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New Product Development Strategies: A Case Study of Samsung Electronics

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Abstract: This paper develops and analyzes a theoretical framework for new product development; it also presents a case study of the electronics giant and the flagship subsidiary of Samsung Group, Samsung Electronics Company. The theoretical part provides a basis for analyzing new product development, dividing it into stages of pre-development, development, marketing, and launch; and the case study of Samsung Electronics highlights the main steps in the company's development and its unique development of new products, worldwide and in Kazakhstan. A survey of Kazakhstani customers identified the values they perceive in Samsung's products. The paper identifies similarities and differences between the theoretical base and the case study. Issues discussed include technology transfer and patent wars.

JEL classifications: M11, M13, M15, M31

Keywords: New Product Development, Technology Transfer, Patent Wars, Launch Activities

1. Introduction

In many industries, the development of new products is a vital factor driving the firm's success. Why has it become so important? Schilling and Hill (1998) explain that new product development as a competitive advantage results from the globalization of markets, the fragmentation of markets into niches, and from the shortening of product life-cycles. Companies depend on new products even though failure rates continue to be high. According to research released by the Product Development Institute in 2011, the percentage of new products that turned out to be commercial failures or that were cancelled before they were launched ranges from 38% for the top-performing firms to 55% for the bottom performers. Still, companies strive for innovation. Wong (2010) estimates that more than 250,000 products are launched globally each year.

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The most common definition of new product development is as the transformation of an innovative idea into a product or service. The main aim of this work is to trace this process by investigating Samsung Electronics, a South Korean company specializing in multinational electronics and information technology. This work provides a theoretical framework of new product development, as well as a case study of Samsung Electronics; it analyzes Samsung's process of product development process by comparing it to the theoretical framework. This paper will explore models of the process used by Samsung in Kazakhstan; and it will assess whether the models suit the Kazakhstani business environment.

We chose to study Samsung Electronics partly to learn how new product development helps it to stay competitive and satisfy the diverse needs of customers worldwide; to identify peculiarities associated with the South Korean chaebol; and to see how models of product development apply in Kazakhstan.

2. Literature Review

The theoretical base for this paper is mainly derived from a book by Trott (2008) that focuses on the concepts of innovation management and product development. Our framework includes the four stages of product development: pre-development, development, marketing, and launch. We now detail each stage.

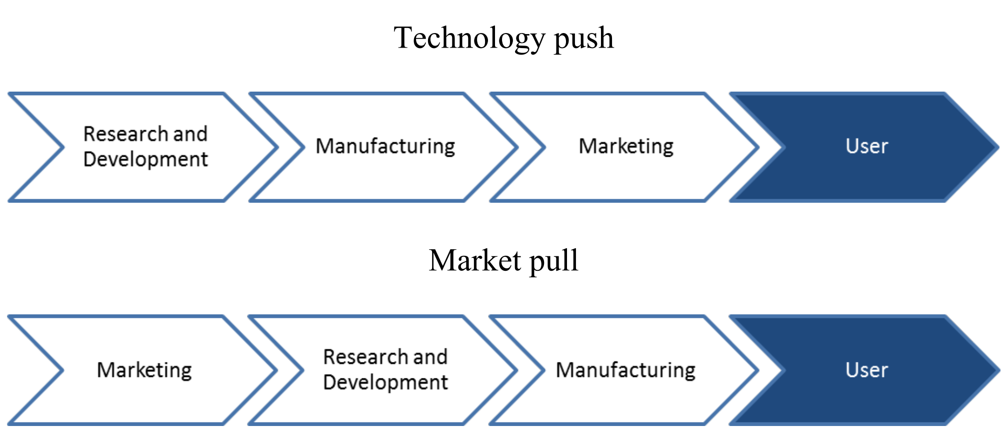
2.1 Pre-development

Pre-development defines the source of an innovation or a new idea, as well as the type of innovation. It also identifies the government's role in product development. The source of innovation is addressed by either the market-based view or the resource-based view. In the market-based view, the market is the main influence on the firm's innovations; in the resource-based view, the firm's innovations depend on its resources and their productivity.

The linear model often shapes how one perceives the company's innovation. This model appeared after the Second World War and dominated science for over 40 years (Trott, 2008). The model is popular because it is simple, since it is a direct sequence of the activities. The two variations of linear models represent the two main schools of thought on innovation—the technology driven model ("technology push") and the market driven model ("market pull"), each illustrated in Figure 1 (adapted from Trott, 2008).

