement time is on the horizontal line. Moreover, in order to depict more insights a 'locally weighted regression' or lowess (Cleveland, 1979) can be used, which is especially useful when the measurement time has different intervals. In our study we use the same time period for the measurement. For example; iPhone's CIS in 2015 or Samsung Note's CIS in 2015, even though every product innovativeness is judged on the time of its market release. Due to the fact that those flagship models are released once every year but at different times, which are usually in August and September (Apple.com; Samsung.com). Finally, the analysis of graphical model-

checking based on residuals is performed to assess the adequacy of any postulated model for longitudinal data, which is also useful tool to identify outliers in the data.

3.5.3 Causal analysis in longitudinal research

As a result of our data collection, the longitudinal data is generated as it produces the compound product innovativeness score (CPIS) for every product over time. Thus, it gives an opportunity to conduct causal analysis with non-experimental panel data. Consequently, we can investigate the relationship between product innovativeness (CPIS) and the stock price or profitability of a firm, which is of the prime interest in business studies. Moreover, the causal analysis can be used to validate the new measure in the empirical context. In order to conduct the causal analysis with non-experimental longitudinal data, which are data that contain observations for multiple cases at multiple time, evenly-spaced time, we may consider the following method.

Causal analysis in structural equation modelling: SEM starts with positing a linear causal model based on theoretical considerations (Greenberg, 2008). In our case, it could start as writing a linear structural equation model for stock prices (SP), which is continuous and dependent variable at time 2. If the CPIS is an independent variable, the most general equation will utilise SP at time 1 and CPIS at time 1 and 2, as predictors of SP at time 2, with random error term e :

$$SP_{i2} = a + b_1 \cdot SP_{i1} + b_2 \cdot CPIS_{i1} + b_3 \cdot CPIS_{i2} + e_i \quad [1]$$

The model demonstrates that the stock prices (SP) at time 2 could be caused by its value at previous time (i.e. time 1) and product innovativeness scores (CPIS) of the product at both time 1 and 2. If parameters of the model show a substantial impact with higher statistical significance the model could exhibit causal relationship between the variables.

3.6 Conclusion of Chapter 3

In this chapter, the author discuss research design, research approach, research methodology, and research methods that are used to conduct this research. In summary, it is quantitative research, in which the author employs positivist paradigm to approach the problem. Because this particular way of studying the phenomenon can ensure to fulfil the overall aim of the study. In relation to the specific goal of the research, the author implies the formative scale development methodology in the first part of the thesis. Moreover, longitudinal research design is used to study further the phenomenon once all the data collection is completed. The data is collected through the structured observation method as a result longitudinal data regarding product innovativeness of smartphones are generated. In terms of analysis methods, the product innovativeness measurement (the CPIS) is performed to generated data and measure the variable, as for descriptive analysis in longitudinal research, the standard scatter-plot method and the analysis of graphical model-checking based on residuals are executed. Finally, to validate the new measure and investigate its relationship with other variables the causal analysis with non-experimental longitudinal data are performed, which includes causal analysis in structural equation modelling.

CHAPTER 4. DESIGN AND PROPOSITIONS OF THE MEASUREMENT MODEL

Outline of Chapter 4

4.1 Introduction

In this chapter, the design and propositions of the measurement model are discussed. To commence, the different approaches in measurement design are explored, specifically evaluating both reflective and formative measurement model designs in section 4.2. In section 4.3, justifications and reasons why the formative model has been selected for this research are presented with theoretical and empirical arguments. As suggested in Chapter 3, the new measurement model is designed from a positivist approach to ensure objectivity of the measurement process. In order to build a measurement model that can assess product innovativeness directly and contemporaneously as cardinal values, in section 4.4 six desired properties of the model are argued in detail. Next, in section 4.5, theoretical propositions of the new measure of product innovativeness are defined, where technical novelty and market novelty are discussed. Constructs of the technical and

market novelty dimensions are described individually and their relationships are considered through a series of propositions, which are essential for the working of the measurement. Section 4.6 provides further detail on the measurement model based on the propositions, internal mechanics and mathematical solutions. Finally, this chapter concludes with section 4.7, where a summary of the contents of this chapter are presented.

4.2 Reflective and Formative Measurement Models

Generally, a measurement model depicts relationships between a construct and its measures. On the other hand, a structural model establishes possible links between various constructs (Edwards and Bagozzi, 2000; Scholderer and Balderjahn, 2006). Therefore, it is important to develop and utilize an objective measurement model, prior to assigning any meaning to analysis of the structural model (Anderson and Gerbing (1982). Scholars have been measuring latent variables of their interest for over 30 years in social science (e.g., Churchill, 1979; Duncan, 1984; Nunally, 1978). Latent variables are representations of theoretical and empirical phenomena in studies, that cannot be directly observed, therefore should be assessed by manifest measures which are observable (Diamantopoulos, Riefler, and Roth, 2008). As pointed out above, the dimension model indicates the correlation between measures and constructs. The relationship, in this view, can result from two diverse directions, which include (a) formative measurement (from the measures to the construct) and (b) reflective measurement (from the construct to the measures). The reflective measurement model form of requirement (Figure 14) has an extensive history in social sciences and is closely related to traditional testing of hypotheses (Lord and Novick, 1968). In accordance with this theory, measures signify impacts of an underlying fundamental construct (Bollen and Lennox, 1991).

Thus, causality originates from the construct to the measures. The latent variable α specifically signifies the general cause common to all items x_i showing the construct, where all items correspond to a linear function of its causal construct and measurement error.

$$x_i = \mu_i \cdot \alpha + \varepsilon_i \quad [1]$$

where x_i is the i -th indicator of the latent variable α , ε_i is the measurement error for the i -th indicator, and μ_i is a coefficient (loading) capturing the effect of α on x_i . Measurement errors are assumed to be independent (i.e., $\text{cov}(\varepsilon_i, \varepsilon_j) = 0$, for $i \neq j$) and unrelated to the latent variable (i.e., $\text{cov}(\alpha, \varepsilon_i) = 0$, for all i).

Figure 14. Reflective measurement model

A primary feature of reflective models is that an alteration in the latent variable concurrently leads to changes in every measure. In addition, all dimensions in a reflective measurement model have to be interrelated (Bollen, 1984). The formative measurement model was first proposed by Curtis and Jackson (1962), and they queried the attribute of optimistically interrelated measures as a specified state of the reflective model. Land (1970) and Blalock (1964, 1968, and 1971) describe this unusual measurement standpoint in harmony with which measures causes the construct instead of its effects (see Figure 15). In this view, the indicators establish the latent variable, which derives its definition

from the previous one. Some distinctive cases are career success (Judge and Bretz, 1994), quality of life (Bollen and Ting, 2000, Fayers, Hand, Bjordal and Groenvold, 1997), socioeconomic status (Hauser and Goldberger, 1971; Hauser, 1973), or career success (e.g., Judge and Bretz, 1994). The formal specification of the formative measurement model is:

$$\alpha = \sum_{i=1}^n \mu_i x_i + \omega \quad [2]$$

where μ_i is a coefficient capturing the effect of indicator x_i on the latent variable α , and ω is a disturbance term. The latter comprises all remaining causes of the construct which are not represented in the indicators and are not correlated to the latter; thus following the assumption that $\text{cov}(x_i, \omega) = 0$.

Diamantopoulos and Winklhofer (2001) discuss important characteristics that distinguish this model from the reflective model and these characteristics are suitable for our highly objective measurement of product innovativeness.

- i) The indicators distinguish a set of different bases, which are not the same since every indicator shows a particular feature of the construct's field (Jarvis, MacKenzie, and Podsakoff, 2003; and Rossiter, 2002). Indeed, the nature of the

Figure 15. Formative measurement model

construct is potentially altered by the omission of an indicator (Bollen and Lennox, 1991). This is true for the measurements used in this thesis, in which market and technical novelties are the main dimensions, and eliminating either of the two dimensions directly affect the measurement result due to the nature of formative models.

- ii) Precise prospects about the outlines or degree of intercorrelations amongst the indicators do not exist because formative indicators could positively or negatively relate, or lack any relationship (Bollen, 1984). Therefore, unlike the reflective model, the internal consistency is not an issue in this case. This also fits the nature of the measurement model in this thesis as the two dimensions are totally independent of each other. Therefore, it cannot be expected that a certain type of novelty should be related to another type of novelty as, for example, a higher degree of style changes in a product cannot guarantee a high level of technical novelty, or visa-versa.
- iii) Formative indicators have no individual measurement error terms, that is, they are assumed to be error-free in a conventional sense (Edwards and Bagozzi, 2000). The error term (ζ) is specified at the construct level (MacCallum and Browne, 1993) and does not constitute measurement error (Diamantopoulos, 2006). In our model, there is no error term due to construction of composite indicators in the model rather than causal indicators.
- iv) In isolation, the formative measurement model is underspecified and, thus, may not be estimated (Bollen, 1989; Bollen and Davis, 1994).

4.3 Choosing an Effective Design for the New Measurement

While the reflective analysis model rules the management and psychological sciences, the formative analysis is widespread in sociology and economics (Coltman, Devinney, Midgley, and Venaik, 2008). Anderson and Gerbing (1988) stated that the dissimilarity between reflective and formative measures is essential since appropriate requirement of a measurement model is compulsory in assigning important relationships in the structural model.

Considerations of Coltman et al (2008) were used in this thesis, which propose that three extensive hypothetical considerations are vital in settling on whether the measurement model is reflective or formative. Such considerations incorporate, (i) the nature of the construct, (ii) the course of causality between the indicators and (iii) the features of the indicators used to measure the construct. At the same time, they suggest three empirical considerations that reveal the knowledge of the measurement model including (iv) measurement error and collinearity, (v) indicator correlations with construct precursors and effects and (vi) indicator intercorrelation. We will discuss each consideration in relation to our product innovativeness measurement model, and then decide which model is more suitable for our measurement. In the fourth column of Table 5 and 6, characteristics of our measurement are discussed according to the three theoretical and the three empirical considerations.

After the author decides which model is suitable for the measurement based on the three theoretical and three empirical considerations, the next step is to determine how to construct the measurement model in the formative way. According to Bollen and Bauldry (2011), the formative model can be built through two main approaches: causal model based on causal indicators, and composite model based on composite indicators.

A framework for assessing reflective and formative models (Coltman et al., 2008): Theoretical and empirical considerations

Table 5. Theoretical considerations (Coltman et al., 2008)

Theoretical considerations	Reflective model	Formative model	Our measurement model	Relevant literature
1. Nature of construct	Latent construct exists. <ul style="list-style-type: none"> Latent construct exists independent of the measures used 	Latent construct is formed. <ul style="list-style-type: none"> Latent constructs is a combination of its indicators 	The latent construct, Product Innovativeness, is formed by combination of market and technical novelty dimensions.	Borsboom et al. (2003, 2004)
2. Direction of causality between items and latent construct	Causality from construct to items <ul style="list-style-type: none"> Variation in the construct causes variation in the item measures Variation in item measures does not cause variation in the construct 	Causality from items to construct <ul style="list-style-type: none"> Variation in the construct does not cause variation in the item measures Variation in item measures causes variation in the construct 	In our model, the direction of the causality is items to the construct. To be specific, a combination of types of technical and market novelties determine how innovative the product is.	Bollen and Lennox (1991); Edwards and Bagozzi (2000); Rossiter (2002); Jarvis et al. (2003)
3. Characteristics of items used to measure the construct	Items are manifested by the construct <ul style="list-style-type: none"> Items share a common theme Items are interchangeable Adding or dropping an item does not change the conceptual domain of the construct 	Items define the construct <ul style="list-style-type: none"> Items need not to share a common theme Items are not interchangeable Adding or dropping an item may change the conceptual domain of the construct 	In the new measurement model, items and dimensions are independent. They do not share common theme, thus they are not interchangeable. Addition and elimination of an item can dramatically alter the domain.	Rossiter (2002) ; Jarvis et al. (2003)

Table 6. Empirical considerations (Coltman et al., 2008)

Theoretical considerations	Reflective model	Formative model	Our measurement model	Relevant literature
4. Item intercorrelation	<p>Items should have high positive intercorrelations</p> <ul style="list-style-type: none"> Empirical tests: assessing internal consistency and reliability by Cronbach alpha, average variance extracted, and factor loadings (e.g., from common or confirmatory factor analysis) 	<p>Items can have any pattern of intercorrelation but should possess the same directional relationship</p> <ul style="list-style-type: none"> Empirical test: no empirical assessment of indicator reliability possible; various preliminary analyses are useful to check directionality between items and construct 	In the new model, items have the same directional relationship.	Cronbach (1951); Nunnally and Bernstein (1994); Churchill (1979); Diamantopoulos and Siguaw (2006)
5. Item relationships with construct antecedents and consequences	<p>Items have similar sign and significance of relationships with the antecedents/ consequences as the construct</p> <ul style="list-style-type: none"> Empirical tests: establishing content validity by theoretical considerations, assessing convergent and discriminant validity empirically 	<p>Items may not have similar significance of relationships with the antecedents/ consequences as the construct</p> <ul style="list-style-type: none"> Empirical tests: assessing nomological validity by using a MIMIC model, and/or structural linkage with another criterion variable 	In our model, items do not have to possess significance of relationships with antecedents/ consequences as the construct.	Bollen and Lennox (1991); Diamantopoulos and Winklhofer (2001); Diamantopoulos and Siguaw (2006)
6. Identifying the error term in items is possible	<p>Identifying the error term in items is possible</p> <ul style="list-style-type: none"> Empirical test: identifying and extracting measurement error by common factor analysis 	<p>Identifying the error term is not possible if the formative measurement model is estimated in isolation</p> <ul style="list-style-type: none"> Empirical test: using the vanishing tetrad test to determine if the formative items behave as predicted Collinearity should be ruled out by standard diagnostics such as the condition index 	In our case, there is no error term as the construct is defined by addition of dimensions. However, we should test the multicollinearity issue in our model as a form of validation.	Bollen and Ting (2000); Diamantopoulos (2006)

In the causal model, the construct is defined as a causal effect of items or the causal indicators (Bollen, 1989 and Goldberger, 1973), while the composite model is built by a combination/addition/summation of composite indicators, thus it does not require an error term (Bollen and Bauldry, 2011). For example; Human Development Index (HDI), which is defined by a combination of (i.e. geometric mean) of three indicators namely Life expectancy, Education and Income distribution (Human Development Report, 2013). In the present case, the measurement is built through the composite model, because we do not try to determine product innovativeness as a causal measure, instead it is formed by a combination of composite indicators.

Figure 16. Measurement model of Product Innovativeness

In brief, the new measurement model is designed as formative by defining product innovativeness with indicators (items), and is constructed through the composite model, which uses object variables to assess innovativeness of a product.

4.4 Properties of the New Measure of Product Innovativeness

We now proceed to discuss principles of the model by demonstrating that a reliable measure of product innovativeness must be direct, highly objective, contemporary, and cardinal. As a result, it is possible to design the measure that avoids pitfalls of the prior measurements used in the literature.

Figure 17. Defining and Building principles of the model

Source: Developed for this work

4.4.1 Directness of the Innovativeness Measure

We advocate that product innovativeness should be measured at the product level. In the prior literature, however, product innovativeness mainly has been measured at the firm level, via (i) *inputs*, namely efforts made toward creating product innovation (Geroski, 1994), such as R&D intensity/expenditures (e.g., McAlister, Srinivasan, and Kim, 2007)

and/or number of patents (e.g., Tellis et al., 2009); (ii) *processes*, which can be openness to new ideas as an aspect of firms' organizational culture (Hurley and Hult, 1998), and (iii) *outputs*, which are consequences of innovation activities visible to consumers (Geroski, 1994), such as number of new products or service introductions (e.g. Zhou, Yim, and Tse 2005). Recently Story, Boso, and Cadogan (2015) identified three key factors that scholars have used to determine innovativeness at firm levels: these include 1) spending on R&D (e.g. Özçelik and Taymaz, 2004), 2) innovation capabilities (e.g. Hult and Ketchen, 2001), and 3) internal and external firm-level environmental and institutional factors (see Deshpandé and Farley, 2004; Kyrgidou and Spyropoulou, 2013). In some cases, scholars utilize measurement at the individual level (e.g. Oldham and Cummings, 1996) and the team level (e.g. Im, Montoya, and Workman, 2013). While these proxy measures may provide a more holistic assessment of product innovativeness where issues of data availability or convenience are concerned, they also introduce measurement error into empirical analyses, because the relationship between these firm, individual, or team-level measures and innovativeness at the product level is not necessarily highly correlated. These measures cannot be relied upon across firms or over time due to differences in and changes of the variables and practices at the higher levels. Measuring product innovativeness directly at the product level is expected to provide more reliable data for empirical analyses. What should be measured at the product level is discussed subsequently in this paper.

4.4.2 Objectiveness of the Innovativeness Measure

Measures of product innovativeness at the product level have typically been subjective measures, derived from questionnaire surveys that require the respondent to choose a score on an ordinal scale. For instance, Sethi, Iqbal and Sethi (2012) utilised a three-item, seven-point Likert-type scale for dimensions such as technological newness and market

newness, while Chandy and Tellis (2000) used technology and customer benefits as dimensions, measuring these on a 1-9 Likert scale where 1 indicates no difference at all (technology dimension) and no benefits at all (customer benefits dimension) and the 9 indicates substantial technology difference and higher customer benefits. In the entrepreneurship literature, scholars operationalize innovativeness through single-item (e.g. Shepherd and DeTienne, 2005) and multi-item scale (e.g. Collewaert and Sapienza, 2016), and in-depth interviews (Partanen, Chetty, and Rajala, 2014). The Community Innovation Survey (CIS) has frequently been utilized by scholars (e.g. Cefis and Marsili, 2012). A measure of Innovation Orientation is also commonly used construct to determine innovativeness (e.g. Zhou, Brown, and Dev, 2009 and Rosenbusch et al., 2011). However, using questionnaire methods with ordinal scales is most likely to produce subjective evaluations that are highly individualistic perceptions of reality (Bechky, 2003; Maitlis, 2005), so that they might not always be consistent across firms nor over time. Even though the above measures are valuable indications of product innovativeness, they are vulnerable to some biases associated with survey methods, such as social desirability and self-reporting (Fisher, 1993). Therefore, a model is proposed here that only assesses observable objective novel features that are embedded in innovative products and is independent of the opinions of managers, customers, and competitors.

4.4.3 Contemporaneousness of the Innovativeness Measure

Rather than reflecting recollection of past periods and/or anticipating the future, product innovativeness should be measured at the time of market entry, since observations over a period of time will be confounded by the appearance of other firms' new products also within that time period. A firm's product innovation may be new to the market one week, but if introduced a week or month later might not be new to the market due to another

firm's launch of a similar new product. Arguably, this aspect of the measurement of innovativeness may be one of the crucial gaps in the literature. Szymanski et al., (2007) noted in their meta-analysis of studies in product innovativeness that measurement of product innovativeness must be good at covering the true qualities of an event over time as a modification of research tools. Product innovativeness has also been measured as reflection of the past activities such as the Oslo Manual-Guidelines for Collecting and Interpreting Innovation Data (2005) and Community Innovation Survey (2014), in which participants asked to report on their last three and two year's innovativeness respectively, while some scholars use ex-ante measures (e.g. Hyytinen et al., 2015) that focus on future innovativeness to avoid ex-post indicators that tend to be biased toward innovators that are more likely to be successful (Buddelmeyer et al., 2009). Whilst acknowledging the significance of these retrospective and prospective measures, we intend to expand them by developing a model that measures product innovativeness at the current time because innovativeness is a highly context-dependent variable, thus when and where the product was measured directly impacts its innovativeness value. A contemporary measure of product innovativeness allows accurate recording of innovativeness over time, which is not affected by retrospective and selective memory biases. Furthermore, the contemporary measure opens research possibilities such as conducting longitudinal analysis (e.g. an event study), identifying specific lagging, and leading factors relating to product innovativeness.

4.4.4 Cardinality of the Innovativeness Measure

To evaluate product innovativeness scholars have used categorical measures such as high, moderate, or low innovativeness; incremental or radical innovativeness; new or not new; and routine or radical (Garcia and Calantone, 2002). Recently, Hyytinen et al., (2015) used a binary measure (innovative or non-innovative) to investigate a relationship

between start-up survival rate and its innovativeness. But compared to categorical measures, continuous measures increase the likelihood that the underlying nature of the relationship will not be distorted (Cohen and Cohen, 1983). Some scholars have acknowledged the need for continuous measures but have operationalized the variable as an ordinal variable by the use of Likert scales as wide as 1-10 (e.g. Shepherd and DeTienne, 2005; McNally et al., 2010; Schultz et al., 2013; Chan and Parhankangas, 2017). Although capturing product innovativeness as a quasi-continuous variable over a wide Likert scale is likely to preserve the properties inherent in the phenomenon and should produce estimates of relationship strength that may be reasonably accurate on average, such ordinal measures make it difficult to aggregate and compare their values across industry as they are reflections of managers' (subjective) assessments of their own products.

Accordingly, we propose a measure of product innovativeness that is cardinal and is operationalized by counting the numbers of novelties (new aspects) embodied in the new product. The *cardinality* of a set A, is the number of elements in A. Cardinality may be interpreted as "set size" or "the number of elements in a set" (Clapham and Nicholson, 2009). Therefore, cardinal numbers indicate absolute values of the phenomenon as they provide the possibility to execute the measurement objectively and compare different phenomenon independently, which were not possible when ordinal measures are used. In our model, the set is 'product', and the cardinality of the set is 'the number of novelties'. When a cardinal measure demonstrates product innovativeness, it uses a whole number (with no fractional or decimal part, as well as no negatives), it can reveal more specific and detailed information regarding the innovativeness. Consequently, the proposed innovativeness measure can indicate exactly what type of and how many technical novelties have been achieved in the product, and how many of those novelties

can be considered new to the firm, or new to the market, or new to the world. We consider these distinctions in detail later in chapter 5.

4.4.5 Universality of the Innovativeness Measure

Products characteristics or dimensions are diverse, and consequently, a range of innovativeness measures has been introduced to build and use particular industry innovation measures. For example, Agarwal and Prasad (1998) introduced innovativeness constructs specifically designed for the IT domain; Avlonitis, Papastathopoulou and Gounaris, (2001) developed items for new financial services; and Pauwels, Silva-Risso, Srinivasan, and Hanssens (2004) proposed measures for the automobile industry. These domain-related measures are effective in a way that considers the uniqueness of their products or industries. However, this approach may limit compatibility and applicability of the measures. Moreover, because of different criteria being used for the measures, they might cause opaqueness on what they are reporting especially for comparative analysis across industries. Szymanski et al. (2007) note that various contextual and measurement differences could contribute to the confusion on what studies are actually capturing and reporting. Here it is argued that there is a need for a universal and simple product innovativeness measure in entrepreneurship research, which allows different products and industries to be studied and compared with adequate reliability. The proposed measure can be applied universally across various firms and industries, and the measure's applicability and reliability will not be affected by contextual factors that may be more appropriately regarded as moderators of the innovativeness and other concept relationship (e.g. innovativeness-profitability nexus), rather than being involved in the measure of innovativeness.

4.4.6 Multidimensionality of the Innovativeness Measure

The accuracy and effectiveness of single-criterion measures have been questioned in the literature (e.g. Kerlinger, 1999). Our proposed new measure examines two multidimensional categories to evaluate product innovativeness objectively. ‘Technical novelty’ is categorised into four sub-categories, and ‘market novelty’ is categorised into three sub-categories. The proposed measure is based on a two-stage assessment (i.e. as a combination of the dimensions that produces a crosstab analysis), rather than measuring the construct of interest only once (e.g. see McNally et al., 2010). In the following section, we will discuss in detail how the measurement assesses product innovativeness using the multi-dimensional approach.

The new measure may ensure independence or objectivity of the measurement values and assure the ability to produce replicable and consistent findings, as it is based on observable objective evidence. Subsequently, a quantitative expression of the observed phenomenon can be determined as the degree of product innovativeness.

4.5 Theoretical Propositions for a New Measure of Innovativeness

The new measure defines innovativeness objectively by considering both the technical novelty and the market novelty of the product innovation relative to the firm’s prior products; and to the products of local competitors (i.e. those that are in the same geographic market in the same product category); and to remote competitors (those that compete in other markets for the same product category). Accordingly, we determine the product innovativeness construct through conceptualizing a combination of two dimensions that can be measured objectively: namely type of technical novelty and type market novelty.

This approach is different from previous work. For example, Sethi et al., (2012) used technological newness and market newness, which is similar to our model, but their dimensions are proxy rather than direct. They operationalized market newness as the degree to which the new product targets new markets and requires new sales and customer support infrastructure compared with other products of the business unit, which is a type of consequence measure. Moreover, the technological newness in their work assessed the extent to which the product requires new technologies, engineering and design skills, and production processes compared with other products of the business unit, which is a type of antecedent measure. In contrast, our measure directly focuses on a product and measures its innovativeness through the dimensions that can be observed directly, which ensures the validity of the measurement. In terms of a procedure, the model is also different from other works, such as McNally et al. (2010) who applied technological, marketing, and customer discontinuity dimensions with 9 items in total, and Schultz et al., (2013) who determined innovativeness by evaluating four factors encompassing 21 items. However, these studies assessed their 9 and 21 items concurrently (at once, in a single score) rather than sequentially in a compound score. By contrast, our model will evaluate product innovativeness through intersections of dimensions (i.e. cross-checking one dimension with the other dimension), which should increase the accuracy and consistency of the evaluation.

Thus, we conceptualize a model that screens a product through two stages (types of technical novelty and types of market novelty) in order to observe and record innovative and novel elements that are embodied in the product, to arrive at a summative estimation of product innovativeness. We do not use dimensions such as technological, customer, and marketing discontinuities (McNally et al., 2010) for our highly objective innovativeness model because these factors are proxies and are usually evaluated by

subjective measures. It is noted that a technological discontinuity can be considered as an *antecedent* for innovativeness because firms that operate in the new technological domain (Song and Montoya-Weiss, 2001) are expected to deliver at least some product innovativeness, while customer and marketing discontinuities can occur as *consequence* of product innovation. Incorporating market success variables is avoided since these would confound the estimation of the innovation-profitability relationship.

When determining product innovativeness, scholars usually treat a product as a whole unit. However there is some work that considers products in detail, such as Pauwels, Silva-Risso, Srinivasan, and Hanssens (2004) who broke down product innovativeness into five levels, but these are applicable only to the automobile industry. Other scholars study product newness separately as technological (e.g. Gemunden, Salomo, and Krieger, 2005) and design newness (e.g. Talke, Salomo, Wieringa, and Lutz, 2009). In our model, we utilise a new taxonomy for the type of newness, which recognises generic types of newness that can be manifested in a product as a result of the innovation process. Therefore, product innovativeness will not be assessed monolithically by the whole product but rather through four different levels of technical novelty, and three different types of market novelty observed in the product, so that the overall measurement may reveal more detailed information regarding the product's innovativeness.

4.5.1 Technical Novelty Dimension

Novelty refers to the extent to which a concept, idea, or object differs from conventional practice within the domain of interest (Sethi et al., 2001). We argue that for simplicity and universality of the measurement we decompose technical novelty into four general categories that can be applied to any product in any market, namely style changes, function improvement, function addition, and “really new products” (Lehmann, 1994; p.6). We conceptualize that these technical novelty types can be ranked in order in terms

of innovativeness from a technological discontinuity perspective, which implies that style changes are the least innovative category, followed by function improvements, then function additions, and finally really new products, which are the most innovative type in our technical novelty taxonomy.

Style changes refer to the visual newness of a product, which we refer to in broad terms as style or appearance of a product (Micheli, Jaina, Goffin, Lemke, and Verganti, 2012). Products are multidimensional in terms of their attributes (Salavou, 2004) and one of the critical dimensions from the customer's perspective is external design or visual appearance (Yamamoto and Lambert, 1994; Talke et al., 2009). Scholars in design literature define various concepts to determine design newness, such as originality (e.g. Runco and Charles, 1993); novelty (e.g., Hekkert, Snelders, and van Wieringen, 2003); uniqueness (e.g., Bloch, 1995); or atypicality (e.g., Loken and Ward, 1990). However, Talke et al., (2009) noted that all the above concepts describe the deviation in a product design from the prior design state. Thus, the newer a product design is (i.e., the more atypical it is of a category), the less attributes it shares with other members of the product category (Loken and Ward, 1990) at the time it is launched. This product category view implies that the design newness of a product can be determined by comparing its appearance with those of competing products (Talke et al., 2009). Therefore, in our model, we determine design newness or style changes of a product by identifying the number of design differences that are new to the firm (relative to its prior products); new to the market (relative to the products of its immediate competitors); and new to the world level (relative to products of its remote competitors). We argue that the design newness represents the least innovative type of newness as it only alters the external appearance by aesthetic changes such as in colour, texture, shape, and design. More formally, we assume:

Assumption 1. Style changes are the least innovative form of technical novelty in our objective product-innovativeness measurement model.

Function improvement. A product function refers to the product's ability to serve specific customer needs and/or problems (Ziamou and Ratneshwar, 2003). A function improvement implies a performance improvement for one function of the product and is perhaps the most common type of technical novelty. A new product might simultaneously incorporate several function improvements relative to its earlier version and to competing products. In this model, we account for all function improvements in a new product by comparing the new product to existing products to identify how many function improvements have been achieved in the new version. As an objective model, it does not consider qualitative aspects of the improvements, which can be perceived differently by individual consumers across the market, such as importance, value, or usefulness. Therefore, if a product has a greater number of function improvements, it will be considered to be more technically novel in this function improvement type of product innovation.

We argue that function improvements are more innovative than style changes as they change the performance of the product relative to former offerings. To complement the hierarchy of the four types of technical innovation, and to allow the summation of the types of innovation to provide a single cardinal measure of innovativeness, we assume that no matter how many style changes are manifested in a new product, the aggregated innovativeness of those style changes will not be greater than the innovativeness of a single improvement in the functional capability of the product. This assumption is necessary to avoid arbitrary weights leading to nonsensical outcomes. For example, if the weights chosen were 1 for style changes, 5 for function improvements, and 10 for function additions, this would result in (e.g.) 6 style changes being judged to be more innovative than 1 function addition. Thus we state formally:

Assumption 2. A single function-capability improvement is more technically novel than any number of style changes.

Function addition. A function addition occurs when a product has been enhanced by a new function that did not exist in the previous version of the product, such as the introduction of mobile phones of built-in cameras by the Nokia 7650 and the Sanyo SPC-5300 models in 2002 (Hill, 2013). The measurement of function additions will be conducted in the same manner as the previous innovations by listing the product's new function additions that are new to the firm, market, and the world. As a result, the absolute value of the measurement outcome indicates how many new function additions have been integrated into the new product compared to prior products. We assume that a single function addition is more innovative than the collective innovativeness associated with improving the performance of any number of existing functions, as it creates new dimensions to the product from both technological and market points of view. Thus:

Assumption 3. A single function addition is considered more technically novel than any number of function improvements in our product-innovativeness measurement model.

Really new products create a new product category (Song and Montoya-Weiss, 1998; Füller and Matzler, 2007) and provide functionalities using different technologies compared to prior products, for example, the Segway personal transporter (Gourville, 2006). Really new products (RNPs) let consumers do new things, but at the cost of greater uncertainty regarding benefits and cost-benefit trade-offs, and requiring greater changes in consumer behavior for successful use (Wood and Hoeffler, 2013). Logically, RNPs are the most innovative form of product innovativeness, since they break new ground in both technology and market dimensions. We argue that any number of lower-degree technical novelties (i.e. style changes, function improvements, or function addition), can never be equal to a single RNP in our objective technical novelty scale. Therefore, if a firm offers

a RNP, the product innovativeness score will be higher than for new products that offer a restyled, improved, and/or expanded product. Stated formally:

Assumption 4. A single really new product is considered more technically novel than any number of additional functions in our product-innovativeness measurement model.

Style changes, function improvement, and function addition have previously been collectively called ‘incremental’ product innovation, which is defined as new products that remain within the same product category as before, and where the benefits and cost-benefit trade-offs are more certain than for RNPs (Hoeffler, 2003). Incremental product innovation does not require consumers to change significantly their behavior in order to enjoy the promised benefits. Similarly, RNPs alternatively may be called ‘radical’ or ‘breakthrough’ innovation, typically requiring changes in consumer and producer behaviour. We note that the binary categorisation of technical novelty (i.e. incremental vs radical) compresses three of our technical novelty types into the ‘incremental’ product innovation category, which would serve to potentially conceal detail in the innovativeness measure.

4.5.2 Market Novelty Dimension

Rosanna and Calantone (2002), identified several different perspectives of market newness, namely ‘new to the world’ (Song and Montoya-Weiss, 1998); ‘new to the firm’ (Ettlie and Rubenstein, 1987); ‘new to the market’ (Kleinschmidt and Cooper, 1991; Meyers and Tucker, 1989); and ‘new to the customer’ (Atuahene-Gima, 1995). Furthermore, they defined newness as ‘new to industry’ and ‘new to firm’ as consequences of marketing and technology discontinuities at the macro and micro levels. Since ‘new to the customer’ contains potential overlap with new to the market, and since it begs the question of consumer ignorance (Shepherd, Douglas and Shanley, 2000) we choose to analyze market novelty across three levels of newness, namely new to the firm,

new to the market, and new to the world (i.e. new to the industry). Thus, the model determines product innovativeness by assessing technical newness in the product (i.e. decomposed as four types) from three market newness perspectives (i.e. new to the firm, new to the market, and new to the world), which we now discuss in turn.

New to the firm is the base case of market novelty – the least degree of market newness is found in a new product is when it is simply new to a particular firm. To be considered as ‘new to firm’, the new product must offer a novelty in any type of technical novelty (i.e. style change, function improvement, function addition, or really new product), compared to any prior products from that firm. For example, it could be new style alone, with functionality remaining the same as the firm’s prior product. Nonetheless, the new product contains a noticeable element of newness, namely the style change. Thus we state:

Assumption 5: ‘New to firm’ is the base case of market novelty.

New to market is a criterion that examines whether the product as a whole or in the technical novelties that are evident in the product (e.g. style changes, function improvement, or function addition) are introduced into the market by the focal firm before its competitors do that. However, new to one specific market may not be new to other markets for the same product. For example, a function improvement in the new product (e.g. an automatic toilet seat) can be considered as ‘new to market’ improvement when it was first released in England, yet it was no longer new to the market in Japan (where it was new-to-the-world at an earlier juncture). Markets may also be psychographically separated, such as women’s and men’s cosmetics. A market may be an actual or nominal place in which demand and supply meet, including the internet, and is usually bordered by geographic, psychographic, and legal limitations. Thus, the ‘new to market’ is a local characteristic, which varies across geographical markets for the same product and is valid

for only a specific geographic market context. In other words, this level of newness happens when the product introduces technical novelties compared to its immediate competitors who are operating in the same market for the same customers. In the measurement process, to avoid double counting, if a new product or any of its innovations are ‘new to the market’ this supersedes and replaces ‘new to the firm’, therefore any technical novelty will be measured once at its highest level. Stated formally:

Assumption 6: ‘New to the market’ is a higher level of market novelty than ‘new to the firm’ for a new product and its four types of technical novelty.

New to the world is the highest level of market novelty in our model. It implies a new product in which one or more of its four types of technical novelty is/are totally new to both its immediate competitors (i.e. new to market) and also to remote competitors (i.e. competitors operating in different geographic markets for customers with the same needs and wants). We argue that ‘new to the world’ implies that it must also be new to the relevant industry. However, it is different from the ‘new to industry’ newness that was previously conceptualized by Garcia and Calantone (2002), where they considered that ‘newness to industry’ was effectively the same as ‘newness to market’ if the industry is defined locally, and thus they felt that ‘newness to market’ did not need to be explicitly modelled. However, in our model it should be explicitly modelled because ‘newness to market’ does not guarantee ‘newness to industry’ as international markets differ in terms of their competitiveness and technological advancement. Note that if a new product or any of its technical novelties are ‘new to the world’ this supersedes and replaces their ‘new to the market’ status. Stated formally:

Assumption 7: ‘New to the world’ is the highest level of market novelty and implies that any type of technical novelty in a product can be considered as ‘new to the world’ only if it has been introduced for the first time in the product’s worldwide industry.

4.6 Conclusion of Chapter 4

In this chapter, the design of the product innovativeness measure is discussed. We outlined both formative and reflective models, the two main measurement models that have been used by scholars to establish measurements. Based on the three theoretical and three empirical considerations to ensure a suitable approach to the research, a formative model studying innovativeness at the product level was selected. The following section described the properties of the new measures that can ensure a reliable assessment of product innovativeness. Then, the two dimensions of the model and their sub-categories were explained in detail. Finally, the internal logic of the measurement model has been defined as series of assumptions, which serve as a foundation to mathematical modelling of the measurement in the next chapter.

CHAPTER 5. DEVELOPMENT OF THE MEASUREMENT MODEL

Outline of Chapter 5

5.1 Introduction

In this chapter, the development of the measurement model is discussed in detail. In section 5.2, the product innovativeness matrix is introduced, which is designed to systematically identify and register all novelties in the product. It provides a 3x4 matrix, which can account up to twelve different inputs of novelties that can be found in a new product through a combination of market and technical novelty constructs that were defined in the previous chapter. Subsequently, in section 5.3, the model development is presented, which explains how the innovativeness matrix is used to provide a calculation of the compound product innovativeness score (CPIS). In section 5.4, the double-transformation method that is specifically designed for the model is explained using an illustrative example. The double-transformation method combines a linear and an inverse function, to represent values of technical and market novelties. Next, in order to

demonstrate how the measure actually assesses product innovativeness, a hypothetical example is employed, and the CPIS result for that particular case is shown in section 5.5. In section 5.6, the academic and managerial implications, and limitations of the model, are discussed. Finally, this chapter concludes with a summary in section 5.7.

5.2 The Innovativeness Matrix

To develop a highly objective innovation measurement that assesses a given product’s innovativeness, we propose a product innovativeness matrix that combines both market novelty and technical novelty, having three and four levels respectively, as shown in Figure 15. As a result, there will be twelve different combinations of technical and market novelties in the cells of the matrix. The purpose of the matrix is to systematically identify and register the innovative elements that are evident in the product, so that it provides necessary information for estimation of a final compound product innovativeness score of the product. The number of novelties in each cell of the matrix captures the raw data that is collected by objective observation of the product. Consequently, the matrix serves as a systematic assessment framework that facilitates the evaluation of the product’s overall innovativeness, which is determined by a two-stage transformation method that transforms the raw data into a single value that can represent all novelties in the product.

Figure 15. Product-Innovativeness Matrix

The measurement model is designed to systematically process the different technical and market novelties (in a new product) into a single cardinal measure. As the prior chapters highlighted, existing measures are difficult to compare and aggregate, thus a new model is proposed that combines the two different dimensions, subject to the assumptions 1 to 7 which demonstrate hierarchy differences of product innovativeness. Product innovativeness cannot be defined by directly adding up all novelties in the product, as some extant measures do with patents or citation numbers (e.g. Buddelmeyer et al., 2009; Helmers and Rogers, 2010; Colombelli, Haned, and Le Bas, 2013) because there are 12 different possible novelties that can be identified in the matrix through the combination of the two dimensions. In this case, lexicographical ordering, a type of conditional ordering, where the vector components are ordered conditionally based on some of their marginal components (Aptoula and Lefevre, 2008), could be used as it assesses and orders the novelties in the product without using arbitrary weights by considering the qualitative aspects through ranking them according to the conditions we set as the assumptions. For instance; a product that has the most function additions is the highest, with the most function improvements breaking any ties for function additions, and the most style changes breaking any ties for function improvements according to the foundational assumptions. However, lexicographical ordering is an ordinal measure and cannot provide an absolute or relative value of individual products' innovativeness.

Therefore, we need a model that considers qualitative differences among novelties in a lexicographic manner, yet can combine them to provide a final innovativeness score without using arbitrary weights. Arbitrary weights are problematic when combining all novelties in the product as they might lead to an illogical conclusion, perhaps implying that, for instance, five novelties that are new-to-the-firm are equal to one new-to-the-market novelty if we assign them constant weight values such as 1, 5, and

so on. Scholars collectively agree on a notion that developing something new-to-the-firm is less innovative than new-to-the-world (e.g. Garcia and Calantone, 2002), but we do not know how much more innovative in terms of numbers. Nevertheless, scholars in new product development literature such as Sethi et al., (2001) used constant weights to combine two dimensions that are novelty and appropriateness, which can be problematic as it could imply that a certain amount of novelty is equal to some amount of appropriateness. We avoid this pitfall by not using constant weight values in the new model.

5.3 Two-stage Transformation Method for Product Innovativeness

In order to measure product innovativeness as a whole, the model should evaluate product innovativeness in two phases. In the first phase, the technical novelties should be evaluated and categorised as style changes, improved functionality, and new functionality, and subsequently these technical novelties are each evaluated in terms of their market novelty, through a two-stage transformation method. When the market novelties are calculated, the final product innovativeness score, which we call the Compound Product Innovativeness Score (CPIS), is calculated by combining each level of market novelty values. Figure 16 provides an overview of the procedure for the product innovativeness measurement.

5.3.1 Technical Novelty Score

The question arises whether novelties inherent in a new product should aggregate linearly or nonlinearly in some particular way. Should four style changes be considered twice as innovative in total compared to two style changes? To avoid such arbitrary assumptions and to achieve a tractable model we have assumed that product innovativeness is measured by a combination of inverse and linear functions to capture each of the four types of technical novelty, and, similarly, each of the three types of market novelty.

Figure 16. Procedure of the Measurement Model

Source: Developed for this work

After conducting a series of analyses to determine the appropriate mathematical functions that would not provide illogical or incompatible results, we found that to satisfy assumptions 1 to 7, and therefore comply with the logic of the measurement model, the Technical Novelty Score (TNS), representing the technical novelty types of product innovativeness, should be measured by the functions shown in Table 7.

Table 7. Technical novelty equations

	Technical novelty types	Functions to measure
Stage I.	Style changes	Inverse function with horizontal asymptote
	Equation:	$NV_t^{sc} = 1 - \frac{1}{ax_t + 1} \quad [1]$
	Function improvement	Linear function
	Equation:	$NV_t^{fi} = y_t \quad [2]$
Stage II.	A combination of style changes and function improvements	Inverse function with horizontal asymptote
	Equation:	$NV_t^{com} = 1 - \frac{1}{b(NV_t^{sc} + NV_t^{fi}) + 1} \quad [3]$
	Function addition	Linear function
	Equation:	$NV_t^{fa} = z_t \quad [4]$
Result	Technical Novelty Score (TNS)	Sum of all technical novelties
	Equation:	$TNS_t = NV_t^{com} + NV_t^{fa} \quad [5]$

Where:

TNS_t – Technical novelty score (Sum of all technical novelties)

NV_t^{sc} – Novelty value of style changes at time t

NV_t^{fi} - Novelty value of function improvements at time t

N_t^{fa} – Novelty value of function additions at time t

N_t^{com} – Combined novelty values of style change and function improvement at time t

x_t – Number of style changes at time t

y_t – Number of function improvements at time t

z_t – Number of function additions at time t

In stage 1, the functional relationship between the novelty values (the vertical axis) and each of the novelties (the horizontal axis) is best approximated by an inverse function with a horizontal asymptote (see equation [1]) as an upper limit, in which the novelty values approach the upper limit value as numbers of novelties increase but will never reach the asymptote (see Figure 17). Therefore, any value of function improvements, which is represented by a linear function (see equation [2]), will always be greater than that of the style changes (reflecting our assumptions 1, 2, and 3 that a single novelty of a particular type would represent more innovativeness than any number of novelties of an inferior type). The numbers of novelties are whole numbers (i.e. 0, 1, 2 ...), as they indicate how many of a certain type of novelties have been embodied in the new product. Thus, if a new product has one function improvement, its novelty value is one, which is higher than any number of style changes that is represented by the inverse function with a horizontal asymptote ($y = 1$). Novelty values of the style changes increase as numbers of style changes increase, but the rate of the novelty values decrease due to the horizontal asymptote that rules how the function will behave at extreme values of the graph (see the equation [1]). By combining the two different functions (i.e. equations [1] and [2]), in which the one is linear and limitless and the other one is nonlinear and limited, we can define the main characteristics of our measurement model (i.e. the assumptions 1 to 7), namely that novelty values of any number of novelties in a lower degree of technical

novelty will be less than the novelty value of a single novelty in a higher degree of technical novelty. This approach allows a measurement model to satisfy the underlying assumptions 1 to 7 and to avoid nonsensical results.

Figure 17. Demonstration of determining technical novelty values

Stage 1. Technical Novelty Value (Style changes and Function improvements)

Stage 2. Technical Novelty Value (Combination of Stage 1 and Function addition)

In stage 2, while the inverse function (equation [3]) exhibits possible novelty values that the combination of novelty values of style changes and function improvements, the linear function (equation [4]) shows all possible values that can be generated by any number of function additions. By combining the two lesser-degree technical novelties (i.e. style changes and function improvement) and demonstrating their values by the inverse function (equation [3]), we ensure the validity of the underlying assumptions, as the higher degree of technical novelty, the function addition, is defined by the linear function (i.e. the equation [4]). Thus, any (especially large) number of novelties of style changes and function improvements will be less than a novelty value of a single function addition. After the second stage, that is defining novelty values of the function additions and the combination of style changes and function improvements, the technical novelty score (TNS) can be determined by the equation [5] combining the results. The TNS basically indicates the total technical novelty value for any given product and every product has three TNSs, namely those are the TNS at firm-level, TNS at market-level, and TNS at the world-level. Therefore, using the same two-stage transformation method, we can determine the TNS for each level, and they will be used to define the compound innovativeness score (CPIS) of a new product. In addition, the TNS gives unprecedented ways to study and analyze product innovativeness as the TNSs of the firm, market and the world levels can be used in the more detailed analysis regarding product innovativeness of firms such as breaking down innovativeness of firms and identify which firms are more active in what level of innovativeness. By utilising the two-stage transformation method, we can systematically transform any case of technical novelties that can be various combinations of numbers of technical novelties into technical novelty values while maintaining and contrasting the qualitative differences (i.e. style changes, function improvements, and function additions) among the novelties.

Stage 3. Calculating total score of technical novelties

Technical Novelty Score (TNS) is $TNS_t = NV_t^{com} + NV_t^{fa}$

5.3.2 Market Novelty Values

The three TNSs that are determined in each level (i.e. firm, market, and the world) cannot simply be added together because they all represent different types of novelties, or to be precise, three different levels of technical novelties. Therefore, under the assumptions 5, 6 and 7, they have to follow the same logic and the same procedure as the determination of the technical novelty values (see Figure 18), i.e. that any score of firm-level (i.e. new to firm) innovativeness will be less than any score of market level (i.e. new to market) innovativeness, while any score of market level innovativeness should be less than any score of the world level (i.e. new to the world) innovativeness. In Table 8, all the equations to calculate market novelties are shown.

Table 8. Market Novelty equations

	Market novelty types	Functions to measure
Stage I.	New to firm	Inverse function with horizontal asymptote
	Equation:	$MNS_t^f = 1 - \frac{1}{c(TNS_t^f)+1}$ [6]
	New to market	Linear function
	Equation:	$MNS_t^m = (TNS_t^m)$ [7]
Stage II.	A combination of ‘new to firm’ and ‘new to market’	Inverse function with horizontal asymptote
	Equation:	$MNS_t^{com} = 1 - \frac{1}{d(MNS_t^f + MNS_t^m)+1}$ [8]
	New to the world	Linear function
	Equation:	$MNS_t^w = (TNS_t^w)$ [9]

Result	Compound Product Innovativeness Score (CPIS)	Sum of all market novelties
	Equation: $CPIS_t = MNS_t^{com} + MNS_t^w$ [10]	

Where:

$CPIS_t$ – Compound innovativeness Score (Sum of all market and technical novelties)

MNS_t^f – Firm-level market novelty score at time t

MNS_t^m – Market-level market novelty score at time t

MNS_t^w – World-level market novelty score at time t

MNS_t^{com} – Combined market novelty scores of firm-level and market-level at time t

TNS_t^f – Technical novelty score at the firm-level at time t

TNS_t^m – Technical novelty score at the market-level at time t

TNS_t^w – Technical novelty score at the world-level at time t

In stage 1, the functional relationship between the market novelty value (the vertical axis) and the TNS^f (the horizontal axis) is best approximated by an inverse function with a horizontal asymptote (see equation [6]) as an upper limit, in which the novelty values approach the upper limit value as numbers of novelties increase but will never reach the asymptote (see Figure 18).

Figure 18. Demonstration of how market novelty values are determined

Stage 3. Calculating total score of technical novelties

The final innovativeness score (CPIS) is $CPIS_t = MNS_t^{com} + MNS_t^w$

Novelty values of the 'new to firm' increase as the TNS^f at the firm increases, but the rate of the novelty values decrease due to the horizontal asymptote that rules how the function will behave at extreme values of the graph (see the equation [6]). This approach allows a measurement model to satisfy the underlying assumptions 5 to 7 and to avoid nonsensical results. In stage 2, while the inverse function (equation [8]) exhibits possible novelty values that the combination of novelty values of 'new to firm' and 'new to market', the linear function (equation [9]) shows all possible values that can be generated by any number of 'new to the world' novelty. After the second stage, the technical novelty score (TNS) can be determined by equation [10] as combining the results. The CPIS then indicates the total score of product innovativeness that has been calculated as a combination of market and technical novelty values.

5.3.3 The Compound Product Innovativeness Score

The CPIS is a single value that can indicate how innovative a certain product is by transforming absolute numbers of all the different types of novelties that are registered in the product innovativeness matrix. Moreover, this value depends on time, and can be broken down into sub-categories to reveal exactly what type and level of novelties make the CPIS value what it is. We can represent the CPIS as follows:

$$CPIS_t = MNS_t^{com} + MNS_t^w$$

Where:

$$MNS_t^{com} = 1 - \frac{1}{d(MNS_t^f + MNS_t^m) + 1}$$

$CPIS_t$ – Compound Innovativeness Score (Sum of all market and technical novelties)

MNS_t^f – Firm-level market novelty value at time t

MNS_t^m – Market-level market novelty value at time t

MNS_t^w – World-level market novelty value at time t

MNS_t^{com} – Combined novelty values of firm-level and market-level novelties at time t

5.3.4 Parameters of the functions

To apply the model to specific new products it is necessary to assume values for the constants a , b , c , and d which are the parameters for the equations. To satisfy the underlying assumptions, the least degree of technical novelty, the style changes, should be given the lowest value, such as $a = 0.1$ and $b = 0.3$. Similarly in the market novelty stage, ‘new to firm’ novelties should have a lower parameter than the combined market novelty values of ‘new to firm’ and ‘new to market’ such as $c = 0.2$ and $d = 0.6$ respectively. The actual values are not important, but their relative weights are. In Table 9, technical novelty equations with the parameters are shown.

Table 9. Technical Novelty Estimation

	Technical novelty types	Equations	Estimation order
Stage I.	1. Style changes	$NV_t^{sc} = 1 - \frac{1}{0.1x_t + 1}$	
	2. Function improvement	$NV_t^{fi} = y_t$	
Stage II.	3. A combination of style changes and function improvements	$NV_t^{com} = 1 - \frac{1}{0.3(NV_t^{sc} + NV_t^{fi}) + 1}$	
	4. Function addition	$NV_t^{fa} = z_t$	
Result	5. Technical Novelty Score (TNS)	$TNS_t = NV_t^{com} + NV_t^{fa}$	

Where:

TNS_t – Technical novelty score (Sum of all technical novelties)

NV_t^{sc} – Novelty value of style changes at time t

NV_t^{fi} - Novelty value of function improvements at time t

NV_t^{fa} – Novelty value of function additions at time t

NV_t^{com} – Combined novelty values of style change and function improvement at time t

x_t – Number of style changes at time t

y_t – Number of function improvements at time t

z_t – Number of function additions at time t

For researchers and practitioners to calculate the TNS, MNS and CPIS values easily, an Excel template has been prepared that calculates these scores instantly after insertion of the novelty values in the innovation matrix. It would be a simple next step to incorporate this into an App for personal devices. Furthermore, the next chapters' empirical studies will use these procedures and equations to conduct a longitudinal analysis in the smartphone industry and to perform the event study, in which the relationship between Apple Inc.'s stock market prices and iPhone's CPISs will be investigated. Table 10 shows the market novelty equations with parameters.

Table 10. Market Novelty Estimation

	Market novelty types	Equations	Estimation order
Stage I.	1. New to firm	$MNS_t^f = 1 - \frac{1}{0.2(TNS_t^f) + 1}$	<pre> graph TD 1((1)) --> 2((2)) 2 --> 3((3)) 3 --> 4((4)) 4 --> 5((5)) </pre>
	2. New to market	$MNS_t^m = (TNS_t^m)$	
Stage II.	3. A combination of ‘new to firm’ and ‘new to market’	$MNS_t^{com} = 1 - \frac{1}{0.6(MNS_t^f + MNS_t^m) + 1}$	
	4. New to the world	$MNS_t^w = (TNS_t^w)$	
Result	5. Compound Innovativeness Score (CPIS)	$CPIS_t = MNS_t^{com} + MNS_t^w$	

Where:

$CPIS_t$ – Compound Innovativeness Score (Sum of all market and technical novelties)

MNS_t^f – Firm-level novelty value at time t

MNS_t^m - Market-level novelty value at time t

MNS_t^w – World-level novelty value at time t

MNS_t^{com} – Combined novelty values of firm-level and market-level novelties at time t

TNS_t^f – Technical novelty score in the firm-level at time t

TNS_t^m – Technical novelty score in the market-level at time t

TNS_t^w – Technical novelty score in the world-level at time t

5.4 An Illustrative Example of Technical Novelty Score

Our measurement model is designed to systematically process the different technical and market novelties (in a new product) into a single cardinal measure. The problem of aggregating dissimilar constructs is exemplified by the common problem of ranking the nations competing at the Olympic Games by their ‘medal count’. Every athlete knows that a gold medal is worth more than any number of silver medals, and in turn, a silver medal is worth more than any number of bronze medals. The ranking method adopted by

the International Olympic Committee (IOC) is lexicographic ordering, in which qualities and quantities of the medals are assessed and ordered by who won the most gold, then the most silver, and the lastly the most bronze medals. Since lexicographical ordering considers the qualitative aspect of the medals it can demonstrate the qualitative ranking more accurately than ranking by the total number of medals. Table 11 shows that total numbers of medals that were won in past Olympics by 15 countries as ranked by a lexicographical ordering. Note that there is an inconsistency between the lexicographic ordering and the ‘total medals’ ranking between China (ranked 7th with 385 medals in total) and Hungary (ranked 8th with 458 medals in total), because the lexicographical ordering prioritizes gold over silver, and silver over bronze (medals).

Table 11. Countries ranking (1896 to 2016) and their TNS scores

Lexicographical order	Countries	Gold	Silver	Bronze	Total	TNS*
1	USA	930	728	639	2297	930.995
2	Soviet Union	395	319	296	1010	395.990
3	Germany (incl. west)	247	284	320	851	247.988
4	Great Britain	207	255	252	714	207.987
5	France	192	212	234	638	192.985
6	Italy	190	157	174	521	190.979
7	China	163	117	105	385	163.973
8	Hungary	159	140	159	458	159.977
9	East Germany	153	129	127	409	153.975
10	Sweden	142	160	173	475	142.980
11	Australia	131	137	164	432	131.976
12	Japan	123	112	125	360	123.971
13	Russia	108	97	112	317	108.967
14	Finland	101	83	115	299	101.962
15	Romania	86	89	117	292	86.964

*Source: IOC Database 2017. *TNS = Technical Novelty Score*

Note that the lexicographical ordering is an ordinal measure and cannot provide an absolute or relative value of individual countries’ sporting prowess. Some studies of

Olympic results use their own variables to represent the achievements of countries to investigate the dependence of those variables on social and economic factors. Bernard and Busse (2004) used share of total medals awarded as the measure of success in the Olympics, while Lui and Suen (2008) utilised a weighted variable by assigning 3 as a weight for a gold medal, 2 for a silver medal, and 1 for a bronze medal. We argue that neither of above cases accurately measure a country's success in the Olympics objectively, as the first one is reliant on the total number of medals and the second weights the medals with arbitrary values. For the first, if given information regarding only China and Hungary but not the total number of medals, one cannot calculate the variables. For the second, weighting with constant values can lead to confusion because the measure would calculate (e.g.) that two silver medals are better than a gold medal, or that three bronze are equal to one gold medal.

The final column in Table 11 shows our Technical Novelty Score (TNS) measure applied to the Olympic medals data. Our method aggregates different sets of qualitative items and represents them as a single compound value that considers both quantitative and qualitative aspects at the same time. It can be seen that our measure accurately aligns with the lexicographical ordering that counts both quality and quantity, but in contrast to the lexicographic ordering it provides a cardinal value which allows comparison of relative scores of the competing nations. According to our TNS measure, China's score of 163.97 is somewhat higher than that of Hungary (159.98) because China won more gold medals than Hungary, notwithstanding that Hungary won more silver and bronze medals. The assumptions 1 to 7 can be translated in this example as saying that a single gold medal is better than any number of silver medals, while a silver medal is better than any number of bronze medals. Because there is no consensus that a certain number of bronze medals should be equal to a silver or a gold medal, we avoid subjective measures

and utilise only objective data, by using assumptions that are consistent across all entities to be evaluated on some criterion (e.g. sporting performance, or product innovativeness). The consistency of the TNS across competing products allows it to be used as an independent variable to explain differences in dependent variables, such as the relative market shares or profitability of competing firms, without pre-judging the relative quality differences in technical (e.g. firm A's style change versus firm B's style change) or market novelty (e.g. firm A's new-to-the-market technical innovation versus firm B's new-to-the-market technical innovation).

5.5 A Hypothetical Example of Determining Product Innovativeness

The author now presents a hypothetical example to demonstrate how the CPIS measure of product innovativeness works. Let's assume that there are only three products (A, B, and C) in a particular category in the world, two of which (A and B) are directly competing against each other in the same geographical area (e.g. offered in the same country). The other product (C) is targeting similar customers, who are in a different geographical area (e.g. offered in a different country). For illustrative purposes assume that these products are plastic garbage bags used for household waste collection. We will proceed in three distinct stages.

- I. Creating profiles of A, B, and C products through observations (see Table 12);
- II. Building the innovativeness matrix for A, B, and C products (see Table 13, 14, and 15);
- III. Determining the CPIS values through the two-stage transformation method (see Table 16)

Table 12. Profiles of Products A, B, and C

	Product A	Product B	Product C
Style changes	Before (t_0): Colours: Red, Black	Before (t_0): Colours: Red, Transparent	Before (t_0): Colours: Transparent
	Present (t_1): Colours: Yellow, green (new colours offered)	Present (t_1): Colours: Rainbow (new colour added)	Present (t_1): Colours: no change (no style changes)
Function improvement	Before (t_0): Thickness: 0.07 mm	Before (t_0): Thickness: 0.06 mm	Before (t_0): Thickness: 0.07 mm
	Present (t_1): Thickness: 0.08 mm (stronger bags)	Present (t_1): Thickness: 0.06 mm (no changes)	Present (t_1): Thickness: 0.09 mm (stronger bags)
Function addition	Before (t_0): No drawstring	Before (t_0): No scent	Before (t_0): Has drawstring
	Present (t_1): Drawstring added	Present (t_1): Pleasant floral aroma	Present (t_1): (No changes)

In Table 13, the matrix shows the number of novelties in each cell for Product A after comparing the product's features with its predecessor and direct (i.e. in the same country) and remote (in a different country) rivals' products through observations.

Table 13. Product Innovation matrix for Product A

	Style changes	Function improvement	Function addition
New-to-the-firm	-	-	-
New-to-the-market	-	1	1
New-to-the-world	2	-	-

In Table 14, the matrix shows numbers of novelties in each combination for Product B after comparing the product's features with its predecessor and direct (i.e. in the same country) and remote (in a different country) rivals' products through observations.

Table 14. Product Innovation matrix for Product B

	Style changes	Function improvement	Function addition
New-to-the-firm	-	-	-
New-to-the-market	-	-	-
New-to-the-world	1	-	1

In Table 15, the matrix shows numbers of novelties in each combination for Product C after comparing the product's features with its predecessor and remote (in a different country) rivals' products through observations. Because for the product C, there is no direct rival.

Table 15. Product Innovation matrix for Product C

	Style changes	Function improvement	Function addition
New-to-the-firm	-	-	-
New-to-the-market	-	-	-
New-to-the-world	-	1	-

Table 16. Compound Innovativeness Scores for Products A, B, and C

Product A	Technical Novelty Values	Market Novelty Values	Innovativeness Score
New-to-the-firm	$TNS_t^{firm} = 0$	$MNS_t^f = 0$	$CIS_t = 1.6200$
New-to-the-market	$TNS_t^{market} = 1.2308$	$MNS_t^m = 2.2308$	
New-to-the-world	$TNS_t^{world} = 0.0476$	$MNS_t^w = 1.0476$	

Product B	Technical novelty values	Market novelty values	Innovativeness Score
New-to-the-firm	$TNS_t^{firm} = 0$	$MNS_t^f = 0$	$CIS_t = 2.0265$
New-to-the-market	$TNS_t^{market} = 0$	$MNS_t^m = 0$	
New-to-the-world	$TNS_t^{world} = 1.0265$	$MNS_t^w = 2.0265$	

Product C	Technical novelty values	Market novelty values	Innovativeness Score
New-to-the-firm	$TNS_t^{firm} = 0$	$MNS_t^f = 0$	$CIS_t = 1.2308$
New-to-the-market	$TNS_t^{market} = 0$	$MNS_t^m = 0$	
New-to-the-world	$TNS_t^{world} = 0.2308$	$MNS_t^w = 1.2308$	

5.5.1 Explanations of the matrix results

First, let's look at how the matrix result is defined for Product A (see Table 16). In order to identify and register possible novelties in the Product A, we have to conduct an observation on the product. According to the model, we should scan the product's technical novelties through the three different types of novelties. On the profile of Product A, it says that Product A has two additional colour options (i.e. yellow and green) that were not there before (i.e. at t_0). Moreover, these new colours are not offered by other competitors at the time. Thus, the style changes, which is materialised in the form of colour changes, is considered new to the world, and there are two of them. Consequently, the cell, which is a cross-tab of style changes and new to the world novelties, displays 2. It means that Product A achieves 2 style changes that are new to the world. In terms of the function improvement, Product A manages to improve the thickness up to 0.08mm, which is the highest in the market (compared to Product B because they are operating in the same market), yet not in the world due to the fact that Product C produces 0.09 mm thickness, which is the highest in the world. Therefore, in the cell of the matrix, we should account it as 1 function improvement that is new to the market. Furthermore, Product A comes up with a new function at this time as it adds 'Drawstring' to the bag, which is new to the market (compared to Product B). However, it is not a totally new function because Product C has it already (i.e. at t_0), yet it still is innovative in their market. Thus, it is a function addition novelty that is new to the market.

Based on the measurement results we can deem that Product B is the most innovative as it achieves more technical novelties that are new-to-the-world, while Product A, which has a greater number of novelties, is the second-most innovative because Product C manages a novelty that has a lesser degree of technical complexity (i.e. function improvement), yet a higher market newness (i.e. new-to-the-world).

5.6 Implications and Limitations of the Model

Although every product has its own unique characteristics, we argue that those characteristics can be generally defined by the two dimensions that are technical and market novelties. As a result, we can develop a baseline model for product innovativeness, that can be used universally for all products. The measure is not developed for a specific type of product, since such measure which tend to be inapplicable to other products and remain as ad-hoc measures. The measurement results ($CPIS_t$) can range from 0 to ∞ , in which ‘0’ means that there was no observable novelty in a product, so it is not an innovative product at all. If the $CPIS_t$ is $0 < CPIS_t < 1$, it means that the product has novelties that are ‘new-to-the-firm’ and/or ‘new-to-the-market’, whereas if $CPIS_t > 1$, it implies that the product achieves a certain type of new-to-the-world novelty. In terms of the technical complexity, we can easily read the results. If $0 < TNS_t < 1$, it means that the product has style change and/or function improvement types of novelties at time t for a particular level, while $TNS_t > 1$ indicates presences of a higher degree of technical complexity (i.e. new function addition) in the product. Furthermore, the technical novelty values at all levels can be interpreted as shown in Table 17.

Table 17. Values of the CPIS

$CPIS_t$ values	General meanings
$CPIS_t = 0$	Product is not innovative at all.
$0 < CPIS_t < 1$	Product has novelties that are ‘new to firm’ and/or ‘new to market’
$CPIS_t > 1$	Product has novelties, some of which are new to the world.

For instance; if $TNS_t = 0.5$, it means that the product has the style change and/or function improvement types of novelties at time t for a particular level (see, Table 18). Because, for all levels that are firm, market, and the world the technical novelties are measured and explained the same as we mentioned earlier.

Table 18. Values of TNS

TNS_t values	General meanings
$TNS_t = 0$	There is no technical novelty.
$0 < TNS_t < 1$	Novelties exist that are style changes and/or function improvements.
$TNS_t > 1$	There is at least a novelty in a form of function addition.

Therefore, it provides unprecedented possibility to analyse novelties by the three levels. For example; we can determine TNS_t^f , TNS_t^m , and TNS_t^w for any given product, which means that we can measure how much technical novelty is materialized at firm, market and the world levels individually. Therefore, we can perform more specific analysis such as which firm's product has more market or world level technical novelty, what type of novelties make a certain product more innovative than others, and so on.

This new innovativeness measure has both managerial and research implications. For managerial implications, this new measure can provide more nuanced understanding regarding product innovativeness, which is independent of personal opinions and biases. A highly objective measure of innovativeness is important for managers in their efforts to achieve a competitive advantage over other firms, and the measurement model demonstrates exactly which type of novelties are more/less innovative at which level (firm, market, the world), and when. Based on the analysis, firms can allocate their resources more efficiently by focusing on the particular type of technical novelties of their products and develop innovative advantages over their competitors' products. Also, this measure enables better clarification on market situations which enable or hinder product innovativeness. Managers can evaluate products in the current markets and are able to depict the current positioning of competing products in their market and to determine where their new products are located relative to other firm's products.

Moreover, any firm or anyone can assess all products in the market without requiring confidential financial and operational data from their producers as the measurement's unit of

analysis is the products themselves. It is especially useful for entrepreneurs, who often do not have R&D units with big budgets and experts, registered patents, and prior involvement in their current markets, yet the ability to offer innovative products is the key to their survival in the market – they can evaluate how their new offering is more innovative than existing products objectively. This understanding can lead to increased chances of survival. Also, it can lead to a better decision making regarding their future product development.

5.6.1 Limitations of the model

Although the CPIS measure objectively assesses product innovativeness, it is based on underlying assumptions that might limit the accuracy of the measurement. Firstly, the model assumes that all novelties in the same type are considered as the same in terms of their usefulness, meaning, and value. For instance, some could argue that a certain colour has a more appealing effect than others, while in our model all colour changes are equal. Under our model assumptions, which enables objectivity and universality of the measurement, all novelties in the same categories are the same in terms of their complexity from an innovativeness point of view, therefore they will be evaluated only by their quantities rather than their qualities. Unlike the common practice of counting numbers of patents, citations, and R&D dollars regardless of their technical complexities or quality, the new measure differentiate them into 12 different novelties, so that it may produce indications that are more precise. However, scholars agree that usefulness, meaning, or the intrinsic value of novelties are factors that could influence the market success of product innovativeness, and that these variables naturally vary across individual customers, customer segments, markets, and time. However, an objective measurement model for product innovativeness must be established on physical and concrete factors that cannot incorporate context-specific effects to ensure the consistency across different cases. Hence, it was necessary to delineate this assumption for the model. Nevertheless, when we are creating a universal measurement for products that

exist in a huge range of categories, such simplification ensures that the measure remains highly objective and useful across product categories.

Our CPIS measure can be used in innovation, entrepreneurship, marketing, and other studies of business firms and decision-making. Product innovation can be studied more specifically and more deeply. For instance, while the $CPIS_t$ shows the final innovativeness score for a product, the TNS_t^f , TNS_t^m , and TNS_t^w scores demonstrate innovativeness at the firm, market and the world levels, respectively. Therefore, we gain more insights about innovativeness by performing analysis at the firm, market, and world level separately. If some firms tend to get high scores for TNS_t^f (Technical Novelty – firm level), it means that they are innovative but prefer to follow the leader. Certain firms can be considered as local leaders who lead their market if TNS_t^m is higher, yet they still follow the global leader in the product development. This type of analysis can reveal more detailed insights into firms' ways of innovating, strategies, capabilities and executions. Also, based on the innovativeness level analysis (i.e. TNS_t^f , TNS_t^m , and TNS_t^w) we can determine how a certain technical novelty elevates competitive advantages of the entire product portfolio of the firm.

For entrepreneurship studies, the measurement can be operationalised as a tangible indication of an entrepreneur's effort regarding innovation. Thus, it can be used in studies such as how innovative the entrepreneur is, the antecedent and consequence factors of entrepreneurs' innovativeness, and so on, in which subjective measures are dominantly used. In the past the traditional firm-level and perceptual measures have been difficult to compare and replicate. In a marketing context, for instance, the measurement can be applied to determine product differentiation in terms of innovativeness in the market by analysing product positioning and advancement through objective measurements. In addition, the measurement can be a useful tool to enhance market analysis as it provides detailed information over time regarding products in the market. Products should be the unit of

analysis, because this is where “the rubber hits the road” for innovative businesses, because it is products that customers evaluate, compare, purchase and use. Finally, the measurement can be adopted in empirical business studies, such as in an event study to assess or investigate the impact of product innovativeness on the subsequent profitability and market value of a firm.

5.7 Conclusion of Chapter 5

This chapter discussed the new measurement model that was developed for this thesis, and how to make calculations of the measure through a detailed process analysis and comparison. It outlined two dimensions of the model and their sub-categories, followed by the product innovativeness matrix. Moreover, a substantial part of the chapter is dedicated to examine the mathematical model which we can measure product innovativeness cardinally and contemporarily. The model is specifically developed for this research and it has been tested extensively. To explain and demonstrate how the model transforms novelties that are different in terms of their technical complexity and market newness, an illustrative example using the Olympic medals ranking case, which is easy to understand and identical to the ways this new measure evaluates product innovativeness. In addition, some limitations of the model have been addressed in this chapter. Finally, this chapter discusses how to interpret, understand, and study the results of the measure and ways to apply the measure for research and practice.

CHAPTER 6. EMPIRICAL STUDY OF PRODUCT INNOVATIVENESS

Outline of Chapter 6

6.1 Introduction

In this chapter, an empirical study of the new CPIS measurement model is conducted in the US smartphone industry. In section 6.2, the justifications for industry selection, specific products in the industry, and the time frame, are discussed in detail. The main issues related to the operationalisation of the measurement are explained in section 6.2, and these include dimensions of the measurement and the constructs and items that are used to assess smartphone product innovativeness. Then, in section 6.4, the results of the product innovativeness measurement (which specifically exhibits how the chosen products have been upgraded every year in the US smartphone industry) are reported and analysed. Next, comparative analysis of the CPIS and particular innovations of the smartphones is carried out to further demonstrate the differences in the compound measurement results in section 6.5. Lastly, section 6.6 provides a summary of the chapter.

6.2 The Empirical Research Context: The Smartphone Industry in the US

Empirical research uses empirical evidence to support (or deny) theoretical knowledge by means of direct and indirect observation or experience. To this end, the new CPIS measure will be tested in the U.S. smartphone industry. The dominant players in the smartphone industry, Apple Inc. and Samsung Electronics Co., Ltd typically releases new innovations annually (Cecere, Corrocher, and Battaglia, 2015) providing valuable data that can be assessed.

6.2.1 The Smartphone Industry

To select an industry for the empirical study, we follow Jennings and Young (1990) who established the requirements to demonstrate and analyse differences in objective and subjective product innovation measurement. First, it should be an industry in which reliable and published information regarding products are available. Second, it should be an industry in which innovation is a regular activity. In addition, it is preferable to select products that are familiar to readers, since explaining a new measurement method on a new type of product or an unfamiliar product may confound the understanding of the measure of the novelties in a new product. On this basis, the smartphone industry in the US market is selected, where we focus on the two dominant firms' flagship models. These two major firms (i.e. Apple Inc. and Samsung Electronics Co. Ltd) tend to introduce the latest and biggest innovations in their flagship models and these product improvements are later incorporated into their lesser models, and tend to be imitated (or invented around) subsequently by the minor firms contesting the market.

6.2.2 Sampled products

The two dominant firms are Apple Inc. and Samsung Electronics Co. Ltd who together share 74% of the US smartphone market (comScore MobiLens®, 2017). During the

sampling period, 2008-2017, there were other firms such as Blackberry, and there have been newcomers as well, such as Huawei and Google Pixels. However, a preliminary study revealed that the other firms tend to employ a fast-follower strategy regarding their technological innovation (Barczak, 1995) and tend to offer lower price alternatives, whereas iPhones and Samsung Galaxy Notes have been consistently innovative at both market and firm levels. In the methodology chapter, the sampling frame and the dominance of the two firms in this industry were explained. The selected brands and their specific models are shown in Table 19.

Table 19. Sampled products by year

Brands	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
iPhone series	3G	3GS	4	4S	5	5S	6Plus	6SPlus	7Plus	X
Galaxy Note series	i910	i8910	G-S	Note	Note2	Note3	NoteEdge	Note5	S7Edge	Note8

Note that the Galaxy S7 Edge model has been selected to represent Samsung's flagship model in 2016 instead of Galaxy Note 7, due to a technical issue that resulted in the model being recalled and withdrawn from sale. Although the recalled model had some innovative features, it was not reliable in terms of its functioning. Thus we excluded this particular model from our sample and replaced it with the Samsung's second most innovative model for that year, because it is not our purpose here to study new products that are malfunctioning.

6.3 Measurement Dimensions, Constructs, Items and Operationalization

As outlined in chapters 4 and 5, the new CPIS measure evaluates product innovativeness through two main dimensions: technical novelty and market novelty. In this chapter, we explain how the technical and market novelty dimensions are operationalised to assess the product innovation in the case of smartphones.

6.3.1 Technical Novelty Dimension

The new model assesses the technical novelty by four types of technical innovations, namely style changes, function improvements, function addition, and ‘really new’ product. It is important to explicitly demonstrate how many and what kind of criteria are used to evaluate certain products in our case smartphone technology innovations. Because what constitutes function improvements and additions vary in relation to industries.

The smartphone is a device with multiple features and attribute complexity, so to fully assess its innovativeness we need broad criteria that include hardware, software, and style or design aspects of the device. Based on the trend of technological advancement of smartphones, and preferences of consumers and experts, we use 12 main criteria that include a total of 174 individual elements to measure smartphone’s technical novelties, which may be the most comprehensive assessment on a single consumer product in business research (see Figure 19).

Figure 19. Relationship between the dimension and items

Table 20 shows the 12 criteria, which typically evaluate the device from both consumer and producer perspectives, used to evaluate the construct and the number of items within each criterion. To illustrate what kind of items were used to assess each criteria, one criterion will be discussed in detail here. (To see the full item list, please see Table 1 to 5 in the Appendix).

The criterion to be exemplified here is “Display” which is arguably one of the most important part of a smartphone as it enables all interactions with the device and it is highly influential for improved user experience. Accordingly, smartphone developers pay a lot of attention to upgrading and advancing the display technology in order to deliver a superior user experience, and when producers announce new smartphones, they try to improve the display and add new features in that department. In this example, we measure the display with 10 specific items that are based on observable data, as shown in Figure 20. Each item/element is designed to assess the display performance, function, and durability in terms of technology and is used by industry experts and customers to assess any smartphone display in the market. In Table 20, the operationalization of the technical novelty is shown.

Table 20. Items and criteria for the technical novelty dimension

Construct	Criteria	Items
Technical novelty	1. Design	2
	2. Ruggedness	3
	3. Display	10
	4. Attached Pen	4
	5. Camera	97
	5.1 Rear camera	51
	5.2 Front camera	24
	5.3 Camcorder (video resolution)	22
	6. Hardware	10
	7. Battery	4
	8. Audio	4
	9. Video	2
	10. Cellular	4
	11. Connectivity	3
	Positioning	9
	12. Phone Features	5
	Sensors	17
		174

Figure 20. Operationalization of Display

To illustrate the objectivity of the technical novelty measure of “display”, these ten items are now briefly defined.

Physical size refers to size of the display, and it is a diagonal measurement. A noticeable trend is that displays are getting larger on same-sized or even smaller devices to ensure that users get the most out of the entertainment and business services that the devices offer. For instance, Galaxy S8 has more overall screen area than larger phones owing to its curved edges and as a result, it challenges the traditional diagonal measure of the display.

Resolution. The display resolution of a smartphone is the number of distinct pixels in the display area and is the product of the number of columns and the number of rows of pixels creating the display (e.g. 480 x 800 pixels, 720 x 1280 pixels, or 1440 x 2560 pixels). It is one of the important factors to demonstrate the clearness and sharpness of displays.

Pixel density refers the number of pixels per unit of area (e.g. square centimetre) not the total number of pixels. The term "display resolution" is used to mean the number of pixels in each dimension (e.g. 1440 x 2560), which does not indicate the pixel density of the display on which the image is actually formed. Therefore, experts use the term to determine the actual potential of the display in terms of visual clarity and sharpness.

Technology refers to how the display works which directly impacts the quality and depth of displays. There are two major technologies on the market: AMOLED and IPS LCD. They have been upgraded and developed over the years. Thus we will measure the technological evolution or progress within the two categories.

Peak brightness. Screen brightness is one of the main factors that impact image quality, screen viewability and readability in relation to the current level of ambient lighting, which varies extremely from sunny days to dark nights. Thus, the ability to produce a high-quality output without causing eyestrain or headaches depends on how much brightness the display can generate and this is measured by a unit called "nits".

Screen-to-body ratio. Another important indication of the display size is a screen-to-body ratio, which is a measure that shows how much of the upper surface of the device is comprised by the screen. Thus, a 100% ratio would mean the upper surface is entirely composed of the screen. Arguably, this is the current target of smartphones in the market (Digitaltrends, 2017).

Protection. The most important part of the smartphone, the display, has to be protected from damage in every day usage, especially given that the nature of the user interaction is touch-based. Thus, the protection of the screen and its development have been a concern for consumers and producers. Therefore, when producers announce new products, they often offer better and more effective solutions such as Oleophobic Coating, Corning Gorilla Glass, and Scratch-resistant Glass.

3D touch is a pressure-sensitive display technology, which provides the possibility to sense and analyse how long and hard the screen is pressed. It enables another way of interacting with the device. Consequently, it becomes one of the desirable features in smartphones.

Multitouch. Another critical innovation in smartphones is the multitouch. Since all interactions with the device are touch-based, it is vital to broaden the ways of communication to the device. In that aspect, the multitouch feature enables a surface (a trackpad or touchscreen) to recognise the presence of more than one or more points of contact with the surface at the same time.

Shape. Most smartphones have flat-displays. However, the recent trend of curved display technology is becoming more popular (Techspot, 2016). This gives unprecedented user experience and the impression that the phones are made entirely of glass and increases the perception of display area in the device.

In this analysis, every smartphone's display is assessed against the above ten items, and its result is recorded in our database. Measuring the other 11 criteria follow the same procedure as the display criterion, and they all have their own sub-items to measure the criteria. The assessment of the technical novelty dimension is completed when the empirical observations and evaluations of all 12 criteria and 172 items have been completed (see Table 18). By performing this collection of data, all the technical novelties will be ready for the next stage of analysis.

6.3.2 Market Novelty Dimension

The second dimension of the new model is the market novelty. It is designed to assess newness of the technical novelties that are identified in the technical novelty evaluation through the assessment of the 174 items in the previous stage. As explained in the

previous chapter, this dimension has three criteria: new-to-the-firm, new-to-the-market, and new-to-the-world (see Figure 21).

Figure 21. Operationalization of the market novelty dimension

A brief definition of the items that are used to measure the market novelty will now be restated. *New-to-the-firm* specifically assesses whether each technical novelty that is identified in the previous analysis has ever before offered that novelty. If it is the first time that firm ever introduced such a novelty, then it means the novelty is new-to-the-firm. However, the novelty may already have been introduced by other firms in the market or globally.

New-to-the-market is the next level of newness after new-to-the-firm. It applies only if a new-to-the-firm technical novelty determined in the previous newness analysis also qualifies as new-to-the-market. To be classified as the new-to-the-market, the new-to-the-firm novelty must not have been introduced before by any other firm in the relevant market (although, it can have been available in other markets, such as overseas markets).

New-to-the-world assesses whether a particular new-to-the-market novelty is also new-to-the-world. That is, it is offered for the first time in the industry that combines all geographical markets in the world. For example, in 2014 Apple Inc. introduced the 3D touch technology that can detect and react accordingly to different levels of pressing forces on the display (Apple Inc.: Annual report 2015). It opened new ways of communicating with the device not only in the US market because it was totally new

technology that had never been offered in smartphones before in any markets in the world. Thus, the novelty has been identified as the new-to-the-world when it was introduced for the first time. However, in this illustrative example, focusing on the US smartphone industry, only new-to-the-firm and new-to-the-market analysis will be conducted due to the difficulty of gaining simultaneous innovation data in other markets (particularly Japan and China). For the most part, because Apple and Samsung have been the technology leaders in this industry globally, their relative innovativeness will be captured effectively by considering new-to-the-firm and new-to-the-market innovations alone.

6.3.3 Product Innovativeness Matrix

The next stage of the analysis is developing the product innovativeness matrix for each product in the sample based on the empirical observations of technical novelty and market novelty. Table 21 shows product innovation matrices 2008 to 2017 of iPhone series. The numbers in the matrix indicate types of the technical novelties and their newness levels and quantities of the novelties in a particular model.

Table 21. Product innovation matrices of iPhones

		Style Changes	Function Improvements	Function Additions
iPhone 3G (2008)	New-to-the-world			
	New-to-the-market		2	3
	New-to-the-firm			
iPhone 3GS (2009)	New-to-the-world			
	New-to-the-market	1	1	3
	New-to-the-firm		4	4
iPhone 4 (2010)	New-to-the-world			
	New-to-the-market	1	1	3
	New-to-the-firm		4	4
iPhone 4S (2011)	New-to-the-world			
	New-to-the-market		5	5
	New-to-the-firm		3	
	New-to-the-world			

iPhone 5 (2012)	New-to-the-market		6	4
	New-to-the-firm		9	1
iPhone 5S (2013)	New-to-the-world			
	New-to-the-market		2	1
	New-to-the-firm	3	7	3
iPhone 6Plus (2014)	New-to-the-world			
	New-to-the-market		6	3
	New-to-the-firm		9	4
iPhone 6S Plus (2015)	New-to-the-world			
	New-to-the-market		4	6
	New-to-the-firm	1	9	1
iPhone 7 Plus (2016)	New-to-the-world			
	New-to-the-market	2	7	6
	New-to-the-firm		12	4
iPhone X (2017)	New-to-the-world			
	New-to-the-market		10	6
	New-to-the-firm	1	4	2

Table 22. Product innovation matrices of Samsung Galaxy Note series

		Style Changes	Function Improvements	Function Additions
Samsung i8910 (2009)	New-to-the-world			
	New-to-the-market		8	6
	New-to-the-firm	1	1	2
Galaxy S (2010)	New-to-the-world			
	New-to-the-market		9	3
	New-to-the-firm	1	4	1
Galaxy Note (2011)	New-to-the-world			
	New-to-the-market		6	6
	New-to-the-firm	1	7	4
Galaxy Note 2 (2012)	New-to-the-world			
	New-to-the-market	1	8	2
	New-to-the-firm		3	3
Galaxy Note 3 (2013)	New-to-the-world			
	New-to-the-market		6	4

	New-to-the-firm	1	13	7
Galaxy Note Edge (2014)	New-to-the-world			
	New-to-the-market	1	7	8
	New-to-the-firm		4	4
Galaxy Note 5 (2015)	New-to-the-world			
	New-to-the-market		10	4
	New-to-the-firm	2	4	2
Galaxy S7 Edge (2016)	New-to-the-world			
	New-to-the-market	1	4	4
	New-to-the-firm		2	2
Galaxy Note 8 (2017)	New-to-the-world			
	New-to-the-market		5	9
	New-to-the-firm	4	7	14

For example, in Table 21 we can see iPhone 3G in 2008 offered two function improvements that are new-to-the-market, and three additional functions that are also new-to-the-market in 2008, and similarly Table 22 indicates that Samsung Note introduced a total of 24 innovations in 2011. From the model's product innovation matrix, we can see the innovations in detail. For example, this particular model brought six function improvements and six function additions, which are new-to-the-market. Also, it offered one style change, seven function improvements, and four function additions, which are new-to-the-firm. In conclusion, Samsung Note introduced 12 new-to-the-market novelties and 12 new-to-the-firm market novelties in 2011 (Table 22).

6.3.4 Verifying Objectivity in the CPIS measurement

To exhibit the objectiveness of the measure, we use the above example to explain how it registers novelties under the very limited influence of subjectivity. As enumerated earlier, we utilise 12 main objective criteria for product innovativeness such as a display, camera, hardware, battery, audio, video, cellular, connectivity and so forth. Moreover, each of the criteria has objective sub-categories, for example, the camera consists of sub-categories

of front camera, rear camera, hardware features, software features, and shooting modes. In total, 174 items are used for the assessment of smartphone product innovativeness that reflects all the 12 main criteria and their sub-categories. In Table 23, two main criteria (i.e. camera and battery), one sub-category (i.e. rear camera), and four items (pixels, flash, capacity, and type) are shown as an example.

Table 23. Demonstration of how novelties are registered

Release date	2010(Jun 24)	2011 (Oct 14)	2010(Jun 4)	New-to-the-firm novelties	New-to-the-market novelties
Product model	iPhone 4	iPhone 4S	Galaxy S		
CAMERA					
Rear camera					
Pixels	5.0	8.0	5.0		1
Flash	LED	LED	none	no change	
BATTERY					
Capacity	1420 mAh	1432 mAh	1500 mAh	1	
Type	lithium-ion	lithium-ion	lithium-ion	no change	

The data in Table 23 shows that the iPhone 4S improved its rear camera pixels from 5 to 8 megapixels, which is noted as a function improvement in the existing technical novelty dimension of the measure. Subsequently, in terms the market novelty dimension, this particular pixel improvement is not only new-to-the-firm, it is new-to-the-market, as the rival's current product at that time was 5 megapixels. As a result, improving the pixels to 8 megapixels, the iPhone 4S mobile phone was the highest megapixel camera on the market. As noted by assumption 6 in chapter 4, new-to-the-market is more innovative than new-to-the-firm, so this improvement is recognised as having a higher degree of novelty. Therefore, this improvement is registered as new-to-the-market novelty column as 1. There is no change in the flash of the iPhone 4S compared to its predecessor model. However, iPhone 4S improved its battery capacity from 1420 mAh to 1432 mAh, which is registered as only new-to-the-firm because the competitor's product already has a higher capacity battery. Hence, the improvement is recorded in the new-to-the-firm

column. The observation of all 174 product attributes are carried out in this manner, and once this process is completed all the novelties are transformed into a cardinal value (CPIS) that indicates the innovativeness of the product.

6.3.5 Procedures of the empirical research

For greater clarity, the procedures of how the empirical research is conducted are shown schematically in Figure 22, before proceeding to the final CPIS results in this example. In terms of structures, our model is not built as a typical composite model, where indicators are constructed/built in a parallel way (e.g. Diamantopoulos and Winklhofer, 2001; Bollen and Bauldry, 2011). Instead it is built sequentially: first, the technical novelty dimension is assessed, and then the market novelty dimension is evaluated, therefore it avoids the multicollinearity issue (Diamantopoulos and Winklhofer, 2001) between technical and market indicators, which would affect the validity of the model.

Figure 22. Procedures of the empirical study

6.4 Results of the Compound Product Innovativeness Measurement (CPIS)

The final CPISs of the products are shown in Figure 23, which are composed of only new-to-the-firm and new-to-the-market scores in this analysis. The new-to-the-world assessment has not been done, as the analysis does not consider products in other countries. However, there may not be a substantial difference in this case as being new-to-the-market in the US smartphone industry is likely to be equivalent to new-to-the-world, due to the fact that it is the largest and most prominent market for smartphones that attracts entry from players all over the world.

Figure 23. Product Innovativeness Scores

In Figure 23, it can be seen that the iPhone 4S was launched on 14th of October 2011, and its compound product innovativeness score was 0.77. This CPIS score is derived from a combination of $TNS(f)=0.474$ (its new-to-the-firm technical novelty score), and $TNS(m)=5.6$ (its new-to-the-market technical novelty score). This clearly indicates that the 4S model was very innovative, as most of the novelties were new-to-the-market (i.e. $TNS(m)>TNS(f)$), which means it introduced function improvements and

new functions that had not been offered before in the market. This method allows the researcher to decompose product innovativeness in ways that may be helpful to understand the product innovation strategies based on the facts of product innovation. In Figures 24 and 25 it can be seen which company tended to produce technological innovations that are new-to-the-firm or new-to-the-market, respectively, which may inform discussion regarding innovators vs imitators, for example.

Figure 24. New-to-the-firm innovativeness: iPhone vs Samsung Note

Figure 25. New-to-the-market innovativeness: iPhone vs Samsung Note

Based on the analysis of descriptive statistics (see Table 24), the Samsung Note series has, on average, a higher innovativeness score (TNS) at both firm and market level than the iPhone series, however, the results vary each year. For example, in 2016 iPhone's innovativeness was higher in the technical novelty scale than the Samsung product. In addition, both products are consistently innovative as the new-to-the-firm innovativeness scores are lower than the new-to-the-market scores, which means that every year they introduce novelties that tend to be new-to-the-market. Conversely, new-to-the-firm TNS scores indicate they are catching up with their rival.

Table 24. Descriptive Statistics of TNS(f) and TNS(m)

	Mean	St.dev	Max	Min
New-to-the-firm innovativeness				
TNS(f) iPhone series	2.793	1.761	4.783	0.000
TNS(f) Samsung Note series	4.879	4.131	14.686	1.551
New-to-the-market innovativeness				
TNS(m) iPhone series	4.646	1.776	6.750	1.375
TNS(m) Samsung Note series	5.779	2.294	9.600	2.708

Finally, to provide more detailed information regarding the phenomenon, the two products' product innovativeness can be demonstrated by the levels of innovativeness in the same graphs in order to reveal what type of innovativeness was crucial to make up the final CPIS for each product every year. Figure 26 shows moderate declines in 2013 and 2014 for iPhone's CPIS, which means during that period the new iPhones were not as innovative as their predecessors – that was the only time when the iPhone's new-to-the-market innovativeness was lower its new-to-the-firm innovativeness, except 2009. In other words, most innovation effort from Apple Inc. on the iPhone was undertaken to catch up with its competitors during that time.

Figure 26. Levels of Product Innovativeness: iPhone

As for the Samsung Note, their latest model was more innovative compared to its predecessors and iPhones (see Figure 27). Especially, their new-to-the-market innovation was much lower in 2015 and 2016. However, it increased dramatically in 2017 along with the new-to-the-firm innovations.

Figure 27. Levels of PI: Samsung Note Series

6.5 Comparative Analysis of the CPIS and some particular innovations

This section focuses on differences between the compound product innovativeness score that has been developed to measure overall innovativeness of a product and individual function improvements over time in the case of iPhone series. This analysis demonstrates how technical innovation improvements take place in reality and how they may influence the final CPIS. Furthermore, it signals the ways a firm makes decisions on its product innovation strategy, which Li and Atuahene-Gima (2001) define as “product innovation strategy as a reflection of a firm's commitment to developing and marketing products that are new to the firm and/or the market”.

Figure 28. Comparison of Pixel density and CPIS

Based on Figure 28, the pixel density has been upgraded every 3-4 years, rather than every year. This lag may be a result of cost or may be due to their unwillingness to cannibalise their own investment in that technology (Chandy and Tellis, 1998). Willingness to cannibalise refers to the extent to which a firm is prepared to reduce the actual or potential value of its investments. It is an attitudinal trait of the key decision makers of the firm and resides in the culture, or shared values and beliefs, of the firm (Deshpande and Webster, 1989).

Figure 29. Comparison of Built-in storage and CPIS

In Figure 29, note that the built-in storage of iPhones is similarly upgraded in steps; however, the frequency of the upgrades has tended to increase as they improved the storage size twice in the last four years. Finally, upgrades of three more individual features (i.e. system memory (MB), processor speed (GHz), and pixels (MP)) have been depicted in Figure 30. Like the other features, they show similar patterns of developments in the features throughout the period.

Figure 30. Upgrades of some critical features of iPhones

6.6 Conclusion of Chapter 6

This chapter first discussed the operationalisation of the technical novelty and the market novelty dimensions. It then provides an empirical example of the new CPIS measure, assessing iPhones from Apple Inc. and Galaxy Notes from Samsung Electronics Co., Ltd. Features of both products have been measured at two levels (i.e. new-to-the-firm and new-to-the-market) by the new measure, and the final CPISs have been calculated for each product that was launched from 2008 to 2017. A total of 174 individual items were used to measure objectively the technical novelty construct such that the product innovativeness matrices were generated based on the actual observation of the products' attributes. In order to demonstrate the objectivity in the measurement, the procedures of the data collection were illustrated, confirming that no subjective bias enters into the measure. In the last section, the comparative analysis of the CPIS and individual feature upgrades were performed to exhibit differences between dynamics of individual features' improvements and the compound innovativeness scores. It shows that even though the CPIS varied each year, it does not mean all the features were improving every year. The analysis reveals that iPhone's main individual features were upgraded every three years, however the innovation frequency increased in more recent years, which may reflect increasing dynamic conditions in the industry as a result of more rival product entrants, or more sophisticated customers who demand (or expect) new innovations (Paik and Zhu, 2016).

CHAPTER 7. VALIDATION AND LONGITUDINAL ANALYSIS

Outline of Chapter 7

7.1 Introduction

This chapter focuses on validity and reliability analysis of the new CPIS measure using longitudinal research. In section 7.2, the content and indicator specification analysis are discussed, which are the initial forms of the validation process. Indicator collinearity analysis is performed in the three base indicators of the measure, which is the next stage of the validity analysis. Then section 7.4 discusses the most advanced level of the validation process for formative models, which is the external validity analysis of the measure, in which Structural Equation Modelling (SEM) is used. SEM is used to test the hypothesis that CPIS has a significant impact on sales of the product and the share price of the company. Next, in section 7.5, causal analysis of the PIS in longitudinal research is performed, using structural equation modelling. Finally, in section 6.6, the contents of this chapter are summarised.

7.2 Validation of the new measure: Content and Indicator Specifications

Every measurement should be validated in an appropriate way to demonstrate its reliability. However, conventional procedures for assessing the legitimacy and dependability of scales consisting of reflective indicators (such as factor study and review of internal reliability) are not suitable for complex variables (for instance indexes) with formative indicators (Diamantopoulos & Winklhofer, 2001). Conventional validity estimations and traditional test hypothesis, according to Bollen (1989), may not work for causal indicators. On the other hand, Bagozzi (1994, p222) states that consistency in the internal reliability logic and construct legitimacy based on discriminant and convergent validity are not important when indexes are constructed as a linear summation of measurements. Different from scale development, with comprehensive step-by-step directions for construct measurement, item choice and refinement, and scale corroboration (such as Churchill, 1979; DeVellis, 1991; Spector, 1992), frameworks for creating indexes in terms of formative indicators are difficult to get. Nonetheless, Diamantopoulos and Winklhofer (2001) suggest alternative approaches to evaluate the quality of measurements that are formed by indicators. Accordingly we follow their procedures, which consists of the content specification, indicator specification, indicator collinearity, and external validity.

7.2.1 Content specification

The specification of the scope of the latent variable is the first important issue in index development, which defines the domain of content the index is intended to capture (Diamantopoulos and Winklhofer, 2001). This is especially critical because “an index is more abstract and ambiguous than a latent variable measured with reflective indicators” Bagozzi (1994). Because under formative measurement the latent variable is determined by its indicators rather than vice versa, the content specification is inextricably linked

with indicator specification. Therefore, “breadth of definition is extremely important to causal indicators” (Nunnally and Bernstein, 1994, p.484), not least because failure to examine all characters of the construct will cause omission of relevant indicators. For construct validity and reliability it is important to isolate the inherent product-level innovativeness (comprising technology newness and market newness) from the subsequent market reaction to the new product. This is particularly important for studies attempting to explain the firm’s market performance (e.g. sales volumes or profitability) using measures of product innovativeness.

7.2.2 Indicator specification

For a formative specification, a census of indicators is required (Bollen and Lennox, 1991) to define the construct. The items used as indicators must cover the entire scope of the latent variable as described under the content specification (Diamantopoulos and Winklhofer, 2001). Therefore, the indicators must capture the novelties in product innovation. However, unlike the reflective model, exclusion of a potential indicator would impact the composition of the latent variable. To fully capture all the indicators that can define product innovation, we conducted an extensive literature review (see Appendix: Table 1 to 5) and determined the indicators. Not all product innovation are the same regarding their technological discontinuity. Thus, based on prior literature (e.g. Heany, 1983; Rothwell and Gardinar, 1988) we define the following types of innovation in a new product as indicators of product innovativeness: design and style changes, improvements in existing functions, and additions of new functions. Therefore, the base of product innovativeness (i.e. the focal construct) is determined by the composition of three indicators, namely style changes, function improvement, and function addition. It specifically draws the line, which specifies which novelty is assessed for the measure (see Figure 31).

Figure 31. Measurement model

*Indicator 1: **Style changes*** refers to the visual newness of a product, which we refer to in broad terms as style or appearance of a product (Micheli, Jaina, Goffin, Lemke, and Verganti, 2012) such as colour.

*Indicator 2: **Function improvement*** implies a performance improvement of an existing function in a product (Heany, 1983; Rothwell and Gardinar, 1988). For example, the rear camera of iPhones is an indicator which solely focuses on the existing function.

*Indicator 3: **Function addition*** occurs when a product has been enhanced by a new function that did not exist in the previous version of the product, such as the introduction of mobile phones of built-in cameras by the Nokia 7650 and the Sanyo SPC-5300 models in 2002 (Hill, 2013). Therefore, this particular indicator only targets new functions.

Note that there is no indicator for “really new” products, because the measure is designed to measure the innovativeness of incremental innovations, which are defined as “the gradual development and value-added improvement of existing products and technologies” (Ettlie & Rubenstein, 1987; Garcia & Calantone, 2002). Therefore, the new measure evaluates how innovative is a product within its category by comparing it to its predecessors and competing products in the market, while really new products are revolutionary products due to radical innovation. They are the first of their kind and totally new to market (Song and Montoya-Weiss, 1998) and often create new markets. As

a result, there is no solid base to compare this kind of innovation in terms of their degrees of innovativeness. For example, it is hard to define which is more innovative when two really new products are considered, such as 3D printers versus Drones.

To further demonstrate independence of the indicators, which is a crucial issue for validity of the formative model (Diamantopoulos and Winklhofer, 2001), the actual data has been presented below (see Table 25). However, in the next section we discuss the issue specifically by using statistical tests and analysis.

Table 25. Indicator independence

Technical Specification	iPhone 6 Plus (2014)	iPhone 6S Plus (2015)	Indicator 1	Indicator 2	Indicator 3
			Style changes	Function Improvement	Function Addition
1. DESIGN					
Materials	Aluminum alloy	Aluminum alloy			
Colours	Gold, Gray, Silver	Gold, Gray, Silver, Pink, White	2		
2. CAMERA					
<i>Rear camera</i>					
Pixels	8	12		1	
Flash	Dual LED	Dual LED			
True tone flash	yes	yes			
Aperture size	2.2	2.2			
<i>Front camera</i>					
Pixels	1.2	5		1	
Flash		yes			1
Aperture size	2.2	2.2			
<i>Comments</i>			The colour variation was expanded by two options: Pink and White	The rear and front camera pixels were improved as 8MP to 12MP and 1.2 MP to 5MP respectively. In total, we can see two function improvements.	The flashlight was added to the selfie camera as a new function in 2015.

7.3 Validation of the new measure: Indicator Collinearity Analysis

Multicollinearity is a critical problem that threatens the validity of formative indicators. The stability of the indicator coefficients is influenced by the size of the sample and power of the indicator relationships, thus making the formative measurement model to be based on multiple regressions (Diamantopoulos & Winklhofer, 2001, p. 272). However, multicollinearity in the reflective measure cannot be a problem since only simple regressions are involved. Researchers propose diverse methods for handling multicollinearity problem. Bollen & Lennox (1991) stated that highly intercorrelative indicators are likely to contain similar information.

For this reason, a number of authors (such as Diamantopoulos & Winklhofer, 2001; Götz & Liehr-Gobbers, 2004) advocate for elimination of indicators according to the variance inflation factor (VIF), which evaluates the extent of multicollinearity. Various empirical studies on formative measure development, such as Diamantopoulos & Siguaw (2006), Helm (2005), Sánchez-Pérez & Iniesta-Bonillo (2004) and Witt & Rode (2005) usually adhere to this advice by using the acceptable cut-off value of VIF N10 or its acceptance equivalent (Giere, Wirtz, and Schilke, 2006; Hair, Anderson, Tatham, and Black, 1998; Kennedy, 2003). In addition, correlation analysis and auxiliary regression analysis can provide certain tests as an alternative to VIF. Using these three methods, we can definitively rule out the issue.

Therefore, we test our indicators' multicollinearity through correlation analysis, the auxiliary regression analysis between the indicators or independent variables, and VIF analysis. First, the correlation analysis is done, so that we could identify possible inter-relations between the indicators. The indicators are continuous variables; therefore Pearson Correlation is the most accurate. N is our sample size, which is a sum of the two products. The correlation coefficients between the indicators are 0.010, 0.043, and 0.211,

and P values are 0.967, 0.860, and 0.385 respectively. Thus, we can assume that there is no significant relationship between the indicators (see Table 26).

Table 26. Correlation analysis output

		Style Changes	Function Improvement	Function Addition
Style Changes	Pearson Correlation	1	0.010	0.043
	Sig. (2-tailed)*		0.967	0.860
	N	19	19	19
Function Improvement	Pearson Correlation	0.010	1	0.211
	Sig. (2-tailed)*	0.967		0.385
	N	19	19	19
Function Addition	Pearson Correlation	0.043	0.211	1
	Sig. (2-tailed)*	0.860	0.385	
	N	19	19	19

*indicates statistical sign at 5%

Secondly, using auxiliary regressions between the three indicators (i.e. independent variables), we can check for a possible multicollinearity issue. There can be three different combinations of auxiliary regressions as follows:

$$\begin{cases} ST_i = \alpha_1 + \alpha_2 \cdot FI_i + \mu_i \rightarrow \text{Model A} \\ FI_i = \beta_1 + \beta_2 \cdot FA_i + \varepsilon_i \rightarrow \text{Model B} \\ ST_i = \gamma_1 + \gamma_2 \cdot FA_i + \theta_i \rightarrow \text{Model C} \end{cases}$$

If t statistics and R^2 of the auxiliary regressions are statistically significant, then there is a chance of collinearity among our indicators. Estimation results of the regressions are shown in Table 27, 28, and 29.

Table 27. Estimation result of Model A

	Unstandardized Coefficients		t	Sig.
Model A	α	Std. Error		
(Constant)	0.457	0.447	1.021	0.322*
FI	0.003	0.067	0.043	0.967*
R^2			0	
F			0.002	

*indicates statistical significance at 5%

Table 28. Estimation result of Model B

	Unstandardized Coefficients		t	Sig.
Model B	β	Std. Error		
(Constant)	4.747	1.518	3.127	0.006*
FA	0.362	0.406	0.891	0.385*
R ²			0.045	
F			0.794	

*indicates statistical significance at 5%

Table 29. Estimation result of Model C

	Unstandardized Coefficients		t	Sig.
Model C	γ	Std. Error		
(Constant)	0.405	0.431	0.940	0.360*
FA	0.021	0.115	0.179	0.860*
R ²			0.002	
F			0.032	

*indicates statistical significance at 5%

The slopes are very low, and the R² statistics are extremely low as well. Also, the F statistics are much lower than their critical values. All the result are supporting our initial findings in the correlation analysis. Therefore, based on the analysis, we can conclude that among the indicators there is no collinearity. Finally, VIF analysis is performed for each variable (See Table 30, 31, and 32). All the VIF and Tolerance values are much lower than the threshold (i.e. VIF<10; TOL>0.1). Therefore, we can definitively rule out any possibility of a collinearity issue among our indicators.

Table 30. VIF result of Model 1. (DV: Style Changes)

Model 1: SC=f(FA;FI)	Tolerance	VIF
Function addition	0.955	1.047
Function improvement	0.955	1.047
Dependent variable: Style Changes		

Table 31. VIF result of Model 2. (DV: Function Addition)

Model 2: FA=f(SC;FI)	Tolerance	VIF
Style changes	1.000	1.000
Function improvement	1.000	1.000
Dependent variable: Function Addition		

Table 32. VIF result of Model 3. (DV: Function Improvement)

Model 3: FI=f(SC;FA)	Tolerance	VIF
Style changes	0.998	1.002
Function addition	0.998	1.002
Dependent variable: Function Improvement		

Based on the indicator collinearity analysis (Table 30 to 32), which is a part of the validity analysis of the formative measure, we can keep all the indicators in the model with no modifications necessary. Therefore, style changes, function improvement, and function addition are reliable indicators to determine the product innovativeness construct compositely.

7.4 Validation of the CPIS measure: External Validity Analysis

Internal consistency assessments (e.g., Cronbach's alpha) are not suitable for formative indicators (Bagozzi, 1994), and several scholars instead suggest testing the external validity of a formatively measured construct (e.g., Bagozzi, 1994; Diamantopoulos and Winklhofer, 2001; Jarvis et al., 2003). From a theory development perspective, the external validity examines whether or not an observed causal relationship in a group can be generalised to or across different groups (Calder, Phillips, and Tybout, 1982), yet the definition varies among scholars (Newman, Joseph, and Feitosa, 2015). Likewise, testing the external validity of the formative measure is a not a straightforward process as there is still vagueness surrounding how it should be performed. Diamantopoulos and Winklhofer (2001, p.272) suggest a way that can test the external validity is “to use a global item as an external criterion that summarizes the essence of the construct that the

index purports to measure”. This has been used subsequently by scholars (e.g. Bruhn, Georgi, and Hadwich, 2008) to demonstrate a formative measure validity.

In our case, we examine the external validity of the new measure by adopting the above approach. Therefore, we assume that the global item in our case can be sales volume of the product, which is an external criterion, because successful product innovation is expected to be linked to performance variables such as sales (Banbury and Mitchell, 1995; Soni, Lilien, and Wilson, 1993). Regardless of the product innovativeness measure’s construction, theory suggests that product innovativeness should be explaining at least some part of the subsequent variance in sales volume of the product. For instance, more innovative products should create more opportunities for differentiation and competitive advantage, thus impacting positively on sales performance (Kleinschmidt and Cooper, 1991; Danneels and Kleinschmidt, 2003). On the other hand, more innovations lead to riskier, more complicated, and less linear processes (Samuelsson and Davidsson, 2009) and (potentially) to more-skewed returns (Scherer and Harhoff, 2000). Either way, we can expect that innovativeness of the new product can impact on performance. Consequently, we can hypothesise that if the new measure explains most variations of the underlying construct of product innovativeness, it will help to explain variations in sales of the product and of the stock prices of its firm. The hypothesis will be tested by using iPhone series innovativeness scores and Apple Inc. stock prices. Thus:

H₁: A product’s compound product innovativeness score (CPIS), has a positive relationship with a sales volume of the product.

H₂: A product’s TNSM, the market-level technical novelty score, has a positive relationship with a sales volume of the product.

H₃: A product’s TNSF, the firm-level technical novelty score, has a positive relationship with a sales volume of the product.

H₄: A product's CPIS, the compound product innovativeness score, has a positive relationship with stock prices of the firm.

H₅: A product's TNSM, the market level novelty score, has a positive relationship with stock prices of the firm.

H₆: A product's TNSF, the firm level novelty score, has a positive relationship with stock prices of the firm.

Second-order structural equation modelling (SEM) is used to test the hypothesis. To be precise, the model is constructed by formative first order with observed variables and formative second order with objective variable, as defined by Diamantopoulos, Riefler, and Roth, (2008). Using SEM provides the possibility to define the true value of product innovativeness as a latent variable, which is determined by formative indicators CPIS, TNSM, and TNSF. Thus, it may yield more explanatory power than directly defining product innovativeness through the CPIS measure alone.

7.4.1 The link between product innovativeness and sales of the products

To investigate the relationship a Second Order Formative Model is used to demonstrate the link between Product Innovativeness and Sales, as indicated in Figure 32.

Figure 32. Model of Product Innovativeness and Sales Volume

Where:

Sales – Sales volume of the product

PI – Product Innovativeness

CPIS – Compound Product Innovativeness Score

TNSM – Market-level Technical Novelty Score

TNSF – Firm-level Technical Novelty Score

e1, e2, and e3 – error terms

d1 – disturbance term

Results of the model estimation, a summary of the variables, covariances, and correlations are shown in Tables 33, 34, and 35.

Table 33. Variables of the model

Number of variables in the model:	9	
Number of observed variables:	4	CPIS, TNSM, sales, TNSF
Number of unobserved variables:	5	PI, e3, e2, d0, e0
Number of exogenous variables:	5	PI, e3, e2, d0, e0
Number of endogenous variables:	4	CPIS, TNSM, sales, TNSF

Table 34. Sample Covariances

	TNSF	sales	TNSM	CPIS
TNSF	2.322			
sales	21.132	6357.414		
TNSM	-0.575	68.804	2.837	
CPIS	-0.021	2.293	0.135	0.007

Table 35. Sample Correlations

	TNSF	sales	TNSM	CPIS
TNSF	1			
sales	0.174	1		
TNSM	-0.224	0.512	1	
CPIS	-0.167	0.342	0.953	1

Table 36. The Model Result (The first model)

Minimum was achieved

Chi-square = 0.809
Degrees of freedom = 2
Probability level = 0.667

The result (see Table 36) shows that the fitted model has a χ^2 fit statistic of 0.809. The p-value for a χ^2 value of 0.667 with 2 degrees of freedom. This suggests the model is a very good fitting model. Because the lower χ^2 and the higher p-value ($0.667 > 0.05$) implies that there is no difference between implied variances and covariances and the matrix of empirical sample variances and covariances for multivariate normal data (Gulliksen and Tukey, 1958).

Table 37. Estimation of the parameters

			Estimate	S.E.	C.R.	P
CPIS	<=	PI	1			
TNSM	<=	PI	33.798	15.244	2.217	0.027
Sales	<=	PI	512.266	311.121	1.647	0.1
TNSF	<=	PI	-5.503	4.577	-1.202	0.229

Table 38. Standardized Regression Weights

			Estimate
CPIS	<=	PI	0.748
TNSM	<=	PI	1.263
Sales	<=	PI	0.405
TNSF	<=	PI	-0.227

In terms of impact sizes, the regression weights are quite significant (see Table 37). However, t-values in the Critical Ratio (C.R.) column, and p-values in the P column for statistical significance, are higher than 0.05 for all variables at the 0.05 significance level, meaning that these coefficients is not significantly different from zero (at the 0.05 level).

The model shows great fit statistics as RMSEA (Root Mean-Square Error of Approximation) is 0 (lower than 0.05), PCLOSE is 0.673 (higher than 0.05), and LO90=0.

However, RMR (Root Mean-square Residual) is 10.217, which is a large value when all the fit indices suggest good fit. Thus, it may indicate outliers in the raw data. We do not prefer to deal with the outliers by fixing (manipulating) the raw data, which are observed variables and can have various values in theoretical and practical senses.

Figure 33. Model estimation result

Table 39. Hypothesis decisions

Hypothesis	Decisions
H ₁ : The CPIS has the positive relationship with sales	Reject
H ₂ : The TNSM has the positive relationship with sales.	Reject
H ₃ : The TNSF has the positive relationship with sales.	Reject

Scholars note that innovation effects on firm performance measures such as sales are subject to many other strategic and environmental factors (Sood and Tellis, 2009), so it is hard to explain the path of causality through one factor due to data unavailability.

7.4.2 Relationship between Product Innovativeness and the Stock Prices

In this section, we perform the second SEM to investigate the possible relationship between the indicators and dependent variable of stock prices. As a result, Hypotheses 4, 5, and 6 can be tested. Figure 34 shows the model and its structure.

Figure 34. Model of product innovativeness and

Where:

PI – Product Innovativeness

SP – stock prices

CPIS – Compound Product Innovativeness Score

TNSM – Market Level Novelty Score

TNSF – Firm Level Novelty Score

e1, e2, and e3 – error terms

d1 – disturbance term

Table 40. Variables of the model

Number of variables in the model:	9	
Number of observed variables:	4	CPIS, TNSM, SP, TNSF
Number of unobserved variables:	5	PI, e3, e2, d0, e0
Number of exogenous variables:	5	PI, e3, e2, d0, e0
Number of endogenous variables:	4	CPIS, TNSM, SP, TNSF

Table 41. Sample Covariances

	TNSF	SP	TNSM	CPIS
TNSF	2.322			
SP	4.091	1673.839		
TNSM	-0.575	44.146	2.837	
CPIS	-0.021	1.696	0.135	0.007

Table 42. Sample Correlations

	TNSF	SP	TNSM	CPIS
TNSF	1			
SP	0.066	1		
TNSM	-0.224	0.641	1	
CPIS	-0.167	0.492	0.953	1

Table 43. The Model Result (The Second model)

Minimum was achieved
Chi-square = 0.558
Degrees of freedom = 2
Probability level = 0.756

The result (see Table 43) shows that the fitted model has a χ^2 fit statistic of 0.558. The p-value for a χ^2 value of 0.558 with 2 degrees of freedom. This suggests the model is a very good fitting model, because the lower χ^2 and the higher p-value ($0.756 > 0.05$) implies that there is no difference between implied variances and covariances and the

matrix of empirical sample variances and covariances for multivariate normal data (Gulliksen and Tukey, 1958).

Table 44. Estimation of the parameters

			Estimate	S.E.	C.R.	P
CPIS	<=	PI	1			
TNSM	<=	PI	27.965	7.289	3.837	***
TNSF	<=	PI	-5.916	4.92	-1.203	0.229
SP	<=	PI	320.65	153.297	2.092	0.036

Table 45. Standardized Regression Weights

			Estimate
CPIS	<=	PI	0.824
TNSM	<=	PI	1.151
TNSF	<=	PI	-0.269
SP	<=	PI	0.543

In terms of impact sizes, the regression weights are significant (see Table 44). Moreover, t-values in the C.R. column are higher than 2 for TNSM and SP, and the p-value in the P column for statistical significance of TNSM is lower than 0.05 at the 0.05 significance level. This means that the TNSM is significantly different from zero (at the 0.05 level). Thus, there is a positive relationship between SP and TNSM.

The model shows great fit statistics as RMSEA (Root Mean-Square Error of Approximation) is 0 (lower than 0.05), PCLOSE is 0.761 (higher than 0.05), and LO90=0. Furthermore, RMR (Root Mean-square Residual) is 4.192, which is much lower than that of the previous model. Overall, this model has much better fit statistics than the previous model, in sales and product innovativeness were studied. As a result, we can conclude that our measures explain some variations in the stock price of the firm. In the previous model, we used total sales volume of iPhones instead of sales of the particular models

whose innovativeness scores had been measured due to data unavailability. Thus, it must have influenced the estimation of the relationship and model fit as well.

Table 46. Hypothesis decisions

<i>Hypothesis</i>	<i>Decisions</i>
H ₁ : The CPIS has the positive relationship with SP.	Reject
H ₂ : The TNSM has the positive relationship with SP.	Accepted
H ₃ : The TNSF has the positive relationship with SP.	Reject

Figure 35. The model estimation result

Table 47. Effect sizes of the variables

	PI (Product Innovativeness)
TNSF (Firm-level Technical Novelty Score)	-.269
SP (Stock price)	.543
TNSM (Market-level Technical Novelty Score)	1.151
CPIS (Compound Product Innovativeness Score)	.824

As an external validity analysis, two models have been estimated: 1) the relationship between Sales volume and Product Innovativeness, and 2) the relationship between Stock price and Product Innovativeness. Even though both models' fit statistics were good, the first model's regression weights were statistically insignificant. On the other hand, the second model's regression weight was statistically significant and the fit indices were even better than the first model. Thus, it shows that the new measure of product innovation can explain a certain part of stock price changes of the firm. Consequently, it leads to the successful validation of the measure. In fact, we validated the new measure in four different ways (i.e. content specification, indicator specification, indicator collinearity analysis, and external validity analysis) and the results were consistent throughout.

Based on the model result (Table 47), we can see that the market-level technical novelty has more effect on stock prices than does firm-level technical novelty. The finding supports common sense and the theory as it demonstrates that if a firm produces more innovation that is new to the market, its overall product innovativeness will be higher; as a result it leads to higher stock price or higher demand of the stocks of the firm due to the market reaction. Indirect standardised effect of TNSM (Market-level Novelty Score) on stock price (SP) is 0.621, which means that for a one standard deviation increase in TNSM there is a 0.621 standard deviation increase in SP (see Table 47). Finally, another interesting suggestion that was consistent in both models was that the relationship

directions of TNSF (Firm-level Novelty Score) and SP (also Sales) were negative. Thus, a higher TNSF would result in a lower SP and Sales. In other words, it implies that if a firm is doing more 'catching up' work, it will impact their sales and stock prices negatively. Therefore, the ideal strategy would be a higher TNSM (possibly also TNSW but we have not measured that in the empirical study) and a lower TNSF.

7.5 Causal analysis in longitudinal research

In this section, we conduct the causal analysis in longitudinal research to investigate the relationship between the stock price at time t and product innovativeness at time $t-1$. Sood and Tellis (2009) published similar research by using an event study (Fama, 1998), analysing innovation projects, a much broader variable which includes R&D and other activities, rather than only product innovativeness. This chapter extends this work by investigating the relationship between degrees of product innovation and a financial variable. Having developed the new CPIS measure of product innovativeness makes causal analysis possible, in which the direct measure of product innovativeness is utilised to test a possible causality effect on other performance variables. In the previous section, we found the relationship between stock prices and product innovativeness that is operationalised as a latent variable and is defined by three innovativeness measures. However, only the market-level innovativeness was found to have a substantial effect on stock prices and was statistically significant among the measures. Thus, in our model, we use the market-level innovativeness score (i.e. TNSM) as the product innovativeness measure in an attempt to develop a more reliable causal model.

We posit a linear structural equation model for stock prices (SP), which is a continuous and dependent variable at time t . If the TNSM is an independent variable, the most general equation will utilise SP at time $t-1$, and TNSM at time $t-1$ and t , as predictors of SP at time t , with random error term e :

$$SP_t = \alpha + \beta_1 \cdot SP_{t-1} + \beta_2 \cdot TNSM_t + \beta_3 \cdot TNSM_{t-1} + e_t \quad [1]$$

The model demonstrates that the stock prices (SP) at time t could be caused by its value at the previous time (i.e. time t-1) and the product innovativeness scores (TNSM) of the product at both time t and t-1. If parameters of the model show a substantial impact with higher statistical significance, the model could exhibit a causal relationship between the variables.

As a lag-model, it is likely to present a risk of autocorrelation (Anderson, 1954), which occurs when the error term is no longer random (as e_t will be correlated with e_{t-1} and threatens efficiency of the regression coefficients). Thus, the autocorrelation issue has to be tested before proceeding to the model estimation. To test the serial correlation, the Breusch–Godfrey serial correlation LM test is used as it enables a higher order correlation test (Godfrey, 1978) unlike Durbin-Watson, which tests only first-order autocorrelation in the regression model. Table 48 shows the result of Breusch–Godfrey serial correlation LM test, which estimates first and second order autocorrelations.

Table 48. Result of the LM test

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.04	0.61	0.07	0.95
LOG_SP_LAG_1	0.03	0.19	0.16	0.88
LOG_TNSM	-0.11	0.26	-0.41	0.71
LOG_TNSM_LAG_1	-0.01	0.28	-0.03	0.98
RESID(-1)	-0.53	0.78	-0.69	0.54*
RESID(-2)	0.01	0.99	0.01	0.99*

*indicates statistical significance at 5%

Table 49. Regression result

R-squared	0.167
Adjusted R-squared	-1.218
F-statistic	0.121
Prob(F-statistic)	0.977*

*indicates statistical significance at 5%

The first and second order autocorrelation have been tested due to our limited sample size, which is nine years after the one-year-lag transformation in the data. According to the test result (see Table 48 and 49), in the model, it does not show first and second order autocorrelation as t-stats are much lower than their critical value and p values are much higher than 0.05. As well, the whole model's statistical significance (i.e. R^2 and F) rules out the possibility of the second degree autocorrelation in the model.

The next possible issue that needs to be tested is multicollinearity, which happens when there is a high correlation among independent variables in the model (Hair, Anderson, Tatham, Black, 2006). It might be the case because there are very similar variables in terms of their nature (i.e. $TNSM_t$ and $TNSM_{t-1}$) among the regressors. The variance inflation factor (VIF) analysis is used to test the issue (see Table 50). The tolerance and VIF values are well below the threshold values of 4 (O'brien, 2007). Finally, to avoid possible heteroscedasticity issue, which may appears when there is large variations in the data, all the variables are logarithmised (Johnston and DiNardo, 1972).

Table 50. Result of VIF

Independent Variables	Collinearity Statistics	
	Tolerance	VIF
LOG_SP_LAG_1	0.888	1.126
LOG_TNSM	0.919	1.088
LOG_TNSM_LAG_1	0.860	1.163

The model shows promising results (see Table 51) given the limited sample size. Especially, the whole model statistics indicate that this kind of particular model could explain variations in stock prices as F-stats and its p-value are statistically significant and Adjusted R-squared 0.86. Nevertheless, individual statistics of a couple of coefficients (i.e. LOG_TNSM and LOG_TNSM_LAG_1, which are logarithmised values of the market level innovativeness) are not significant, especially the LOG_TNSM_LAG_1 has a much lower impact size and t stats, and thus it may be excluded in the future modelling.

However, all the statistics can be improved substantially if the sample is large enough, which is usually the case for financial analysis.

Table 51. Causal regression analysis result

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.509	0.514	0.991	0.367*
LOG_SP_LAG_1	0.860	0.129	6.658	0.001*
LOG_TNSM	0.317	0.174	1.828	0.127*
LOG_TNSM_LAG_1	-0.138	0.188	-0.735	0.495*

Dependent variable: Log_SP_t

R-squared	0.917
Adjusted R-squared	0.867
F-statistic	18.331
Prob (F-statistic)	0.004*
Durbin-Watson stat	2.247

*indicates statistical significance at 5%

Figure 36. The model's fit graphic

Sood and Tellis (2009) also find the relationship between innovation projects, which is operationalised by three different sets of activities that are initiation, development, and commercialisation, and stock market returns. According to their result,

new product launch has a positive effect on market returns, however it does not account for the degree of innovativeness of the new products. Therefore, the new CPIS measure has a potential to enhance this type of research further.

In our case, the event study, which is a type of time-series analysis, is not suitable because the nature of the event study only focuses on a possible difference in pre and post event (Sharpe, 1964; Fama 1998) in the financial market, which implies the ‘quality’ of the event. Hence, it is used to study the effects of events such as new product announcement, merger or acquisition announcement, and announcements of top management changes.

7.6 Conclusion of Chapter 7

In this section, we focused on validation of the new measure. To validate the measure, we follow Diamantopoulos and Winklhofer (2001) suggestion that consists of four stage of validation process: content specification, indicator specification, indicator collinearity, and external validity. First, the content specification precisely defines what the focal construct is, and the breadth of the definition of product innovativeness based on the prior literature. Second, the indicator specification was analysed, in which three specific indicators (i.e. style changes, function improvement, function addition) that determine the focal construct were defined and explained by using the empirical example. To further validate the measure, the indicator collinearity analysis was performed. The tests found no sign of multicollinearity issue in all three tests. To test the collinearity issue, we utilise three different methods (i.e. correlation analysis, the auxiliary regression analysis between the indicators or independent variables, and VIF analysis), all of which consistently rule out any risk of multicollinearity in our indicators. Lastly, the external validity, which is an important validity in the formative model, is carried out. As an external validity, we develop SEM to test product innovativeness relationship with sales

of iPhones and stock prices. The model of stock price and product innovativeness shows statistically significant results, which indicates the new measure explains certain variations in stock price variations. Longitudinal analysis of the stock price of Apple Inc. and the product innovativeness of their flagship models of iPhone series was conducted in the last section to demonstrate the new measure's application further. The model estimation is statistically significant, thus it supports the development and application of the new measure in business research.

CHAPTER 8. DISCUSSION, CONTRIBUTIONS, IMPLICATIONS

Outline of Chapter 8

8.1 Introduction

This concluding chapter covers a discussion and conclusions of the research, which comprises the theoretical development of the new CPIS measure, its validation analysis, and its empirical application both cross-sectionally and longitudinally to the smartphone market in the US. The research results, validation analysis, and the building of the new measurement model are discussed in section 8.2. In section 8.3, the main findings of the empirical study and the validation analysis are summarised, and the contributions are discussed. Next, the implications of the measurement model are outlined, which includes academic research, managerial, and policy-making implications of the measure in section 8.4. Moreover, section 8.5 discusses the limitations of the model and further research possibilities utilising the new measure, and section 8.6 summarises this chapter.

8.2 Discussion

This thesis has emphasised the highly objective nature of the measurement process for product innovativeness because subjectivity has presented problems in previous product innovativeness measures. In the new CPIS measure the objective elements of product innovativeness are separated from the subjective interpretation of the antecedents and/or consequences of product innovativeness, to achieve a baseline measure of product innovativeness. The new measure is illustrated based upon the collection of quantitative improvement and innovation data in the contested smartphone market. Our measure provides inter-firm comparisons between products and longitudinal within-firm comparisons by utilising a measurement of product innovativeness over time. This process avoids the inconsistency problems associated with the existing heterogeneous subjective assessment of innovativeness and shifts of subjective innovation assessments over time.

Beyond the objective count of measureable changes in an innovation process, we must acknowledge that perceived value of these changes may be subjective. They say that “beauty is in the eye of the beholder”, and a specific style change might be found more attractive/valuable by some (or by many) buyers (or managers or pundits), and subsequently drive greater gains in market share and/or profitability, yet is counted in the CPIS as a single style change the same as any other (less effective) style change. In our schema, the subsequent market performance of the innovation is a consequence of the innovation rather than a characteristic of the innovation.

As a second common objection, relating to the perceptions of objective/subjective innovation measures, concerns impact on performance. For example, a function improvement leading to a 10% product performance gain (such as in battery memory) might be viewed as more innovative than one that makes possible a 5% product

performance gain, yet the CPIS measure simply counts them both as a single function improvement. If this aspect of product performance is measurable and publicized, then that performance metric can be included (as an index) as a separate independent variable in a regression model attempting to explain the firm's sales, profits, or some other measure of the firm's market performance.

Another misperception of the CPIS measure is that collection of the required data would be time-consuming and costly. Yet statistics indicate the rise in data availability due to "big data" (McAfee and Brynjolfsson, 2012). These trends are expected to continue and will provide rich opportunities for using this new tool. With increasing customer demands on transparency (Greenberg, 2010), we expect, at a minimum, published data made available by the manufacturers or retailing firms, which can be used for CPIS assessments, since it is in the firms' best interest to inform markets regarding their new and innovative products and features.

Some scholars (e.g. Cozza *et al.* 2012) note that scholars often use the Community Innovation Survey or other similar surveys to study innovativeness because they provide a representative sample of small and new firms, which are often under-represented or even completely excluded from the analysis when other indicators for innovativeness (such as patents or R&D expenditures) are adopted. This new CPIS measure instead offers a baseline model for product innovativeness that can be used universally for all products, through objectively measurable technical and market novelty dimensions.

To avoid misinterpretation it was emphasised that development of the CPIS is not a scale development exercise (e.g. DeVellis, 2016), as it has been built as a formative measurement model (e.g. Blalock, 1964; Edwards and Bagozzi 2000; Diamantopoulos and Winklhofer, 2011) with composite indicators (Bollen and Bauldry, 2011) that assess objective novelties in a product. The model evaluates product innovativeness through a

combination of technical and market novelty dimensions and time. With a temporal focus on the present, the CPIS product innovativeness measure can enable other innovation-related studies, such as determining product innovation, effectiveness, and efficiency (Alegre, Lapiedra, and Chiva, 2006); and measuring the velocity/intensity of product innovativeness over time.

The new measure has been validated by the four stages of validation process recommended specifically for formative models (Diamantopoulos and Winklhofer, 2001) and the results are consistent. Based on these tests, the measure can be considered valid and applicable for innovation research. Further tests of longitudinal analysis using the CPIS measure were conducted, and the results reveal insightful findings.

The new product innovativeness measure provides the new possibility to analyse product innovativeness in detail by decomposing it into technical and market newness. Therefore, we can perform more specific analyses, such as which firm's product has more market-level or world-level technical novelties; what type of novelties make a certain product more innovative than others, and so on. Further, it could be used to determine proactiveness of entrepreneurs, as the indicators show that whether the product is new-to-the-world, new-to-the-market, or just new-to-the-firm itself, which mostly occurs when a firm is not 'proactive' in their product innovation and are instead implementing a 'me-too' follower strategy. Moreover, the new measure provides another level of analysis, i.e. the product level, for entrepreneurship research and enables multi-level approaches (Low and MacMillan, 1988), in which the firm and individual levels have dominated (Davidsson and Wiklund, 2007). As a result, the CPIS measure has the potential to foster a new round of entrepreneurship and innovation research.

Meanings of the CPIS values

The CPIS at a point in time ($CPIS_t$) can range from 0 to ∞ , in which '0' means that there was no observable novelty in a product, so the product is (currently) not innovative at all. If $0 < CPIS_t < 1$, this indicates that the new product contains technical novelties that are 'new-to-the-firm' and/or 'new-to-the-market', whereas if $CPIS_t > 1$, it implies that the product contains at least one new-to-the-world technical novelty. In terms of the underlying technical complexity, we can also easily interpret the results. For instance, if $0 < TNS_t < 1$, it means that the product has only style changes and/or function improvement technical novelties at time t , while $TNS_t > 1$ indicates a higher degree of technical complexity (i.e. at least one new function addition) in the product.

8.3 The main findings and contributions

This research has been concerned with the construct clarity (Suddaby, 2010) and operationalisation of the product innovativeness (PI) construct, such that it might be utilised by entrepreneurship researchers to reliably and consistently measure the inherent innovativeness of new products (including product upgrades). We argue that the PI measure should not be confounded by antecedent nor subsequent factors which are not only indirect or subjective indicators of PI but which also create challenges for the use of the PI measure as either the dependent variable (for studies of antecedent causes of PI) or for studies where PI is an independent variable (for studies seeking the antecedent causes of profits, sales growth or other firm performance metrics).

We propose a second-degree formative PI measurement model with composite indicators to measure product innovativeness directly and objectively for greater validity and reliability in empirical studies, especially in the new and small venture context where limited track record and informal R&D activity are likely to present data availability and measurement problems. The new CPIS measure avoids reliability issues (e.g. self-

reporting, social desirability, and selective memory issues), that tend to result from direct but subjective measures. Indeed the CPIS is designed to overcome the six main problem areas identified in the PI measurement literature (detailed in chapter 4), and thus has the potential to improve the accuracy and reliability of PI measurement.

Further, the measure has been validated and demonstrated here using longitudinal research. The external validation analysis reveals interesting findings regarding product innovation as it decomposes product innovativeness into two levels: firm-level and market-level product innovativeness. According to the results, market-level innovativeness is more impactful than that at the firm-level. In fact, the firm-level innovativeness shows negative relations to the performance variables such as the sales volume and the stock price as the firm-level innovativeness value increases, the performance variables decrease. Therefore, it could imply that if a firm is playing catch-up with its market competitors, this will impact the firm's market performance negatively. On the other hand, a higher market-level innovativeness value can be expected to lead to better performance in sales volume, profits, and the stock price.

8.4 Implications

This new PI measure has important managerial, research, and policy implications. For managers, the measure can provide more detailed and factual measurement of PI, independent of personal opinions and biases. The highly objective measurement of innovativeness is critical for managers in their efforts to achieve a competitive advantage over other firms. The measurement model demonstrates precisely which type of novelties are more/less innovative at which level (firm, market, the world), and when. The CPIS measure of PI can be achieved by simply inputting the count of technical and market novelties into a publicly-available spreadsheet template containing the algorithms. Based on the CPIS measure, firms can allocate their resources more efficiently by focusing on

particular types of technical novelties in their products and develop innovative advantages over their competitors' products. Also, the CPIS measure helps to understand and recognise market opportunities for product innovativeness. Managers can evaluate rival products in the current market and can depict their current positioning relative to their own existing or planned new products.

Moreover, any firm or any researcher can assess all products in the market without requiring confidential financial and operational data from the producers, as the CPIS measure's unit of analysis is the products themselves. It is especially useful for entrepreneurs as the ability to offer innovative products is the key to their survival in the market. Therefore, it is essential for entrepreneurs to evaluate their products in the current market context objectively for (1) better decision-making regarding their future product development and (2) more substantive valuations of their businesses for negotiation with investors (Douglas, Carlsson-Wall and Hjelstrom, 2014) as it can indicate how innovative their products are compared to other products and because greater innovativeness is expected to lead to greater profitability.

The implications for future entrepreneurship research are quite numerous. For the first time, all new and small firms can be included in studies involving innovativeness, rather than many being excluded for reasons of lack of explicit R&D budgets or other data more commonly found in established and larger firms. The use of a more reliable measure of PI may help to build new theory regarding the financial performance of new ventures, including the failure or survival rates and the profitability and longevity rates of new ventures, and may provide another type of innovation analysis for SMEs, which has been limited (Love and Roper, 2015). Use of a product innovativeness measure that is isolated from antecedent and consequential variables may allow the identification of

the moderating and perhaps also mediating variables that intervene in the relationship between innovativeness and new venture performance.

Finally, entrepreneurship has been a fundamental value of great economies through job creation (e.g. job creation was 34.2% in the US) and innovation (e.g. innovation intensity was 39% in North America). And most certainly, it will continue to be a central driver of growth in rising economies of China (i.e. job expectation and innovation values were 26.7% and 28.8%), India (i.e. job expectation and innovation values were 28% and 5.2%) and other nations (GEM, 2017). If entrepreneurship is the core component of prospering nations, innovation is the principal essence of that prosperity. This logic leads to the rationale that innovation is prerequisite to a nation's prosperity. Hence, many governments act to support entrepreneurship and innovative entrepreneurs. For instance, the Australian Government supports innovative entrepreneurs as a solution to the inevitable decline of employment in (and taxes from) the mining industry, which exploits non-renewable resources. Thus, the CPIS measure can be applied for policy-making to define more-promising innovative new products while providing an objective means of selecting among the applicants for such public financial support.

8.5 Limitations and further research

Although the CPIS measure objectively assesses product innovativeness, it is based on underlying assumptions that might limit its power to explain the market performance of firms – it assumes that all novelties in the same type are considered equal in terms of their usefulness, meaning, and value. Scholars agree that usefulness, meaning, and/or the intrinsic value of novelties are factors that could influence the market success of product innovativeness and that these variables naturally vary across individual customers, customer segments, markets, and time. For example, one could argue that a certain colour has a more appealing effect on consumers than others. Yet under our model assumptions,

which enables objectivity and universality of the measurement, all novelties in the same categories are the same in terms of their qualities from an innovativeness point of view. Therefore they will be evaluated only by their quantities rather than their qualities. We note that this is no different from the common practice of counting the number of patents, citations, and R&D dollars regardless of their technical complexities or inherent quality.

But note that if research can demonstrate that some colours at some times have greater usefulness, meaning, and value to consumers, and if researchers can provide a continuous or categorical scale of consumers' subjective valuations of particular colours, then this scale can be included in quantitative studies of market performance as a separate independent explanatory variable, (alongside the CPIS, like the 'battery capacity' example mentioned earlier). To build an objective measurement model for product innovativeness, it must be established on physical and concrete factors that cannot incorporate context-specific effects (to ensure the consistency of the measure across different cases and over time). Hence, it was necessary to set restrictive assumptions for the model which limit the measurement of innovativeness in some qualitative ways. When creating a universal measurement for products that exist in a huge range of categories, such simplification is both inevitable and necessary. But to the extent that the qualitative impact of the technical novelty can be measured reliably and consistently, that quantitative measure of the qualitative variable can be utilised in empirical studies of firm performance alongside the purely objective CPIS measure of product innovativeness to explain more of the variance in firm performance.

Further research can be focused on a holistic model of the relationship between PI and firm performance. In Figure 37, a simple model of the relationship between

Product Innovativeness and Firm Performance is depicted, with that relationship being positively moderated by Customer Appreciation and by Advertising Intensity.

Figure 37. A holistic model of PI and firm performance.

More complex models could be investigated, of course, as there are other important factors that likely play a significant role as mediating, moderating, and control variables. Importantly, Figure 37 demonstrates that PI is separately defined from other compounding variables that are usually a consequence of market reactions, such as Customer Appreciation and the firm's marketing support of the innovations. Unencumbered by these consequential variables, the CPIS measure provides the opportunity to investigate the pure effect of PI on firm performance separately from the effects of market reactions and the marketing activities of the firm.

8.6 Conclusion of Chapter 8

In this chapter, we focused on discussion, contributions, and implications of the new CPIS measure. First, the conceptual development of the measurement model, its validation, and longitudinal research using the measure has been discussed, including the main findings of an empirical study of the US smartphone market, external validity analysis, and longitudinal analysis. The contributions of this research to the product innovation and entrepreneurship literatures were then outlined. The implications of the new CPIS measure in three main areas, namely research, managerial, and policy making, were

outlined. This was followed by discussion of the limitations of the CPIS measurement model, in which the advantages and disadvantages of ignoring the qualitative differences in technical novelties were examined, culminating in the conclusion that if qualitative differences in technical novelties can be measured they should be used as separate independent explanatory variables to explain (whichever) dependent variable is to be explained, alongside the highly objective measure of product innovativeness. Finally, the future research possibilities were considered, which promise to provide unprecedented insights into many crucial aspects of entrepreneurship and innovation studies.

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APPENDIX

Table: 1. Product innovation measurement operationalization (including the seminal works)

Author	Construct name	Factors	# of items	Alpha or R	Variance explained	Scale	Categories	# of products/projects	Dependent variable
Cooper (1979)	Product innovativeness	Newness to the firm	8	NR	10.10%	0-10 Likert	Continuum	195	New product success
		Product uniqueness (Pioneer)	6		2.20%	0-10 Likert			
		Product uniqueness/superiority	3		9.00%	0-10 Likert			
Lawton & Parasuraman (1980)	Product innovativeness	Change in behavioral patterns	1	NR		1-7 Likert	High/medium/low	107	Adoption of marketing concepts
		Product newness	1			1-7 Likert	High/medium/low		
More (1982)	Marketing task similarity		10	NR		NR	Continuum	43	Accept/reject decision
	Production complexity		5	NR		NR			
	Distribution difficulty		5	NR		NR			
	Development complexity		5	NR		NR			
Maidique & Ziger (1984)	Degree of technical content		NR	NR		NR	Radical breakthrough/ significant technical change/ incremental change	Survey I n=78, Survey II n=58.	Success/failure
Yoon & Lilien (1985)	Innovation type					NR	True/adoption	112	New product performance
	Product type					NR	Original new products/reformulated new products		

Table: 2. Product innovation measurement operationalization (including the seminal works)

Author	Construct name	Factors	# of items	Alpha or R	Variance explained	Scale	Categories	# of products/projects	Dependent variable
Cooper & de Brentani (1991)	Synergy		7	0.867		1-7 Likert	Continuum	106	New service success
	Newness to the firm		7	0.724		1-7 Likert			
	Innovativeness of the service product		3	0.71		1-7 Likert			
	Product uniqueness and superiority		6	0.75		1-7 Likert			
Kleinschmidt & Cooper (1991)	Product/market fit		3	0.712		1-7 Likert	Highly/moderate/low innovativeness	195	New product performance
	Product innovation		6	NR		NR			
	Product type								
McDonough (1993)	Technical innovativeness of product		1	-		1-5 Likert	Routine/radical	32	New product development speed
Lee & Na (1994)	Product innovativeness		3	0.77		1-7 Likert	Incrementally improving/radical	75	Technical performance
Ali, Kraffel & Labahn (1995)	Technical content		3	0.82		1-7 Likert	Continuum	73	Cycle time
	Product innovativeness		6		3%	1-7 Likert			
Green, Gavin & Alman-Smith (1995)	Radicalness of innovation	Technical uncertainty	3		18%	1-7 Likert	Radical	213	None-factor analysis
		Technical inexperience	3		11%	1-7 Likert			
		Technology cost	3			1-7 Likert			
		Business experience	4		61%	1-7 Likert			

Table: 3. Product innovation measurement operationalization (including the seminal works)

Author	Construct name	Factors	# of items	Alpha or R	Variance explained	Scale	Categories	# of products/projects	Dependent variable
Atuahene-Gima (1995)	Product newness	Newness to customers Newness to firm	6 1	0.78			Radical/Incremental	119 103	New product performance Incremental
Olson, Walker & Ruekert (1995)	Product innovativeness	Newness of product	5	0.81	NR	1-7 Likert	Radical/Incremental	45	Product and financial outcomes efficiency outcomes Psychosocial outcomes
Mishra, Kim & Lee (1996)	General characteristics	Product innovativeness	1	r=0.675		1-7 Likert	Continuum	144	New product success
		Customization of the product	1	r=0.629					
		Technology content	1	r=0.621					
	Newness to the firm		8	NR		0-10 Likert			
Souder & Song (1997)	Radicalness		3	0.74		1-5 Likert	Continuum	156	New product success
Schmidt & Calatone (1998)	Product innovativeness		-	-		High/Low	Innovative/Incremental	161	Likelihood of failure/self-reported commitment/go/stop decision
Colarelli O'Connor (1998)	Source of technology		5	NR			Discontinuous	9	Market learning
	Nature of market needs		4	NR					
Song & Montoya-Weiss (1998)	Product innovativeness		NR	NR			Really new/Incremental	163 really new/ 169 incremental	New product success

Table 4. Product innovation measurement operationalization (including the seminal works)

Author	Construct name	Factors	# of items	Alpha or R	Variance explained	Scale	Categories	# of products/projects	Dependent variable
Verzer (1998)	Discontinuity index	Discontinuity of product benefits	NR		NR	NR	High/Medium/Low	7	Customer input/Customer evaluation
		Discontinuity of technological capabilities	NR		NR	NR			
		Discontinuity of consumption	NR		NR	NR			
Goldenberg, Lehmann & Mazursky (1999)	Newness	Newness to the market	1		-	0-2	High/Moderate/Low	197	New product success
		Newness to the firm	1			0-1	New/Not new		
		Newness of the technology	1			0-2	High/Moderate/Low		
Kessler & Chakrabarti (1999)	Product radicalness		2	NR		1-5	Radical/Incremental	42 radical 33 incremental	Innovation speed
Chandy & Telis (2000)	Radical product innovation	Technology difference	1		-	1-9	Continuum	64	Radical product innovation
		Customer benefits	1		-	1-9			
Henard & Szymanski (2001)	Product innovativeness	Perceived newness/ originality/ uniqueness /radicalness of the product	1	0.3		NR	Continuum	149	New product success
Calantone et al. (2006)	Product innovativeness		1	NR		0-10	Continuum	451	New Product Profitability
		Marketing Discontinuity	3	0.58		0-10			
McNally et al. (2010)	Product innovativeness	Technological Discontinuity	3	0.44		0-10	Continuum	444	financial performance
		Customer Discontinuity	3	0.85		0-10			

Table: 5. Product innovation measurement operationalization (including the seminal works)

Author	Construct name	Factors	# of items	Alpha or R	Variance explained	Scale	Categories	# of products/projects	Dependent variable
Evanschitzky Et al. (2012)	Product innovativeness		1	0.11		NR	Continuum	233	New product success
Edison et al. (2013)	Innovation measurement	Capability, output, performance	3	-	-	NR	Continuum	-	Innovativeness

Table: 6. Observation result of new-to-market and new-to-firm novelties: iPhone 3G

<i>Launched year</i>	2007	2008		
Technical Specification	iPhone	iPhone 3G	FIRM	MARKET
1. DESIGN				
Materials	Plastic	Plastic	no-inno	no-inno
Colours	Black	Black	no-inno	no-inno
2. RUGGEDNESS				
Splash	xx	xx	xx	xx
Water	xx	xx	xx	xx
Dust	xx	xx	xx	xx
3. DISPLAY				
Physical size	3.5	3.5	no-inno	no-inno
Resolution	480 x 320	480 x 320	no-inno	no-inno
Pixel density	165	165	no-inno	no-inno
Technology	xx	xx	xx	xx
Screen-to-body ratio	52.35	52.35	no-inno	no-inno
Peak brightness	xx	xx	xx	xx
Protection	xx	xx	xx	xx
Damage resistant glass	xx	xx	xx	xx
3D touch	xx	xx	xx	xx
Multitouch	yes	yes	no-inno	no-inno
Shape	Flat	Flat	no-inno	no-inno
4. ATTACHED PEN				
Pressure levels	xx	xx	xx	xx
Pen Tip diameter	xx	xx	xx	xx
Rugged	xx	xx	xx	xx
<i>Live message</i>	xx	xx	xx	xx
<i>Samsung Notes</i>	xx	xx	xx	xx
<i>Screen off memo</i>	xx	xx	xx	xx
<i>Smart select</i>	xx	xx	xx	xx
<i>Screen write</i>	xx	xx	xx	xx
<i>Translate</i>	xx	xx	xx	xx
<i>Bixby Vision</i>	xx	xx	xx	xx
<i>Glance</i>	xx	xx	xx	xx
<i>Magnify</i>	xx	xx	xx	xx
5. CAMERA				
Rear camera (wide angel)				
Pixels	2	2	no-inno	no-inno

Flash	xx	xx	xx	xx
True tone flash	xx	xx	xx	xx
Aperture size	xx	xx	xx	xx
Pixel size	xx	xx	xx	xx
FOV	xx	xx	xx	xx
Rear camera (telephoto)				
Pixels	xx	xx	xx	xx
Aperture size	xx	xx	xx	xx
Camera sensor size	xx	xx	xx	xx
FOV	xx	xx	xx	xx
Hardware Features				
<i>Optical image stabilization</i>	xx	xx	xx	xx
<i>Autofocus</i>	xx	xx	xx	xx
<i>Live focus (blur background)</i>	xx	xx	xx	xx
<i>Sapphire crystal lens cover</i>	xx	xx	xx	xx
<i>Back-illuminated sensor</i>	xx	xx	xx	xx
Optical zoom	xx	xx	xx	xx
Software Features				
<i>Manual focus</i>	xx	xx	xx	xx
<i>Portrait lighting</i>	xx	xx	xx	xx
<i>RAW image capture</i>	xx	xx	xx	xx
<i>Touch to focus</i>	xx	xx	xx	xx
<i>Smile detection</i>	xx	xx	xx	xx
<i>Face detection</i>	xx	xx	xx	xx
<i>Body detection</i>	xx	xx	xx	xx
<i>Grid line</i>	xx	xx	xx	xx
<i>Auto image stabilisation</i>	xx	xx	xx	xx
<i>Hybrid IR filter</i>	xx	xx	xx	xx
<i>Filters</i>	xx	xx	xx	xx
<i>Motion/Live photo</i>	xx	xx	xx	xx
<i>Voice activation</i>	xx	xx	xx	xx
<i>Live stickers</i>	xx	xx	xx	xx
<i>Stamps</i>	xx	xx	xx	xx
<i>Dual capture</i>	xx	xx	xx	xx
<i>Noise reduction</i>	xx	xx	xx	xx
<i>Self-timer</i>	xx	xx	xx	xx
<i>Digital zoom</i>	xx	xx	xx	xx
<i>Geo tagging</i>		yes		1
Settings				

<i>Exposure compensation</i>	xx	xx	xx	xx
<i>ISO control</i>	xx	xx	xx	xx
<i>White balance presets</i>	xx	xx	xx	xx
<i>Shutter speed control</i>	xx	xx	xx	xx
Shooting Modes				
<i>Burst mode</i>	xx	xx	xx	xx
<i>Portrait mode</i>	xx	xx	xx	xx
<i>High Dynamic Range (HDR)</i>	xx	xx	xx	xx
<i>Panorama</i>	xx	xx	xx	xx
<i>Virtual shot</i>	xx	xx	xx	xx
<i>Slow motion</i>	xx	xx	xx	xx
<i>Macro mode</i>	xx	xx	xx	xx
<i>Scene mode</i>	xx	xx	xx	xx
<i>Food mode</i>	xx	xx	xx	xx
<i>Pro mode</i>	xx	xx	xx	xx
<i>Manual mode</i>	xx	xx	xx	xx
Front camera				
Pixels	xx	xx	xx	xx
Flash	xx	xx	xx	xx
Aperture size	xx	xx	xx	xx
Pixel size	xx	xx	xx	xx
FOV	xx	xx	xx	xx
Front camera features				
<i>Animoji</i>	xx	xx	xx	xx
<i>HD video recording</i>	xx	xx	xx	xx
<i>Auto HDR</i>	xx	xx	xx	xx
<i>Backside illumination sensor</i>	xx	xx	xx	xx
<i>Face detection</i>	xx	xx	xx	xx
<i>Body detection</i>	xx	xx	xx	xx
<i>Auto image stabilisation</i>	xx	xx	xx	xx
<i>Burst mode</i>	xx	xx	xx	xx
<i>Portrait mode</i>	xx	xx	xx	xx
<i>Exposure control</i>	xx	xx	xx	xx
<i>Timer mode</i>	xx	xx	xx	xx
<i>Grid line</i>	xx	xx	xx	xx
<i>Filters</i>	xx	xx	xx	xx
<i>Selective focus</i>	xx	xx	xx	xx
<i>Virtual shot</i>	xx	xx	xx	xx
<i>Live stickers</i>	xx	xx	xx	xx

<i>Stamps</i>	xx	xx	xx	xx
<i>Voice control</i>	xx	xx	xx	xx
Camcorder (video resolution)				
<i>3840x2160 (4K)</i>	xx	xx	xx	xx
<i>1920x1080 (1080p HD)</i>	xx	xx	xx	xx
<i>1280x720 (720p HD)</i>	xx	xx	xx	xx
<i>Video recoder</i>	xx	xx	xx	xx
Video features				
<i>Time-lapse video</i>	xx	xx	xx	xx
<i>Hyperlapse</i>	xx	xx	xx	xx
<i>Continuous autofocus</i>	xx	xx	xx	xx
<i>Tracking AF</i>	xx	xx	xx	xx
<i>Picture-taking during video recording</i>	xx	xx	xx	xx
<i>Video light</i>	xx	xx	xx	xx
<i>Video calling</i>	xx	xx	xx	xx
<i>Video geo-tagging</i>	xx	xx	xx	xx
<i>Optical zoom</i>	xx	xx	xx	xx
<i>Digital zoom</i>	xx	xx	xx	xx
<i>Slow motion</i>	xx	xx	xx	xx
<i>Face detection</i>	xx	xx	xx	xx
<i>Body detection</i>	xx	xx	xx	xx
<i>Playback zoom</i>	xx	xx	xx	xx
<i>Digital video stabilisation</i>	xx	xx	xx	xx
<i>Optical video stablisation</i>	xx	xx	xx	xx
<i>Cinematic video stabilisation</i>	xx	xx	xx	xx
<i>Noise reduction</i>	xx	xx	xx	xx
6. HARDWARE				
System chip	xx	xx	xx	xx
Processor speed	0.4	0.4	no-inno	no-inno
Core	Single-core	Single-core	no-inno	no-inno
Graphic processor GPU	xx	xx	xx	xx
System memory	128	128	no-inno	no-inno
Built-in storage	16GB	16GB	no-inno	no-inno
Storage expansion	xx	xx	xx	xx
64-BIT	xx	xx	xx	xx
Nano sim	xx	xx	xx	xx
Dual sim	xx	xx	xx	xx
7. BATTERY				

Capacity	1400	1150	no-inno	no-inno
Type		lithium-ion	no-inno	no-inno
Wireless charging	xx	xx	xx	xx
Fast-charge capability	xx	xx	xx	xx
8. AUDIO				
High quality playback	xx	xx	xx	xx
Recording quality	xx	xx	xx	xx
Speakers	xx	xx	xx	xx
<i>Earpiece</i>	yes	yes	no-inno	no-inno
<i>Stereo speakers</i>	xx	xx	xx	xx
<i>Loudspeaker</i>	yes	yes	no-inno	no-inno
HD Voice	xx	xx	xx	xx
9. VIDEO				
Split screen	xx	xx	xx	xx
TV connection	xx	xx	xx	xx
10. CELLULAR				
2G	yes	yes	no-inno	no-inno
3G		yes		1
4G LTE	xx	xx	xx	xx
CDMA together	xx	xx	xx	xx
11. CONNECTIVITY				
Bluetooth	2	2	no-inno	no-inno
Wi-Fi				
<i>802.11 a</i>	xx	xx	xx	xx
<i>802.11 b</i>	yes	yes	no-inno	no-inno
<i>802.11 g</i>	yes	yes	no-inno	no-inno
<i>802.11 n</i>	xx	xx	xx	xx
<i>802.11 ac</i>	xx	xx	xx	xx
<i>802.11n 5GHz</i>	xx	xx	xx	xx
<i>Dual Band</i>	xx	xx	xx	xx
<i>WiFi MiMO</i>	xx	xx	xx	xx
<i>WiFi hotspot</i>	xx	xx	xx	xx
Mobile hotspot	xx	xx	xx	xx
Mobile Payment	xx	xx	xx	xx
Positioning				
<i>GPS</i>	xx	xx	xx	xx
<i>A-GPS</i>		yes		1
<i>Glomass</i>	xx	xx	xx	xx
<i>Galileo</i>	xx	xx	xx	xx

<i>Cell ID</i>		yes		1
<i>BeiDou</i>	xx	xx	xx	xx
<i>QZSS</i>	xx	xx	xx	xx
<i>Wi-Fi positioning</i>		yes		1
<i>iBeacon micro-location</i>	xx	xx	xx	xx
12. PHONE FEATURES				
Haptic feedback	xx	xx	xx	xx
Hearing aid compatibility	xx	xx	xx	xx
3D facial recognition	xx	xx	xx	xx
Sensors				
<i>Accelerometer</i>	yes	yes	no-inno	no-inno
<i>Iris sensor</i>	xx	xx	xx	xx
<i>Geomagnetic sensor</i>	xx	xx	xx	xx
<i>Pressure sensor</i>	xx	xx	xx	xx
<i>Fingerprint sensor</i>	xx	xx	xx	xx
<i>HR sensor</i>	xx	xx	xx	xx
<i>Face ID</i>	xx	xx	xx	xx
<i>Gyroscope</i>	xx	xx	xx	xx
<i>Compass</i>	xx	xx	xx	xx
<i>Hall (for flip covers)</i>	xx	xx	xx	xx
<i>Barometer</i>	xx	xx	xx	xx
<i>Thermometer</i>	xx	xx	xx	xx
<i>Hygrometer</i>	xx	xx	xx	xx
<i>Light sensor</i>	yes	yes	no-inno	no-inno
<i>Proximity sensor</i>	yes	yes	no-inno	no-inno
Voice command	xx	xx	xx	xx
<i>Proximity sensor</i>	xx	xx	xx	xx
<i>Gesture sensor</i>	xx	xx	xx	xx
<i>UV sensor</i>	xx	xx	xx	xx
Voice command	xx	xx	xx	xx

Table: 7. Observation result of new-to-market and new-to-firm novelties: iPhone 3GS

<i>Launched year</i>	2008	2009(Jun)	2009(May)		
Technical Specification	iPhone 3G	iPhone 3GS	i8910	FIRM	MARKET
1. DESIGN					
Materials	Plastic	Plastic		no-inno	no-inno
Colours	Black	Black, White	Black		1
2. RUGGEDNESS					
Splash	xx	xx	xx	xx	xx
Water	xx	xx	xx	xx	xx
Dust	xx	xx	xx	xx	xx
3. DISPLAY					
Physical size	3.5	3.5	3.7	no-inno	no-inno
Resolution	480 x 320	480 x 320	360 x 640	no-inno	no-inno
Pixel density	165	165	198	no-inno	no-inno
Technology			AMOLED	no-inno	no-inno
Screen-to-body ratio	52.35	52.35	52.9	no-inno	no-inno
Peak brightness					
Protection		Fingerprint-resistant oleophobic coating	Corning Gorilla Glass	1	
Damage resistant glass	xx	xx	xx	xx	xx
3D touch	xx	xx	xx	xx	xx
Multitouch	yes	yes			
Shape	Flat	Flat			
4. ATTACHED PEN					
Pressure levels	xx	xx	xx	xx	xx
Pen Tip diameter	xx	xx	xx	xx	xx
Rugged	xx	xx	xx	xx	xx
<i>Live message</i>	xx	xx	xx	xx	xx
<i>Samsung Notes</i>	xx	xx	xx	xx	xx
<i>Screen off memo</i>	xx	xx	xx	xx	xx
<i>Smart select</i>	xx	xx	xx	xx	xx
<i>Screen write</i>	xx	xx	xx	xx	xx
<i>Translate</i>	xx	xx	xx	xx	xx
<i>Bixby Vision</i>	xx	xx	xx	xx	xx
<i>Glance</i>	xx	xx	xx	xx	xx
<i>Magnify</i>	xx	xx	xx	xx	xx
5. CAMERA					
Rear camera (wide angel)					

Pixels	2	3	8	1	
Flash			LED	no-inno	no-inno
True tone flash	xx	xx	xx	xx	xx
Aperture size		2.8		no-inno	no-inno
Pixel size	xx	xx	xx	xx	xx
FOV	xx	xx	xx	xx	xx
Rear camera (telephoto)					
Pixels	xx	xx	xx	xx	xx
Aperture size	xx	xx	xx	xx	xx
Camera sensor size	xx	xx	xx	xx	xx
FOV	xx	xx	xx	xx	xx
Hardware Features					
<i>Optical image stabilization</i>	xx	xx	xx	xx	xx
<i>Autofocus</i>		yes	yes	1	
<i>Live focus (blur background)</i>	xx	xx	xx	xx	xx
<i>Sapphire crystal lens cover</i>	xx	xx	xx	xx	xx
<i>Back-illuminated sensor</i>	xx	xx	xx	xx	xx
Optical zoom	xx	xx	xx	xx	xx
Software Features					
<i>Manual focus</i>	xx	xx	xx	xx	xx
<i>Portrait lighting</i>	xx	xx	xx	xx	xx
<i>RAW image capture</i>	xx	xx	xx	xx	xx
<i>Touch to focus</i>		yes			1
<i>Smile detection</i>			yes	no-inno	no-inno
<i>Face detection</i>			yes	no-inno	no-inno
<i>Body detection</i>	xx	xx	xx	xx	xx
<i>Grid line</i>	xx	xx	xx	xx	xx
<i>Auto image stabilisation</i>			yes	no-inno	no-inno
<i>Hybrid IR filter</i>	xx	xx	xx	xx	xx
<i>Filters</i>	xx	xx	xx	xx	xx
<i>Motion/Live photo</i>	xx	xx	xx	xx	xx
<i>Voice activation</i>	xx	xx	xx	xx	xx
<i>Live stickers</i>	xx	xx	xx	xx	xx
<i>Stamps</i>	xx	xx	xx	xx	xx
<i>Dual capture</i>	xx	xx	xx	xx	xx
<i>Noise reduction</i>	xx	xx	xx	xx	xx
<i>Self-timer</i>			yes	no-inno	no-inno
<i>Digital zoom</i>			yes	no-inno	no-inno
<i>Geo tagging</i>	yes	yes	yes	no-inno	no-inno

Settings					
<i>Exposure compensation</i>	xx	xx	xx	xx	xx
<i>ISO control</i>	xx	xx	xx	xx	xx
<i>White balance presets</i>	xx	xx	xx	xx	xx
<i>Shutter speed control</i>	xx	xx	xx	xx	xx
Shooting Modes					
<i>Burst mode</i>			yes	no-inno	no-inno
<i>Portrait mode</i>	xx	xx	xx	xx	xx
<i>High Dynamic Range (HDR)</i>	xx	xx	xx	xx	xx
<i>Panorama</i>			yes	no-inno	no-inno
<i>Virtual shot</i>	xx	xx	xx	xx	xx
<i>Slow motion</i>	xx	xx	xx	xx	xx
<i>Macro mode</i>	xx	xx	xx	xx	xx
<i>Scene mode</i>	xx	xx	xx	xx	xx
<i>Food mode</i>	xx	xx	xx	xx	xx
<i>Pro mode</i>	xx	xx	xx	xx	xx
<i>Manual mode</i>	xx	xx	xx	xx	xx
Front camera					
Pixels			0.1	no-inno	no-inno
Flash	xx	xx	xx	xx	xx
Aperture size	xx	xx	xx	xx	xx
Pixel size	xx	xx	xx	xx	xx
FOV	xx	xx	xx	xx	xx
Front camera features					
<i>Animoji</i>	xx	xx	xx	xx	xx
<i>HD video recording</i>	xx	xx	xx	xx	xx
<i>Auto HDR</i>	xx	xx	xx	xx	xx
<i>Backside illumination sensor</i>	xx	xx	xx	xx	xx
<i>Face detection</i>	xx	xx	xx	xx	xx
<i>Body detection</i>	xx	xx	xx	xx	xx
<i>Auto image stabilisation</i>	xx	xx	xx	xx	xx
<i>Burst mode</i>	xx	xx	xx	xx	xx
<i>Portrait mode</i>	xx	xx	xx	xx	xx
<i>Exposure control</i>	xx	xx	xx	xx	xx
<i>Timer mode</i>	xx	xx	xx	xx	xx
<i>Grid line</i>	xx	xx	xx	xx	xx
<i>Filters</i>	xx	xx	xx	xx	xx
<i>Selective focus</i>	xx	xx	xx	xx	xx
<i>Virtual shot</i>	xx	xx	xx	xx	xx

<i>Motion/Live photo</i>	xx	xx	xx	xx	xx
<i>Live stickers</i>	xx	xx	xx	xx	xx
<i>Stamps</i>	xx	xx	xx	xx	xx
<i>Voice control</i>	xx	xx	xx	xx	xx
Camcorder (video resolution)					
<i>3840x2160 (4K)</i>	xx	xx	xx	xx	xx
<i>1920x1080 (1080p HD)</i>	xx	xx	xx	xx	xx
<i>1280x720 (720p HD)</i>			24fps	no-inno	no-inno
<i>Video recoder</i>		yes		1	
Video features					
<i>Time-lapse video</i>	xx	xx	xx	xx	xx
<i>Hyperlapse</i>	xx	xx	xx	xx	xx
<i>Continuous autofocus</i>	xx	xx	xx	xx	xx
<i>Tracking AF</i>	xx	xx	xx	xx	xx
<i>Picture-taking during video recording</i>	xx	xx	xx	xx	xx
<i>Video light</i>	xx	xx	xx	xx	xx
<i>Video calling</i>	xx	xx	xx	xx	xx
<i>Video geo-tagging</i>		yes			1
<i>Optical zoom</i>	xx	xx	xx	xx	xx
<i>Digital zoom</i>	xx	xx	xx	xx	xx
<i>Slow motion</i>	xx	xx	xx	xx	xx
<i>Face detection</i>	xx	xx	xx	xx	xx
<i>Body detection</i>	xx	xx	xx	xx	xx
<i>Playback zoom</i>	xx	xx	xx	xx	xx
<i>Digital video stabilisation</i>	xx	xx	xx	xx	xx
<i>Optical video stablisation</i>	xx	xx	xx	xx	xx
<i>Cinematic video stabilisation</i>	xx	xx	xx	xx	xx
<i>Noise reduction</i>	xx	xx	xx	xx	xx
6. HARDWARE					
System chip	xx	xx	xx	xx	xx
Processor speed	0.4	0.6	0.6	1	
Core	Single-core	Single-core		no-inno	no-inno
Graphic processor GPU	xx	xx	xx	xx	xx
System memory	128	256	256MB	1	
Built-in storage	16GB	16GB	16GB	no-inno	no-inno
Storage expansion			yes	no-inno	no-inno
64-BIT	xx	xx	xx	xx	xx
Nano sim	xx	xx	xx	xx	xx

Dual sim	xx	xx	xx	xx	xx
7. BATTERY					
Capacity	1150 mAh	1219 mAh	1500 mAh	1	
Type	lithium-ion	lithium-ion	lithium-ion	no-inno	no-inno
Wireless charging	xx	xx	xx	xx	xx
Fast-charge capability	xx	xx	xx	xx	xx
8. AUDIO					
High quality playback	xx	xx	xx	xx	xx
Recording quality	xx	xx	xx	xx	xx
Speakers	xx	xx	xx	xx	xx
<i>Earpiece</i>	yes	yes	yes	no-inno	no-inno
<i>Stereo speakers</i>	xx	xx	xx	xx	xx
<i>Loudspeaker</i>	yes	yes	yes	no-inno	no-inno
HD Voice	xx	xx	xx	xx	xx
9. VIDEO					
Split screen	xx	xx	xx	xx	xx
TV connection	xx	xx	xx	xx	xx
10. CELLULAR					
2G	yes	yes		no-inno	no-inno
3G	yes	yes		no-inno	no-inno
4G LTE	xx	xx	xx	xx	xx
CDMA together	xx	xx	xx	xx	xx
11. CONNECTIVITY					
Bluetooth	2	2.1	2		1
Wi-Fi					
<i>802.11 a</i>	xx	xx	xx	xx	xx
<i>802.11 b</i>	yes	yes	yes	no-inno	no-inno
<i>802.11 g</i>	yes	yes	yes	no-inno	no-inno
<i>802.11 n</i>	xx	xx	xx	xx	xx
<i>802.11 ac</i>	xx	xx	xx	xx	xx
<i>802.11n 5GHz</i>	xx	xx	xx	xx	xx
<i>Dual Band</i>	xx	xx	xx	xx	xx
<i>WiFi MiMO</i>	xx	xx	xx	xx	xx
<i>WiFi hotspot</i>	xx	xx	xx	xx	xx
Mobile hotspot	xx	xx	xx	xx	xx
Mobile Payment	xx	xx	xx	xx	xx
Positioning					
<i>GPS</i>	xx	xx	xx	xx	xx
<i>A-GPS</i>	yes	yes	yes	no-inno	no-inno

<i>Glonass</i>	xx	xx	xx	xx	xx
<i>Galileo</i>	xx	xx	xx	xx	xx
<i>Cell ID</i>	yes	yes		no-inno	no-inno
<i>BeiDou</i>	xx	xx	xx	xx	xx
<i>QZSS</i>	xx	xx	xx	xx	xx
<i>Wi-Fi positioning</i>	yes	yes		no-inno	no-inno
<i>iBeacon micro-location</i>	xx	xx	xx	xx	xx
12. PHONE FEATURES					
Haptic feedback	xx	xx	xx	xx	xx
Hearing aid compatibility	xx	xx	xx	xx	xx
3D facial recognition	xx	xx	xx	xx	xx
Bixby	xx	xx	xx	xx	xx
Sensors					
<i>Accelerometer</i>	yes	yes	yes	no-inno	no-inno
<i>Iris sensor</i>	xx	xx	xx	xx	xx
<i>Geomagnetic sensor</i>	xx	xx	xx	xx	xx
<i>Pressure sensor</i>	xx	xx	xx	xx	xx
<i>Fingerprint sensor</i>	xx	xx	xx	xx	xx
<i>HR sensor</i>	xx	xx	xx	xx	xx
<i>Face ID</i>	xx	xx	xx	xx	xx
<i>Gyroscope</i>	xx	xx	xx	xx	xx
<i>Compass</i>		yes	yes	1	
<i>Hall (for flip covers)</i>	xx	xx	xx	xx	xx
<i>Barometer</i>	xx	xx	xx	xx	xx
<i>Thermometer</i>	xx	xx	xx	xx	xx
<i>Hygrometer</i>	xx	xx	xx	xx	xx
<i>Light sensor</i>	yes	yes			1
<i>Proximity sensor</i>	yes	yes	yes	no-inno	no-inno
<i>Gesture sensor</i>	xx	xx	xx	xx	xx
<i>UV sensor</i>	xx	xx	xx	xx	xx
Voice command	xx	xx	xx	xx	xx

Table: 8. Observation result of new-to-market and new-to-firm novelties: iPhone 4

<i>Launched year</i>	2009(June)	2010(Jun 24)	2010(Jun 4)		
Technical Specification	iPhone 3GS	iPhone 4	Galaxy S	FIRM	MARKET
1. DESIGN					
Materials	Plastic	Glass; Aluminium			1
Colours	Black, White	Black, White	Black, White	no-inno	no-inno
2. RUGGEDNESS					
Splash	xx	xx	xx	xx	xx
Water	xx	xx	xx	xx	xx
Dust	xx	xx	xx	xx	xx
3. DISPLAY					
Physical size	3.5	3.5	4	no-inno	no-inno
Resolution	480 x 320	960 x 640	480 x 800		1
Pixel density	165	326	233		1
Technology		Retina display	Super AMOLED	1	
Screen-to-body ratio	52.35	55.77	57.88	1	
Peak brightness		500 cd/m ²		no-inno	no-inno
Protection	Fingerprint- resistant oleophobic coating	Fingerprint- resistant oleophobic coating	Corning Gorilla Glass	no-inno	no-inno
Damage resistant glass	xx	xx	xx	xx	xx
3D touch	xx	xx	xx	xx	xx
Multitouch	yes	yes		no-inno	no-inno
Shape	Flat	Flat		no-inno	no-inno
4. ATTACHED PEN					
Pressure levels	xx	xx	xx	xx	xx
Pen Tip diameter	xx	xx	xx	xx	xx
Rugged	xx	xx	xx	xx	xx
<i>Live message</i>	xx	xx	xx	xx	xx
<i>Samsung Notes</i>	xx	xx	xx	xx	xx
<i>Screen off memo</i>	xx	xx	xx	xx	xx
<i>Smart select</i>	xx	xx	xx	xx	xx
<i>Screen write</i>	xx	xx	xx	xx	xx
<i>Translate</i>	xx	xx	xx	xx	xx
<i>Bixby Vision</i>	xx	xx	xx	xx	xx
<i>Glance</i>	xx	xx	xx	xx	xx
<i>Magnify</i>	xx	xx	xx	xx	xx
5. CAMERA					

Rear camera (wide angel)					
Pixels	3	5	5	1	
Flash		LED			1
True tone flash	xx	xx	xx	xx	xx
Aperture size	2.8	2.8		no-inno	no-inno
Pixel size		1.75		no-inno	no-inno
FOV	xx	xx	xx	xx	xx
Rear camera (telephoto)					
Pixels	xx	xx	xx	xx	xx
Aperture size	xx	xx	xx	xx	xx
Camera sensor size	xx	xx	xx	xx	xx
FOV	xx	xx	xx	xx	xx
Hardware Features					
<i>Optical image stabilization</i>	xx	xx	xx	xx	xx
<i>Autofocus</i>	yes	yes	yes	no-inno	no-inno
<i>Live focus (blur background)</i>	xx	xx	xx	xx	xx
<i>Sapphire crystal lens cover</i>	xx	xx	xx	xx	xx
<i>Back-illuminated sensor</i>		yes			1
Optical zoom	xx	xx	xx	xx	xx
Software Features					
<i>Manual focus</i>	xx	xx	xx	xx	xx
<i>Portrait lighting</i>	xx	xx	xx	xx	xx
<i>RAW image capture</i>	xx	xx	xx	xx	xx
<i>Touch to focus</i>	yes	yes		no-inno	no-inno
<i>Smile detection</i>			yes	no-inno	no-inno
<i>Face detection</i>	xx	xx	xx	xx	xx
<i>Body detection</i>	xx	xx	xx	xx	xx
<i>Grid line</i>	xx	xx	xx	xx	xx
<i>Auto image stabilisation</i>	xx	xx	xx	xx	xx
<i>Hybrid IR filter</i>	xx	xx	xx	xx	xx
<i>Filters</i>	xx	xx	xx	xx	xx
<i>Motion/Live photo</i>	xx	xx	xx	xx	xx
<i>Voice activation</i>	xx	xx	xx	xx	xx
<i>Live stickers</i>	xx	xx	xx	xx	xx
<i>Stamps</i>	xx	xx	xx	xx	xx
<i>Dual capture</i>	xx	xx	xx	xx	xx
<i>Noise reduction</i>	xx	xx	xx	xx	xx
<i>Self-timer</i>			yes	no-inno	no-inno
<i>Digital zoom</i>		5x	yes	1	

<i>Geo tagging</i>	yes	yes		no-inno	no-inno
Settings					
<i>Exposure compensation</i>	xx	xx	xx	xx	xx
<i>ISO control</i>			yes	no-inno	no-inno
<i>White balance presets</i>	xx	xx	xx	xx	xx
<i>Shutter speed control</i>	xx	xx	xx	xx	xx
Shooting Modes					
<i>Burst mode</i>			yes	no-inno	no-inno
<i>Portrait mode</i>	xx	xx	xx	xx	xx
<i>High Dynamic Range (HDR)</i>	xx	xx	xx	xx	xx
<i>Panorama</i>			yes	no-inno	no-inno
<i>Virtual shot</i>	xx	xx	xx	xx	xx
<i>Slow motion</i>	xx	xx	xx	xx	xx
<i>Macro mode</i>	xx	xx	xx	xx	xx
<i>Scene mode</i>	xx	xx	xx	xx	xx
<i>Food mode</i>	xx	xx	xx	xx	xx
<i>Pro mode</i>	xx	xx	xx	xx	xx
<i>Manual mode</i>	xx	xx	xx	xx	xx
Front camera					
Pixels		0.3	0.3	1	
Flash	xx	xx	xx	xx	xx
Aperture size	xx	xx	xx	xx	xx
Pixel size	xx	xx	xx	xx	xx
FOV	xx	xx	xx	xx	xx
Front camera features					
<i>Animoji</i>	xx	xx	xx	xx	xx
<i>HD video recording</i>	xx	xx	xx	xx	xx
<i>Auto HDR</i>	xx	xx	xx	xx	xx
<i>Backside illumination sensor</i>	xx	xx	xx	xx	xx
<i>Face detection</i>	xx	xx	xx	xx	xx
<i>Body detection</i>	xx	xx	xx	xx	xx
<i>Auto image stabilisation</i>	xx	xx	xx	xx	xx
<i>Burst mode</i>	xx	xx	xx	xx	xx
<i>Portrait mode</i>	xx	xx	xx	xx	xx
<i>Exposure control</i>	xx	xx	xx	xx	xx
<i>Timer mode</i>	xx	xx	xx	xx	xx
<i>Grid line</i>	xx	xx	xx	xx	xx
<i>Filters</i>	xx	xx	xx	xx	xx
<i>Selective focus</i>	xx	xx	xx	xx	xx

<i>Virtual shot</i>	xx	xx	xx	xx	xx
<i>Motion/Live photo</i>	xx	xx	xx	xx	xx
<i>Live stickers</i>	xx	xx	xx	xx	xx
<i>Stamps</i>	xx	xx	xx	xx	xx
<i>Voice control</i>	xx	xx	xx	xx	xx
Camcorder (video resolution)					
<i>3840x2160 (4K)</i>	xx	xx	xx	xx	xx
<i>1920x1080 (1080p HD)</i>	xx	xx	xx	xx	xx
<i>1280x720 (720p HD)</i>		30	30	1	
<i>Video recoder</i>	yes	yes		no-inno	no-inno
Video features					
<i>Time-lapse video</i>	xx	xx	xx	xx	xx
<i>Hyperlapse</i>	xx	xx	xx	xx	xx
<i>Continuous autofocus</i>	xx	xx	xx	xx	xx
<i>Tracking AF</i>	xx	xx	xx	xx	xx
<i>Picture-taking during video recording</i>	xx	xx	xx	xx	xx
<i>Video light</i>		yes			1
<i>Video calling</i>		yes	yes	1	
<i>Video geo-tagging</i>	yes	yes		no-inno	no-inno
<i>Optical zoom</i>	xx	xx	xx	xx	xx
<i>Digital zoom</i>	xx	xx	xx	xx	xx
<i>Slow motion</i>	xx	xx	xx	xx	xx
<i>Face detection</i>	xx	xx	xx	xx	xx
<i>Body detection</i>	xx	xx	xx	xx	xx
<i>Playback zoom</i>	xx	xx	xx	xx	xx
<i>Digital video stabilisation</i>	xx	xx	xx	xx	xx
<i>Optical video stablisation</i>	xx	xx	xx	xx	xx
<i>Cinematic video stabilisation</i>	xx	xx	xx	xx	xx
<i>Noise reduction</i>	xx	xx	xx	xx	xx
6. HARDWARE					
System chip		A4		no-inno	no-inno
Processor speed	0.6	0.8	1	1	
Core	Single-core	Single-core	Single-core	no-inno	no-inno
Graphic processor GPU	xx	xx	xx	xx	xx
System memory	256	512	0.5GB	1	
Built-in storage	16GB	32GB	16GB	no-inno	no-inno
Storage expansion			yes	no-inno	no-inno
64-BIT	xx	xx	xx	xx	xx

Nano sim	xx	xx	xx	xx	xx
Dual sim	xx	xx	xx	xx	xx
7. BATTERY					
Capacity	1219 mAh	1420 mAh	1500 mAh	1	
Type	lithium-ion	lithium-ion	lithium-ion	no-inno	no-inno
Wireless charging	xx	xx	xx	xx	xx
Fast-charge capability	xx	xx	xx	xx	xx
8. AUDIO					
High quality playback	xx	xx	xx	xx	xx
Recording quality	xx	xx	xx	xx	xx
Speakers	xx	xx	xx	xx	xx
<i>Earpiece</i>	yes	yes		no-inno	no-inno
<i>Stereo speakers</i>	xx	xx	xx	xx	xx
<i>Loudspeaker</i>	yes	yes		no-inno	no-inno
HD Voice	xx	xx	xx	xx	xx
9. VIDEO					
Split screen	xx	xx	xx	xx	xx
TV connection	xx	xx	xx	xx	xx
10. CELLULAR					
2G	yes	yes	yes	no-inno	no-inno
3G	yes	yes	yes	no-inno	no-inno
4G LTE	xx	xx	xx	xx	xx
CDMA together	xx	xx	xx	xx	xx
11. CONNECTIVITY					
Bluetooth	2.1	2.1	3	no-inno	no-inno
Wi-Fi					
<i>802.11 a</i>					
<i>802.11 b</i>	yes	yes	yes	no-inno	no-inno
<i>802.11 g</i>	yes	yes	yes	no-inno	no-inno
<i>802.11 n</i>		yes	yes	1	
<i>802.11 ac</i>	xx	xx	xx	xx	xx
<i>802.11n 5GHz</i>	xx	xx	xx	xx	xx
<i>Dual Band</i>	xx	xx	xx	xx	xx
<i>WiFi MiMO</i>	xx	xx	xx	xx	xx
<i>WiFi hotspot</i>		yes			1
Mobile hotspot		yes			1
Mobile Payment	xx	xx	xx	xx	xx
Positioning					
<i>GPS</i>	xx	xx	xx	xx	xx

<i>A-GPS</i>	yes	yes	yes	no-inno	no-inno
<i>Glomass</i>	xx	xx	xx	xx	xx
<i>Galileo</i>	xx	xx	xx	xx	xx
<i>Cell ID</i>	yes	yes		no-inno	no-inno
<i>BeiDou</i>	xx	xx	xx	xx	xx
<i>QZSS</i>	xx	xx	xx	xx	xx
<i>Wi-Fi positioning</i>	yes	yes		no-inno	no-inno
<i>iBeacon micro-location</i>	xx	xx	xx	xx	xx
12. PHONE FEATURES					
Haptic feedback	xx	xx	xx	xx	xx
Hearing aid compatibility	xx	xx	xx	xx	xx
3D facial recognition	xx	xx	xx	xx	xx
Bixby	xx	xx	xx	xx	xx
Sensors					
<i>Accelerometer</i>	yes	yes	yes	no-inno	no-inno
<i>Iris sensor</i>	xx	xx	xx	xx	xx
<i>Geomagnetic sensor</i>	xx	xx	xx	xx	xx
<i>Pressure sensor</i>	xx	xx	xx	xx	xx
<i>Fingerprint sensor</i>	xx	xx	xx	xx	xx
<i>HR sensor</i>	xx	xx	xx	xx	xx
<i>Face ID</i>	xx	xx	xx	xx	xx
<i>Gyroscope</i>		yes			1
<i>Compass</i>	yes	yes	yes	no-inno	no-inno
<i>Hall (for flip covers)</i>	xx	xx	xx	xx	xx
<i>Barometer</i>	xx	xx	xx	xx	xx
<i>Thermometer</i>	xx	xx	xx	xx	xx
<i>Hygrometer</i>	xx	xx	xx	xx	xx
<i>Light sensor</i>	yes	yes	yes	no-inno	no-inno
<i>Proximity sensor</i>	yes	yes	yes	no-inno	no-inno
<i>Gesture sensor</i>	xx	xx	xx	xx	xx
<i>UV sensor</i>	xx	xx	xx	xx	xx
Voice command	xx	xx	xx	xx	xx

Table: 9. Observation result of new-to-market and new-to-firm novelties: iPhone 4S

<i>Launched year</i>	2010(Jun 24)	2011 (Oct 14)	2010(Jun 4)		
Technical Specification	iPhone 4	iPhone 4S	Galaxy S	FIRM	MARKET
1. DESIGN					
Materials	Glass; Aluminium	Glass; Aluminium		no-inno	no-inno
Colours	Black, White	Black, White	Black, White	no-inno	no-inno
2. RUGGEDNESS					
Splash	xx	xx	xx	xx	xx
Water	xx	xx	xx	xx	xx
Dust	xx	xx	xx	xx	xx
3. DISPLAY					
Physical size	3.5	3.5	4	no-inno	no-inno
Resolution	960 x 640	960 x 640	480 x 800	no-inno	no-inno
Pixel density	326	326	233	no-inno	no-inno
Technology	Retina display	Retina display	Super AMOLED	no-inno	no-inno
Screen-to-body ratio	55.77	55.27	57.88	no-inno	no-inno
Peak brightness	500 cd/m ²	500 cd/m ²		no-inno	no-inno
Protection	Fingerprint-resistant oleophobic coating	Fingerprint-resistant oleophobic coating	Corning Gorilla Glass	no-inno	no-inno
Damage resistant glass	xx	xx	xx	xx	xx
3D touch	xx	xx	xx	xx	xx
Multitouch	yes	yes		no-inno	no-inno
Shape	Flat	Flat		no-inno	no-inno
4. ATTACHED PEN					
Pressure levels	xx	xx	xx	xx	xx
Pen Tip diameter	xx	xx	xx	xx	xx
Rugged	xx	xx	xx	xx	xx
<i>Live message</i>	xx	xx	xx	xx	xx
<i>Samsung Notes</i>	xx	xx	xx	xx	xx
<i>Screen off memo</i>	xx	xx	xx	xx	xx
<i>Smart select</i>	xx	xx	xx	xx	xx
<i>Screen write</i>	xx	xx	xx	xx	xx
<i>Translate</i>	xx	xx	xx	xx	xx
<i>Bixby Vision</i>	xx	xx	xx	xx	xx
<i>Glance</i>	xx	xx	xx	xx	xx
<i>Magnify</i>	xx	xx	xx	xx	xx
5. CAMERA					

Rear camera (wide angel)					
Pixels	5	8	5		1
Flash	LED	LED		no-inno	no-inno
True tone flash	xx	xx	xx	xx	xx
Aperture size	2.8	2.4		1	
Pixel size	1.75	1.4		1	
FOV	xx	xx	xx	xx	xx
Rear camera (telephoto)					
Pixels	xx	xx	xx	xx	xx
Aperture size	xx	xx	xx	xx	xx
Camera sensor size	xx	xx	xx	xx	xx
FOV	xx	xx	xx	xx	xx
Hardware Features					
<i>Optical image stabilization</i>	xx	xx	xx	xx	xx
<i>Autofocus</i>	yes	yes	yes	no-inno	no-inno
<i>Live focus (blur background)</i>	xx	xx	xx	xx	xx
<i>Sapphire crystal lens cover</i>	xx	xx	xx	xx	xx
<i>Back-illuminated sensor</i>	yes	yes		no-inno	no-inno
Optical zoom	xx	xx	xx	xx	xx
Software Features					
<i>Manual focus</i>	xx	xx	xx	xx	xx
<i>Portrait lighting</i>	xx	xx	xx	xx	xx
<i>RAW image capture</i>	xx	xx	xx	xx	xx
<i>Touch to focus</i>	yes	yes		no-inno	no-inno
<i>Smile detection</i>			yes	no-inno	no-inno
<i>Face detection</i>		yes			1
<i>Body detection</i>	xx	xx	xx	xx	xx
<i>Grid line</i>	xx	xx	xx	xx	xx
<i>Auto image stabilisation</i>	xx	xx	xx	xx	xx
<i>Hybrid IR filter</i>		yes			1
<i>Filters</i>	xx	xx	xx	xx	xx
<i>Motion/Live photo</i>	xx	xx	xx	xx	xx
<i>Voice activation</i>	xx	xx	xx	xx	xx
<i>Live stickers</i>	xx	xx	xx	xx	xx
<i>Stamps</i>	xx	xx	xx	xx	xx
<i>Dual capture</i>	xx	xx	xx	xx	xx
<i>Noise reduction</i>	xx	xx	xx	xx	xx
<i>Self-timer</i>			yes	no-inno	no-inno
<i>Digital zoom</i>	5x	5x	yes	no-inno	no-inno

<i>Geo tagging</i>	yes	yes		no-inno	no-inno
Settings					
<i>Exposure compensation</i>	xx	xx	xx	xx	xx
<i>ISO control</i>			yes	no-inno	no-inno
<i>White balance presets</i>	xx	xx	xx	xx	xx
<i>Shutter speed control</i>	xx	xx	xx	xx	xx
Shooting Modes					
<i>Burst mode</i>			yes	no-inno	no-inno
<i>Portrait mode</i>	xx	xx	xx	xx	xx
<i>High Dynamic Range (HDR)</i>	xx	xx	xx	xx	xx
<i>Panorama</i>			yes	no-inno	no-inno
<i>Virtual shot</i>	xx	xx	xx	xx	xx
<i>Slow motion</i>	xx	xx	xx	xx	xx
<i>Macro mode</i>	xx	xx	xx	xx	xx
<i>Scene mode</i>	xx	xx	xx	xx	xx
<i>Food mode</i>	xx	xx	xx	xx	xx
<i>Pro mode</i>	xx	xx	xx	xx	xx
<i>Manual mode</i>	xx	xx	xx	xx	xx
Front camera					
Pixels	0.3	0.3	0.3	no-inno	no-inno
Flash	xx	xx	xx	xx	xx
Aperture size	xx	xx	xx	xx	xx
Pixel size	xx	xx	xx	xx	xx
FOV	xx	xx	xx	xx	xx
Front camera features					
<i>Animoji</i>	xx	xx	xx	xx	xx
<i>HD video recording</i>	xx	xx	xx	xx	xx
<i>Auto HDR</i>	xx	xx	xx	xx	xx
<i>Backside illumination sensor</i>	xx	xx	xx	xx	xx
<i>Face detection</i>	xx	xx	xx	xx	xx
<i>Body detection</i>	xx	xx	xx	xx	xx
<i>Auto image stabilisation</i>	xx	xx	xx	xx	xx
<i>Burst mode</i>	xx	xx	xx	xx	xx
<i>Portrait mode</i>	xx	xx	xx	xx	xx
<i>Exposure control</i>	xx	xx	xx	xx	xx
<i>Timer mode</i>	xx	xx	xx	xx	xx
<i>Grid line</i>	xx	xx	xx	xx	xx
<i>Filters</i>	xx	xx	xx	xx	xx
<i>Selective focus</i>	xx	xx	xx	xx	xx

<i>Virtual shot</i>	xx	xx	xx	xx	xx
<i>Motion/Live photo</i>	xx	xx	xx	xx	xx
<i>Live stickers</i>	xx	xx	xx	xx	xx
<i>Stamps</i>	xx	xx	xx	xx	xx
<i>Voice control</i>	xx	xx	xx	xx	xx
Camcorder (video resolution)					
<i>3840x2160 (4K)</i>	xx	xx	xx	xx	xx
<i>1920x1080 (1080p HD)</i>		30			1
<i>1280x720 (720p HD)</i>	30		30	no-inno	no-inno
<i>Video recoder</i>	yes	yes		no-inno	no-inno
Video features					
<i>Time-lapse video</i>	xx	xx	xx	xx	xx
<i>Hyperlapse</i>	xx	xx	xx	xx	xx
<i>Continuous autofocus</i>	xx	xx	xx	xx	xx
<i>Tracking AF</i>	xx	xx	xx	xx	xx
<i>Picture-taking during video recording</i>	xx	xx	xx	xx	xx
<i>Video light</i>	yes	yes		no-inno	no-inno
<i>Video calling</i>	yes	yes	yes	no-inno	no-inno
<i>Video geo-tagging</i>	yes	yes		no-inno	no-inno
<i>Optical zoom</i>	xx	xx	xx	xx	xx
<i>Digital zoom</i>	xx	xx	xx	xx	xx
<i>Slow motion</i>	xx	xx	xx	xx	xx
<i>Face detection</i>	xx	xx	xx	xx	xx
<i>Body detection</i>	xx	xx	xx	xx	xx
<i>Playback zoom</i>	xx	xx	xx	xx	xx
<i>Digital video stabilisation</i>		yes			1
<i>Optical video stablisation</i>	xx	xx	xx	xx	xx
<i>Cinematic video stabilisation</i>	xx	xx	xx	xx	xx
<i>Noise reduction</i>	xx	xx	xx	xx	xx
6. HARDWARE					
System chip	A4	A5			
Processor speed	0.8	0.8	1	no-inno	no-inno
Core	Single-core	Dual-Core	Single-core		1
Graphic processor GPU	xx	xx	xx	xx	xx
System memory	512	512MB	0.5GB	no-inno	no-inno
Built-in storage	32GB	64GB	16GB		1
Storage expansion			yes	no-inno	no-inno
64-BIT	xx	xx	xx	xx	xx

Nano sim	xx	xx	xx	xx	xx
Dual sim	xx	xx	xx	xx	xx
7. BATTERY					
Capacity	1420 mAh	1432 mAh	1500 mAh	1	
Type	lithium-ion	lithium-ion	lithium-ion	no-inno	no-inno
Wireless charging	xx	xx	xx	xx	xx
Fast-charge capability	xx	xx	xx	xx	xx
8. AUDIO					
High quality playback	xx	xx	xx	xx	xx
Recording quality	xx	xx	xx	xx	xx
Speakers	xx	xx	xx	xx	xx
<i>Earpiece</i>	yes	yes		no-inno	no-inno
<i>Stereo speakers</i>	xx	xx	xx	xx	xx
<i>Loudspeaker</i>	yes	yes		no-inno	no-inno
HD Voice	xx	xx	xx	xx	xx
9. VIDEO					
Split screen	xx	xx	xx	xx	xx
TV connection		yes			1
10. CELLULAR					
2G	yes	yes	yes		
3G	yes	yes	yes		
4G LTE	xx	xx	xx	xx	xx
CDMA together		yes			1
11. CONNECTIVITY					
Bluetooth	2.1	4	3		1
Wi-Fi					
<i>802.11 a</i>	xx	xx	xx	xx	xx
<i>802.11 b</i>	yes	yes	yes	no-inno	no-inno
<i>802.11 g</i>	yes	yes	yes	no-inno	no-inno
<i>802.11 n</i>	yes	yes	yes	no-inno	no-inno
<i>802.11 ac</i>	xx	xx	xx	xx	xx
<i>802.11n 5GHz</i>	xx	xx	xx	xx	xx
<i>Dual Band</i>	xx	xx	xx	xx	xx
<i>WiFi MiMO</i>	xx	xx	xx	xx	xx
<i>WiFi hotspot</i>	yes	yes		no-inno	no-inno
Mobile hotspot	yes	yes		no-inno	no-inno
Mobile Payment	xx	xx	xx	xx	xx
Positioning					
<i>GPS</i>	xx	xx	xx	xx	xx

<i>A-GPS</i>	yes	yes	yes	no-inno	no-inno
<i>Glomass</i>	xx	xx	xx	xx	xx
<i>Galileo</i>	xx	xx	xx	xx	xx
<i>Cell ID</i>	yes	yes		no-inno	no-inno
<i>BeiDou</i>	xx	xx	xx	xx	xx
<i>QZSS</i>	xx	xx	xx	xx	xx
<i>Wi-Fi positioning</i>	yes	yes		no-inno	no-inno
<i>iBeacon micro-location</i>	xx	xx	xx	xx	xx
12. PHONE FEATURES					
Haptic feedback	xx	xx	xx	xx	xx
Hearing aid compatibility	xx	xx	xx	xx	xx
3D facial recognition	xx	xx	xx	xx	xx
Bixby	xx	xx	xx	xx	xx
Sensors					
<i>Accelerometer</i>	yes	yes	yes	no-inno	no-inno
<i>Iris sensor</i>	xx	xx	xx	xx	xx
<i>Geomagnetic sensor</i>	xx	xx	xx	xx	xx
<i>Pressure sensor</i>	xx	xx	xx	xx	xx
<i>Fingerprint sensor</i>	xx	xx	xx	xx	xx
<i>HR sensor</i>	xx	xx	xx	xx	xx
<i>Face ID</i>	xx	xx	xx	xx	xx
<i>Gyroscope</i>	yes	yes		no-inno	no-inno
<i>Compass</i>	yes	yes	yes	no-inno	no-inno
<i>Hall (for flip covers)</i>	xx	xx	xx	xx	xx
<i>Barometer</i>	xx	xx	xx	xx	xx
<i>Thermometer</i>	xx	xx	xx	xx	xx
<i>Hygrometer</i>	xx	xx	xx	xx	xx
<i>Light sensor</i>	yes	yes	yes	no-inno	no-inno
<i>Proximity sensor</i>	yes	yes	yes	no-inno	no-inno
<i>Gesture sensor</i>	xx	xx	xx	xx	xx
<i>UV sensor</i>	xx	xx	xx	xx	xx
Voice command		yes			1

Table: 10. Observation result of new-to-market and new-to-firm novelties: iPhone 5

	2011 (Oct 14)	2012 (Sep 26)	2012 (Sep 21)		
Technical Specification	iPhone 4S	iPhone 5	Note II	firm	market
1. DESIGN					
Materials	Glass; Aluminium	Aluminium alloy		no-inno	no-inno
Colours	Black, White	Black, White	Blue, White	no-inno	no-inno
2. RUGGEDNESS					
Splash	xx	xx	xx	xx	xx
Water	xx	xx	xx	xx	xx
Dust	xx	xx	xx	xx	xx
3. DISPLAY					
Physical size	3.5	4	5.5	1	
Resolution	960 x 640	1136 x 640	1280 x 720	1	
Pixel density	326	326	265	no-inno	no-inno
Technology	Retina display	Retina display	Super AMOLED	no-inno	no-inno
Screen-to-body ratio	55.27	60.82	69.9	1	
Peak brightness	500 cd/m ²	500 cd/m ²		no-inno	no-inno
Protection	Fingerprint- resistant oleophobic coating	Fingerprint- resistant oleophobic coating		no-inno	no-inno
Damage resistant glass	xx	xx	xx	xx	xx
3D touch	xx	xx	xx	xx	xx
Multitouch	yes	yes	yes	no-inno	no-inno
Shape	Flat	Flat		no-inno	no-inno
4. ATTACHED PEN					
Pressure levels			yes	no-inno	no-inno
Pen Tip diameter	xx	xx	xx	xx	xx
Rugged	xx	xx	xx	xx	xx
<i>Live message</i>	xx	xx	xx	xx	xx
<i>Samsung Notes</i>	xx	xx	xx	xx	xx
<i>Screen off memo</i>	xx	xx	xx	xx	xx
<i>Smart select</i>	xx	xx	xx	xx	xx
<i>Screen write</i>	xx	xx	xx	xx	xx
<i>Translate</i>	xx	xx	xx	xx	xx
<i>Bixby Vision</i>	xx	xx	xx	xx	xx
<i>Glance</i>	xx	xx	xx	xx	xx
<i>Magnify</i>	xx	xx	xx	xx	xx
5. CAMERA					

Rear camera (wide angel)					
Pixels	8	8	8 mp	no-inno	no-inno
Flash	LED	LED	LED	no-inno	no-inno
True tone flash	xx	xx	xx	xx	xx
Aperture size	2.4	2.4	2.6	no-inno	no-inno
Pixel size	1.4	1.4		no-inno	no-inno
FOV	xx	xx	xx	xx	xx
Rear camera (telephoto)					
Pixels	xx	xx	xx	xx	xx
Aperture size	xx	xx	xx	xx	xx
Camera sensor size	xx	xx	xx	xx	xx
FOV	xx	xx	xx	xx	xx
Hardware Features					
<i>Optical image stabilization</i>	xx	xx	xx	xx	xx
<i>Autofocus</i>	yes	yes	yes	no-inno	no-inno
<i>Live focus (blur background)</i>	xx	xx	xx	xx	xx
<i>Sapphire crystal lens cover</i>		yes			1
<i>Back-illuminated sensor</i>	yes	yes	yes	no-inno	no-inno
Optical zoom	xx	xx	xx	xx	xx
Software Features					
<i>Manual focus</i>	xx	xx	xx	xx	xx
<i>Portrait lighting</i>	xx	xx	xx	xx	xx
<i>RAW image capture</i>	xx	xx	xx	xx	xx
<i>Touch to focus</i>	yes	yes	yes	no-inno	no-inno
<i>Smile detection</i>			yes	no-inno	no-inno
<i>Face detection</i>	yes	yes	yes	no-inno	no-inno
<i>Body detection</i>	xx	xx	xx	xx	xx
<i>Grid line</i>	xx	xx	xx	xx	xx
<i>Auto image stabilisation</i>		yes			1
<i>Hybrid IR filter</i>	yes	yes		no-inno	no-inno
<i>Filters</i>	xx	xx	xx	xx	xx
<i>Motion/Live photo</i>	xx	xx	xx	xx	xx
<i>Voice activation</i>	xx	xx	xx	xx	xx
<i>Live stickers</i>	xx	xx	xx	xx	xx
<i>Stamps</i>	xx	xx	xx	xx	xx
<i>Dual capture</i>	xx	xx	xx	xx	xx
<i>Noise reduction</i>	xx	xx	xx	xx	xx
<i>Self-timer</i>	xx	xx	xx	xx	xx
<i>Digital zoom</i>	5x	5x	4x	no-inno	no-inno

<i>Geo tagging</i>	yes	yes	yes	no-inno	no-inno
Settings					
<i>Exposure compensation</i>		yes			1
<i>ISO control</i>	xx	xx	xx	xx	xx
<i>White balance presets</i>	xx	xx	xx	xx	xx
<i>Shutter speed control</i>	xx	xx	xx	xx	xx
Shooting Modes					
<i>Burst mode</i>			yes	no-inno	no-inno
<i>Portrait mode</i>	xx	xx	xx	xx	xx
<i>High Dynamic Range (HDR)</i>		yes	yes		1
<i>Panorama</i>		28	yes		1
<i>Virtual shot</i>	xx	xx	xx	xx	xx
<i>Slow motion</i>	xx	xx	xx	xx	xx
<i>Macro mode</i>	xx	xx	xx	xx	xx
<i>Scene mode</i>	xx	xx	xx	xx	xx
<i>Food mode</i>	xx	xx	xx	xx	xx
<i>Pro mode</i>	xx	xx	xx	xx	xx
<i>Manual mode</i>	xx	xx	xx	xx	xx
Front camera					
Pixels	0.3	1.2	1.9	1	
Flash	xx	xx	xx	xx	xx
Aperture size	xx	xx	xx	xx	xx
Pixel size	xx	xx	xx	xx	xx
FOV	xx	xx	xx	xx	xx
Front camera features					
<i>Animoji</i>	xx	xx	xx	xx	xx
<i>HD video recording</i>		720p			1
<i>Auto HDR</i>	xx	xx	xx	xx	xx
<i>Backside illumination sensor</i>		yes			1
<i>Face detection</i>		yes			1
<i>Body detection</i>	xx	xx	xx	xx	xx
<i>Auto image stabilisation</i>	xx	xx	xx	xx	xx
<i>Burst mode</i>	xx	xx	xx	xx	xx
<i>Portrait mode</i>	xx	xx	xx	xx	xx
<i>Exposure control</i>	xx	xx	xx	xx	xx
<i>Timer mode</i>	xx	xx	xx	xx	xx
<i>Grid line</i>	xx	xx	xx	xx	xx
<i>Filters</i>	xx	xx	xx	xx	xx
<i>Selective focus</i>	xx	xx	xx	xx	xx

<i>Virtual shot</i>	xx	xx	xx	xx	xx
<i>Motion/Live photo</i>	xx	xx	xx	xx	xx
<i>Live stickers</i>	xx	xx	xx	xx	xx
<i>Stamps</i>	xx	xx	xx	xx	xx
<i>Voice control</i>	xx	xx	xx	xx	xx
Camcorder (video resolution)					
<i>3840x2160 (4K)</i>	xx	xx	xx	xx	xx
<i>1920x1080 (1080p HD)</i>	30	30	30	no-inno	no-inno
<i>1280x720 (720p HD)</i>	xx	xx	xx	xx	xx
<i>Video recoder</i>	yes	yes		no-inno	no-inno
Video features					
<i>Time-lapse video</i>	xx	xx	xx	xx	xx
<i>Hyperlapse</i>	xx	xx	xx	xx	xx
<i>Continuous autofocus</i>	xx	xx	xx	xx	xx
<i>Tracking AF</i>	xx	xx	xx	xx	xx
<i>Picture-taking during video recording</i>		yes			1
<i>Video light</i>	yes	yes		no-inno	no-inno
<i>Video calling</i>	yes	yes	yes	no-inno	no-inno
<i>Video geo-tagging</i>	yes	yes		no-inno	no-inno
<i>Optical zoom</i>	xx	xx	xx	xx	xx
<i>Digital zoom</i>	xx	xx	xx	xx	xx
<i>Slow motion</i>	xx	xx	xx	xx	xx
<i>Face detection</i>		yes			1
<i>Body detection</i>	xx	xx	xx	xx	xx
<i>Playback zoom</i>	xx	xx	xx	xx	xx
<i>Digital video stabilisation</i>	yes	yes		no-inno	no-inno
<i>Optical video stablisation</i>	xx	xx	xx	xx	xx
<i>Cinematic video stabilisation</i>	xx	xx	xx	xx	xx
<i>Noise reduction</i>	xx	xx	xx	xx	xx
6. HARDWARE					
System chip	A5	A6			
Processor speed	0.8	1.3	1.6	1	
Core	Dual-Core	Dual-Core	Quad-Core	no-inno	no-inno
Graphic processor GPU		266MHz			
System memory	512MB	1GB	2GB	1	
Built-in storage	64GB	64GB	16GB	no-inno	no-inno
Storage expansion			yes	no-inno	no-inno
64-BIT	xx	xx	xx	xx	xx

Nano sim		yes			1
Dual sim	xx	xx	xx	xx	xx
7. BATTERY					
Capacity	1432 mAh	1440 mAh	3100 mAh	1	
Type	lithium-ion	lithium-ion	lithium-ion	no-inno	no-inno
Wireless charging	xx	xx	xx	xx	xx
Fast-charge capability	xx	xx	xx	xx	xx
8. AUDIO					
High quality playback	xx	xx	xx	xx	xx
Recording quality	xx	xx	xx	xx	xx
Speakers	xx	xx	xx	xx	xx
<i>Earpiece</i>	yes	yes	YES	no-inno	no-inno
<i>Stereo speakers</i>	xx	xx	xx	xx	xx
<i>Loudspeaker</i>	yes	yes	YES	no-inno	no-inno
HD Voice	xx	xx	xx	xx	xx
9. VIDEO					
Split screen	xx	xx	xx	xx	xx
TV connection	yes	yes	yes	no-inno	no-inno
10. CELLULAR					
2G	yes	yes		no-inno	no-inno
3G	yes	yes		no-inno	no-inno
4G LTE		yes			1
CDMA together	yes	yes		no-inno	no-inno
11. CONNECTIVITY					
Bluetooth	4	4	4	no-inno	no-inno
Wi-Fi					
<i>802.11a</i>		yes	yes	1	
<i>802.11b</i>	yes	yes	yes	no-inno	no-inno
<i>802.11g</i>	yes	yes	yes	no-inno	no-inno
<i>802.11n</i>	yes	yes	yes	no-inno	no-inno
<i>802.11ac</i>	xx	xx	xx	xx	xx
<i>802.11n 5GHz</i>		yes			1
<i>Dual Band</i>		yes	yes	1	
<i>WiFi MiMO</i>	xx	xx	xx	xx	xx
<i>WiFi hotspot</i>	yes	yes		no-inno	no-inno
Mobile hotspot	yes	yes	yes	no-inno	no-inno
Mobile Payment	xx	xx	xx	xx	xx
Positioning					
<i>GPS</i>	xx	xx	xx	xx	xx

<i>A-GPS</i>	yes	yes	yes	no-inno	no-inno
<i>Glonass</i>		yes	yes	1	
<i>Galileo</i>	xx	xx	xx	xx	xx
<i>Cell ID</i>	yes	yes		no-inno	no-inno
<i>BeiDou</i>	xx	xx	xx	xx	xx
<i>QZSS</i>	xx	xx	xx	xx	xx
<i>Wi-Fi positioning</i>	yes	yes		no-inno	no-inno
<i>iBeacon micro-location</i>	xx	xx	xx	xx	xx
12. PHONE FEATURES					
Haptic feedback			yes	no-inno	no-inno
Hearing aid compatibility		yes	yes	1	
3D facial recognition	xx	xx	xx	xx	xx
Bixby	xx	xx	xx	xx	xx
Sensors					
<i>Accelerometer</i>	yes	yes	yes	no-inno	no-inno
<i>Iris sensor</i>	xx	xx	xx	xx	xx
<i>Geomagnetic sensor</i>	xx	xx	xx	xx	xx
<i>Pressure sensor</i>	xx	xx	xx	xx	xx
<i>Fingerprint sensor</i>	xx	xx	xx	xx	xx
<i>HR sensor</i>	xx	xx	xx	xx	xx
<i>Face ID</i>	xx	xx	xx	xx	xx
<i>Gyroscope</i>	yes	yes	yes	no-inno	no-inno
<i>Compass</i>	yes	yes	yes	no-inno	no-inno
<i>Hall (for flip covers)</i>	xx	xx	xx	xx	xx
<i>Barometer</i>			yes	no-inno	no-inno
<i>Thermometer</i>	xx	xx	xx	xx	xx
<i>Hygrometer</i>	xx	xx	xx	xx	xx
<i>Light sensor</i>	yes	yes	yes	no-inno	no-inno
<i>Proximity sensor</i>	yes	yes	yes	no-inno	no-inno
<i>Gesture sensor</i>	xx	xx	xx	xx	xx
<i>UV sensor</i>	xx	xx	xx	xx	xx
Voice command	yes	yes		no-inno	no-inno

Table: 11. Observation result of new-to-market and new-to-firm novelties: iPhone 5S

<i>Launched year</i>	2012 (Sep 26)	2013 (Sep)	2012 (Sep 21)		
Technical Specification	iPhone 5	iPhone 5S	Note II	FIRM	MARKET
1. DESIGN					
Materials	Aluminium alloy	Aluminium alloy		no-inno	no-inno
Colours	Black, White	Gold, Gray, Silver	Blue, White		3
2. RUGGEDNESS					
Splash	xx	xx	xx	xx	xx
Water	xx	xx	xx	xx	xx
Dust	xx	xx	xx	xx	xx
3. DISPLAY					
Physical size	4	4	5.5	no-inno	no-inno
Resolution	1136 x 640	1136 x 640	1280 x 720	no-inno	no-inno
Pixel density	326	326	265	no-inno	no-inno
Technology	Retina display	Retina display	Super AMOLED	no-inno	no-inno
Screen-to-body ratio	60.82	60.82	69.9	no-inno	no-inno
Peak brightness	500 cd/m ²	500 cd/m ²		no-inno	no-inno
Protection	Fingerprint-resistant oleophobic coating	Fingerprint-resistant oleophobic coating		no-inno	no-inno
Damage resistant glass	xx	xx	xx	xx	xx
3D touch	xx	xx	xx	xx	xx
Multitouch	yes	yes	yes	no-inno	no-inno
Shape	Flat	Flat		no-inno	no-inno
4. ATTACHED PEN					
Pressure levels			yes	no-inno	no-inno
Pen Tip diameter	xx	xx	xx	xx	xx
Rugged	xx	xx	xx	xx	xx
<i>Live message</i>	xx	xx	xx	xx	xx
<i>Samsung Notes</i>	xx	xx	xx	xx	xx
<i>Screen off memo</i>	xx	xx	xx	xx	xx
<i>Smart select</i>	xx	xx	xx	xx	xx
<i>Screen write</i>	xx	xx	xx	xx	xx
<i>Translate</i>	xx	xx	xx	xx	xx
<i>Bixby Vision</i>	xx	xx	xx	xx	xx
<i>Glance</i>	xx	xx	xx	xx	xx
<i>Magnify</i>	xx	xx	xx	xx	xx

5. CAMERA					
Rear camera (wide angel)					
Pixels	8	8	8 mp	no-inno	no-inno
Flash	LED	Dual LED	LED		1
True tone flash		yes		no-inno	no-inno
Aperture size	2.4	2.2	2.6		1
Pixel size	1.4	1.5			
FOV	xx	xx	xx	xx	xx
Rear camera (telephoto)					
Pixels	xx	xx	xx	xx	xx
Aperture size	xx	xx	xx	xx	xx
Camera sensor size	xx	xx	xx	xx	xx
FOV	xx	xx	xx	xx	xx
Hardware Features					
<i>Optical image stabilization</i>	xx	xx	xx	xx	xx
<i>Autofocus</i>	yes	yes	yes	no-inno	no-inno
<i>Live focus (blur background)</i>	xx	xx	xx	xx	xx
<i>Sapphire crystal lens cover</i>	yes	yes		no-inno	no-inno
<i>Back-illuminated sensor</i>	yes	yes	yes	no-inno	no-inno
Optical zoom	xx	xx	xx	xx	xx
Software Features					
<i>Manual focus</i>	xx	xx	xx	xx	xx
<i>Portrait lighting</i>	xx	xx	xx	xx	xx
<i>RAW image capture</i>	xx	xx	xx	xx	xx
<i>Touch to focus</i>	yes	yes	yes	no-inno	no-inno
<i>Smile detection</i>			yes	no-inno	no-inno
<i>Face detection</i>	yes	yes	yes	no-inno	no-inno
<i>Body detection</i>	xx	xx	xx	xx	xx
<i>Grid line</i>	xx	xx	xx	xx	xx
<i>Auto image stabilisation</i>	yes	yes		no-inno	no-inno
<i>Hybrid IR filter</i>	yes	yes		no-inno	no-inno
<i>Filters</i>	xx	xx	xx	xx	xx
<i>Motion/Live photo</i>	xx	xx	xx	xx	xx
<i>Voice activation</i>	xx	xx	xx	xx	xx
<i>Live stickers</i>	xx	xx	xx	xx	xx
<i>Stamps</i>	xx	xx	xx	xx	xx
<i>Dual capture</i>	xx	xx	xx	xx	xx
<i>Noise reduction</i>	xx	xx	xx	xx	xx
<i>Self-timer</i>	xx	xx	xx	xx	xx

<i>Digital zoom</i>	5x	5x	4x	no-inno	no-inno
<i>Geo tagging</i>	yes	yes	yes	no-inno	no-inno
Settings					
<i>Exposure compensation</i>	yes	yes		no-inno	no-inno
<i>ISO control</i>	xx	xx	xx	xx	xx
<i>White balance presets</i>	xx	xx	xx	xx	xx
<i>Shutter speed control</i>	xx	xx	xx	xx	xx
Shooting Modes					
<i>Burst mode</i>		yes	yes	1	
<i>Portrait mode</i>	xx	xx	xx	xx	xx
<i>High Dynamic Range (HDR)</i>	yes	yes	yes	no-inno	no-inno
<i>Panorama</i>	28	28	yes	no-inno	no-inno
<i>Virtual shot</i>	xx	xx	xx	xx	xx
<i>Slow motion</i>	xx	xx	xx	xx	xx
<i>Macro mode</i>	xx	xx	xx	xx	xx
<i>Scene mode</i>	xx	xx	xx	xx	xx
<i>Food mode</i>	xx	xx	xx	xx	xx
<i>Pro mode</i>	xx	xx	xx	xx	xx
<i>Manual mode</i>	xx	xx	xx	xx	xx
Front camera					
Pixels	1.2	1.2	1.9	no-inno	no-inno
Flash	xx	xx	xx	xx	xx
Aperture size		2.4			
Pixel size	xx	xx	xx	xx	xx
FOV	xx	xx	xx	xx	xx
Front camera features					
<i>Animoji</i>	xx	xx	xx	xx	xx
<i>HD video recording</i>	720p	720p		no-inno	no-inno
<i>Auto HDR</i>		yes			1
<i>Backside illumination sensor</i>	yes	yes		no-inno	no-inno
<i>Face detection</i>	yes	yes		no-inno	no-inno
<i>Body detection</i>	xx	xx	xx	xx	xx
<i>Auto image stabilisation</i>	xx	xx	xx	xx	xx
<i>Burst mode</i>	xx	xx	xx	xx	xx
<i>Portrait mode</i>	xx	xx	xx	xx	xx
<i>Exposure control</i>		yes			1
<i>Timer mode</i>	xx	xx	xx	xx	xx
<i>Grid line</i>	xx	xx	xx	xx	xx
<i>Filters</i>	xx	xx	xx	xx	xx

<i>Selective focus</i>	xx	xx	xx	xx	xx
<i>Virtual shot</i>	xx	xx	xx	xx	xx
<i>Motion/Live photo</i>	xx	xx	xx	xx	xx
<i>Live stickers</i>	xx	xx	xx	xx	xx
<i>Stamps</i>	xx	xx	xx	xx	xx
<i>Voice control</i>	xx	xx	xx	xx	xx
Camcorder (video resolution)					
<i>3840x2160 (4K)</i>	xx	xx	xx	xx	xx
<i>1920x1080 (1080p HD)</i>	30	30	30	no-inno	no-inno
<i>1280x720 (720p HD)</i>	xx	xx	xx	xx	xx
<i>Video recoder</i>	yes	yes		no-inno	no-inno
Video features					
<i>Time-lapse video</i>		yes			1
<i>Hyperlapse</i>	xx	xx	xx	xx	xx
<i>Continuous autofocus</i>	xx	xx	xx	xx	xx
<i>Tracking AF</i>	xx	xx	xx	xx	xx
<i>Picture-taking during video recording</i>	yes	yes		no-inno	no-inno
<i>Video light</i>	yes	yes		no-inno	no-inno
<i>Video calling</i>	yes	yes	yes	no-inno	no-inno
<i>Video geo-tagging</i>	yes	yes		no-inno	no-inno
<i>Optical zoom</i>	xx	xx	xx	xx	xx
<i>Digital zoom</i>		3x			1
<i>Slow motion</i>		120			1
<i>Face detection</i>	yes	yes		no-inno	no-inno
<i>Body detection</i>	xx	xx	xx	xx	xx
<i>Playback zoom</i>	xx	xx	xx	xx	xx
<i>Digital video stabilisation</i>	yes	yes		no-inno	no-inno
<i>Optical video stabilisation</i>	xx	xx	xx	xx	xx
<i>Cinematic video stabilisation</i>	xx	xx	xx	xx	xx
<i>Noise reduction</i>	xx	xx	xx	xx	xx
6. HARDWARE					
System chip	A6	A7			
Processor speed	1.3	1.3	1.6	no-inno	no-inno
Core	Dual-Core	Dual-Core	Quad-Core	no-inno	no-inno
Graphic processor GPU	266MHz	450MHz		1	
System memory	1GB	1GB	2GB	no-inno	no-inno
Built-in storage	64GB	64GB	16GB	no-inno	no-inno
Storage expansion			yes	no-inno	no-inno

64-BIT		yes			1
Nano sim	yes	yes		no-inno	no-inno
Dual sim	xx	xx	xx	xx	xx
7. BATTERY					
Capacity	1440 mAh	1560 mAh	3100 mAh	1	
Type	lithium-ion	lithium-ion	lithium-ion	no-inno	no-inno
Wireless charging	xx	xx	xx	xx	xx
Fast-charge capability	xx	xx	xx	xx	xx
8. AUDIO					
High quality playback	xx	xx	xx	xx	xx
Recording quality	xx	xx	xx	xx	xx
Speakers	xx	xx	xx	xx	xx
<i>Earpiece</i>	yes	yes	YES	no-inno	no-inno
<i>Stereo speakers</i>	xx	xx	xx	xx	xx
<i>Loudspeaker</i>	yes	yes	YES	no-inno	no-inno
HD Voice	xx	xx	xx	xx	xx
9. VIDEO					
Split screen	xx	xx	xx	xx	xx
TV connection	yes	yes	yes	no-inno	no-inno
10. CELLULAR					
2G	yes	yes		no-inno	no-inno
3G	yes	yes		no-inno	no-inno
4G LTE	yes	yes		no-inno	no-inno
CDMA together	yes	yes		no-inno	no-inno
11. CONNECTIVITY					
Bluetooth	4	4	4	no-inno	no-inno
Wi-Fi					
<i>802.11a</i>	yes	yes	yes	no-inno	no-inno
<i>802.11b</i>	yes	yes	yes	no-inno	no-inno
<i>802.11g</i>	yes	yes	yes	no-inno	no-inno
<i>802.11n</i>	yes	yes	yes	no-inno	no-inno
<i>802.11ac</i>	xx	xx	xx	xx	xx
<i>802.11n 5GHz</i>	yes	yes		no-inno	no-inno
<i>Dual Band</i>	yes	yes	yes	no-inno	no-inno
<i>WiFi MiMO</i>	xx	xx	xx	xx	xx
<i>WiFi hotspot</i>	yes	yes		no-inno	no-inno
Mobile hotspot	yes	yes	yes	no-inno	no-inno
Mobile Payment	xx	xx	xx	xx	xx
Positioning					

<i>GPS</i>	xx	xx	xx	xx	xx
<i>A-GPS</i>	yes	yes	yes	no-inno	no-inno
<i>Glonass</i>	yes	yes	yes	no-inno	no-inno
<i>Galileo</i>	xx	xx	xx	xx	xx
<i>Cell ID</i>	yes	yes		no-inno	no-inno
<i>BeiDou</i>	xx	xx	xx	xx	xx
<i>QZSS</i>	xx	xx	xx	xx	xx
<i>Wi-Fi positioning</i>	yes	yes		no-inno	no-inno
<i>iBeacon micro-location</i>		yes			1
12. PHONE FEATURES					
Haptic feedback			yes	no-inno	no-inno
Hearing aid compatibility	yes	yes	yes	no-inno	no-inno
3D facial recognition	xx	xx	xx	xx	xx
Bixby	xx	xx	xx	xx	xx
Sensors					
<i>Accelerometer</i>	yes	yes	yes	no-inno	no-inno
<i>Iris sensor</i>	xx	xx	xx	xx	xx
<i>Geomagnetic sensor</i>	xx	xx	xx	xx	xx
<i>Pressure sensor</i>	xx	xx	xx	xx	xx
<i>Fingerprint sensor</i>		yes			1
<i>HR sensor</i>	xx	xx	xx	xx	xx
<i>Face ID</i>	xx	xx	xx	xx	xx
<i>Gyroscope</i>	yes	yes	yes	no-inno	no-inno
<i>Compass</i>	yes	yes	yes	no-inno	no-inno
<i>Hall (for flip covers)</i>	xx	xx	xx	xx	xx
<i>Barometer</i>			yes	no-inno	no-inno
<i>Thermometer</i>	xx	xx	xx	xx	xx
<i>Hygrometer</i>	xx	xx	xx	xx	xx
<i>Light sensor</i>	yes	yes	yes	no-inno	no-inno
<i>Proximity sensor</i>	yes	yes	yes	no-inno	no-inno
<i>Gesture sensor</i>	xx	xx	xx	xx	xx
<i>UV sensor</i>	xx	xx	xx	xx	xx
Voice command	yes	yes		no-inno	no-inno

Table: 12. Observation result of new-to-market and new-to-firm novelties: iPhone 6Plus

<i>Launched year</i>	2013 (Sep)	2014 (Sep)	2013 (Oct)		
Technical Specification	iPhone 5S	iPhone 6 Plus	Note 3	FIRM	MARKET
1. DESIGN					
Materials	Aluminium alloy	Aluminium alloy		no-inno	no-inno
Colours	Gold, Gray, Silver	Gold, Gray, Silver	Black, Pink, White	no-inno	no-inno
2. RUGGEDNESS					
Splash	xx	xx	xx	xx	xx
Water	xx	xx	xx	xx	xx
Dust	xx	xx	xx	xx	xx
3. DISPLAY					
Physical size	4	5.5	5.7	1	
Resolution	1136 x 640	1920 x 1080	1920 x 1080	1	
Pixel density	326	401	386		1
Technology	Retina display	Retina HD display	Super AMOLED	1	
Screen-to-body ratio	60.82	67.91	74.78	1	
Peak brightness	500 cd/m ²	500 cd/m ²		no-inno	no-inno
Protection	Fingerprint-resistant oleophobic coating	Fingerprint-resistant oleophobic coating	Corning Gorilla Glass 3	no-inno	no-inno
Damage resistant glass	xx	xx	xx	xx	xx
3D touch	xx	xx	xx	xx	xx
Multitouch	yes	yes	yes	no-inno	no-inno
Shape	Flat	Flat		no-inno	no-inno
4. ATTACHED PEN					
Pressure levels			yes	no-inno	no-inno
Pen Tip diameter	xx	xx	xx	xx	xx
Rugged	xx	xx	xx	xx	xx
<i>Live message</i>	xx	xx	xx	xx	xx
<i>Samsung Notes</i>	xx	xx	xx	xx	xx
<i>Screen off memo</i>	xx	xx	xx	xx	xx
<i>Smart select</i>	xx	xx	xx	xx	xx
<i>Screen write</i>	xx	xx	xx	xx	xx
<i>Translate</i>	xx	xx	xx	xx	xx
<i>Bixby Vision</i>	xx	xx	xx	xx	xx
<i>Glance</i>	xx	xx	xx	xx	xx
<i>Magnify</i>	xx	xx	xx	xx	xx

5. CAMERA					
Rear camera (wide angel)					
Pixels	8	8	13	no-inno	no-inno
Flash	Dual LED	Dual LED	LED	no-inno	no-inno
True tone flash	yes	yes		no-inno	no-inno
Aperture size	2.2	2.2	2.2	no-inno	no-inno
Pixel size	1.5	1.5	1.12	no-inno	no-inno
FOV	xx	xx	xx	xx	xx
Rear camera (telephoto)					
Pixels	xx	xx	xx	xx	xx
Aperture size	xx	xx	xx	xx	xx
Camera sensor size	xx	xx	xx	xx	xx
FOV	xx	xx	xx	xx	xx
Hardware Features					
<i>Optical image stabilization</i>		yes			1
<i>Autofocus</i>	yes	yes	yes	no-inno	no-inno
<i>Live focus (blur background)</i>	xx	xx	xx	xx	xx
<i>Sapphire crystal lens cover</i>	yes	yes		no-inno	no-inno
<i>Back-illuminated sensor</i>	yes	yes	yes	no-inno	no-inno
Optical zoom	xx	xx	xx	xx	xx
Software Features					
<i>Manual focus</i>	xx	xx	xx	xx	xx
<i>Portrait lighting</i>	xx	xx	xx	xx	xx
<i>RAW image capture</i>	xx	xx	xx	xx	xx
<i>Touch to focus</i>	yes	yes	yes	no-inno	no-inno
<i>Smile detection</i>			yes	no-inno	no-inno
<i>Face detection</i>	yes	yes	yes	no-inno	no-inno
<i>Body detection</i>	xx	xx	xx	xx	xx
<i>Grid line</i>	xx	xx	xx	xx	xx
<i>Auto image stabilisation</i>	yes	yes	yes	no-inno	no-inno
<i>Hybrid IR filter</i>	yes	yes		no-inno	no-inno
<i>Filters</i>	xx	xx	xx	xx	xx
<i>Motion/Live photo</i>	xx	xx	xx	xx	xx
<i>Voice activation</i>	xx	xx	xx	xx	xx
<i>Live stickers</i>	xx	xx	xx	xx	xx
<i>Stamps</i>	xx	xx	xx	xx	xx
<i>Dual capture</i>	xx	xx	xx	xx	xx
<i>Noise reduction</i>	xx	xx	xx	xx	xx
<i>Self-timer</i>		yes	yes	1	

<i>Digital zoom</i>	5x	5x	4x	no-inno	no-inno
<i>Geo tagging</i>	yes	yes	yes	no-inno	no-inno
Settings					
<i>Exposure compensation</i>	yes	yes	yes	no-inno	no-inno
<i>ISO control</i>			yes	no-inno	no-inno
<i>White balance presets</i>			yes	no-inno	no-inno
<i>Shutter speed control</i>	xx	xx	xx	xx	xx
Shooting Modes					
<i>Burst mode</i>	yes	yes	yes	no-inno	no-inno
<i>Portrait mode</i>	xx	xx	xx	xx	xx
<i>High Dynamic Range (HDR)</i>	yes	yes	yes	no-inno	no-inno
<i>Panorama</i>	28	43	yes	1	
<i>Virtual shot</i>	xx	xx	xx	xx	xx
<i>Slow motion</i>	xx	xx	xx	xx	xx
<i>Macro mode</i>	xx	xx	xx	xx	xx
<i>Scene mode</i>			yes	no-inno	no-inno
<i>Food mode</i>	xx	xx	xx	xx	xx
<i>Pro mode</i>	xx	xx	xx	xx	xx
<i>Manual mode</i>	xx	xx	xx	xx	xx
Front camera					
Pixels	1.2	1.2	2	no-inno	no-inno
Flash	xx	xx	xx	xx	xx
Aperture size	2.4	2.2		1	
Pixel size	xx	xx	xx	xx	xx
FOV	xx	xx	xx	xx	xx
Front camera features					
<i>Animoji</i>	xx	xx	xx	xx	xx
<i>HD video recording</i>	720p	720p		no-inno	no-inno
<i>Auto HDR</i>	yes	yes		no-inno	no-inno
<i>Backside illumination sensor</i>	yes	yes		no-inno	no-inno
<i>Face detection</i>	yes	yes		no-inno	no-inno
<i>Body detection</i>	xx	xx	xx	xx	xx
<i>Auto image stabilisation</i>	xx	xx	xx	xx	xx
<i>Burst mode</i>		yes			1
<i>Portrait mode</i>	xx	xx	xx	xx	xx
<i>Exposure control</i>	yes	yes		no-inno	no-inno
<i>Timer mode</i>		yes			1
<i>Grid line</i>	xx	xx	xx	xx	xx
<i>Filters</i>	xx	xx	xx	xx	xx

<i>Selective focus</i>	xx	xx	xx	xx	xx
<i>Virtual shot</i>	xx	xx	xx	xx	xx
<i>Motion/Live photo</i>	xx	xx	xx	xx	xx
<i>Live stickers</i>	xx	xx	xx	xx	xx
<i>Stamps</i>	xx	xx	xx	xx	xx
<i>Voice control</i>	xx	xx	xx	xx	xx
Camcorder (video resolution)					
<i>3840x2160 (4K)</i>	xx	xx	xx	xx	xx
<i>1920x1080 (1080p HD)</i>	30	30, 60	60	1	
<i>1280x720 (720p HD)</i>		240	120 fps		
<i>Video recoder</i>	yes	yes		no-inno	no-inno
Video features					
<i>Time-lapse video</i>	yes	yes		no-inno	no-inno
<i>Hyperlapse</i>	xx	xx	xx	xx	xx
<i>Continuous autofocus</i>		yes	yes		
<i>Tracking AF</i>	xx	xx	xx	xx	xx
<i>Picture-taking during video recording</i>	yes	yes		no-inno	no-inno
<i>Video light</i>	yes	yes		no-inno	no-inno
<i>Video calling</i>	yes	yes		no-inno	no-inno
<i>Video geo-tagging</i>	yes	yes		no-inno	no-inno
<i>Optical zoom</i>	xx	xx	xx	xx	xx
<i>Digital zoom</i>	3x	3x	yes	no-inno	no-inno
<i>Slow motion</i>	120	120		no-inno	no-inno
<i>Face detection</i>	yes	yes	yes	no-inno	no-inno
<i>Body detection</i>	xx	xx	xx	xx	xx
<i>Playback zoom</i>	xx	xx	xx	xx	xx
<i>Digital video stabilisation</i>	yes			no-inno	no-inno
<i>Optical video stablisation</i>	xx	xx	xx	xx	xx
<i>Cinematic video stabilisation</i>		yes		1	
<i>Noise reduction</i>	xx	xx	xx	xx	xx
6. HARDWARE					
System chip	A7	A8			
Processor speed	1.3	1.4	2.3	1	
Core	Dual-Core	Dual-Core	Quad-Core	no-inno	no-inno
Graphic processor GPU	450MHz	450MHz		no-inno	no-inno
System memory	1GB	1GB	3GB	no-inno	no-inno
Built-in storage	64GB	128GB	64GB	no-inno	no-inno
Storage expansion			yes	no-inno	no-inno

64-BIT	yes	yes		no-inno	no-inno
Nano sim	yes	yes		no-inno	no-inno
Dual sim	xx	xx	xx	xx	xx
7. BATTERY					
Capacity	1560 mAh	2915 mAh	3200 mAh	1	
Type	lithium-ion	lithium-ion	lithium-ion	no-inno	no-inno
Wireless charging	xx	xx	xx	xx	xx
Fast-charge capability	xx	xx	xx	xx	xx
8. AUDIO					
High quality playback	xx	xx	xx	xx	xx
Recording quality	xx	xx	xx	xx	xx
Speakers	xx	xx	xx	xx	xx
<i>Earpiece</i>	yes	yes	YES	no-inno	no-inno
<i>Stereo speakers</i>	xx	xx	xx	xx	xx
<i>Loudspeaker</i>	yes	yes	YES	no-inno	no-inno
HD Voice		yes			1
9. VIDEO					
Split screen	xx	xx	xx	xx	xx
TV connection	yes	yes		no-inno	no-inno
10. CELLULAR					
2G	yes	yes	yes	no-inno	no-inno
3G	yes	yes	yes	no-inno	no-inno
4G LTE	yes	yes	yes	no-inno	no-inno
CDMA together	yes	yes	yes	no-inno	no-inno
11. CONNECTIVITY					
Bluetooth	4	4.2	4		1
Wi-Fi					
<i>802.11a</i>	yes	yes	yes	no-inno	no-inno
<i>802.11b</i>	yes	yes	yes	no-inno	no-inno
<i>802.11g</i>	yes	yes	yes	no-inno	no-inno
<i>802.11n</i>	yes	yes	yes	no-inno	no-inno
<i>802.11ac</i>			yes	no-inno	no-inno
<i>802.11n 5GHz</i>	yes	yes		no-inno	no-inno
<i>Dual Band</i>	yes	yes	yes	no-inno	no-inno
<i>WiFi MiMO</i>	xx	xx	xx	xx	xx
<i>WiFi hotspot</i>	yes	yes	yes	no-inno	no-inno
Mobile hotspot	yes	yes	yes	no-inno	no-inno
Mobile Payment		yes			1
Positioning					

<i>GPS</i>			yes	no-inno	no-inno
<i>A-GPS</i>	yes	yes	yes	no-inno	no-inno
<i>Glonass</i>	yes	yes	yes	no-inno	no-inno
<i>Galileo</i>	xx	xx	xx	xx	xx
<i>Cell ID</i>	yes	yes		no-inno	no-inno
<i>BeiDou</i>	xx	xx	xx	xx	xx
<i>QZSS</i>	xx	xx	xx	xx	xx
<i>Wi-Fi positioning</i>	yes	yes		no-inno	no-inno
<i>iBeacon micro-location</i>	yes	yes		no-inno	no-inno
12. PHONE FEATURES					
Haptic feedback		yes			1
Hearing aid compatibility	yes	yes	yes	no-inno	no-inno
3D facial recognition	xx	xx	xx	xx	xx
Bixby	xx	xx	xx	xx	xx
Sensors					
<i>Accelerometer</i>	yes	yes	yes	no-inno	no-inno
<i>Iris sensor</i>	xx	xx	xx	xx	xx
<i>Geomagnetic sensor</i>	xx	xx	xx	xx	xx
<i>Pressure sensor</i>	xx	xx	xx	xx	xx
<i>Fingerprint sensor</i>	yes	yes		no-inno	no-inno
<i>HR sensor</i>	xx	xx	xx	xx	xx
<i>Face ID</i>	xx	xx	xx	xx	xx
<i>Gyroscope</i>	yes	yes	yes	no-inno	no-inno
<i>Compass</i>	yes	yes	yes	no-inno	no-inno
<i>Hall (for flip covers)</i>			yes	no-inno	no-inno
<i>Barometer</i>		yes	yes	1	
<i>Thermometer</i>			yes	no-inno	no-inno
<i>Hygrometer</i>			yes	no-inno	no-inno
<i>Light sensor</i>	yes	yes	yes	no-inno	no-inno
<i>Proximity sensor</i>	yes	yes	yes	no-inno	no-inno
<i>Gesture sensor</i>	xx	xx	xx	xx	xx
<i>UV sensor</i>	xx	xx	xx	xx	xx
Voice command	yes	yes		no-inno	no-inno

Table: 13. Observation result of new-to-market and new-to-firm novelties: iPhone 6S Plus

<i>Launched year</i>	2014 (Sep)	2015 (Sep)	2015 (Aug)		
Technical Specification	iPhone 6 Plus	iPhone 6S Plus	Note 5	firm	market
1. DESIGN					
Materials	Aluminium alloy	Aluminium alloy	Glass; Metal	no-inno	no-inno
Colours	Gold, Gray, Silver	Gold, Gray, Silver, Pink, White	Black, Gold, Silver, White	1	
2. RUGGEDNESS					
Splash	xx	xx	xx	xx	xx
Water	xx	xx	xx	xx	xx
Dust	xx	xx	xx	xx	xx
3. DISPLAY					
Physical size	5.5	5.5	5.7	no-inno	no-inno
Resolution	1920 x 1080	1920 x 1080	2560 x 1440	no-inno	no-inno
Pixel density	401	401	518	no-inno	no-inno
Technology	Retina HD display	Retina HD display, LCD	Super AMOLED	1	
Screen-to-body ratio	67.91	67.91	76.62	no-inno	no-inno
Peak brightness	500 cd/m ²	500 cd/m ²		no-inno	no-inno
Protection	Fingerprint-resistant oleophobic coating	Fingerprint-resistant oleophobic coating	Corning Gorilla Glass 4	no-inno	no-inno
Damage resistant glass	xx	xx	xx	xx	xx
3D touch		Yes			1
Multitouch	yes	Yes	yes	no-inno	no-inno
Shape	Flat	Flat		no-inno	no-inno
4. ATTACHED PEN					
Pressure levels			yes	no-inno	no-inno
Pen Tip diameter	xx	xx	xx	xx	xx
Rugged	xx	xx	xx	xx	xx
<i>Live message</i>	xx	xx	xx	xx	xx
<i>Samsung Notes</i>	xx	xx	xx	xx	xx
<i>Screen off memo</i>	xx	xx	xx	xx	xx
<i>Smart select</i>	xx	xx	xx	xx	xx
<i>Screen write</i>	xx	xx	xx	xx	xx
<i>Translate</i>	xx	xx	xx	xx	xx
<i>Bixby Vision</i>	xx	xx	xx	xx	xx
<i>Glance</i>	xx	xx	xx	xx	xx
<i>Magnify</i>	xx	xx	xx	xx	xx

5. CAMERA					
Rear camera (wide angel)					
Pixels	8	12	16	1	
Flash	Dual LED	Dual LED	Dual LED	no-inno	no-inno
True tone flash	yes	Yes		no-inno	no-inno
Aperture size	2.2	2.2	1.9	no-inno	no-inno
Pixel size	1.5	1.22	1.12	1	
FOV	xx	xx	xx	xx	xx
Rear camera (telephoto)					
Pixels	xx	xx	xx	xx	xx
Aperture size	xx	xx	xx	xx	xx
Camera sensor size	xx	xx	xx	xx	xx
FOV	xx	xx	xx	xx	xx
Hardware Features					
<i>Optical image stabilization</i>	yes	Yes	yes	no-inno	no-inno
<i>Autofocus</i>	yes	Yes	yes	no-inno	no-inno
<i>Live focus (blur background)</i>	xx	xx	xx	xx	xx
<i>Sapphire crystal lens cover</i>	yes	Yes		no-inno	no-inno
<i>Back-illuminated sensor</i>	yes	Yes	yes	no-inno	no-inno
Optical zoom	xx	xx	xx	xx	xx
Software Features					
<i>Manual focus</i>		Yes			1
<i>Portrait lighting</i>	xx	xx	xx	xx	xx
<i>RAW image capture</i>			yes	no-inno	no-inno
<i>Touch to focus</i>	yes	Yes	yes	no-inno	no-inno
<i>Smile detection</i>	xx	xx	xx	xx	xx
<i>Face detection</i>	yes	Yes	yes	no-inno	no-inno
<i>Body detection</i>	xx	xx	xx	xx	xx
<i>Grid line</i>	xx	xx	xx	xx	xx
<i>Auto image stabilisation</i>	yes	Yes	yes	no-inno	no-inno
<i>Hybrid IR filter</i>	yes	Yes		no-inno	no-inno
<i>Filters</i>	xx	xx	xx	xx	xx
<i>Motion/Live photo</i>		Yes			1
<i>Voice activation</i>	xx	xx	xx	xx	xx
<i>Live stickers</i>	xx	xx	xx	xx	xx
<i>Stamps</i>	xx	xx	xx	xx	xx
<i>Dual capture</i>	xx	xx	xx	xx	xx
<i>Noise reduction</i>		Yes			1
<i>Self-timer</i>	yes	Yes	yes	no-inno	no-inno

<i>Digital zoom</i>	5x	5x	8x	no-inno	no-inno
<i>Geo tagging</i>	yes	Yes	yes	no-inno	no-inno
Settings					
<i>Exposure compensation</i>	yes	Yes	yes	no-inno	no-inno
<i>ISO control</i>			yes	no-inno	no-inno
<i>White balance presets</i>			yes	no-inno	no-inno
<i>Shutter speed control</i>			yes	no-inno	no-inno
Shooting Modes					
<i>Burst mode</i>	yes	Yes	yes	no-inno	no-inno
<i>Portrait mode</i>	xx	xx	xx	xx	xx
<i>High Dynamic Range (HDR)</i>	yes	Yes	yes	no-inno	no-inno
<i>Panorama</i>	43	63	yes	1	
<i>Virtual shot</i>	xx	xx	xx	xx	xx
<i>Slow motion</i>			120 fps	no-inno	no-inno
<i>Macro mode</i>			yes	no-inno	no-inno
<i>Scene mode</i>			yes	no-inno	no-inno
<i>Food mode</i>	xx	xx	xx	xx	xx
<i>Pro mode</i>	xx	xx	xx	xx	xx
<i>Manual mode</i>	xx	xx	xx	xx	xx
Front camera					
Pixels	1.2	5	5	1	
Flash		Yes			1
Aperture size	2.2	2.2		no-inno	no-inno
Pixel size	xx	xx	xx	xx	xx
FOV	xx	xx	xx	xx	xx
Front camera features					
<i>Animoji</i>	xx	xx	xx	xx	xx
<i>HD video recording</i>	720p	720p		no-inno	no-inno
<i>Auto HDR</i>	yes	Yes		no-inno	no-inno
<i>Backside illumination sensor</i>	yes	Yes		no-inno	no-inno
<i>Face detection</i>	yes	Yes		no-inno	no-inno
<i>Body detection</i>	xx	xx	xx	xx	xx
<i>Auto image stabilisation</i>	xx	xx	xx	xx	xx
<i>Burst mode</i>	yes	Yes		no-inno	no-inno
<i>Portrait mode</i>	xx	xx	xx	xx	xx
<i>Exposure control</i>	yes	Yes		no-inno	no-inno
<i>Timer mode</i>	yes			no-inno	no-inno
<i>Grid line</i>	xx	xx	xx	xx	xx
<i>Filters</i>	xx	xx	xx	xx	xx

<i>Selective focus</i>	xx	xx	xx	xx	xx
<i>Virtual shot</i>	xx	xx	xx	xx	xx
<i>Motion/Live photo</i>	xx	xx	xx	xx	xx
<i>Live stickers</i>	xx	xx	xx	xx	xx
<i>Stamps</i>	xx	xx	xx	xx	xx
<i>Voice control</i>	xx	xx	xx	xx	xx
Camcorder (video resolution)					
<i>3840x2160 (4K)</i>		30	30	1	
<i>1920x1080 (1080p HD)</i>	30, 60	30, 60	60	no-inno	no-inno
<i>1280x720 (720p HD)</i>	240	30	yes	no-inno	no-inno
<i>Video recoder</i>	yes	Yes		no-inno	no-inno
Video features					
<i>Time-lapse video</i>	yes	Yes		no-inno	no-inno
<i>Hyperlapse</i>	xx	xx	xx	xx	xx
<i>Continuous autofocus</i>	yes	Yes	yes	no-inno	no-inno
<i>Tracking AF</i>			yes	no-inno	no-inno
<i>Picture-taking during video recording</i>	yes	8mp		no-inno	no-inno
<i>Video light</i>	yes	dual-led			1
<i>Video calling</i>	yes	yes	yes	no-inno	no-inno
<i>Video geo-tagging</i>	yes	Yes		no-inno	no-inno
<i>Optical zoom</i>	xx	xx	xx	xx	xx
<i>Digital zoom</i>	3x	3x		no-inno	no-inno
<i>Slow motion</i>	120	120fps		no-inno	no-inno
<i>Face detection</i>	yes	Yes		no-inno	no-inno
<i>Body detection</i>	xx	xx	xx	xx	xx
<i>Playback zoom</i>		Yes			1
<i>Digital video stabilisation</i>			yes	no-inno	no-inno
<i>Optical video stabilisation</i>		yes	yes	1	
<i>Cinematic video stabilisation</i>	yes	Yes		no-inno	no-inno
<i>Noise reduction</i>		Yes			1
6. HARDWARE					
System chip	A8	A9			
Processor speed	1.4	1.84 GHz	2.1GHz, 1.5GHz;	no-inno	no-inno
Core	Dual-Core	Duo-Core	Octa-core	no-inno	no-inno
Graphic processor GPU	450MHz			no-inno	no-inno
System memory	1GB	2GB	4GB	1	
Built-in storage	128GB	128GB	32GB	no-inno	no-inno
Storage expansion	xx	xx	xx	xx	xx

64-BIT	yes	Yes	yes	no-inno	no-inno
Nano sim	yes	Yes	yes	no-inno	no-inno
Dual sim	xx	xx	xx	xx	xx
7. BATTERY					
Capacity	2915 mAh	2750 mAh	3000 mAh	no-inno	no-inno
Type	lithium-ion	lithium-ion	lithium-ion	no-inno	no-inno
Wireless charging			yes	no-inno	no-inno
Fast-charge capability			yes	no-inno	no-inno
8. AUDIO					
High quality playback	xx	xx	xx	xx	xx
Recording quality	xx	xx	xx	xx	xx
Speakers	xx	xx	xx	xx	xx
<i>Earpiece</i>	yes	yes	yes	no-inno	no-inno
<i>Stereo speakers</i>	xx	xx	xx	xx	xx
<i>Loudspeaker</i>	yes	yes	yes	no-inno	no-inno
HD Voice	yes	Yes		no-inno	no-inno
9. VIDEO					
Split screen	xx	xx	xx	xx	xx
TV connection	yes	yes		no-inno	no-inno
10. CELLULAR					
2G	yes	yes	yes	no-inno	no-inno
3G	yes	yes	yes	no-inno	no-inno
4G LTE	yes	yes	yes	no-inno	no-inno
CDMA together	yes	yes	yes	no-inno	no-inno
11. CONNECTIVITY					
Bluetooth	4.2	4.2	4.2	no-inno	no-inno
Wi-Fi					
<i>802.11a</i>	yes	yes	yes	no-inno	no-inno
<i>802.11b</i>	yes	yes	yes	no-inno	no-inno
<i>802.11g</i>	yes	yes	yes	no-inno	no-inno
<i>802.11n</i>	yes	yes	yes	no-inno	no-inno
<i>802.11ac</i>		yes	yes	1	
<i>802.11n 5GHz</i>	yes	yes	yes	no-inno	no-inno
<i>Dual Band</i>	yes	yes	yes	no-inno	no-inno
<i>WiFi MiMO</i>			yes	no-inno	no-inno
<i>WiFi hotspot</i>	yes	Yes	yes	no-inno	no-inno
Mobile hotspot	yes	yes	yes	no-inno	no-inno
Mobile Payment	yes	yes	yes	no-inno	no-inno
Positioning					

<i>GPS</i>			yes	no-inno	no-inno
<i>A-GPS</i>	yes	yes		no-inno	no-inno
<i>Glonass</i>	yes	yes	yes	no-inno	no-inno
<i>Galileo</i>		yes			1
<i>Cell ID</i>	yes	yes		no-inno	no-inno
<i>BeiDou</i>			yes	no-inno	no-inno
<i>QZSS</i>		yes			1
<i>Wi-Fi positioning</i>	yes	yes		no-inno	no-inno
<i>iBeacon micro-location</i>	yes	yes		no-inno	no-inno
12. PHONE FEATURES					
Haptic feedback	yes	yes		no-inno	no-inno
Hearing aid compatibility	yes	yes		no-inno	no-inno
3D facial recognition	xx	xx	xx	xx	xx
Bixby	xx	xx	xx	xx	xx
Sensors					
<i>Accelerometer</i>	yes	yes	yes	no-inno	no-inno
<i>Iris sensor</i>	xx	xx	xx	xx	xx
<i>Geomagnetic sensor</i>			yes	xx	xx
<i>Pressure sensor</i>	xx	xx	xx	xx	xx
<i>Fingerprint sensor</i>	yes	yes	yes	xx	xx
<i>HR sensor</i>			yes	xx	xx
<i>Face ID</i>	xx	xx	xx	xx	xx
<i>Gyroscope</i>	yes	yes	yes	xx	xx
<i>Compass</i>	yes	yes		xx	xx
<i>Hall (for flip covers)</i>			yes	xx	xx
<i>Barometer</i>	yes	yes	yes	xx	xx
<i>Thermometer</i>	xx	xx	xx	xx	xx
<i>Hygrometer</i>	xx	xx	xx	xx	xx
<i>Light sensor</i>	yes	yes	yes	xx	xx
<i>Proximity sensor</i>	yes	yes	yes	xx	xx
<i>Gesture sensor</i>	xx	xx	xx	xx	xx
<i>UV sensor</i>	xx	xx	xx	xx	xx
Voice command	yes	yes		xx	xx

Table: 14. Observation result of new-to-market and new-to-firm novelties: iPhone 7 Plus

<i>Launched year</i>	2015 (Sep)	2016 (Sep)	2016 (Mar)		
Technical Specification	iPhone 6S Plus	iPhone 7Plus	Galaxy S7 Edge	FIRM	MARKET
1. DESIGN					
Materials	Aluminium alloy	Aluminium alloy	Glass; Aluminum	no-inno	no-inno
Colours	Gold, Gray, Silver, Pink, White	Rose Gold, Gold, Silver, Black, Jet Black	Silver, Titanium		2
2. RUGGEDNESS					
Splash		IP67			
Water		IP67	IP68	1	
Dust		IP67	IP68	1	
3. DISPLAY					
Physical size	5.5	5.5	5.5	no-inno	no-inno
Resolution	1920 x 1080	1920 x 1080	2560 x 1440	no-inno	no-inno
Pixel density	401	401	534	no-inno	no-inno
Technology	Retina HD display, LCD	Retina HD display, widescreen LCD	Super AMOLED	1	
Screen-to-body ratio	67.91	67.58	76.09		
Peak brightness	500 cd/m ²	625 cd/m ²		1	
Protection	Fingerprint-resistant oleophobic coating	Fingerprint-resistant oleophobic coating	Corning Gorilla Glass 6	no-inno	no-inno
Damage resistant glass	xx	xx	xx	xx	xx
3D touch	Yes			no-inno	no-inno
Multitouch	Yes	Yes	yes	no-inno	no-inno
Shape	Flat	Flat	edge	no-inno	no-inno
4. ATTACHED PEN					
Pressure levels	xx	xx	xx	xx	xx
Pen Tip diameter	xx	xx	xx	xx	xx
Rugged	xx	xx	xx	xx	xx
<i>Live message</i>	xx	xx	xx	xx	xx
<i>Samsung Notes</i>	xx	xx	xx	xx	xx
<i>Screen off memo</i>	xx	xx	xx	xx	xx
<i>Smart select</i>	xx	xx	xx	xx	xx
<i>Screen write</i>	xx	xx	xx	xx	xx
<i>Translate</i>	xx	xx	xx	xx	xx
<i>Bixby Vision</i>	xx	xx	xx	xx	xx

<i>Glance</i>	xx	xx	xx	xx	xx
<i>Magnify</i>	xx	xx	xx	xx	xx
5. CAMERA					
Rear camera (wide angel)					
Pixels	12	12	12	no-inno	no-inno
Flash	Dual LED	Quad LED	Dual LED		1
True tone flash	Yes	Yes		no-inno	no-inno
Aperture size	2.2	1.8	1.7	1	
Pixel size	1.22	1.22	1.4	no-inno	no-inno
FOV	xx	xx	xx	xx	xx
Rear camera (telephoto)					
Pixels		12	12	no-inno	no-inno
Aperture size		2.8		no-inno	no-inno
Camera sensor size	xx	xx	xx	xx	xx
FOV	xx	xx	xx	xx	xx
Hardware Features					
<i>Optical image stabilization</i>	Yes	yes	yes	no-inno	no-inno
<i>Autofocus</i>	Yes	Yes	yes	no-inno	no-inno
<i>Live focus (blur background)</i>	xx	xx	xx	xx	xx
<i>Sapphire crystal lens cover</i>	Yes	Yes		no-inno	no-inno
<i>Back-illuminated sensor</i>	Yes	Yes		no-inno	no-inno
Optical zoom		2x			1
Software Features					
<i>Manual focus</i>	Yes	yes		no-inno	no-inno
<i>Portrait lighting</i>		yes			1
<i>RAW image capture</i>		Yes	yes	1	
<i>Touch to focus</i>	Yes	Yes	yes	no-inno	no-inno
<i>Smile detection</i>			yes	no-inno	no-inno
<i>Face detection</i>	Yes	Yes		no-inno	no-inno
<i>Body detection</i>		Yes			1
<i>Grid line</i>	xx	xx	xx	xx	xx
<i>Auto image stabilisation</i>	Yes	Yes		no-inno	no-inno
<i>Hybrid IR filter</i>	Yes	Yes		no-inno	no-inno
<i>Filters</i>	xx	xx	xx	xx	xx
<i>Motion/Live photo</i>	Yes	Yes		no-inno	no-inno
<i>Voice activation</i>	xx	xx	xx	xx	xx
<i>Live stickers</i>	xx	xx	xx	xx	xx
<i>Stamps</i>	xx	xx	xx	xx	xx
<i>Dual capture</i>	xx	xx	xx	xx	xx

Noise reduction	Yes	yes		no-inno	no-inno
Self-timer	Yes	yes	yes	no-inno	no-inno
Digital zoom	5x	10x		1	
Geo tagging	Yes	yes	yes	no-inno	no-inno
Settings					
Exposure compensation	Yes	yes	yes	no-inno	no-inno
ISO control			yes	no-inno	no-inno
White balance presets			yes	no-inno	no-inno
Shutter speed control	xx	xx	xx	xx	xx
Shooting Modes					
Burst mode	Yes	yes	yes	no-inno	no-inno
Portrait mode		yes			1
High Dynamic Range (HDR)	Yes	yes	yes	no-inno	no-inno
Panorama	63	63	yes	no-inno	no-inno
Virtual shot	xx	xx	xx	xx	xx
Slow motion	xx	xx	xx	xx	xx
Macro mode		yes			1
Scene mode		yes	yes	1	
Food mode	xx	xx	xx	xx	xx
Pro mode	xx	xx	xx	xx	xx
Manual mode	xx	xx	xx	xx	xx
Front camera					
Pixels	5	7	5		1
Flash	Yes	yes		no-inno	no-inno
Aperture size	2.2	2.2		no-inno	no-inno
Pixel size	xx	xx	xx	xx	xx
FOV	xx	xx	xx	xx	xx
Front camera features					
Animoji	xx	xx	xx	xx	xx
HD video recording	720p	1080p		1	
Auto HDR	Yes	Yes	yes	no-inno	no-inno
Backside illumination sensor	Yes	Yes		no-inno	no-inno
Face detection	Yes	yes		no-inno	no-inno
Body detection		Yes			1
Auto image stabilisation		Yes			1
Burst mode	Yes	Yes		no-inno	no-inno
Portrait mode	xx	xx	xx	xx	xx
Exposure control	Yes	Yes		no-inno	no-inno
Timer mode	xx	xx	xx	xx	xx

<i>Grid line</i>	xx	xx	xx	xx	xx
<i>Filters</i>	xx	xx	xx	xx	xx
<i>Selective focus</i>	xx	xx	xx	xx	xx
<i>Virtual shot</i>	xx	xx	xx	xx	xx
<i>Motion/Live photo</i>	xx	xx	xx	xx	xx
<i>Live stickers</i>	xx	xx	xx	xx	xx
<i>Stamps</i>	xx	xx	xx	xx	xx
<i>Voice control</i>	xx	xx	xx	xx	xx
Camcorder (video resolution)					
<i>3840x2160 (4K)</i>	30	30	30	no-inno	no-inno
<i>1920x1080 (1080p HD)</i>	30, 60	30, 60	60	no-inno	no-inno
<i>1280x720 (720p HD)</i>	30	30	240	no-inno	no-inno
<i>Video recoder</i>	Yes	yes	yes	no-inno	no-inno
Video features					
<i>Time-lapse video</i>	Yes	yes		no-inno	no-inno
<i>Hyperlapse</i>	xx	xx	xx	xx	xx
<i>Continuous autofocus</i>	Yes	yes		no-inno	no-inno
<i>Tracking AF</i>	xx	xx	xx	xx	xx
<i>Picture-taking during video recording</i>	8mp	8mp	yes	no-inno	no-inno
<i>Video light</i>	dual-led	quad-led		no-inno	no-inno
<i>Video calling</i>	yes	yes	yes	no-inno	no-inno
<i>Video geo-tagging</i>	Yes	yes		no-inno	no-inno
<i>Optical zoom</i>		2x			1
<i>Digital zoom</i>	3x	6x		1	
<i>Slow motion</i>	120fps	240fps	240fps	1	
<i>Face detection</i>	Yes	yes		no-inno	no-inno
<i>Body detection</i>		yes			1
<i>Playback zoom</i>	Yes	yes		no-inno	no-inno
<i>Digital video stabilisation</i>	xx	xx	xx	xx	xx
<i>Optical video stablisation</i>	yes	yes		no-inno	no-inno
<i>Cinematic video stabilisation</i>	Yes	yes		no-inno	no-inno
<i>Noise reduction</i>	Yes	yes		no-inno	no-inno
6. HARDWARE					
System chip	A9	A10 Fusion			
Processor speed	1.84 GHz	2.4 GHz	2.15GHz,1.6GHz	1	
Core	Duo-Core	Quad-Core	Quad-Core	1	
Graphic processor GPU	xx	xx	xx	xx	xx
System memory	2GB	3GB	4GB	1	

Built-in storage	128GB	256GB	64GB	1	
Storage expansion			yes	no-inno	no-inno
64-BIT	Yes	Yes	yes	no-inno	no-inno
Nano sim	Yes	Yes	yes	no-inno	no-inno
Dual sim	xx	xx	xx	xx	xx
7. BATTERY					
Capacity	2750 mAh	2900 mAh	3600 mAh	1	
Type	lithium-ion	lithium-ion	lithium-ion	no-inno	no-inno
Wireless charging			yes	no-inno	no-inno
Fast-charge capability			yes	no-inno	no-inno
8. AUDIO					
High quality playback	xx	xx	xx	xx	xx
Recording quality	xx	xx	xx	xx	xx
Speakers	xx	xx	xx	xx	xx
<i>Earpiece</i>	yes	yes	yes	no-inno	no-inno
<i>Stereo speakers</i>		yes			1
<i>Loudspeaker</i>	yes	yes	yes	no-inno	no-inno
HD Voice	Yes	yes	yes	no-inno	no-inno
9. VIDEO					
Split screen	xx	xx	xx	xx	xx
TV connection	yes	yes		no-inno	no-inno
10. CELLULAR					
2G	yes	yes	yes	no-inno	no-inno
3G	yes	yes	yes	no-inno	no-inno
4G LTE	yes	yes	yes	no-inno	no-inno
CDMA together	yes	yes	yes	no-inno	no-inno
11. CONNECTIVITY					
Bluetooth	4.2	4.2	4.2	no-inno	no-inno
Wi-Fi					
<i>802.11 a</i>	yes	yes	yes	no-inno	no-inno
<i>802.11 b</i>	yes	yes	yes	no-inno	no-inno
<i>802.11 g</i>	yes	yes	yes	no-inno	no-inno
<i>802.11 n</i>	yes	yes	yes	no-inno	no-inno
<i>802.11 ac</i>	yes	yes	yes	no-inno	no-inno
<i>802.11n 5GHz</i>	yes	yes	yes	no-inno	no-inno
<i>Dual Band</i>	yes	yes	yes	no-inno	no-inno
<i>WiFi MiMO</i>			yes	no-inno	no-inno
<i>WiFi hotspot</i>	Yes	yes		no-inno	no-inno
Mobile hotspot	yes	yes	yes	no-inno	no-inno

Mobile Payment	yes	yes	yes	no-inno	no-inno
Positioning					
<i>GPS</i>			yes	no-inno	no-inno
<i>A-GPS</i>	yes	yes		no-inno	no-inno
<i>Glonass</i>	yes	yes	yes	no-inno	no-inno
<i>Galileo</i>	yes	yes		no-inno	no-inno
<i>Cell ID</i>	yes	yes		no-inno	no-inno
<i>BeiDou</i>			yes	no-inno	no-inno
<i>QZSS</i>	yes	yes		no-inno	no-inno
<i>Wi-Fi positioning</i>	yes	yes		no-inno	no-inno
<i>iBeacon micro-location</i>	yes	yes		no-inno	no-inno
12. PHONE FEATURES					
Haptic feedback	yes	yes	yes	no-inno	no-inno
Hearing aid compatibility	yes	yes	yes	no-inno	no-inno
3D facial recognition	xx	xx	xx	xx	xx
Bixby	xx	xx	xx	xx	xx
Sensors					
<i>Accelerometer</i>	yes	yes	yes	no-inno	no-inno
<i>Iris sensor</i>	xx	xx	xx	xx	xx
<i>Geomagnetic sensor</i>			yes	no-inno	no-inno
<i>Pressure sensor</i>	xx	xx	xx	xx	xx
<i>Fingerprint sensor</i>	yes	yes	yes	no-inno	no-inno
<i>HR sensor</i>			yes	no-inno	no-inno
<i>Face ID</i>	xx	xx	xx	xx	xx
<i>Gyroscope</i>	yes	yes	yes	no-inno	no-inno
<i>Compass</i>	yes	yes		no-inno	no-inno
<i>Hall (for flip covers)</i>			yes	no-inno	no-inno
<i>Barometer</i>	yes	yes	yes	no-inno	no-inno
<i>Thermometer</i>	xx	xx	xx	xx	xx
<i>Hygrometer</i>	xx	xx	xx	xx	xx
<i>Light sensor</i>	yes	yes	yes	no-inno	no-inno
<i>Proximity sensor</i>	yes	yes	yes	no-inno	no-inno
<i>Gesture sensor</i>	xx	xx	xx	xx	xx
<i>UV sensor</i>	xx	xx	xx	xx	xx
Voice command	yes	yes		no-inno	no-inno

Table: 15. Observation result of new-to-market and new-to-firm novelties: iPhone X

<i>Launched year</i>	2016 (Sep)	2017 (Nov)	2017 (Sep)		
Technical Specification	iPhone 7Plus	iPhone X	Note 8	firm	market
1. DESIGN					
Materials	Aluminium alloy	Glass, Stainless steel	Glass; Aluminum		1
Colours	Rose Gold, Gold, Silver, Black, Jet Black	Silver, Space Gray	Midnight Black, Deepsea Blue, Orchid Gray, Maple Gold	no-inno	no-inno
2. RUGGEDNESS					
Splash	IP67	IP67		no-inno	no-inno
Water	IP67	IP67	IP68	no-inno	no-inno
Dust	IP67	IP67	IP68	no-inno	no-inno
3. DISPLAY					
Physical size	5.5	5.8	6.3	1	
Resolution	1920 x 1080	2436 x 1125	2960 x 1440	1	
Pixel density	401	458 ppi	521	1	
Technology	Retina HD display, widescreen LCD	Super Retina HD display, OLED	Super AMOLED	1	
Screen-to-body ratio	67.58	82.35	82.98	1	
Peak brightness	625 cd/m ²	625 cd/m ²		no-inno	no-inno
Protection	Fingerprint-resistant oleophobic coating	Fingerprint-resistant oleophobic coating	Corning Gorilla Glass 5	no-inno	no-inno
Damage resistant glass	xx	xx	xx	xx	xx
3D touch	Yes	Yes		no-inno	no-inno
Multitouch	Yes	Yes	yes	no-inno	no-inno
Shape	Flat	Flat	edge	no-inno	no-inno
4. ATTACHED PEN					
Pressure levels			4096	no-inno	no-inno
Pen Tip diameter			0.7	no-inno	no-inno
Rugged			IP68	no-inno	no-inno
<i>Live message</i>			yes	no-inno	no-inno
<i>Samsung Notes</i>			yes	no-inno	no-inno
<i>Screen off memo</i>			yes	no-inno	no-inno
<i>Smart select</i>			yes	no-inno	no-inno
<i>Screen write</i>			yes	no-inno	no-inno
<i>Translate</i>			yes	no-inno	no-inno
<i>Bixby Vision</i>			yes	no-inno	no-inno

<i>Glance</i>			yes	no-inno	no-inno
<i>Magnify</i>			yes	no-inno	no-inno
5. CAMERA					
Rear camera (wide angel)					
Pixels	12	12	12	no-inno	no-inno
Flash	Quad LED	Quad LED	Dual LED	no-inno	no-inno
True tone flash	Yes	Yes		no-inno	no-inno
Aperture size	1.8	1.8	1.7	no-inno	no-inno
Pixel size	1.22	1.22	1.4	no-inno	no-inno
FOV			77	no-inno	no-inno
Rear camera (telephoto)					
Pixels	12	12	12	no-inno	no-inno
Aperture size	2.8	2.4	2.4	1	
Camera sensor size			3.6	no-inno	no-inno
FOV			45	no-inno	no-inno
Hardware Features					
<i>Optical image stabilization</i>	yes	yes	yes	no-inno	no-inno
<i>Autofocus</i>	Yes	yes	yes	no-inno	no-inno
<i>Live focus (blur background)</i>		yes	yes	1	
<i>Sapphire crystal lens cover</i>	Yes	yes		no-inno	no-inno
<i>Back-illuminated sensor</i>	Yes	yes		no-inno	no-inno
Optical zoom	2x	2x	2x	no-inno	no-inno
Software Features					
<i>Manual focus</i>	yes	yes	yes	no-inno	no-inno
<i>Portrait lighting</i>	yes	yes		no-inno	no-inno
<i>RAW image capture</i>	Yes	yes	yes	no-inno	no-inno
<i>Touch to focus</i>	Yes	yes	yes	no-inno	no-inno
<i>Smile detection</i>			yes	no-inno	no-inno
<i>Face detection</i>	Yes	yes	yes	no-inno	no-inno
<i>Body detection</i>	Yes	yes		no-inno	no-inno
<i>Grid line</i>			yes	no-inno	no-inno
<i>Auto image stabilisation</i>	Yes	yes		no-inno	no-inno
<i>Hybrid IR filter</i>	Yes	Yes		no-inno	no-inno
<i>Filters</i>			yes	no-inno	no-inno
<i>Motion/Live photo</i>	Yes	yes	yes	no-inno	no-inno
<i>Voice activation</i>			yes	no-inno	no-inno
<i>Live stickers</i>			yes	no-inno	no-inno
<i>Stamps</i>			yes	no-inno	no-inno
<i>Dual capture</i>			yes	no-inno	no-inno

Noise reduction	yes	yes		no-inno	no-inno
Self-timer	yes	yes	yes	no-inno	no-inno
Digital zoom	10x	10x	10x	no-inno	no-inno
Geo tagging	yes	yes	yes	no-inno	no-inno
Settings					
Exposure compensation	yes	yes	yes	no-inno	no-inno
ISO control		yes	yes	1	
White balance presets		yes	yes	1	
Shutter speed control			yes	no-inno	no-inno
Shooting Modes					
Burst mode	yes	yes	yes	no-inno	no-inno
Portrait mode	yes	yes		no-inno	no-inno
High Dynamic Range (HDR)	yes	yes	yes	no-inno	no-inno
Panorama	63	63	yes	no-inno	no-inno
Virtual shot			yes	no-inno	no-inno
Slow motion			120 fps	no-inno	no-inno
Macro mode	yes	yes		no-inno	no-inno
Scene mode	yes	yes		no-inno	no-inno
Food mode			yes	no-inno	no-inno
Pro mode	xx	xx	xx	xx	xx
Manual mode	xx	xx	xx	xx	xx
Front camera					
Pixels	7	7	8	no-inno	no-inno
Flash	yes	yes		no-inno	no-inno
Aperture size	2.2	2.2	1.7	no-inno	no-inno
Pixel size			1.22	no-inno	no-inno
FOV			80	no-inno	no-inno
Front camera features					
Animoji		yes			1
HD video recording	1080p	1080p		no-inno	no-inno
Auto HDR	Yes	yes	yes	no-inno	no-inno
Backside illumination sensor	Yes	yes		no-inno	no-inno
Face detection	yes	yes		no-inno	no-inno
Body detection	Yes	yes		no-inno	no-inno
Auto image stabilisation	Yes	yes		no-inno	no-inno
Burst mode	Yes	yes		no-inno	no-inno
Portrait mode		yes			1
Exposure control	Yes	yes		no-inno	no-inno
Timer mode		yes	yes	1	

<i>Grid line</i>			yes	no-inno	no-inno
<i>Filters</i>			yes	no-inno	no-inno
<i>Selective focus</i>	xx	xx	xx	xx	xx
<i>Virtual shot</i>			yes	no-inno	no-inno
<i>Motion/Live photo</i>			yes	no-inno	no-inno
<i>Live stickers</i>			yes	no-inno	no-inno
<i>Stamps</i>			yes	no-inno	no-inno
<i>Voice control</i>			yes	no-inno	no-inno
Camcorder (video resolution)					
<i>3840x2160 (4K)</i>	30	24, 30, 60	30		1
<i>1920x1080 (1080p HD)</i>	30, 60	30, 60	30, 60	no-inno	no-inno
<i>1280x720 (720p HD)</i>	30	30	240	no-inno	no-inno
<i>Video recoder</i>	yes	yes	yes	no-inno	no-inno
Video features					
<i>Time-lapse video</i>	yes	yes	yes	no-inno	no-inno
<i>Hyperlapse</i>			yes	no-inno	no-inno
<i>Continuous autofocus</i>	yes	yes	yes	no-inno	no-inno
<i>Tracking AF</i>		yes	yes	1	
<i>Picture-taking during video recording</i>	8mp	8mp	9mp	no-inno	no-inno
<i>Video light</i>	quad-led	quad-led	High CRI LED flash	no-inno	no-inno
<i>Video calling</i>	yes	yes	yes	no-inno	no-inno
<i>Video geo-tagging</i>	yes	yes	yes	no-inno	no-inno
<i>Optical zoom</i>	2x	2x	2x	no-inno	no-inno
<i>Digital zoom</i>	6x	6x	10x	no-inno	no-inno
<i>Slow motion</i>	240fps	240fps	240fps	no-inno	no-inno
<i>Face detection</i>	yes	yes	yes	no-inno	no-inno
<i>Body detection</i>	yes	yes		no-inno	no-inno
<i>Playback zoom</i>	yes	yes	yes	no-inno	no-inno
<i>Digital video stabilisation</i>			yes	no-inno	no-inno
<i>Optical video stabilisation</i>	yes	yes	yes	no-inno	no-inno
<i>Cinematic video stabilisation</i>	yes	yes		no-inno	no-inno
<i>Noise reduction</i>	yes	yes		no-inno	no-inno
6. HARDWARE					
System chip	A10 Fusion	A11 Bionic	Qualcomm Snapdragon		
Processor speed	2.4 GHz	2.4 GHz	2.35GHz Quad + 1.9GHz Quad	no-inno	no-inno
Core	Quad-Core	Hexa-Core	Octa-core	1	
Graphic processor GPU	xx	xx	xx	xx	xx

System memory	3GB	3GB	6GB	no-inno	no-inno
Built-in storage	256GB	256GB	256GB	no-inno	no-inno
Storage expansion			yes	no-inno	no-inno
64-BIT	Yes	yes	yes	no-inno	no-inno
Nano sim	Yes	yes	yes	no-inno	no-inno
Dual sim			yes	no-inno	no-inno
7. BATTERY					
Capacity	2900 mAh	2716 mAh	3300 mAh	no-inno	no-inno
Type	lithium-ion	lithium-ion	lithium-ion	no-inno	no-inno
Wireless charging		yes	yes	1	
Fast-charge capability		yes	yes	1	
8. AUDIO					
High quality playback			yes	no-inno	no-inno
Recording quality			High AOP Mic	no-inno	no-inno
Speakers	xx	xx	xx	xx	xx
<i>Earpiece</i>	yes	yes	yes	no-inno	no-inno
<i>Stereo speakers</i>	yes	yes		no-inno	no-inno
<i>Loudspeaker</i>	yes	yes	yes	no-inno	no-inno
HD Voice	yes	yes	yes	no-inno	no-inno
9. VIDEO					
Split screen			yes	no-inno	no-inno
TV connection	yes	yes	yes	no-inno	no-inno
10. CELLULAR					
2G	yes	yes	yes	no-inno	no-inno
3G	yes	yes	yes	no-inno	no-inno
4G LTE	yes	yes	yes	no-inno	no-inno
CDMA together	yes	yes	yes	no-inno	no-inno
11. CONNECTIVITY					
Bluetooth	4.2	5	5	1	
Wi-Fi					
<i>802.11 a</i>	yes	yes	yes	no-inno	no-inno
<i>802.11 b</i>	yes	yes	yes	no-inno	no-inno
<i>802.11 g</i>	yes	yes	yes	no-inno	no-inno
<i>802.11 n</i>	yes	yes	yes	no-inno	no-inno
<i>802.11 ac</i>	yes	yes	yes	no-inno	no-inno
<i>802.11n 5GHz</i>	yes	yes	yes	no-inno	no-inno
<i>Dual Band</i>	yes	yes	yes	no-inno	no-inno
<i>WiFi MiMO</i>		yes	yes	1	
<i>WiFi hotspot</i>	yes	yes	yes	no-inno	no-inno

Mobile hotspot	yes	yes	yes	no-inno	no-inno
Mobile Payment	yes	yes	yes	no-inno	no-inno
Positioning					
<i>GPS</i>			yes	no-inno	no-inno
<i>A-GPS</i>	yes	yes	yes	no-inno	no-inno
<i>Glomass</i>	yes	yes	yes	no-inno	no-inno
<i>Galileo</i>	yes	yes	yes	no-inno	no-inno
<i>Cell ID</i>	yes	yes	yes	no-inno	no-inno
<i>BeiDou</i>			yes	no-inno	no-inno
<i>QZSS</i>	yes	yes		no-inno	no-inno
<i>Wi-Fi positioning</i>	yes	yes	yes	no-inno	no-inno
<i>iBeacon micro-location</i>	yes	yes		no-inno	no-inno
12. PHONE FEATURES					
Haptic feedback	yes	yes	yes	no-inno	no-inno
Hearing aid compatibility	yes	yes	yes	no-inno	no-inno
3D facial recognition		yes			1
Bixby			yes	no-inno	no-inno
Sensors					
<i>Accelerometer</i>	yes	yes	yes	no-inno	no-inno
<i>Iris sensor</i>			yes	no-inno	no-inno
<i>Geomagnetic sensor</i>			yes	no-inno	no-inno
<i>Pressure sensor</i>			yes	no-inno	no-inno
<i>Fingerprint sensor</i>	yes		yes	no-inno	no-inno
<i>HR sensor</i>			yes	no-inno	no-inno
<i>Face ID</i>		yes			1
<i>Gyroscope</i>	yes	yes	yes	no-inno	no-inno
<i>Compass</i>	yes	yes		no-inno	no-inno
<i>Hall (for flip covers)</i>			yes	no-inno	no-inno
<i>Barometer</i>	yes	yes	yes	no-inno	no-inno
<i>Thermometer</i>	xx	xx	xx	xx	xx
<i>Hygrometer</i>	xx	xx	xx	xx	xx
<i>Light sensor</i>	yes	yes	yes	no-inno	no-inno
<i>Proximity sensor</i>	yes	yes	yes	no-inno	no-inno
<i>Gesture sensor</i>	xx	xx	xx	xx	xx
<i>UV sensor</i>	xx	xx	xx	xx	xx
Voice command	yes	yes	yes	no-inno	no-inno

Table: 16. Observation result of new-to-market and new-to-firm novelties: SG i910

<i>Launched year</i>	2008	2009 (May)	2008 (Jun)		
Technical Specification	i910	i8910	iPhone 3G	FIRM	MARKET
1. DESIGN					
Materials	Plastic	Plastic	Plastic	no-inno	no-inno
Colours	Silver	Black	Black	1	
2. RUGGEDNESS					
Splash	xx	xx	xx	xx	xx
Water	xx	xx	xx	xx	xx
Dust	xx	xx	xx	xx	xx
3. DISPLAY					
Physical size	3.2	3.7	3.5		1
Resolution	240 x 400	360 x 640	480 x 320		1
Pixel density	146	198	165		1
Technology	LCD	AMOLED			
Screen-to-body ratio	45.73	52.9	52.35		1
Peak brightness	xx	xx	xx	xx	xx
Protection		Corning Gorilla Glass			1
Damage resistant glass	xx	xx	xx	xx	xx
3D touch	xx	xx	xx	xx	xx
Multitouch			yes	no-inno	no-inno
Shape			Flat	no-inno	no-inno
4. ATTACHED PEN					
Pressure levels	xx	xx	xx	xx	xx
Pen Tip diameter	xx	xx	xx	xx	xx
Rugged	xx	xx	xx	xx	xx
<i>Live message</i>	xx	xx	xx	xx	xx
<i>Samsung Notes</i>	xx	xx	xx	xx	xx
<i>Screen off memo</i>	xx	xx	xx	xx	xx
<i>Smart select</i>	xx	xx	xx	xx	xx
<i>Screen write</i>	xx	xx	xx	xx	xx
<i>Translate</i>	xx	xx	xx	xx	xx
<i>Bixby Vision</i>	xx	xx	xx	xx	xx
<i>Glance</i>	xx	xx	xx	xx	xx
<i>Magnify</i>	xx	xx	xx	xx	xx
5. CAMERA					
Rear camera (wide angel)					

Pixels	5	8	2		1
Flash	LED	LED		no-inno	no-inno
True tone flash	xx	xx	xx	xx	xx
Aperture size	xx	xx	xx	xx	xx
Pixel size	xx	xx	xx	xx	xx
FOV	xx	xx	xx	xx	xx
Rear camera (telephoto)					
Pixels	xx	xx	xx	xx	xx
Aperture size	xx	xx	xx	xx	xx
Camera sensor size	xx	xx	xx	xx	xx
FOV	xx	xx	xx	xx	xx
Hardware Features					
<i>Optical image stabilization</i>	xx	xx	xx	xx	xx
<i>Autofocus</i>	yes	yes		no-inno	no-inno
<i>Live focus (blur background)</i>	xx	xx	xx	xx	xx
<i>Sapphire crystal lens cover</i>	xx	xx	xx	xx	xx
<i>Back-illuminated sensor</i>	xx	xx	xx	xx	xx
Optical zoom	xx	xx	xx	xx	xx
Software Features					
<i>Manual focus</i>	xx	xx	xx	xx	xx
<i>Portrait lighting</i>	xx	xx	xx	xx	xx
<i>RAW image capture</i>	xx	xx	xx	xx	xx
<i>Touch to focus</i>	xx	xx	xx	xx	xx
<i>Smile detection</i>	yes	yes		no-inno	no-inno
<i>Face detection</i>	yes	yes		no-inno	no-inno
<i>Body detection</i>	xx	xx	xx	xx	xx
<i>Grid line</i>	xx	xx	xx	xx	xx
<i>Auto image stabilisation</i>	yes	yes		no-inno	no-inno
<i>Hybrid IR filter</i>	xx	xx	xx	xx	xx
<i>Filters</i>	xx	xx	xx	xx	xx
<i>Motion/Live photo</i>	xx	xx	xx	xx	xx
<i>Voice activation</i>	xx	xx	xx	xx	xx
<i>Live stickers</i>	xx	xx	xx	xx	xx
<i>Stamps</i>	xx	xx	xx	xx	xx
<i>Dual capture</i>	xx	xx	xx	xx	xx
<i>Noise reduction</i>	xx	xx	xx	xx	xx
<i>Self-timer</i>		yes			1
<i>Digital zoom</i>		yes			1
<i>Geo tagging</i>		yes	yes	1	

Settings					
<i>Exposure compensation</i>	xx	xx	xx	xx	xx
<i>ISO control</i>	xx	xx	xx	xx	xx
<i>White balance presets</i>	xx	xx	xx	xx	xx
<i>Shutter speed control</i>	xx	xx	xx	xx	xx
Shooting Modes					
<i>Burst mode</i>		yes			1
<i>Portrait mode</i>	xx	xx	xx	xx	xx
<i>High Dynamic Range (HDR)</i>	xx	xx	xx	xx	xx
<i>Panorama</i>	yes	yes		no-inno	no-inno
<i>Virtual shot</i>	xx	xx	xx	xx	xx
<i>Slow motion</i>	xx	xx	xx	xx	xx
<i>Macro mode</i>	xx	xx	xx	xx	xx
<i>Scene mode</i>	xx	xx	xx	xx	xx
<i>Food mode</i>	xx	xx	xx	xx	xx
<i>Pro mode</i>	xx	xx	xx	xx	xx
<i>Manual mode</i>	xx	xx	xx	xx	xx
Front camera					
Pixels		0.1			1
Flash	xx	xx	xx	xx	xx
Aperture size	xx	xx	xx	xx	xx
Pixel size	xx	xx	xx	xx	xx
FOV	xx	xx	xx	xx	xx
Front camera features					
<i>Animoji</i>	xx	xx	xx	xx	xx
<i>HD video recording</i>	xx	xx	xx	xx	xx
<i>Auto HDR</i>	xx	xx	xx	xx	xx
<i>Backside illumination sensor</i>	xx	xx	xx	xx	xx
<i>Face detection</i>	xx	xx	xx	xx	xx
<i>Body detection</i>	xx	xx	xx	xx	xx
<i>Auto image stabilisation</i>	xx	xx	xx	xx	xx
<i>Burst mode</i>	xx	xx	xx	xx	xx
<i>Portrait mode</i>	xx	xx	xx	xx	xx
<i>Exposure control</i>	xx	xx	xx	xx	xx
<i>Timer mode</i>	xx	xx	xx	xx	xx
<i>Grid line</i>	xx	xx	xx	xx	xx
<i>Filters</i>	xx	xx	xx	xx	xx
<i>Selective focus</i>	xx	xx	xx	xx	xx
<i>Virtual shot</i>	xx	xx	xx	xx	xx

<i>Motion/Live photo</i>	xx	xx	xx	xx	xx
<i>Live stickers</i>	xx	xx	xx	xx	xx
<i>Stamps</i>	xx	xx	xx	xx	xx
<i>Voice control</i>	xx	xx	xx	xx	xx
Camcorder (video resolution)					
<i>3840x2160 (4K)</i>	xx	xx	xx	xx	xx
<i>1920x1080 (1080p HD)</i>	xx	xx	xx	xx	xx
<i>1280x720 (720p HD)</i>		24fps			1
<i>Video recoder</i>	yes			no-inno	no-inno
Video features					
<i>Time-lapse video</i>	xx	xx	xx	xx	xx
<i>Hyperlapse</i>	xx	xx	xx	xx	xx
<i>Continuous autofocus</i>	xx	xx	xx	xx	xx
<i>Tracking AF</i>	xx	xx	xx	xx	xx
<i>Picture-taking during video recording</i>	xx	xx	xx	xx	xx
<i>Video light</i>	xx	xx	xx	xx	xx
<i>Video calling</i>	xx	xx	xx	xx	xx
<i>Video geo-tagging</i>	xx	xx	xx	xx	xx
<i>Optical zoom</i>	xx	xx	xx	xx	xx
<i>Digital zoom</i>	xx	xx	xx	xx	xx
<i>Slow motion</i>	xx	xx	xx	xx	xx
<i>Face detection</i>	xx	xx	xx	xx	xx
<i>Body detection</i>	xx	xx	xx	xx	xx
<i>Playback zoom</i>	xx	xx	xx	xx	xx
<i>Digital video stabilisation</i>	xx	xx	xx	xx	xx
<i>Optical video stablisation</i>	xx	xx	xx	xx	xx
<i>Cinematic video stabilisation</i>	xx	xx	xx	xx	xx
<i>Noise reduction</i>	xx	xx	xx	xx	xx
6. HARDWARE					
System chip	xx	xx	xx	xx	xx
Processor speed	0.6	0.6	0.4	no-inno	no-inno
Core	Single-core	Single-core	Single-core	no-inno	no-inno
Graphic processor GPU	xx	xx	xx	xx	xx
System memory	128MB	256MB	128		1
Built-in storage	8GB	16GB	16GB	1	
Storage expansion	yes	yes		no-inno	no-inno
64-BIT	xx	xx	xx	xx	xx
Nano sim	xx	xx	xx	xx	xx

Dual sim	xx	xx	xx	xx	xx
7. BATTERY					
Capacity	1400 mAh	1500 mAh	1150 mAh		1
Type		lithium-ion	lithium-ion	no-inno	no-inno
Wireless charging	xx	xx	xx	xx	xx
Fast-charge capability	xx	xx	xx	xx	xx
8. AUDIO					
High quality playback	xx	xx	xx	xx	xx
Recording quality	xx	xx	xx	xx	xx
Speakers	xx	xx	xx	xx	xx
<i>Earpiece</i>		yes	yes	no-inno	no-inno
<i>Stereo speakers</i>	xx	xx	xx	xx	xx
<i>Loudspeaker</i>		yes	yes	no-inno	no-inno
HD Voice	xx	xx	xx	xx	xx
9. VIDEO					
Split screen	xx	xx	xx	xx	xx
TV connection	yes			no-inno	no-inno
10. CELLULAR					
2G			yes	no-inno	no-inno
3G			yes	no-inno	no-inno
4G LTE	xx	xx	xx	xx	xx
CDMA together	only CDMA			no-inno	no-inno
11. CONNECTIVITY					
Bluetooth	2	2	2	no-inno	no-inno
Wi-Fi					
<i>802.11a</i>	xx	xx	xx	xx	xx
<i>802.11b</i>	yes	yes	yes	no-inno	no-inno
<i>802.11g</i>	yes	yes	yes	no-inno	no-inno
<i>802.11n</i>	xx	xx	xx	xx	xx
<i>802.11ac</i>	xx	xx	xx	xx	xx
<i>802.11n 5GHz</i>	xx	xx	xx	xx	xx
<i>Dual Band</i>	xx	xx	xx	xx	xx
<i>WiFi MiMO</i>	xx	xx	xx	xx	xx
<i>WiFi hotspot</i>	xx	xx	xx	xx	xx
Mobile hotspot	xx	xx	xx	xx	xx
Mobile Payment	xx	xx	xx	xx	xx
Positioning					
<i>GPS</i>	yes			no-inno	no-inno
<i>A-GPS</i>		yes	yes	1	

<i>Glonass</i>	xx	xx	xx	xx	xx
<i>Galileo</i>	xx	xx	xx	xx	xx
<i>Cell ID</i>			yes	no-inno	no-inno
<i>BeiDou</i>	xx	xx	xx	xx	xx
<i>QZSS</i>	xx	xx	xx	xx	xx
<i>Wi-Fi positioning</i>			yes	no-inno	no-inno
<i>iBeacon micro-location</i>	xx	xx	xx	xx	xx
12. PHONE FEATURES					
Haptic feedback	xx	xx	xx	xx	xx
Hearing aid compatibility	yes			no-inno	no-inno
3D facial recognition	xx	xx	xx	xx	xx
Bixby	xx	xx	xx	xx	xx
Sensors					
<i>Accelerometer</i>	yes	yes	yes	no-inno	no-inno
<i>Iris sensor</i>	xx	xx	xx	xx	xx
<i>Geomagnetic sensor</i>	xx	xx	xx	xx	xx
<i>Pressure sensor</i>	xx	xx	xx	xx	xx
<i>Fingerprint sensor</i>	xx	xx	xx	xx	xx
<i>HR sensor</i>	xx	xx	xx	xx	xx
<i>Face ID</i>	xx	xx	xx	xx	xx
<i>Gyroscope</i>	xx	xx	xx	xx	xx
<i>Compass</i>		yes			1
<i>Hall (for flip covers)</i>	xx	xx	xx	xx	xx
<i>Barometer</i>	xx	xx	xx	xx	xx
<i>Thermometer</i>	xx	xx	xx	xx	xx
<i>Hygrometer</i>	xx	xx	xx	xx	xx
<i>Light sensor</i>			yes	no-inno	no-inno
<i>Proximity sensor</i>		yes	yes	1	
<i>Gesture sensor</i>	xx	xx	xx	xx	xx
<i>UV sensor</i>	xx	xx	xx	xx	xx
Voice command	xx	xx	xx	xx	xx

Table: 17. Observation result of new-to-market and new-to-firm novelties: Galaxy S

<i>Launched year</i>	2009 (May)	2010 (Jun)	2009(Jun)		
Technical Specification	i8910	Galaxy S	iPhone 3GS	FIRM	MARKET
1. DESIGN					
Materials	Plastic	Plastic	Plastic	no-inno	no-inno
Colours	Black	Black, White	Black, White	1	
2. RUGGEDNESS					
Splash	xx	xx	xx	xx	xx
Water	xx	xx	xx	xx	xx
Dust	xx	xx	xx	xx	xx
3. DISPLAY					
Physical size	3.7	4	3.5		1
Resolution	360 x 640	480 x 800	480 x 320		1
Pixel density	198	233	165		1
Technology	AMOLED	Super AMOLED		1	
Screen-to-body ratio	52.9	57.88	52.35		1
Peak brightness	xx	xx	xx	xx	xx
Protection	Corning Gorilla Glass	Corning Gorilla Glass	Fingerprint-resistant oleophobic coating	no-inno	no-inno
Damage resistant glass	xx	xx	xx	xx	xx
3D touch	xx	xx	xx	xx	xx
Multitouch			yes	no-inno	no-inno
Shape			Flat	no-inno	no-inno
4. ATTACHED PEN					
Pressure levels	xx	xx	xx	xx	xx
Pen Tip diameter	xx	xx	xx	xx	xx
Rugged	xx	xx	xx	xx	xx
<i>Live message</i>	xx	xx	xx	xx	xx
<i>Samsung Notes</i>	xx	xx	xx	xx	xx
<i>Screen off memo</i>	xx	xx	xx	xx	xx
<i>Smart select</i>	xx	xx	xx	xx	xx
<i>Screen write</i>	xx	xx	xx	xx	xx
<i>Translate</i>	xx	xx	xx	xx	xx
<i>Bixby Vision</i>	xx	xx	xx	xx	xx
<i>Glance</i>	xx	xx	xx	xx	xx
<i>Magnify</i>	xx	xx	xx	xx	xx
5. CAMERA					

Rear camera (wide angel)					
Pixels	8	5	3	no-inno	no-inno
Flash	LED			no-inno	no-inno
True tone flash	xx	xx	xx	xx	xx
Aperture size			2.8	no-inno	no-inno
Pixel size	xx	xx	xx	xx	xx
FOV	xx	xx	xx	xx	xx
Rear camera (telephoto)					
Pixels	xx	xx	xx	xx	xx
Aperture size	xx	xx	xx	xx	xx
Camera sensor size	xx	xx	xx	xx	xx
FOV	xx	xx	xx	xx	xx
Hardware Features					
<i>Optical image stabilization</i>	xx	xx	xx	xx	xx
<i>Autofocus</i>	yes	yes	yes	no-inno	no-inno
<i>Live focus (blur background)</i>	xx	xx	xx	xx	xx
<i>Sapphire crystal lens cover</i>	xx	xx	xx	xx	xx
<i>Back-illuminated sensor</i>	xx	xx	xx	xx	xx
Optical zoom	xx	xx	xx	xx	xx
Software Features					
<i>Manual focus</i>	xx	xx	xx	xx	xx
<i>Portrait lighting</i>	xx	xx	xx	xx	xx
<i>RAW image capture</i>	xx	xx	xx	xx	xx
<i>Touch to focus</i>			yes	no-inno	no-inno
<i>Smile detection</i>	yes	yes		no-inno	no-inno
<i>Face detection</i>	yes			no-inno	no-inno
<i>Body detection</i>	xx	xx	xx	xx	xx
<i>Grid line</i>	xx	xx	xx	xx	xx
<i>Auto image stabilisation</i>	yes			no-inno	no-inno
<i>Hybrid IR filter</i>	xx	xx	xx	xx	xx
<i>Filters</i>	xx	xx	xx	xx	xx
<i>Motion/Live photo</i>	xx	xx	xx	xx	xx
<i>Voice activation</i>	xx	xx	xx	xx	xx
<i>Live stickers</i>	xx	xx	xx	xx	xx
<i>Stamps</i>	xx	xx	xx	xx	xx
<i>Dual capture</i>	xx	xx	xx	xx	xx
<i>Noise reduction</i>	xx	xx	xx	xx	xx
<i>Self-timer</i>	yes	yes		no-inno	no-inno
<i>Digital zoom</i>	yes	yes		no-inno	no-inno

<i>Geo tagging</i>	yes		yes	no-inno	no-inno
Settings					
<i>Exposure compensation</i>	xx	xx	xx	xx	xx
<i>ISO control</i>		yes			1
<i>White balance presets</i>	xx	xx	xx	xx	xx
<i>Shutter speed control</i>	xx	xx	xx	xx	xx
Shooting Modes					
<i>Burst mode</i>	yes	yes		no-inno	no-inno
<i>Portrait mode</i>	xx	xx	xx	xx	xx
<i>High Dynamic Range (HDR)</i>	xx	xx	xx	xx	xx
<i>Panorama</i>	yes	yes		no-inno	no-inno
<i>Virtual shot</i>	xx	xx	xx	xx	xx
<i>Slow motion</i>	xx	xx	xx	xx	xx
<i>Macro mode</i>	xx	xx	xx	xx	xx
<i>Scene mode</i>	xx	xx	xx	xx	xx
<i>Food mode</i>	xx	xx	xx	xx	xx
<i>Pro mode</i>	xx	xx	xx	xx	xx
<i>Manual mode</i>	xx	xx	xx	xx	xx
Front camera					
Pixels	0.1	0.3			1
Flash	xx	xx	xx	xx	xx
Aperture size	xx	xx	xx	xx	xx
Pixel size	xx	xx	xx	xx	xx
FOV	xx	xx	xx	xx	xx
Front camera features					
<i>Animoji</i>	xx	xx	xx	xx	xx
<i>HD video recording</i>	xx	xx	xx	xx	xx
<i>Auto HDR</i>	xx	xx	xx	xx	xx
<i>Backside illumination sensor</i>	xx	xx	xx	xx	xx
<i>Face detection</i>	xx	xx	xx	xx	xx
<i>Body detection</i>	xx	xx	xx	xx	xx
<i>Auto image stabilisation</i>	xx	xx	xx	xx	xx
<i>Burst mode</i>	xx	xx	xx	xx	xx
<i>Portrait mode</i>	xx	xx	xx	xx	xx
<i>Exposure control</i>	xx	xx	xx	xx	xx
<i>Timer mode</i>	xx	xx	xx	xx	xx
<i>Grid line</i>	xx	xx	xx	xx	xx
<i>Filters</i>	xx	xx	xx	xx	xx
<i>Selective focus</i>	xx	xx	xx	xx	xx

<i>Virtual shot</i>	xx	xx	xx	xx	xx
<i>Motion/Live photo</i>	xx	xx	xx	xx	xx
<i>Live stickers</i>	xx	xx	xx	xx	xx
<i>Stamps</i>	xx	xx	xx	xx	xx
<i>Voice control</i>	xx	xx	xx	xx	xx
Camcorder (video resolution)					
<i>3840x2160 (4K)</i>	xx	xx	xx	xx	xx
<i>1920x1080 (1080p HD)</i>	xx	xx	xx	xx	xx
<i>1280x720 (720p HD)</i>	24fps	30		1	
<i>Video recoder</i>			yes	no-inno	no-inno
Video features					
<i>Time-lapse video</i>	xx	xx	xx	xx	xx
<i>Hyperlapse</i>	xx	xx	xx	xx	xx
<i>Continuous autofocus</i>	xx	xx	xx	xx	xx
<i>Tracking AF</i>	xx	xx	xx	xx	xx
<i>Picture-taking during video recording</i>	xx	xx	xx	xx	xx
<i>Video light</i>	xx	xx	xx	xx	xx
<i>Video calling</i>		yes			1
<i>Video geo-tagging</i>			yes	no-inno	no-inno
<i>Optical zoom</i>	xx	xx	xx	xx	xx
<i>Digital zoom</i>	xx	xx	xx	xx	xx
<i>Slow motion</i>	xx	xx	xx	xx	xx
<i>Face detection</i>	xx	xx	xx	xx	xx
<i>Body detection</i>	xx	xx	xx	xx	xx
<i>Playback zoom</i>	xx	xx	xx	xx	xx
<i>Digital video stabilisation</i>	xx	xx	xx	xx	xx
<i>Optical video stablisation</i>	xx	xx	xx	xx	xx
<i>Cinematic video stabilisation</i>	xx	xx	xx	xx	xx
<i>Noise reduction</i>	xx	xx	xx	xx	xx
6. HARDWARE					
System chip	xx	xx	xx	xx	xx
Processor speed	0.6	1	0.6		1
Core	Single-core	Single-core	Single-core	no-inno	no-inno
Graphic processor GPU	xx	xx	xx	xx	xx
System memory	256MB	0.5GB	256		1
Built-in storage	16GB	16GB	16GB	no-inno	no-inno
Storage expansion	yes	yes		no-inno	no-inno
64-BIT	xx	xx	xx	xx	xx

Nano sim	xx	xx	xx	xx	xx
Dual sim	xx	xx	xx	xx	xx
7. BATTERY					
Capacity	1500 mAh	1500 mAh	1219	no-inno	no-inno
Type	lithium-ion	lithium-ion	lithium-ion	no-inno	no-inno
Wireless charging	xx	xx	xx	xx	xx
Fast-charge capability	xx	xx	xx	xx	xx
8. AUDIO					
High quality playback	xx	xx	xx	xx	xx
Recording quality	xx	xx	xx	xx	xx
Speakers	xx	xx	xx	xx	xx
<i>Earpiece</i>	yes		yes	no-inno	no-inno
<i>Stereo speakers</i>	xx	xx	xx	xx	xx
<i>Loudspeaker</i>	yes		yes	no-inno	no-inno
HD Voice	xx	xx	xx	xx	xx
9. VIDEO					
Split screen	xx	xx	xx	xx	xx
TV connection	xx	xx	xx	xx	xx
10. CELLULAR					
2G		yes	yes	1	
3G		yes	yes	1	
4G LTE	xx	xx	xx	xx	xx
CDMA together	xx	xx	xx	xx	xx
11. CONNECTIVITY					
Bluetooth	2	3	2.1		1
Wi-Fi					
<i>802.11 a</i>	xx	xx	xx	xx	xx
<i>802.11 b</i>	yes	yes	yes	no-inno	no-inno
<i>802.11 g</i>	yes	yes	yes	no-inno	no-inno
<i>802.11 n</i>		yes			1
<i>802.11 ac</i>	xx	xx	xx	xx	xx
<i>802.11n 5GHz</i>	xx	xx	xx	xx	xx
<i>Dual Band</i>	xx	xx	xx	xx	xx
<i>WiFi MiMO</i>	xx	xx	xx	xx	xx
<i>WiFi hotspot</i>	xx	xx	xx	xx	xx
Mobile hotspot	xx	xx	xx	xx	xx
Mobile Payment	xx	xx	xx	xx	xx
Positioning					
<i>GPS</i>	xx	xx	xx	xx	xx

<i>A-GPS</i>	yes	yes	yes	no-inno	no-inno
<i>Glonass</i>	xx	xx	xx	xx	xx
<i>Galileo</i>	xx	xx	xx	xx	xx
<i>Cell ID</i>			yes	no-inno	no-inno
<i>BeiDou</i>	xx	xx	xx	xx	xx
<i>QZSS</i>	xx	xx	xx	xx	xx
<i>Wi-Fi positioning</i>			yes	no-inno	no-inno
<i>iBeacon micro-location</i>	xx	xx	xx	xx	xx
12. PHONE FEATURES					
Haptic feedback	xx	xx	xx	xx	xx
Hearing aid compatibility	xx	xx	xx	xx	xx
3D facial recognition	xx	xx	xx	xx	xx
Bixby	xx	xx	xx	xx	xx
Sensors					
<i>Accelerometer</i>	yes	yes	yes	no-inno	no-inno
<i>Iris sensor</i>	xx	xx	xx	xx	xx
<i>Geomagnetic sensor</i>	xx	xx	xx	xx	xx
<i>Pressure sensor</i>	xx	xx	xx	xx	xx
<i>Fingerprint sensor</i>	xx	xx	xx	xx	xx
<i>HR sensor</i>	xx	xx	xx	xx	xx
<i>Face ID</i>	xx	xx	xx	xx	xx
<i>Gyroscope</i>	xx	xx	xx	xx	xx
<i>Compass</i>	yes	yes	yes	no-inno	no-inno
<i>Hall (for flip covers)</i>	xx	xx	xx	xx	xx
<i>Barometer</i>	xx	xx	xx	xx	xx
<i>Thermometer</i>	xx	xx	xx	xx	xx
<i>Hygrometer</i>	xx	xx	xx	xx	xx
<i>Light sensor</i>		yes	yes	1	
<i>Proximity sensor</i>	yes	yes	yes	no-inno	no-inno
<i>Gesture sensor</i>	xx	xx	xx	xx	xx
<i>UV sensor</i>	xx	xx	xx	xx	xx
Voice command	xx	xx	xx	xx	xx

Table: 18. Observation result of new-to-market and new-to-firm novelties: Note

<i>Launched year</i>	2010 (Jun)	2011 (Oct 29)	2011 (Oct 14)		
Technical Specification	Galaxy S	Note	iPhone 4S	FIRM	MARKET
1. DESIGN					
Materials			Glass; Aluminium		
Colours	Black, White	Black, Pink, White	Black, White		1
2. RUGGEDNESS					
Splash	xx	xx	xx	xx	xx
Water	xx	xx	xx	xx	xx
Dust	xx	xx	xx	xx	xx
3. DISPLAY					
Physical size	4	5.3	3.5	1	
Resolution	480 x 800	800 x 1280	960 x 640		1
Pixel density	233	285	326	1	
Technology	Super AMOLED	Super AMOLED	Retina display	no-inno	no-inno
Screen-to-body ratio	57.88	66.8	55.27		1
Peak brightness			500 cd/m ²		
Protection	Corning Gorilla Glass	Corning Gorilla Glass	Fingerprint- resistant oleophobic coating	no-inno	no-inno
Damage resistant glass	xx	xx	xx	xx	xx
3D touch	xx	xx	xx	xx	xx
Multitouch		yes	yes	1	
Shape	Flat	Flat	Flat	no-inno	no-inno
4. ATTACHED PEN					
Pressure levels		yes			1
Pen Tip diameter	xx	xx	xx	xx	xx
Rugged	xx	xx	xx	xx	xx
<i>Live message</i>	xx	xx	xx	xx	xx
<i>Samsung Notes</i>	xx	xx	xx	xx	xx
<i>Screen off memo</i>	xx	xx	xx	xx	xx
<i>Smart select</i>	xx	xx	xx	xx	xx
<i>Screen write</i>	xx	xx	xx	xx	xx
<i>Translate</i>	xx	xx	xx	xx	xx
<i>Bixby Vision</i>	xx	xx	xx	xx	xx
<i>Glance</i>	xx	xx	xx	xx	xx
<i>Magnify</i>	xx	xx	xx	xx	xx

5. CAMERA					
Rear camera (wide angel)					
Pixels	5	8	8	1	
Flash		LED	LED	no-inno	no-inno
True tone flash	xx	xx	xx	xx	xx
Aperture size		2.6	2.4	no-inno	no-inno
Pixel size			1.4	no-inno	no-inno
FOV	xx	xx	xx	xx	xx
Rear camera (telephoto)					
Pixels	xx	xx	xx	xx	xx
Aperture size	xx	xx	xx	xx	xx
Camera sensor size	xx	xx	xx	xx	xx
FOV	xx	xx	xx	xx	xx
Hardware Features					
<i>Optical image stabilization</i>	xx	xx	xx	xx	xx
<i>Autofocus</i>	yes	yes	yes	no-inno	no-inno
<i>Live focus (blur background)</i>	xx	xx	xx	xx	xx
<i>Sapphire crystal lens cover</i>	xx	xx	xx	xx	xx
<i>Back-illuminated sensor</i>		yes	yes	1	
Optical zoom	xx	xx	xx	xx	xx
Software Features					
<i>Manual focus</i>	xx	xx	xx	xx	xx
<i>Portrait lighting</i>	xx	xx	xx	xx	xx
<i>RAW image capture</i>	xx	xx	xx	xx	xx
<i>Touch to focus</i>		yes	yes	1	
<i>Smile detection</i>	yes	yes		no-inno	no-inno
<i>Face detection</i>		yes	yes	1	
<i>Body detection</i>	xx	xx	xx	xx	xx
<i>Grid line</i>	xx	xx	xx	xx	xx
<i>Auto image stabilisation</i>	xx	xx	xx	xx	xx
<i>Hybrid IR filter</i>			yes	no-inno	no-inno
<i>Filters</i>	xx	xx	xx	xx	xx
<i>Motion/Live photo</i>	xx	xx	xx	xx	xx
<i>Voice activation</i>	xx	xx	xx	xx	xx
<i>Live stickers</i>	xx	xx	xx	xx	xx
<i>Stamps</i>	xx	xx	xx	xx	xx
<i>Dual capture</i>	xx	xx	xx	xx	xx
<i>Noise reduction</i>	xx	xx	xx	xx	xx
<i>Self-timer</i>	yes			no-inno	no-inno

<i>Digital zoom</i>	yes		5x	no-inno	no-inno
<i>Geo tagging</i>		yes	yes	1	
Settings					
<i>Exposure compensation</i>	xx	xx	xx	xx	xx
<i>ISO control</i>	yes			no-inno	no-inno
<i>White balance presets</i>	xx	xx	xx	xx	xx
<i>Shutter speed control</i>	xx	xx	xx	xx	xx
Shooting Modes					
<i>Burst mode</i>	yes	yes		no-inno	no-inno
<i>Portrait mode</i>	xx	xx	xx	xx	xx
<i>High Dynamic Range (HDR)</i>		yes			1
<i>Panorama</i>	yes			no-inno	no-inno
<i>Virtual shot</i>	xx	xx	xx	xx	xx
<i>Slow motion</i>	xx	xx	xx	xx	xx
<i>Macro mode</i>	xx	xx	xx	xx	xx
<i>Scene mode</i>		yes			1
<i>Food mode</i>	xx	xx	xx	xx	xx
<i>Pro mode</i>	xx	xx	xx	xx	xx
<i>Manual mode</i>	xx	xx	xx	xx	xx
Front camera					
Pixels	0.3	2	0.3		1
Flash	xx	xx	xx	xx	xx
Aperture size	xx	xx	xx	xx	xx
Pixel size	xx	xx	xx	xx	xx
FOV	xx	xx	xx	xx	xx
Front camera features					
<i>Animoji</i>	xx	xx	xx	xx	xx
<i>HD video recording</i>	xx	xx	xx	xx	xx
<i>Auto HDR</i>	xx	xx	xx	xx	xx
<i>Backside illumination sensor</i>	xx	xx	xx	xx	xx
<i>Face detection</i>	xx	xx	xx	xx	xx
<i>Body detection</i>	xx	xx	xx	xx	xx
<i>Auto image stabilisation</i>	xx	xx	xx	xx	xx
<i>Burst mode</i>	xx	xx	xx	xx	xx
<i>Portrait mode</i>	xx	xx	xx	xx	xx
<i>Exposure control</i>	xx	xx	xx	xx	xx
<i>Timer mode</i>	xx	xx	xx	xx	xx
<i>Grid line</i>	xx	xx	xx	xx	xx
<i>Filters</i>	xx	xx	xx	xx	xx

<i>Selective focus</i>	xx	xx	xx	xx	xx
<i>Virtual shot</i>	xx	xx	xx	xx	xx
<i>Motion/Live photo</i>	xx	xx	xx	xx	xx
<i>Live stickers</i>	xx	xx	xx	xx	xx
<i>Stamps</i>	xx	xx	xx	xx	xx
<i>Voice control</i>	xx	xx	xx	xx	xx
Camcorder (video resolution)					
<i>3840x2160 (4K)</i>	xx	xx	xx	xx	xx
<i>1920x1080 (1080p HD)</i>		30	30	1	
<i>1280x720 (720p HD)</i>	30			no-inno	no-inno
<i>Video recoder</i>			yes	no-inno	no-inno
Video features					
<i>Time-lapse video</i>	xx	xx	xx	xx	xx
<i>Hyperlapse</i>	xx	xx	xx	xx	xx
<i>Continuous autofocus</i>	xx	xx	xx	xx	xx
<i>Tracking AF</i>	xx	xx	xx	xx	xx
<i>Picture-taking during video recording</i>	xx	xx	xx	xx	xx
<i>Video light</i>			yes	no-inno	no-inno
<i>Video calling</i>	yes		yes	no-inno	no-inno
<i>Video geo-tagging</i>			yes	no-inno	no-inno
<i>Optical zoom</i>	xx	xx	xx	xx	xx
<i>Digital zoom</i>	xx	xx	xx	xx	xx
<i>Slow motion</i>	xx	xx	xx	xx	xx
<i>Face detection</i>	xx	xx	xx	xx	xx
<i>Body detection</i>	xx	xx	xx	xx	xx
<i>Playback zoom</i>	xx	xx	xx	xx	xx
<i>Digital video stabilisation</i>			yes	no-inno	no-inno
<i>Optical video stabilisation</i>	xx	xx	xx	xx	xx
<i>Cinematic video stabilisation</i>	xx	xx	xx	xx	xx
<i>Noise reduction</i>	xx	xx	xx	xx	xx
6. HARDWARE					
System chip			A5		
Processor speed	1	1.4	0.8		1
Core	Single-core	Dual-Core	Dual-Core	1	
Graphic processor GPU	xx	xx	xx	xx	xx
System memory	0.5GB	1GB	512MB		1
Built-in storage	16GB	32GB	64GB	1	
Storage expansion	yes	yes		no-inno	no-inno

64-BIT				no-inno	no-inno
Nano sim	xx	xx	xx	xx	xx
Dual sim	xx	xx	xx	xx	xx
7. BATTERY					
Capacity	1500 mAh	2500 mAh	1432 mAh		1
Type	lithium-ion	lithium-ion	lithium-ion	no-inno	no-inno
Wireless charging	xx	xx	xx	xx	xx
Fast-charge capability	xx	xx	xx	xx	xx
8. AUDIO					
High quality playback	xx	xx	xx	xx	xx
Recording quality	xx	xx	xx	xx	xx
Speakers	xx	xx	xx	xx	xx
<i>Earpiece</i>		YES	yes	no-inno	no-inno
<i>Stereo speakers</i>	xx	xx	xx	xx	xx
<i>Loudspeaker</i>		YES	yes	no-inno	no-inno
HD Voice	xx	xx	xx	xx	xx
9. VIDEO					
Split screen	xx	xx	xx	xx	xx
TV connection			yes	no-inno	no-inno
10. CELLULAR					
2G	yes	yes	yes	no-inno	no-inno
3G	yes	yes	yes	no-inno	no-inno
4G LTE	xx	xx	xx	xx	xx
CDMA together			yes	no-inno	no-inno
11. CONNECTIVITY					
Bluetooth	3	3	4	no-inno	no-inno
Wi-Fi					
<i>802.11 a</i>	xx	xx	xx	xx	xx
<i>802.11 b</i>	yes	yes	yes	no-inno	no-inno
<i>802.11 g</i>	yes	yes	yes	no-inno	no-inno
<i>802.11 n</i>	yes	yes	yes	no-inno	no-inno
<i>802.11 ac</i>	xx	xx	xx	xx	xx
<i>802.11n 5GHz</i>	xx	xx	xx	xx	xx
<i>Dual Band</i>	xx	xx	xx	xx	xx
<i>WiFi MiMO</i>	xx	xx	xx	xx	xx
<i>WiFi hotspot</i>			yes	no-inno	no-inno
Mobile hotspot		yes	yes	1	
Mobile Payment	xx	xx	xx	xx	xx
Positioning					

<i>GPS</i>	xx	xx	xx	xx	xx
<i>A-GPS</i>	yes	yes	yes	no-inno	no-inno
<i>Glonass</i>		yes			1
<i>Galileo</i>	xx	xx	xx	xx	xx
<i>Cell ID</i>			yes	no-inno	no-inno
<i>BeiDou</i>	xx	xx	xx	xx	xx
<i>QZSS</i>	xx	xx	xx	xx	xx
<i>Wi-Fi positioning</i>			yes	no-inno	no-inno
<i>iBeacon micro-location</i>	xx	xx	xx	xx	xx
12. PHONE FEATURES					
Haptic feedback	xx	xx	xx	xx	xx
Hearing aid compatibility	xx	xx	xx	xx	xx
3D facial recognition	xx	xx	xx	xx	xx
Bixby	xx	xx	xx	xx	xx
Sensors					
<i>Accelerometer</i>	yes	yes	yes	no-inno	no-inno
<i>Iris sensor</i>	xx	xx	xx	xx	xx
<i>Geomagnetic sensor</i>	xx	xx	xx	xx	xx
<i>Pressure sensor</i>	xx	xx	xx	xx	xx
<i>Fingerprint sensor</i>	xx	xx	xx	xx	xx
<i>HR sensor</i>	xx	xx	xx	xx	xx
<i>Face ID</i>	xx	xx	xx	xx	xx
<i>Gyroscope</i>			yes	no-inno	no-inno
<i>Compass</i>	yes	yes	yes	no-inno	no-inno
<i>Hall (for flip covers)</i>	xx	xx	xx	xx	xx
<i>Barometer</i>		yes			1
<i>Thermometer</i>	xx	xx	xx	xx	xx
<i>Hygrometer</i>	xx	xx	xx	xx	xx
<i>Light sensor</i>	yes	yes	yes	no-inno	no-inno
<i>Proximity sensor</i>	yes	yes	yes	no-inno	no-inno
<i>Gesture sensor</i>	xx	xx	xx	xx	xx
<i>UV sensor</i>	xx	xx	xx	xx	xx
Voice command			yes	no-inno	no-inno

Table: 19. Observation result of new-to-market and new-to-firm novelties: Note II

<i>Launched year</i>	2011 (Oct 29)	2012	2011 (Oct 14)		
Technical Specification	Note	Note II	iPhone 4S	FIRM	MARKET
1. DESIGN					
Materials			Glass; Aluminium		
Colours	Black, Pink, White	Blue, White	Black, White		1
2. RUGGEDNESS					
Splash	xx	xx	xx	xx	xx
Water	xx	xx	xx	xx	xx
Dust	xx	xx	xx	xx	xx
3. DISPLAY					
Physical size	5.3	5.5	3.5		1
Resolution	800 x 1280	1280 x 720	960 x 640		1
Pixel density	285	265	326	no-inno	no-inno
Technology	Super AMOLED	Super AMOLED	Retina display	no-inno	no-inno
Screen-to-body ratio	66.8	69.9	55.27		1
Peak brightness			500 cd/m ²	no-inno	no-inno
Protection	Corning Gorilla Glass		Fingerprint- resistant oleophobic coating	no-inno	no-inno
Damage resistant glass	xx	xx	xx	xx	xx
3D touch	xx	xx	xx	xx	xx
Multitouch	yes	yes	yes	no-inno	no-inno
Shape			Flat	no-inno	no-inno
4. ATTACHED PEN					
Pressure levels	yes	yes		no-inno	no-inno
Pen Tip diameter	xx	xx	xx	xx	xx
Rugged	xx	xx	xx	xx	xx
<i>Live message</i>	xx	xx	xx	xx	xx
<i>Samsung Notes</i>	xx	xx	xx	xx	xx
<i>Screen off memo</i>	xx	xx	xx	xx	xx
<i>Smart select</i>	xx	xx	xx	xx	xx
<i>Screen write</i>	xx	xx	xx	xx	xx
<i>Translate</i>	xx	xx	xx	xx	xx
<i>Bixby Vision</i>	xx	xx	xx	xx	xx
<i>Glance</i>	xx	xx	xx	xx	xx
<i>Magnify</i>	xx	xx	xx	xx	xx

5. CAMERA					
Rear camera (wide angel)					
Pixels	8	8 mp	8	no-inno	no-inno
Flash	LED	LED	LED	no-inno	no-inno
True tone flash	xx	xx	xx	xx	xx
Aperture size	2.6	2.6	2.4	no-inno	no-inno
Pixel size			1.4	no-inno	no-inno
FOV	xx	xx	xx	xx	xx
Rear camera (telephoto)					
Pixels	xx	xx	xx	xx	xx
Aperture size	xx	xx	xx	xx	xx
Camera sensor size	xx	xx	xx	xx	xx
FOV	xx	xx	xx	xx	xx
Hardware Features					
<i>Optical image stabilization</i>	xx	xx	xx	xx	xx
<i>Autofocus</i>	yes	yes	yes	no-inno	no-inno
<i>Live focus (blur background)</i>	xx	xx	xx	xx	xx
<i>Sapphire crystal lens cover</i>	xx	xx	xx	xx	xx
<i>Back-illuminated sensor</i>	yes	yes	yes	no-inno	no-inno
Optical zoom	xx	xx	xx	xx	xx
Software Features					
<i>Manual focus</i>	xx	xx	xx	xx	xx
<i>Portrait lighting</i>	xx	xx	xx	xx	xx
<i>RAW image capture</i>	xx	xx	xx	xx	xx
<i>Touch to focus</i>	yes	yes	yes	no-inno	no-inno
<i>Smile detection</i>	yes	yes		no-inno	no-inno
<i>Face detection</i>	yes	yes	yes	no-inno	no-inno
<i>Body detection</i>	xx	xx	xx	xx	xx
<i>Grid line</i>	xx	xx	xx	xx	xx
<i>Auto image stabilisation</i>	xx	xx	xx	xx	xx
<i>Hybrid IR filter</i>			yes	no-inno	no-inno
<i>Filters</i>	xx	xx	xx	xx	xx
<i>Motion/Live photo</i>	xx	xx	xx	xx	xx
<i>Voice activation</i>	xx	xx	xx	xx	xx
<i>Live stickers</i>	xx	xx	xx	xx	xx
<i>Stamps</i>	xx	xx	xx	xx	xx
<i>Dual capture</i>	xx	xx	xx	xx	xx
<i>Noise reduction</i>	xx	xx	xx	xx	xx
<i>Self-timer</i>	xx	xx	xx	xx	xx

<i>Digital zoom</i>		4x	5x	1	
<i>Geo tagging</i>	yes	yes	yes	no-inno	no-inno
Settings					
<i>Exposure compensation</i>	xx	xx	xx	xx	xx
<i>ISO control</i>	xx	xx	xx	xx	xx
<i>White balance presets</i>	xx	xx	xx	xx	xx
<i>Shutter speed control</i>	xx	xx	xx	xx	xx
Shooting Modes					
<i>Burst mode</i>	yes	yes		no-inno	no-inno
<i>Portrait mode</i>	xx	xx	xx	xx	xx
<i>High Dynamic Range (HDR)</i>	yes	yes		no-inno	no-inno
<i>Panorama</i>		yes			1
<i>Virtual shot</i>	xx	xx	xx	xx	xx
<i>Slow motion</i>	xx	xx	xx	xx	xx
<i>Macro mode</i>	xx	xx	xx	xx	xx
<i>Scene mode</i>	yes			no-inno	no-inno
<i>Food mode</i>	xx	xx	xx	xx	xx
<i>Pro mode</i>	xx	xx	xx	xx	xx
<i>Manual mode</i>	xx	xx	xx	xx	xx
Front camera					
Pixels	2	1.9	0.3	no-inno	no-inno
Flash	xx	xx	xx	xx	xx
Aperture size	xx	xx	xx	xx	xx
Pixel size	xx	xx	xx	xx	xx
FOV	xx	xx	xx	xx	xx
Front camera features					
<i>Animoji</i>	xx	xx	xx	xx	xx
<i>HD video recording</i>	xx	xx	xx	xx	xx
<i>Auto HDR</i>	xx	xx	xx	xx	xx
<i>Backside illumination sensor</i>	xx	xx	xx	xx	xx
<i>Face detection</i>	xx	xx	xx	xx	xx
<i>Body detection</i>	xx	xx	xx	xx	xx
<i>Auto image stabilisation</i>	xx	xx	xx	xx	xx
<i>Burst mode</i>	xx	xx	xx	xx	xx
<i>Portrait mode</i>	xx	xx	xx	xx	xx
<i>Exposure control</i>	xx	xx	xx	xx	xx
<i>Timer mode</i>	xx	xx	xx	xx	xx
<i>Grid line</i>	xx	xx	xx	xx	xx
<i>Filters</i>	xx	xx	xx	xx	xx

<i>Selective focus</i>	xx	xx	xx	xx	xx
<i>Virtual shot</i>	xx	xx	xx	xx	xx
<i>Motion/Live photo</i>	xx	xx	xx	xx	xx
<i>Live stickers</i>	xx	xx	xx	xx	xx
<i>Stamps</i>	xx	xx	xx	xx	xx
<i>Voice control</i>	xx	xx	xx	xx	xx
Camcorder (video resolution)					
<i>3840x2160 (4K)</i>	xx	xx	xx	xx	xx
<i>1920x1080 (1080p HD)</i>	30	30	30	no-inno	no-inno
<i>1280x720 (720p HD)</i>	xx	xx	xx	xx	xx
<i>Video recoder</i>			yes	no-inno	no-inno
Video features					
<i>Time-lapse video</i>	xx	xx	xx	xx	xx
<i>Hyperlapse</i>	xx	xx	xx	xx	xx
<i>Continuous autofocus</i>	xx	xx	xx	xx	xx
<i>Tracking AF</i>	xx	xx	xx	xx	xx
<i>Picture-taking during video recording</i>	xx	xx	xx	xx	xx
<i>Video light</i>			yes	no-inno	no-inno
<i>Video calling</i>		yes	yes	no-inno	no-inno
<i>Video geo-tagging</i>			yes	no-inno	no-inno
<i>Optical zoom</i>	xx	xx	xx	xx	xx
<i>Digital zoom</i>	xx	xx	xx	xx	xx
<i>Slow motion</i>	xx	xx	xx	xx	xx
<i>Face detection</i>	xx	xx	xx	xx	xx
<i>Body detection</i>	xx	xx	xx	xx	xx
<i>Playback zoom</i>	xx	xx	xx	xx	xx
<i>Digital video stabilisation</i>			yes	no-inno	no-inno
<i>Optical video stablisation</i>	xx	xx	xx	xx	xx
<i>Cinematic video stabilisation</i>	xx	xx	xx	xx	xx
<i>Noise reduction</i>	xx	xx	xx	xx	xx
6. HARDWARE					
System chip			A5		
Processor speed	1.4	1.6	0.8		1
Core	Dual-Core	Quad-Core	Dual-Core		1
Graphic processor GPU	xx	xx	xx	xx	xx
System memory	1GB	2GB	512MB		1
Built-in storage	32GB	16GB	64GB	no-inno	no-inno
Storage expansion	yes	yes		no-inno	no-inno

64-BIT	xx	xx	xx	xx	xx
Nano sim	xx	xx	xx	xx	xx
Dual sim	xx	xx	xx	xx	xx
7. BATTERY					
Capacity	2500 mAh	3100 mAh	1432 mAh		1
Type	lithium-ion	lithium-ion	lithium-ion	no-inno	no-inno
Wireless charging	xx	xx	xx	xx	xx
Fast-charge capability	xx	xx	xx	xx	xx
8. AUDIO					
High quality playback	xx	xx	xx	xx	xx
Recording quality	xx	xx	xx	xx	xx
Speakers	xx	xx	xx	xx	xx
<i>Earpiece</i>	YES	YES	yes	no-inno	no-inno
<i>Stereo speakers</i>	xx	xx	xx	xx	xx
<i>Loudspeaker</i>	YES	YES	yes	no-inno	no-inno
HD Voice	xx	xx	xx	xx	xx
9. VIDEO					
Split screen	xx	xx	xx	xx	xx
TV connection		yes	yes	1	
10. CELLULAR					
2G	yes		yes	no-inno	no-inno
3G	yes		yes	no-inno	no-inno
4G LTE	xx	xx	xx	xx	xx
CDMA together			yes	no-inno	no-inno
11. CONNECTIVITY					
Bluetooth	3	4	4	1	
Wi-Fi					
<i>802.11 a</i>		yes		1	
<i>802.11 b</i>	yes	yes	yes	no-inno	no-inno
<i>802.11 g</i>	yes	yes	yes	no-inno	no-inno
<i>802.11 n</i>	yes	yes	yes	no-inno	no-inno
<i>802.11 ac</i>	xx	xx	xx	xx	xx
<i>802.11n 5GHz</i>	xx	xx	xx	xx	xx
<i>Dual Band</i>		yes			1
<i>WiFi MiMO</i>	xx	xx	xx	xx	xx
<i>WiFi hotspot</i>			yes	no-inno	no-inno
Mobile hotspot	yes	yes	yes	no-inno	no-inno
Mobile Payment	xx	xx	xx	xx	xx
Positioning					

<i>GPS</i>	xx	xx	xx	xx	xx
<i>A-GPS</i>	yes	yes	yes	no-inno	no-inno
<i>Glonass</i>	yes	yes		no-inno	no-inno
<i>Galileo</i>	xx	xx	xx	xx	xx
<i>Cell ID</i>			yes	no-inno	no-inno
<i>BeiDou</i>	xx	xx	xx	xx	xx
<i>QZSS</i>	xx	xx	xx	xx	xx
<i>Wi-Fi positioning</i>			yes	no-inno	no-inno
<i>iBeacon micro-location</i>	xx	xx	xx	xx	xx
12. PHONE FEATURES					
Haptic feedback		yes			1
Hearing aid compatibility		yes			1
3D facial recognition	xx	xx	xx	xx	xx
Bixby	xx	xx	xx	xx	xx
Sensors					
<i>Accelerometer</i>	yes	yes	yes	no-inno	no-inno
<i>Iris sensor</i>	xx	xx	xx	xx	xx
<i>Geomagnetic sensor</i>	xx	xx	xx	xx	xx
<i>Pressure sensor</i>	xx	xx	xx	xx	xx
<i>Fingerprint sensor</i>	xx	xx	xx	xx	xx
<i>HR sensor</i>	xx	xx	xx	xx	xx
<i>Face ID</i>	xx	xx	xx	xx	xx
<i>Gyroscope</i>		yes	yes	1	
<i>Compass</i>	yes	yes	yes	no-inno	no-inno
<i>Hall (for flip covers)</i>	xx	xx	xx	xx	xx
<i>Barometer</i>	yes	yes		no-inno	no-inno
<i>Thermometer</i>	xx	xx	xx	xx	xx
<i>Hygrometer</i>	xx	xx	xx	xx	xx
<i>Light sensor</i>	yes	yes	yes	no-inno	no-inno
<i>Proximity sensor</i>	yes	yes	yes	no-inno	no-inno
<i>Gesture sensor</i>	xx	xx	xx	xx	xx
<i>UV sensor</i>	xx	xx	xx	xx	xx
Voice command			yes	no-inno	no-inno

Table: 20. Observation result of new-to-market and new-to-firm novelties: Note III

<i>Launched year</i>	2012	2013 (Oct)	2013 (Sep)		
Technical Specification	Note II	Note 3	iPhone 5S	FIRM	MARKET
1. DESIGN					
Materials			Aluminium alloy		
Colours	Blue, White	Black, Pink, White	Gold, Gray, Silver		1
2. RUGGEDNESS					
Splash	xx	xx	xx	xx	xx
Water	xx	xx	xx	xx	xx
Dust	xx	xx	xx	xx	xx
3. DISPLAY					
Physical size	5.5	5.7	4		
Resolution	1280 x 720	1920 x 1080	1136 x 640		1
Pixel density	265	386	326		1
Technology	Super AMOLED	Super AMOLED	Retina display	no-inno	no-inno
Screen-to-body ratio	69.9	74.78	60.82		1
Peak brightness			500 cd/m ²	no-inno	no-inno
Protection		Corning Gorilla Glass 3	Fingerprint-resistant oleophobic coating	no-inno	no-inno
Damage resistant glass	xx	xx	xx	xx	xx
3D touch	xx	xx	xx	xx	xx
Multitouch	yes	yes	yes	no-inno	no-inno
Shape			Flat	no-inno	no-inno
4. ATTACHED PEN					
Pressure levels	yes	yes		no-inno	no-inno
Pen Tip diameter	xx	xx	xx	xx	xx
Rugged	xx	xx	xx	xx	xx
<i>Live message</i>	xx	xx	xx	xx	xx
<i>Samsung Notes</i>	xx	xx	xx	xx	xx
<i>Screen off memo</i>	xx	xx	xx	xx	xx
<i>Smart select</i>	xx	xx	xx	xx	xx
<i>Screen write</i>	xx	xx	xx	xx	xx
<i>Translate</i>	xx	xx	xx	xx	xx
<i>Bixby Vision</i>	xx	xx	xx	xx	xx
<i>Glance</i>	xx	xx	xx	xx	xx
<i>Magnify</i>	xx	xx	xx	xx	xx

5. CAMERA					
Rear camera (wide angel)					
Pixels	8 mp	13	8		1
Flash	LED	LED	Dual LED	no-inno	no-inno
True tone flash			yes	no-inno	no-inno
Aperture size	2.6	2.2	2.2	1	
Pixel size		1.12	1.5	no-inno	no-inno
FOV	xx	xx	xx	xx	xx
Rear camera (telephoto)					
Pixels	xx	xx	xx	xx	xx
Aperture size	xx	xx	xx	xx	xx
Camera sensor size	xx	xx	xx	xx	xx
FOV	xx	xx	xx	xx	xx
Hardware Features					
<i>Optical image stabilization</i>	xx	xx	xx	xx	xx
<i>Autofocus</i>	yes	yes	yes	no-inno	no-inno
<i>Live focus (blur background)</i>	xx	xx	xx	xx	xx
<i>Sapphire crystal lens cover</i>			yes	xx	xx
<i>Back-illuminated sensor</i>	yes	yes	yes	no-inno	no-inno
Optical zoom	xx	xx	xx	xx	xx
Software Features					
<i>Manual focus</i>	xx	xx	xx	xx	xx
<i>Portrait lighting</i>	xx	xx	xx	xx	xx
<i>RAW image capture</i>	xx	xx	xx	xx	xx
<i>Touch to focus</i>	yes	yes	yes	no-inno	no-inno
<i>Smile detection</i>	yes	yes		no-inno	no-inno
<i>Face detection</i>	yes	yes	yes	no-inno	no-inno
<i>Body detection</i>	xx	xx	xx	xx	xx
<i>Grid line</i>	xx	xx	xx	xx	xx
<i>Auto image stabilisation</i>		yes	yes	1	
<i>Hybrid IR filter</i>			yes	no-inno	no-inno
<i>Filters</i>	xx	xx	xx	xx	xx
<i>Motion/Live photo</i>	xx	xx	xx	xx	xx
<i>Voice activation</i>	xx	xx	xx	xx	xx
<i>Live stickers</i>	xx	xx	xx	xx	xx
<i>Stamps</i>	xx	xx	xx	xx	xx
<i>Dual capture</i>	xx	xx	xx	xx	xx
<i>Noise reduction</i>	xx	xx	xx	xx	xx
<i>Self-timer</i>		yes			1

<i>Digital zoom</i>	4x	4x	5x	no-inno	no-inno
<i>Geo tagging</i>	yes	yes	yes	no-inno	no-inno
Settings					
<i>Exposure compensation</i>		yes	yes	1	
<i>ISO control</i>		yes			1
<i>White balance presets</i>		yes			1
<i>Shutter speed control</i>	xx	xx	xx	xx	xx
Shooting Modes					
<i>Burst mode</i>	yes	yes	yes	no-inno	no-inno
<i>Portrait mode</i>	xx	xx	xx	xx	xx
<i>High Dynamic Range (HDR)</i>	yes	yes	yes	no-inno	no-inno
<i>Panorama</i>	yes	yes	28	no-inno	no-inno
<i>Virtual shot</i>	xx	xx	xx	xx	xx
<i>Slow motion</i>	xx	xx	xx	xx	xx
<i>Macro mode</i>	xx	xx	xx	xx	xx
<i>Scene mode</i>		yes			1
<i>Food mode</i>	xx	xx	xx	xx	xx
<i>Pro mode</i>	xx	xx	xx	xx	xx
<i>Manual mode</i>	xx	xx	xx	xx	xx
Front camera					
Pixels	1.9	2	1.2		1
Flash	xx	xx	xx	xx	xx
Aperture size			2.4	no-inno	no-inno
Pixel size	xx	xx	xx	xx	xx
FOV	xx	xx	xx	xx	xx
Front camera features					
<i>Animoji</i>	xx	xx	xx	xx	xx
<i>HD video recording</i>			720p	no-inno	no-inno
<i>Auto HDR</i>			yes	no-inno	no-inno
<i>Backside illumination sensor</i>			yes	no-inno	no-inno
<i>Face detection</i>			yes	no-inno	no-inno
<i>Body detection</i>	xx	xx	xx	xx	xx
<i>Auto image stabilisation</i>	xx	xx	xx	xx	xx
<i>Burst mode</i>	xx	xx	xx	xx	xx
<i>Portrait mode</i>	xx	xx	xx	xx	xx
<i>Exposure control</i>			yes	no-inno	no-inno
<i>Timer mode</i>	xx	xx	xx	xx	xx
<i>Grid line</i>	xx	xx	xx	xx	xx
<i>Filters</i>	xx	xx	xx	xx	xx

<i>Selective focus</i>	xx	xx	xx	xx	xx
<i>Virtual shot</i>	xx	xx	xx	xx	xx
<i>Motion/Live photo</i>	xx	xx	xx	xx	xx
<i>Live stickers</i>	xx	xx	xx	xx	xx
<i>Stamps</i>	xx	xx	xx	xx	xx
<i>Voice control</i>	xx	xx	xx	xx	xx
Camcorder (video resolution)					
<i>3840x2160 (4K)</i>	xx	xx	xx	xx	xx
<i>1920x1080 (1080p HD)</i>	30	60	30		1
<i>1280x720 (720p HD)</i>		120 fps		no-inno	no-inno
<i>Video recoder</i>			yes	no-inno	no-inno
Video features					
<i>Time-lapse video</i>			yes	no-inno	no-inno
<i>Hyperlapse</i>	xx	xx	xx	xx	xx
<i>Continuous autofocus</i>		yes			1
<i>Tracking AF</i>	xx	xx	xx	xx	xx
<i>Picture-taking during video recording</i>			yes	no-inno	no-inno
<i>Video light</i>			yes	no-inno	no-inno
<i>Video calling</i>	yes		yes	no-inno	no-inno
<i>Video geo-tagging</i>			yes	no-inno	no-inno
<i>Optical zoom</i>	xx	xx	xx	xx	xx
<i>Digital zoom</i>		yes	3x	1	
<i>Slow motion</i>			120	no-inno	no-inno
<i>Face detection</i>		yes	yes	1	
<i>Body detection</i>	xx	xx	xx	xx	xx
<i>Playback zoom</i>	xx	xx	xx	xx	xx
<i>Digital video stabilisation</i>			yes	no-inno	no-inno
<i>Optical video stablisation</i>	xx	xx	xx	xx	xx
<i>Cinematic video stabilisation</i>	xx	xx	xx	xx	xx
<i>Noise reduction</i>	xx	xx	xx	xx	xx
6. HARDWARE					
System chip			A7		
Processor speed	1.6	2.3	1.3		1
Core	Quad-Core	Quad-Core	Dual-Core		1
Graphic processor GPU			450MHz	no-inno	no-inno
System memory	2GB	3GB	1GB		1
Built-in storage	16GB	64GB	64GB	1	
Storage expansion	yes	yes		no-inno	no-inno

64-BIT			yes	no-inno	no-inno
Nano sim			yes	no-inno	no-inno
Dual sim				no-inno	no-inno
7. BATTERY					
Capacity	3100 mAh	3200 mAh	1560 mAh		1
Type	lithium-ion	lithium-ion	lithium-ion	no-inno	no-inno
Wireless charging	xx	xx	xx	xx	xx
Fast-charge capability	xx	xx	xx	xx	xx
8. AUDIO					
High quality playback	xx	xx	xx	xx	xx
Recording quality	xx	xx	xx	xx	xx
Speakers	xx	xx	xx	xx	xx
<i>Earpiece</i>	YES	YES	yes	no-inno	no-inno
<i>Stereo speakers</i>	xx	xx	xx	xx	xx
<i>Loudspeaker</i>	YES	YES	yes	no-inno	no-inno
HD Voice	xx	xx	xx	xx	xx
9. VIDEO					
Split screen	xx	xx	xx	xx	xx
TV connection	yes		yes	no-inno	no-inno
10. CELLULAR					
2G		yes	yes	1	
3G		yes	yes	1	
4G LTE		yes	yes	1	
CDMA together		yes	yes	1	
11. CONNECTIVITY					
Bluetooth	4	4	4	no-inno	no-inno
Wi-Fi					
<i>802.11a</i>	yes	yes	yes	no-inno	no-inno
<i>802.11b</i>	yes	yes	yes	no-inno	no-inno
<i>802.11g</i>	yes	yes	yes	no-inno	no-inno
<i>802.11n</i>	yes	yes	yes	no-inno	no-inno
<i>802.11ac</i>		yes			1
<i>802.11n 5GHz</i>			yes	no-inno	no-inno
<i>Dual Band</i>	yes	yes	yes	no-inno	no-inno
<i>WiFi MiMO</i>	xx	xx	xx	xx	xx
<i>WiFi hotspot</i>		yes	yes	1	
Mobile hotspot	yes	yes	yes	no-inno	no-inno
Mobile Payment	xx	xx	xx	xx	xx
Positioning					

<i>GPS</i>		yes		no-inno	no-inno
<i>A-GPS</i>	yes	yes	yes	no-inno	no-inno
<i>Glonass</i>	yes	yes	yes	no-inno	no-inno
<i>Galileo</i>	xx	xx	xx	xx	xx
<i>Cell ID</i>			yes	no-inno	no-inno
<i>BeiDou</i>	xx	xx	xx	xx	xx
<i>QZSS</i>	xx	xx	xx	xx	xx
<i>Wi-Fi positioning</i>			yes	no-inno	no-inno
<i>iBeacon micro-location</i>			yes	no-inno	no-inno
12. PHONE FEATURES					
Haptic feedback	yes			no-inno	no-inno
Hearing aid compatibility	yes	yes	yes	no-inno	no-inno
3D facial recognition	xx	xx	xx	xx	xx
Bixby	xx	xx	xx	xx	xx
Sensors					
<i>Accelerometer</i>	yes	yes	yes	no-inno	no-inno
<i>Iris sensor</i>	xx	xx	xx	xx	xx
<i>Geomagnetic sensor</i>	xx	xx	xx	xx	xx
<i>Pressure sensor</i>	xx	xx	xx	xx	xx
<i>Fingerprint sensor</i>			yes	no-inno	no-inno
<i>HR sensor</i>	xx	xx	xx	xx	xx
<i>Face ID</i>	xx	xx	xx	xx	xx
<i>Gyroscope</i>	yes	yes	yes	no-inno	no-inno
<i>Compass</i>	yes	yes	yes	no-inno	no-inno
<i>Hall (for flip covers)</i>		yes			1
<i>Barometer</i>	yes	yes		no-inno	no-inno
<i>Thermometer</i>		yes			1
<i>Hygrometer</i>		yes			1
<i>Light sensor</i>	yes	yes	yes	no-inno	no-inno
<i>Proximity sensor</i>	yes	yes	yes	no-inno	no-inno
<i>Gesture sensor</i>	xx	xx	xx	xx	xx
<i>UV sensor</i>	xx	xx	xx	xx	xx
Voice command			yes	no-inno	no-inno

Table: 21. Observation result of new-to-market and new-to-firm novelties: Note Edge

<i>Launched year</i>	2013 (Oct)	2014 (Nov)	2014 (Sep)		
Technical Specification	Note 3	Note Edge	iPhone 6 Plus	FIRM	MARKET
1. DESIGN					
Materials			Aluminium alloy	no-inno	no-inno
Colours	Black, Pink, White	Black, White	Gold, Gray, Silver	no-inno	no-inno
2. RUGGEDNESS					
Splash	xx	xx	xx	xx	xx
Water	xx	xx	xx	xx	xx
Dust	xx	xx	xx	xx	xx
3. DISPLAY					
Physical size	5.7	5.6	5.5		
Resolution	1920 x 1080	2560 x 1440	1920 x 1080		1
Pixel density	386	525	401		1
Technology	Super AMOLED	Super AMOLED	Retina HD display	no-inno	no-inno
Screen-to-body ratio	74.78	69.39	67.91	no-inno	no-inno
Peak brightness			500 cd/m ²	no-inno	no-inno
Protection	Corning Gorilla Glass 3	Corning Gorilla Glass 4	Fingerprint-resistant oleophobic coating	no-inno	no-inno
Damage resistant glass	xx	xx	xx	xx	xx
3D touch	xx	xx	xx	xx	xx
Multitouch	yes	yes	yes	no-inno	no-inno
Shape		edge	Flat		1
4. ATTACHED PEN					
Pressure levels	yes	yes		no-inno	no-inno
Pen Tip diameter	xx	xx	xx	xx	xx
Rugged	xx	xx	xx	xx	xx
<i>Live message</i>	xx	xx	xx	xx	xx
<i>Samsung Notes</i>	xx	xx	xx	xx	xx
<i>Screen off memo</i>	xx	xx	xx	xx	xx
<i>Smart select</i>	xx	xx	xx	xx	xx
<i>Screen write</i>	xx	xx	xx	xx	xx
<i>Translate</i>	xx	xx	xx	xx	xx
<i>Bixby Vision</i>	xx	xx	xx	xx	xx
<i>Glance</i>	xx	xx	xx	xx	xx
<i>Magnify</i>	xx	xx	xx	xx	xx

5. CAMERA					
Rear camera (wide angel)					
Pixels	13	16	8		1
Flash	LED	LED	Dual LED	no-inno	no-inno
True tone flash			yes	no-inno	no-inno
Aperture size	2.2	2.2	2.2	no-inno	no-inno
Pixel size	1.12	1.12	1.5	no-inno	no-inno
FOV	xx	xx	xx	xx	xx
Rear camera (telephoto)					
Pixels	xx	xx	xx	xx	xx
Aperture size	xx	xx	xx	xx	xx
Camera sensor size	xx	xx	xx	xx	xx
FOV	xx	xx	xx	xx	xx
Hardware Features					
<i>Optical image stabilization</i>		yes	yes	1	
<i>Autofocus</i>	yes	yes	yes	no-inno	no-inno
<i>Live focus (blur background)</i>	xx	xx	xx	xx	xx
<i>Sapphire crystal lens cover</i>			yes	no-inno	no-inno
<i>Back-illuminated sensor</i>	yes	yes	yes	no-inno	no-inno
Optical zoom	xx	xx	xx	xx	xx
Software Features					
<i>Manual focus</i>		yes			1
<i>Portrait lighting</i>	xx	xx	xx	xx	xx
<i>RAW image capture</i>	xx	xx	xx	xx	xx
<i>Touch to focus</i>	yes	yes	yes	no-inno	no-inno
<i>Smile detection</i>	yes	yes		no-inno	no-inno
<i>Face detection</i>	yes	yes	yes	no-inno	no-inno
<i>Body detection</i>	xx	xx	xx	xx	xx
<i>Grid line</i>	xx	xx	xx	xx	xx
<i>Auto image stabilisation</i>	yes		yes	no-inno	no-inno
<i>Hybrid IR filter</i>			yes	no-inno	no-inno
<i>Filters</i>	xx	xx	xx	xx	xx
<i>Motion/Live photo</i>	xx	xx	xx	xx	xx
<i>Voice activation</i>	xx	xx	xx	xx	xx
<i>Live stickers</i>	xx	xx	xx	xx	xx
<i>Stamps</i>	xx	xx	xx	xx	xx
<i>Dual capture</i>	xx	xx	xx	xx	xx
<i>Noise reduction</i>	xx	xx	xx	xx	xx
<i>Self-timer</i>	yes	yes	yes	no-inno	no-inno

<i>Digital zoom</i>	4x	4x	5x	no-inno	no-inno
<i>Geo tagging</i>	yes	yes	yes	no-inno	no-inno
Settings					
<i>Exposure compensation</i>	yes	yes	yes	no-inno	no-inno
<i>ISO control</i>	yes	yes		no-inno	no-inno
<i>White balance presets</i>	yes	yes		no-inno	no-inno
<i>Shutter speed control</i>	xx	xx	xx	xx	xx
Shooting Modes					
<i>Burst mode</i>	yes	yes	yes	no-inno	no-inno
<i>Portrait mode</i>	xx	xx	xx	xx	xx
<i>High Dynamic Range (HDR)</i>	yes	yes	yes	no-inno	no-inno
<i>Panorama</i>	yes	yes	43	no-inno	no-inno
<i>Virtual shot</i>	xx	xx	xx	xx	xx
<i>Slow motion</i>		60 fps			1
<i>Macro mode</i>	xx	xx	xx	xx	xx
<i>Scene mode</i>	yes	yes		no-inno	no-inno
<i>Food mode</i>	xx	xx	xx	xx	xx
<i>Pro mode</i>	xx	xx	xx	xx	xx
<i>Manual mode</i>	xx	xx	xx	xx	xx
Front camera					
Pixels	2	3.7	1.2		1
Flash	xx	xx	xx	xx	xx
Aperture size			2.2	no-inno	no-inno
Pixel size	xx	xx	xx	xx	xx
FOV	xx	xx	xx	xx	xx
Front camera features					
<i>Animoji</i>	xx	xx	xx	xx	xx
<i>HD video recording</i>			720p	no-inno	no-inno
<i>Auto HDR</i>			yes	no-inno	no-inno
<i>Backside illumination sensor</i>			yes	no-inno	no-inno
<i>Face detection</i>			yes	no-inno	no-inno
<i>Body detection</i>	xx	xx	xx	xx	xx
<i>Auto image stabilisation</i>	xx	xx	xx	xx	xx
<i>Burst mode</i>			yes	no-inno	no-inno
<i>Portrait mode</i>	xx	xx	xx	xx	xx
<i>Exposure control</i>			yes	no-inno	no-inno
<i>Timer mode</i>			yes	no-inno	no-inno
<i>Grid line</i>	xx	xx	xx	xx	xx
<i>Filters</i>	xx	xx	xx	xx	xx

<i>Selective focus</i>	xx	xx	xx	xx	xx
<i>Virtual shot</i>	xx	xx	xx	xx	xx
<i>Motion/Live photo</i>	xx	xx	xx	xx	xx
<i>Live stickers</i>	xx	xx	xx	xx	xx
<i>Stamps</i>	xx	xx	xx	xx	xx
<i>Voice control</i>	xx	xx	xx	xx	xx
Camcorder (video resolution)					
<i>3840x2160 (4K)</i>		30			1
<i>1920x1080 (1080p HD)</i>	60	30	30, 60	no-inno	no-inno
<i>1280x720 (720p HD)</i>	120 fps		240	no-inno	no-inno
<i>Video recoder</i>			yes	no-inno	no-inno
Video features					
<i>Time-lapse video</i>			yes	no-inno	no-inno
<i>Hyperlapse</i>	xx	xx	xx	xx	xx
<i>Continuous autofocus</i>	yes	yes	yes	no-inno	no-inno
<i>Tracking AF</i>	xx	xx	xx	xx	xx
<i>Picture-taking during video recording</i>		yes	yes	1	
<i>Video light</i>			yes	no-inno	no-inno
<i>Video calling</i>			yes	no-inno	no-inno
<i>Video geo-tagging</i>			yes	no-inno	no-inno
<i>Optical zoom</i>	xx	xx	xx	xx	xx
<i>Digital zoom</i>	yes		3x	no-inno	no-inno
<i>Slow motion</i>		60 fps	120	1	
<i>Face detection</i>	yes		yes	no-inno	no-inno
<i>Body detection</i>	xx	xx	xx	xx	xx
<i>Playback zoom</i>	xx	xx	xx	xx	xx
<i>Digital video stabilisation</i>	xx	xx	xx	xx	xx
<i>Optical video stablisation</i>		yes			1
<i>Cinematic video stabilisation</i>			yes	no-inno	no-inno
<i>Noise reduction</i>	xx	xx	xx	xx	xx
6. HARDWARE					
System chip			A8		
Processor speed	2.3	2.7	1.4		1
Core	Quad-Core	Quad-Core	Dual-Core	no-inno	no-inno
Graphic processor GPU			450MHz	no-inno	no-inno
System memory	3GB	3GB	1GB	no-inno	no-inno
Built-in storage	64GB	32GB	128GB	no-inno	no-inno
Storage expansion	yes	yes		no-inno	no-inno

64-BIT		yes	yes	1	
Nano sim			yes	no-inno	no-inno
Dual sim	xx	xx	xx	xx	xx
7. BATTERY					
Capacity	3200 mAh	3000 mAh	2915 mAh	no-inno	no-inno
Type	lithium-ion	lithium-ion	lithium-ion	no-inno	no-inno
Wireless charging		yes			1
Fast-charge capability		yes			1
8. AUDIO					
High quality playback	xx	xx	xx	xx	xx
Recording quality	xx	xx	xx	xx	xx
Speakers	xx	xx	xx	xx	xx
<i>Earpiece</i>	yes	yes	yes	no-inno	no-inno
<i>Stereo speakers</i>	xx	xx	xx	xx	xx
<i>Loudspeaker</i>	yes	yes	yes	no-inno	no-inno
HD Voice			yes	no-inno	no-inno
9. VIDEO					
Split screen	xx	xx	xx	xx	xx
TV connection	yes	yes	yes	no-inno	no-inno
10. CELLULAR					
2G	yes	yes	yes	no-inno	no-inno
3G	yes	yes	yes	no-inno	no-inno
4G LTE	yes	yes	yes	no-inno	no-inno
CDMA together	yes	yes	yes	no-inno	no-inno
11. CONNECTIVITY					
Bluetooth	4	4.1	4.2	1	
Wi-Fi					
<i>802.11a</i>	yes	yes	yes	no-inno	no-inno
<i>802.11b</i>	yes	yes	yes	no-inno	no-inno
<i>802.11g</i>	yes	yes	yes	no-inno	no-inno
<i>802.11n</i>	yes	yes	yes	no-inno	no-inno
<i>802.11ac</i>	yes	yes		no-inno	no-inno
<i>802.11n 5GHz</i>		yes	yes	1	
<i>Dual Band</i>	yes	yes	yes	no-inno	no-inno
<i>WiFi MiMO</i>		yes			1
<i>WiFi hotspot</i>	yes	yes	yes	no-inno	no-inno
Mobile hotspot	yes	yes	yes	no-inno	no-inno
Mobile Payment			yes	no-inno	no-inno
Positioning					

<i>GPS</i>	yes	yes		no-inno	no-inno
<i>A-GPS</i>	yes		yes	no-inno	no-inno
<i>Glonass</i>	yes	yes	yes	no-inno	no-inno
<i>Galileo</i>	xx	xx	xx	xx	xx
<i>Cell ID</i>			yes	no-inno	no-inno
<i>BeiDou</i>	xx	xx	xx	xx	xx
<i>QZSS</i>	xx	xx	xx	xx	xx
<i>Wi-Fi positioning</i>			yes	no-inno	no-inno
<i>iBeacon micro-location</i>			yes	no-inno	no-inno
12. PHONE FEATURES					
Haptic feedback			yes	no-inno	no-inno
Hearing aid compatibility	yes		yes	no-inno	no-inno
3D facial recognition	xx	xx	xx	xx	xx
Bixby	xx	xx	xx	xx	xx
Sensors					
<i>Accelerometer</i>	yes	yes	yes	no-inno	no-inno
<i>Iris sensor</i>	xx	xx	xx	xx	xx
<i>Geomagnetic sensor</i>		yes			1
<i>Pressure sensor</i>	xx	xx	xx	xx	xx
<i>Fingerprint sensor</i>		yes	yes	1	
<i>HR sensor</i>		yes			1
<i>Face ID</i>	xx	xx	xx	xx	xx
<i>Gyroscope</i>	yes	yes	yes	no-inno	no-inno
<i>Compass</i>	yes		yes	no-inno	no-inno
<i>Hall (for flip covers)</i>	yes	yes		no-inno	no-inno
<i>Barometer</i>	yes	yes	yes	no-inno	no-inno
<i>Thermometer</i>	yes			no-inno	no-inno
<i>Hygrometer</i>	yes			no-inno	no-inno
<i>Light sensor</i>	yes	yes	yes	no-inno	no-inno
<i>Proximity sensor</i>	yes	yes	yes	no-inno	no-inno
<i>Gesture sensor</i>		yes			1
<i>UV sensor</i>		yes			1
Voice command		yes	yes	1	

Table: 22. Observation result of new-to-market and new-to-firm novelties: Note V

<i>Launched year</i>	2014 (Nov)	2015 (Aug)	2014 (Sep)		
Technical Specification	Note Edge	Note 5	iPhone 6 Plus	FIRM	MARKET
1. DESIGN					
Materials		Glass; Metal	Aluminium alloy	1	
Colours	Black, White	Black, Gold, Silver, White	Gold, Gray, Silver	1	
2. RUGGEDNESS					
Splash	xx	xx	xx	xx	xx
Water	xx	xx	xx	xx	xx
Dust	xx	xx	xx	xx	xx
3. DISPLAY					
Physical size	5.6	5.7	5.5	no-inno	no-inno
Resolution	2560 x 1440	2560 x 1440	1920 x 1080	no-inno	no-inno
Pixel density	525	518	401	no-inno	no-inno
Technology	Super AMOLED	Super AMOLED	Retina HD display	no-inno	no-inno
Screen-to-body ratio	69.39	76.62	67.91		1
Peak brightness			500 cd/m ²	no-inno	no-inno
Protection	Corning Gorilla Glass 4	Corning Gorilla Glass 4	Fingerprint-resistant oleophobic coating	no-inno	no-inno
Damage resistant glass	xx	xx	xx	xx	xx
3D touch	xx	xx	xx	xx	xx
Multitouch	yes	yes	yes	no-inno	no-inno
Shape	edge		Flat	no-inno	no-inno
4. ATTACHED PEN					
Pressure levels	yes	yes		no-inno	no-inno
Pen Tip diameter	xx	xx	xx	xx	xx
Rugged	xx	xx	xx	xx	xx
<i>Live message</i>	xx	xx	xx	xx	xx
<i>Samsung Notes</i>	xx	xx	xx	xx	xx
<i>Screen off memo</i>	xx	xx	xx	xx	xx
<i>Smart select</i>	xx	xx	xx	xx	xx
<i>Screen write</i>	xx	xx	xx	xx	xx
<i>Translate</i>	xx	xx	xx	xx	xx
<i>Bixby Vision</i>	xx	xx	xx	xx	xx
<i>Glance</i>	xx	xx	xx	xx	xx
<i>Magnify</i>	xx	xx	xx	xx	xx

5. CAMERA					
Rear camera (wide angel)					
Pixels	16	16	8		1
Flash	LED	Dual LED	Dual LED	1	
True tone flash			yes	no-inno	no-inno
Aperture size	2.2	1.9	2.2		1
Pixel size	1.12	1.12	1.5	no-inno	no-inno
FOV	xx	xx	xx	xx	xx
Rear camera (telephoto)					
Pixels	xx	xx	xx	xx	xx
Aperture size	xx	xx	xx	xx	xx
Camera sensor size	xx	xx	xx	xx	xx
FOV	xx	xx	xx	xx	xx
Hardware Features					
<i>Optical image stabilization</i>	yes	yes	yes	no-inno	no-inno
<i>Autofocus</i>	yes	yes	yes	no-inno	no-inno
<i>Live focus (blur background)</i>	xx	xx	xx	xx	xx
<i>Sapphire crystal lens cover</i>			yes	no-inno	no-inno
<i>Back-illuminated sensor</i>	yes	yes	yes	no-inno	no-inno
Optical zoom	xx	xx	xx	xx	xx
Software Features					
<i>Manual focus</i>	yes			no-inno	no-inno
<i>Portrait lighting</i>	xx	xx	xx	xx	xx
<i>RAW image capture</i>		yes			1
<i>Touch to focus</i>	yes	yes	yes	no-inno	no-inno
<i>Smile detection</i>	yes			no-inno	no-inno
<i>Face detection</i>	yes	yes	yes	no-inno	no-inno
<i>Body detection</i>	xx	xx	xx	xx	xx
<i>Grid line</i>	xx	xx	xx	xx	xx
<i>Auto image stabilisation</i>		yes	yes	1	
<i>Hybrid IR filter</i>			yes	no-inno	no-inno
<i>Filters</i>	xx	xx	xx	xx	xx
<i>Motion/Live photo</i>	xx	xx	xx	xx	xx
<i>Voice activation</i>	xx	xx	xx	xx	xx
<i>Live stickers</i>	xx	xx	xx	xx	xx
<i>Stamps</i>	xx	xx	xx	xx	xx
<i>Dual capture</i>	xx	xx	xx	xx	xx
<i>Noise reduction</i>	xx	xx	xx	xx	xx
<i>Self-timer</i>	yes	yes	yes	no-inno	no-inno

<i>Digital zoom</i>	4x	8x	5x		1
<i>Geo tagging</i>	yes	yes	yes	no-inno	no-inno
Settings					
<i>Exposure compensation</i>	yes	yes	yes	no-inno	no-inno
<i>ISO control</i>	yes	yes		no-inno	no-inno
<i>White balance presets</i>	yes	yes		no-inno	no-inno
<i>Shutter speed control</i>		yes			1
Shooting Modes					
<i>Burst mode</i>	yes	yes	yes	no-inno	no-inno
<i>Portrait mode</i>	xx	xx	xx	xx	xx
<i>High Dynamic Range (HDR)</i>	yes	yes	yes	no-inno	no-inno
<i>Panorama</i>	yes	yes	43	no-inno	no-inno
<i>Virtual shot</i>	xx	xx	xx	xx	xx
<i>Slow motion</i>	60 fps	120 fps			1
<i>Macro mode</i>		yes			1
<i>Scene mode</i>	yes	yes		no-inno	no-inno
<i>Food mode</i>	xx	xx	xx	xx	xx
<i>Pro mode</i>	xx	xx	xx	xx	xx
<i>Manual mode</i>	xx	xx	xx	xx	xx
Front camera					
Pixels	3.7	5	1.2		1
Flash	xx	xx	xx	xx	xx
Aperture size			2.2	no-inno	no-inno
Pixel size	xx	xx	xx	xx	xx
FOV	xx	xx	xx	xx	xx
Front camera features					
<i>Animoji</i>	xx	xx	xx	xx	xx
<i>HD video recording</i>			720p	no-inno	no-inno
<i>Auto HDR</i>			yes	no-inno	no-inno
<i>Backside illumination sensor</i>			yes	no-inno	no-inno
<i>Face detection</i>			yes	no-inno	no-inno
<i>Body detection</i>	xx	xx	xx	xx	xx
<i>Auto image stabilisation</i>	xx	xx	xx	xx	xx
<i>Burst mode</i>			yes	no-inno	no-inno
<i>Portrait mode</i>	xx	xx	xx	xx	xx
<i>Exposure control</i>			yes	no-inno	no-inno
<i>Timer mode</i>			yes	no-inno	no-inno
<i>Grid line</i>	xx	xx	xx	xx	xx
<i>Filters</i>	xx	xx	xx	xx	xx

<i>Selective focus</i>	xx	xx	xx	xx	xx
<i>Virtual shot</i>	xx	xx	xx	xx	xx
<i>Motion/Live photo</i>	xx	xx	xx	xx	xx
<i>Live stickers</i>	xx	xx	xx	xx	xx
<i>Stamps</i>	xx	xx	xx	xx	xx
<i>Voice control</i>	xx	xx	xx	xx	xx
Camcorder (video resolution)					
<i>3840x2160 (4K)</i>	30	30		no-inno	no-inno
<i>1920x1080 (1080p HD)</i>	30	60	30, 60	1	
<i>1280x720 (720p HD)</i>		yes	240	1	
<i>Video recoder</i>			yes	no-inno	no-inno
Video features					
<i>Time-lapse video</i>			yes	no-inno	no-inno
<i>Hyperlapse</i>	xx	xx	xx	xx	xx
<i>Continuous autofocus</i>	yes	yes	yes	no-inno	no-inno
<i>Tracking AF</i>		yes			1
<i>Picture-taking during video recording</i>	yes		yes	no-inno	no-inno
<i>Video light</i>			yes	no-inno	no-inno
<i>Video calling</i>		yes	yes	1	
<i>Video geo-tagging</i>			yes	no-inno	no-inno
<i>Optical zoom</i>	xx	xx	xx	xx	xx
<i>Digital zoom</i>			3x	no-inno	no-inno
<i>Slow motion</i>	60 fps		120	no-inno	no-inno
<i>Face detection</i>			yes	no-inno	no-inno
<i>Body detection</i>	xx	xx	xx	xx	xx
<i>Playback zoom</i>	xx	xx	xx	xx	xx
<i>Digital video stabilisation</i>		yes			1
<i>Optical video stablisation</i>	yes	yes		no-inno	no-inno
<i>Cinematic video stabilisation</i>			yes	no-inno	no-inno
<i>Noise reduction</i>	xx	xx	xx	xx	xx
6. HARDWARE					
System chip			A8		
Processor speed	2.7	2.1GHz, 1.5GHz;	1.4		1
Core	Quad-Core	Octa-core	Dual-Core		1
Graphic processor GPU			450MHz	no-inno	no-inno
System memory	3GB	4GB	1GB		1
Built-in storage	32GB	32GB	128GB	no-inno	no-inno
Storage expansion	yes			no-inno	no-inno

64-BIT	yes	yes	yes	no-inno	no-inno
Nano sim		yes	yes	1	
Dual sim	xx	xx	xx	xx	xx
7. BATTERY					
Capacity	3000 mAh	3000 mAh	2915 mAh	no-inno	no-inno
Type	lithium-ion	lithium-ion	lithium-ion	no-inno	no-inno
Wireless charging	yes	yes		no-inno	no-inno
Fast-charge capability	yes	yes		no-inno	no-inno
8. AUDIO					
High quality playback	xx	xx	xx	xx	xx
Recording quality	xx	xx	xx	xx	xx
Speakers	xx	xx	xx	xx	xx
<i>Earpiece</i>	yes	yes	yes	no-inno	no-inno
<i>Stereo speakers</i>	xx	xx	xx	xx	xx
<i>Loudspeaker</i>	yes	yes	yes	no-inno	no-inno
HD Voice			yes	no-inno	no-inno
9. VIDEO					
Split screen	xx	xx	xx	xx	xx
TV connection	yes		yes	no-inno	no-inno
10. CELLULAR					
2G	yes	yes	yes	no-inno	no-inno
3G	yes	yes	yes	no-inno	no-inno
4G LTE	yes	yes	yes	no-inno	no-inno
CDMA together	yes	yes	yes	no-inno	no-inno
11. CONNECTIVITY					
Bluetooth	4.1	4.2	4.2	1	
Wi-Fi					
<i>802.11a</i>	yes	yes	yes	no-inno	no-inno
<i>802.11b</i>	yes	yes	yes	no-inno	no-inno
<i>802.11g</i>	yes	yes	yes	no-inno	no-inno
<i>802.11n</i>	yes	yes	yes	no-inno	no-inno
<i>802.11ac</i>	yes	yes		no-inno	no-inno
<i>802.11n 5GHz</i>	yes	yes	yes	no-inno	no-inno
<i>Dual Band</i>	yes	yes	yes	no-inno	no-inno
<i>WiFi MiMO</i>	yes	yes		no-inno	no-inno
<i>WiFi hotspot</i>	yes	yes	yes	no-inno	no-inno
Mobile hotspot	yes	yes	yes	no-inno	no-inno
Mobile Payment		yes	yes	1	
Positioning					

<i>GPS</i>	yes	yes		no-inno	no-inno
<i>A-GPS</i>			yes	no-inno	no-inno
<i>Glonass</i>	yes	yes	yes	no-inno	no-inno
<i>Galileo</i>	xx	xx	xx	xx	xx
<i>Cell ID</i>			yes	no-inno	no-inno
<i>BeiDou</i>		yes			1
<i>QZSS</i>	xx	xx	xx	xx	xx
<i>Wi-Fi positioning</i>			yes	no-inno	no-inno
<i>iBeacon micro-location</i>			yes	no-inno	no-inno
12. PHONE FEATURES					
Haptic feedback			yes	no-inno	no-inno
Hearing aid compatibility			yes	no-inno	no-inno
3D facial recognition	xx	xx	xx	xx	xx
Bixby	xx	xx	xx	xx	xx
Sensors					
<i>Accelerometer</i>	yes	yes	yes	no-inno	no-inno
<i>Iris sensor</i>	xx	xx	xx	xx	xx
<i>Geomagnetic sensor</i>	yes	yes		no-inno	no-inno
<i>Pressure sensor</i>	xx	xx	xx	xx	xx
<i>Fingerprint sensor</i>	yes	yes	yes	no-inno	no-inno
<i>HR sensor</i>	yes	yes		no-inno	no-inno
<i>Face ID</i>	xx	xx	xx	xx	xx
<i>Gyroscope</i>	yes	yes	yes	no-inno	no-inno
<i>Compass</i>			yes	no-inno	no-inno
<i>Hall (for flip covers)</i>	yes	yes		no-inno	no-inno
<i>Barometer</i>	yes	yes	yes	no-inno	no-inno
<i>Thermometer</i>	xx	xx	xx	xx	xx
<i>Hygrometer</i>	xx	xx	xx	xx	xx
<i>Light sensor</i>	yes	yes	yes	no-inno	no-inno
<i>Proximity sensor</i>	yes	yes	yes	no-inno	no-inno
<i>Gesture sensor</i>	yes			no-inno	no-inno
<i>UV sensor</i>	yes			no-inno	no-inno
Voice command	yes		yes	no-inno	no-inno

Table: 23. Observation result of new-to-market and new-to-firm novelties: S7 Edge

<i>Launched year</i>	2015 (Aug)	2016 (Mar)	2015 (Sep)		
Technical Specification	Note 5	Galaxy S7 Edge	iPhone 6S Plus	FIRM	MARKET
1. DESIGN					
Materials	Glass; Metal	Glass; Aluminum	Aluminium alloy		
Colours	Black, Gold, Silver, White	Silver, Titanium	Gold, Gray, Silver, Pink, White	1	
2. RUGGEDNESS					
Splash	xx	xx	xx	xx	xx
Water		IP68			1
Dust		IP68			1
3. DISPLAY					
Physical size	5.7	5.5	5.5		
Resolution	2560 x 1440	2560 x 1440	1920 x 1080	no-inno	no-inno
Pixel density	518	534	401		1
Technology	Super AMOLED	Super AMOLED	Retina HD display, LCD	no-inno	no-inno
Screen-to-body ratio	76.62	76.09	67.91	no-inno	no-inno
Peak brightness			500 cd/m ²	no-inno	no-inno
Protection	Corning Gorilla Glass 4	Corning Gorilla Glass 6	Fingerprint- resistant oleophobic coating	1	
Damage resistant glass	xx	xx	xx	xx	xx
3D touch			Yes	no-inno	no-inno
Multitouch	yes	yes	Yes	no-inno	no-inno
Shape		edge	Flat	no-inno	no-inno
4. ATTACHED PEN					
Pressure levels	yes			no-inno	no-inno
Pen Tip diameter	xx	xx	xx	xx	xx
Rugged	xx	xx	xx	xx	xx
<i>Live message</i>	xx	xx	xx	xx	xx
<i>Samsung Notes</i>	xx	xx	xx	xx	xx
<i>Screen off memo</i>	xx	xx	xx	xx	xx
<i>Smart select</i>	xx	xx	xx	xx	xx
<i>Screen write</i>	xx	xx	xx	xx	xx
<i>Translate</i>	xx	xx	xx	xx	xx
<i>Bixby Vision</i>	xx	xx	xx	xx	xx
<i>Glance</i>	xx	xx	xx	xx	xx
<i>Magnify</i>	xx	xx	xx	xx	xx

5. CAMERA					
Rear camera (wide angel)					
Pixels	16	12	12	no-inno	no-inno
Flash	Dual LED	Dual LED	Dual LED	no-inno	no-inno
True tone flash			Yes	no-inno	no-inno
Aperture size	1.9	1.7	2.2	no-inno	no-inno
Pixel size	1.12	1.4	1.22	no-inno	no-inno
FOV	xx	xx	xx	xx	xx
Rear camera (telephoto)					
Pixels		12		no-inno	no-inno
Aperture size	xx	xx	xx	xx	xx
Camera sensor size	xx	xx	xx	xx	xx
FOV	xx	xx	xx	xx	xx
Hardware Features					
<i>Optical image stabilization</i>	yes	yes	Yes	no-inno	no-inno
<i>Autofocus</i>	yes	yes	Yes	no-inno	no-inno
<i>Live focus (blur background)</i>	xx	xx	xx	xx	xx
<i>Sapphire crystal lens cover</i>			Yes	no-inno	no-inno
<i>Back-illuminated sensor</i>	yes		Yes	no-inno	no-inno
Optical zoom	xx	xx	xx	xx	xx
Software Features					
<i>Manual focus</i>			Yes	no-inno	no-inno
<i>Portrait lighting</i>	xx	xx	xx	xx	xx
<i>RAW image capture</i>	yes	yes		no-inno	no-inno
<i>Touch to focus</i>	yes	yes	Yes	no-inno	no-inno
<i>Smile detection</i>		yes			1
<i>Face detection</i>	yes		Yes		
<i>Body detection</i>	xx	xx	xx	xx	xx
<i>Grid line</i>	xx	xx	xx	xx	xx
<i>Auto image stabilisation</i>	yes		Yes	no-inno	no-inno
<i>Hybrid IR filter</i>			Yes		
<i>Filters</i>	xx	xx	xx	xx	xx
<i>Motion/Live photo</i>			Yes	no-inno	no-inno
<i>Voice activation</i>	xx	xx	xx	xx	xx
<i>Live stickers</i>	xx	xx	xx	xx	xx
<i>Stamps</i>	xx	xx	xx	xx	xx
<i>Dual capture</i>	xx	xx	xx	xx	xx
<i>Noise reduction</i>			Yes	no-inno	no-inno
<i>Self-timer</i>	yes	yes	Yes	no-inno	no-inno

<i>Digital zoom</i>	8x		5x	no-inno	no-inno
<i>Geo tagging</i>	yes	yes	Yes	no-inno	no-inno
Settings					
<i>Exposure compensation</i>	yes	yes	Yes	no-inno	no-inno
<i>ISO control</i>	yes	yes		no-inno	no-inno
<i>White balance presets</i>	yes	yes		no-inno	no-inno
<i>Shutter speed control</i>	yes			no-inno	no-inno
Shooting Modes					
<i>Burst mode</i>	yes	yes	Yes	no-inno	no-inno
<i>Portrait mode</i>	xx	xx	xx	xx	xx
<i>High Dynamic Range (HDR)</i>	yes	yes	Yes	no-inno	no-inno
<i>Panorama</i>	yes	yes	63	no-inno	no-inno
<i>Virtual shot</i>	xx	xx	xx	xx	xx
<i>Slow motion</i>	120 fps			no-inno	no-inno
<i>Macro mode</i>	yes			no-inno	no-inno
<i>Scene mode</i>	yes	yes		no-inno	no-inno
<i>Food mode</i>	xx	xx	xx	xx	xx
<i>Pro mode</i>	xx	xx	xx	xx	xx
<i>Manual mode</i>	xx	xx	xx	xx	xx
Front camera					
Pixels	5	5	5	no-inno	no-inno
Flash			Yes	no-inno	no-inno
Aperture size			2.2	no-inno	no-inno
Pixel size	xx	xx	xx	xx	xx
FOV	xx	xx	xx	xx	xx
Front camera features					
<i>Animoji</i>	xx	xx	xx	xx	xx
<i>HD video recording</i>			720p	no-inno	no-inno
<i>Auto HDR</i>		yes	Yes	1	
<i>Backside illumination sensor</i>			Yes	no-inno	no-inno
<i>Face detection</i>			Yes	no-inno	no-inno
<i>Body detection</i>	xx	xx	xx	xx	xx
<i>Auto image stabilisation</i>	xx	xx	xx	xx	xx
<i>Burst mode</i>			Yes	no-inno	no-inno
<i>Portrait mode</i>	xx	xx	xx	xx	xx
<i>Exposure control</i>			Yes	no-inno	no-inno
<i>Timer mode</i>	xx	xx	xx	xx	xx
<i>Grid line</i>	xx	xx	xx	xx	xx
<i>Filters</i>	xx	xx	xx	xx	xx

<i>Selective focus</i>	xx	xx	xx	xx	xx
<i>Virtual shot</i>	xx	xx	xx	xx	xx
<i>Motion/Live photo</i>	xx	xx	xx	xx	xx
<i>Live stickers</i>	xx	xx	xx	xx	xx
<i>Stamps</i>	xx	xx	xx	xx	xx
<i>Voice control</i>	xx	xx	xx	xx	xx
Camcorder (video resolution)					
<i>3840x2160 (4K)</i>	30	30	30	no-inno	no-inno
<i>1920x1080 (1080p HD)</i>	60	60	30, 60	no-inno	no-inno
<i>1280x720 (720p HD)</i>	yes	240	30	no-inno	no-inno
<i>Video recoder</i>	yes	yes	yes	no-inno	no-inno
Video features					
<i>Time-lapse video</i>			Yes	no-inno	no-inno
<i>Hyperlapse</i>	xx	xx	xx	xx	xx
<i>Continuous autofocus</i>	yes		Yes	no-inno	no-inno
<i>Tracking AF</i>	yes			no-inno	no-inno
<i>Picture-taking during video recording</i>		yes	8mp	1	
<i>Video light</i>			dual-led	no-inno	no-inno
<i>Video calling</i>	yes	yes	yes	no-inno	no-inno
<i>Video geo-tagging</i>			Yes	no-inno	no-inno
<i>Optical zoom</i>	xx	xx	xx	xx	xx
<i>Digital zoom</i>			3x	no-inno	no-inno
<i>Slow motion</i>		240fps	120fps		1
<i>Face detection</i>			Yes		
<i>Body detection</i>	xx	xx	xx	xx	xx
<i>Playback zoom</i>			Yes	no-inno	no-inno
<i>Digital video stabilisation</i>	yes			no-inno	no-inno
<i>Optical video stablisation</i>	yes		yes	no-inno	no-inno
<i>Cinematic video stabilisation</i>			Yes	no-inno	no-inno
<i>Noise reduction</i>			Yes	no-inno	no-inno
6. HARDWARE					
System chip			A9		
Processor speed	2.1GHz, 1.5GHz;	2.15GHz, 1.6GHz	1.84 GHz		1
Core	Octa-core	Quad-Core	Duo-Core	no-inno	no-inno
Graphic processor GPU	xx	xx	xx	xx	xx
System memory	4GB	4GB	2GB	no-inno	no-inno
Built-in storage	32GB	64GB	128GB	1	
Storage expansion		yes		1	

64-BIT	yes	yes	Yes		
Nano sim	yes	yes	yes	no-inno	no-inno
Dual sim	xx	xx	xx	xx	xx
7. BATTERY					
Capacity	3000 mAh	3600 mAh	2750 mAh		1
Type	lithium-ion	lithium-ion	lithium-ion	no-inno	no-inno
Wireless charging	yes	yes		no-inno	no-inno
Fast-charge capability	yes	yes		no-inno	no-inno
8. AUDIO					
High quality playback	xx	xx	xx	xx	xx
Recording quality	xx	xx	xx	xx	xx
Speakers	xx	xx	xx	xx	xx
<i>Earpiece</i>	yes	yes	yes	no-inno	no-inno
<i>Stereo speakers</i>	xx	xx	xx	xx	xx
<i>Loudspeaker</i>	yes	yes	yes	no-inno	no-inno
HD Voice		yes	Yes	1	
9. VIDEO					
Split screen	xx	xx	xx	xx	xx
TV connection			yes	no-inno	no-inno
10. CELLULAR					
2G	yes	yes	yes	no-inno	no-inno
3G	yes	yes	yes	no-inno	no-inno
4G LTE	yes	yes	yes	no-inno	no-inno
CDMA together	yes	yes	yes	no-inno	no-inno
11. CONNECTIVITY					
Bluetooth	4.2	4.2	4.2	no-inno	no-inno
Wi-Fi					
<i>802.11 a</i>	yes	yes	yes	no-inno	no-inno
<i>802.11 b</i>	yes	yes	yes	no-inno	no-inno
<i>802.11 g</i>	yes	yes	yes	no-inno	no-inno
<i>802.11 n</i>	yes	yes	yes	no-inno	no-inno
<i>802.11 ac</i>	yes	yes	yes	no-inno	no-inno
<i>802.11n 5GHz</i>	yes	yes	yes	no-inno	no-inno
<i>Dual Band</i>	yes	yes	yes	no-inno	no-inno
<i>WiFi MiMO</i>	yes	yes		no-inno	no-inno
<i>WiFi hotspot</i>	yes		Yes	no-inno	no-inno
Mobile hotspot	yes	yes	yes	no-inno	no-inno
Mobile Payment	yes	yes	yes	no-inno	no-inno
Positioning					

<i>GPS</i>	yes	yes		no-inno	no-inno
<i>A-GPS</i>			yes	no-inno	no-inno
<i>Glomass</i>	yes	yes	yes	no-inno	no-inno
<i>Galileo</i>			yes	no-inno	no-inno
<i>Cell ID</i>			yes	no-inno	no-inno
<i>BeiDou</i>	yes	yes		no-inno	no-inno
<i>QZSS</i>			yes	no-inno	no-inno
<i>Wi-Fi positioning</i>			yes	no-inno	no-inno
<i>iBeacon micro-location</i>			yes	no-inno	no-inno
12. PHONE FEATURES					
Haptic feedback	yes	yes	yes	no-inno	no-inno
Hearing aid compatibility	yes	yes	yes	no-inno	no-inno
3D facial recognition	xx	xx	xx	xx	xx
Bixby	xx	xx	xx	xx	xx
Sensors					
<i>Accelerometer</i>	yes	yes	yes	no-inno	no-inno
<i>Iris sensor</i>	xx	xx	xx	xx	xx
<i>Geomagnetic sensor</i>	yes	yes		no-inno	no-inno
<i>Pressure sensor</i>	xx	xx	xx	xx	xx
<i>Fingerprint sensor</i>	yes	yes	yes	no-inno	no-inno
<i>HR sensor</i>	yes	yes		no-inno	no-inno
<i>Face ID</i>	xx	xx	xx	xx	xx
<i>Gyroscope</i>	yes	yes	yes	no-inno	no-inno
<i>Compass</i>			yes	no-inno	no-inno
<i>Hall (for flip covers)</i>	yes	yes		no-inno	no-inno
<i>Barometer</i>	yes	yes	yes	no-inno	no-inno
<i>Thermometer</i>	xx	xx	xx	xx	xx
<i>Hygrometer</i>	xx	xx	xx	xx	xx
<i>Light sensor</i>	yes	yes	yes	no-inno	no-inno
<i>Proximity sensor</i>	yes	yes	yes	no-inno	no-inno
<i>Gesture sensor</i>	xx	xx	xx	xx	xx
<i>UV sensor</i>	xx	xx	xx	xx	xx
Voice command			yes	no-inno	no-inno

Table: 24. Observation result of new-to-market and new-to-firm novelties: Note 8

<i>Launched year</i>	2016 (Mar)	2017 (Sep)	2016 (Sep)		
Technical Specification	Galaxy S7 Edge	Note 8	iPhone 7Plus	FIRM	MARKET
1. DESIGN					
Materials	Glass; Aluminum	Glass; Aluminum	Aluminium alloy		
Colours	Silver, Titanium	Midnight Black, Deepsea Blue, Orchid Gray, Maple Gold	Rose Gold, Gold, Silver, Black, Jet Black		4
2. RUGGEDNESS					
Splash			IP67	no-inno	no-inno
Water	IP68	IP68	IP67	no-inno	no-inno
Dust	IP68	IP68	IP67	no-inno	no-inno
3. DISPLAY					
Physical size	5.5	6.3	5.5		
Resolution	2560 x 1440	2960 x 1440	1920 x 1080		1
Pixel density	534	521	401	no-inno	no-inno
Technology	Super AMOLED	Super AMOLED	Retina HD display, widescreen LCD	no-inno	no-inno
Screen-to-body ratio	76.09	82.98	67.58		1
Peak brightness			625 cd/m ²	no-inno	no-inno
Protection	Corning Gorilla Glass 6	Corning Gorilla Glass 5	Fingerprint- resistant oleophobic coating	no-inno	no-inno
Damage resistant glass	xx	xx	xx	xx	xx
3D touch	xx	xx	xx	xx	xx
Multitouch	yes	yes	Yes	no-inno	no-inno
Shape	edge	edge	Flat	no-inno	no-inno
4. ATTACHED PEN					
Pressure levels		4096			
Pen Tip diameter		0.7			
Rugged		IP68			1
<i>Live message</i>		yes			
<i>Samsung Notes</i>		yes			
<i>Screen off memo</i>		yes			
<i>Smart select</i>		yes			
<i>Screen write</i>		yes			

<i>Translate</i>		yes			
<i>Bixby Vision</i>		yes			
<i>Glance</i>		yes			
<i>Magnify</i>		yes			
5. CAMERA					
Rear camera (wide angel)					
Pixels	12	12	12	no-inno	no-inno
Flash	Dual LED	Dual LED	Quad LED	no-inno	no-inno
True tone flash			Yes	no-inno	no-inno
Aperture size	1.7	1.7	1.8	no-inno	no-inno
Pixel size	1.4	1.4	1.22	no-inno	no-inno
FOV		77		no-inno	no-inno
Rear camera (telephoto)					
Pixels	12	12	12	no-inno	no-inno
Aperture size		2.4	2.8	no-inno	no-inno
Camera sensor size		3.6		no-inno	no-inno
FOV		45		no-inno	no-inno
Hardware Features					
<i>Optical image stabilization</i>	yes	yes	yes	no-inno	no-inno
<i>Autofocus</i>	yes	yes	Yes	no-inno	no-inno
<i>Live focus (blur background)</i>		yes			1
<i>Sapphire crystal lens cover</i>			Yes	no-inno	no-inno
<i>Back-illuminated sensor</i>			Yes	no-inno	no-inno
Optical zoom		2x	2x	1	
Software Features					
<i>Manual focus</i>		yes	yes	1	
<i>Portrait lighting</i>			yes	no-inno	no-inno
<i>RAW image capture</i>	yes	yes	Yes	no-inno	no-inno
<i>Touch to focus</i>	yes	yes	Yes	no-inno	no-inno
<i>Smile detection</i>	yes	yes		no-inno	no-inno
<i>Face detection</i>		yes	Yes	1	
<i>Body detection</i>			Yes	no-inno	no-inno
<i>Grid line</i>		yes			1
<i>Auto image stabilisation</i>			Yes	no-inno	no-inno
<i>Hybrid IR filter</i>			Yes	no-inno	no-inno
<i>Filters</i>		yes			1
<i>Motion/Live photo</i>		yes	Yes	1	
<i>Voice activation</i>		yes			1
<i>Live stickers</i>		yes			1

<i>Stamps</i>		yes			1
<i>Dual capture</i>		yes			1
<i>Noise reduction</i>			yes	no-inno	no-inno
<i>Self-timer</i>	yes	yes	yes	no-inno	no-inno
<i>Digital zoom</i>		10x	10x	1	
<i>Geo tagging</i>	yes	yes	yes	no-inno	no-inno
Settings					
<i>Exposure compensation</i>	yes	yes	yes	no-inno	no-inno
<i>ISO control</i>	yes	yes		no-inno	no-inno
<i>White balance presets</i>	yes	yes		no-inno	no-inno
<i>Shutter speed control</i>		yes			1
Shooting Modes					
<i>Burst mode</i>	yes	yes	yes	no-inno	no-inno
<i>Portrait mode</i>			yes	no-inno	no-inno
<i>High Dynamic Range (HDR)</i>	yes	yes	yes	no-inno	no-inno
<i>Panorama</i>	yes	yes	63	no-inno	no-inno
<i>Virtual shot</i>		yes			1
<i>Slow motion</i>		120 fps		no-inno	no-inno
<i>Macro mode</i>			yes	no-inno	no-inno
<i>Scene mode</i>	yes		yes	no-inno	no-inno
<i>Food mode</i>		yes			1
<i>Pro mode</i>	xx	xx	xx	xx	xx
<i>Manual mode</i>	xx	xx	xx	xx	xx
Front camera					
Pixels	5	8	7		1
Flash			yes	no-inno	no-inno
Aperture size		1.7	2.2	no-inno	no-inno
Pixel size		1.22		no-inno	no-inno
FOV		80		no-inno	no-inno
Front camera features					
<i>Animoji</i>	xx	xx	xx	xx	xx
<i>HD video recording</i>			1080p	no-inno	no-inno
<i>Auto HDR</i>	yes	yes	Yes	no-inno	no-inno
<i>Backside illumination sensor</i>			Yes	no-inno	no-inno
<i>Face detection</i>			yes	no-inno	no-inno
<i>Body detection</i>			Yes	no-inno	no-inno
<i>Auto image stabilisation</i>			Yes	no-inno	no-inno
<i>Burst mode</i>			Yes	no-inno	no-inno
<i>Portrait mode</i>	xx	xx	xx	xx	xx

<i>Exposure control</i>			Yes	no-inno	no-inno
<i>Timer mode</i>		yes			1
<i>Grid line</i>		yes			1
<i>Filters</i>		yes			1
<i>Selective focus</i>	xx	xx	xx	xx	xx
<i>Virtual shot</i>		yes			1
<i>Motion/Live photo</i>		yes			1
<i>Live stickers</i>		yes			1
<i>Stamps</i>		yes			1
<i>Voice control</i>		yes			1
Camcorder (video resolution)					
<i>3840x2160 (4K)</i>	30	30	30	no-inno	no-inno
<i>1920x1080 (1080p HD)</i>	60	30, 60	30, 60	no-inno	no-inno
<i>1280x720 (720p HD)</i>	240	240	30	no-inno	no-inno
<i>Video recoder</i>	yes	yes	yes	no-inno	no-inno
Video features					
<i>Time-lapse video</i>		yes	yes	1	
<i>Hyperlapse</i>		yes			1
<i>Continuous autofocus</i>		yes	yes	1	
<i>Tracking AF</i>		yes			1
<i>Picture-taking during video recording</i>	yes	9mp	8mp	no-inno	no-inno
<i>Video light</i>		High CRI LED flash	quad-led	no-inno	no-inno
<i>Video calling</i>	yes	yes	yes	no-inno	no-inno
<i>Video geo-tagging</i>		yes	yes	1	
<i>Optical zoom</i>		2x	2x	no-inno	no-inno
<i>Digital zoom</i>		10x	6x	no-inno	no-inno
<i>Slow motion</i>	240fps	240fps	240fps	no-inno	no-inno
<i>Face detection</i>		yes	yes	1	
<i>Body detection</i>			yes	no-inno	no-inno
<i>Playback zoom</i>		yes	yes	1	
<i>Digital video stabilisation</i>		yes			1
<i>Optical video stablisation</i>		yes	yes	1	
<i>Cinematic video stabilisation</i>			yes	no-inno	no-inno
<i>Noise reduction</i>			yes	no-inno	no-inno
6. HARDWARE					
System chip		Qualcomm Snapdragon	A10 Fusion		
Processor speed	2.15GHz,1.6GHz	2.35GHz Quad + 1.9GHz Quad	2.4 GHz	1	

Core	Quad-Core	Octa-core	Quad-Core		1
Graphic processor GPU	xx	xx	xx	xx	xx
System memory	4GB	6GB	3GB		1
Built-in storage	64GB	256GB	256GB	1	
Storage expansion	yes	yes		no-inno	no-inno
64-BIT	yes	yes	Yes	no-inno	no-inno
Nano sim	yes	yes	Yes	no-inno	no-inno
Dual sim		yes			1
7. BATTERY					
Capacity	3600 mAh	3300 mAh	2900 mAh	no-inno	no-inno
Type	lithium-ion	lithium-ion	lithium-ion	no-inno	no-inno
Wireless charging	yes	yes		no-inno	no-inno
Fast-charge capability	yes	yes		no-inno	no-inno
8. AUDIO					
High quality playback		yes		1	
Recording quality		High AOP Mic		no-inno	no-inno
Speakers	xx	xx	xx	xx	xx
<i>Earpiece</i>	yes	yes	yes	no-inno	no-inno
<i>Stereo speakers</i>			yes	no-inno	no-inno
<i>Loudspeaker</i>	yes	yes	yes	no-inno	no-inno
HD Voice	yes	yes	yes	no-inno	no-inno
9. VIDEO					
Split screen		yes			1
TV connection		yes	yes	1	
10. CELLULAR					
2G	yes	yes	yes	no-inno	no-inno
3G	yes	yes	yes	no-inno	no-inno
4G LTE	yes	yes	yes	no-inno	no-inno
CDMA together	yes	yes	yes	no-inno	no-inno
11. CONNECTIVITY					
Bluetooth	4.2	5	4.2		1
Wi-Fi					
<i>802.11a</i>	yes	yes	yes	no-inno	no-inno
<i>802.11b</i>	yes	yes	yes	no-inno	no-inno
<i>802.11g</i>	yes	yes	yes	no-inno	no-inno
<i>802.11n</i>	yes	yes	yes	no-inno	no-inno
<i>802.11ac</i>	yes	yes	yes	no-inno	no-inno
<i>802.11n 5GHz</i>	yes	yes	yes	no-inno	no-inno
<i>Dual Band</i>	yes	yes	yes	no-inno	no-inno

<i>WiFi MiMO</i>	yes	yes		no-inno	no-inno
<i>WiFi hotspot</i>		yes	yes	1	
Mobile hotspot	yes	yes	yes	no-inno	no-inno
Mobile Payment	yes	yes	yes	no-inno	no-inno
Positioning					
<i>GPS</i>	yes	yes		no-inno	no-inno
<i>A-GPS</i>		yes	yes	1	
<i>Glonass</i>	yes	yes	yes	no-inno	no-inno
<i>Galileo</i>		yes	yes	1	
<i>Cell ID</i>		yes	yes	1	
<i>BeiDou</i>	yes	yes		no-inno	no-inno
<i>QZSS</i>			yes	no-inno	no-inno
<i>Wi-Fi positioning</i>		yes	yes	1	
<i>iBeacon micro-location</i>			yes	no-inno	no-inno
12. PHONE FEATURES					
Haptic feedback	yes	yes	yes	no-inno	no-inno
Hearing aid compatibility	yes	yes	yes	no-inno	no-inno
3D facial recognition	xx	xx	xx	xx	xx
Bixby		yes			1
Sensors					
<i>Accelerometer</i>	yes	yes	yes	no-inno	no-inno
<i>Iris sensor</i>		yes			1
<i>Geomagnetic sensor</i>	yes	yes		no-inno	no-inno
<i>Pressure sensor</i>		yes			1
<i>Fingerprint sensor</i>	yes	yes	yes	no-inno	no-inno
<i>HR sensor</i>	yes	yes		no-inno	no-inno
<i>Face ID</i>	xx	xx	xx	xx	xx
<i>Gyroscope</i>	yes	yes	yes	no-inno	no-inno
<i>Compass</i>			yes	no-inno	no-inno
<i>Hall (for flip covers)</i>	yes	yes		no-inno	no-inno
<i>Barometer</i>	yes	yes	yes	no-inno	no-inno
<i>Thermometer</i>	xx	xx	xx	xx	xx
<i>Hygrometer</i>	xx	xx	xx	xx	xx
<i>Light sensor</i>	yes	yes	yes	no-inno	no-inno
<i>Proximity sensor</i>	yes	yes	yes	no-inno	no-inno
<i>Gesture sensor</i>	xx	xx	xx	xx	xx
<i>UV sensor</i>	xx	xx	xx	xx	xx
Voice command		yes	yes	1	