Figure 1

Linear Models

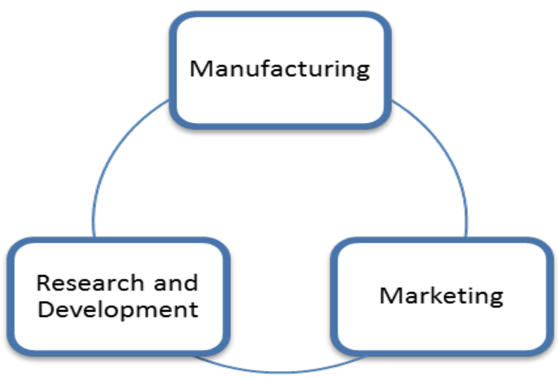


In the technology push model, scientists make discoveries that are developed into technological ideas that lead to manufactured products. These are tested and marketed to the end user. In the market pull model, the customer's needs generate the innovation, which undergoes engineering and manufacturing. Even though the market pull model seems prevalent due to its customer orientation, the technology push model is often useful in product development, depending on the company's technological environment and resources. Effective external links and networks assist the firm in quickly identifying inefficient points in the supply chain. Further, in today's globalized environment, another relevant solution would be technology transfer. This is the transfer of skills, knowledge, resources, and methods of manufacturing between organizations in order to jointly develop a product or technology. Inter-firm technology transfer creates a competitive advantage, since the strategic alliance helps to spread the risks and costs of developing an innovation, obtain economies of scale, increase access to new markets, and to learn technological capabilities from alliance partners (Wahab, Rose, & Osman, 2012).

While the linear model aids in identifying the sequence of transactions that processes the innovative idea, it still does not investigate how innovations occur. In today's world of endless opportunities to acquire knowledge, skills, and technologies, it has become difficult to track down when the innovation occurred (Trott, 2008). Coupling model, or simultaneous coupling model, suggests that it is in fact the result of coupling of knowledge within different functions that serves to create an innovation, where the idea can possibly come from any function or a combination of them. Coupling model is illustrated in Figure 2 (adapted from Trott, 2008).

Figure 2

Coupling Model



The next step in identifying an innovation is defining its type. Even though each innovation has an element of novelty, they vary in their types. Distinguishing between the types of innovations helps to predict their potential sources and manages their development (Chandy & Prabhu, 2009). Some types of innovations include product innovation, service innovation, process innovation, platform innovation, and design innovation.

The final step in pre-development includes exploring the role of government in development of a particular new product. Obviously, the relationship between the government and business differs from one national economy to another (Trott, 2008). This paper explores the relationship with a chaebol, a unique kind of business conglomerate in Korea credited with South Korea's rapid economic growth after the Korean War (Choi, 2008). A chaebol is centralized family ownership (Park & Yuhn, 2012). With aggressive government support and financing, most chaebols have become multinational companies. Considering the influence of government on product development, the chaebol provides the needed support to develop innovations and to acquire knowledge.

2.2 Development

The second stage of product development evaluates the idea (Trott, 2008). The idea not only has to be technically feasible, competitive, and patentable; it must fit the company's channel and strategic structure. The company's channel structure is the way of transferring manufactured goods from production sites to the target consumers (Kotler & Keller, 2011).

If the idea has potential, the next step is to describe and categorize the new product. Defining the category is not easy, since most product innovations fall between a true innovation and an improvement to an existing product. Categories include products that are new to the world, or just to the firm; product improvements; product line extensions; and repositioning. Product improvements strengthen performance or quality, or cut cost. Product line extension is the use of the brand name of the product line for a new product, being somewhat different from the other products in the line. As stated in the marketing literature, product line extensions are divided into two types: line stretching and line filling. Line stretching in turn is divided into three types: down-market stretch, up-market stretch, and two-way stretch. The down-market stretch occurs when the company moves from the upper segment to the lower segment due to such reasons as slowing growth at the higher end or growing competition. In the up-market stretch, the company moves up from the lower segment, mostly to add prestige to existing product lines, to increase profit margins, or to position them as full-line manufacturers. Two-way stretch occurs when companies in the middle sector move up or down depending on the business situation and opportunities. Another type of line extension, line filling, increases the product line by adding items within the range of line to increase market share, use excess capacity, and to fight competition. The final category of new products, replacements, consists of new applications for existing products (Trott, 2008).

To describe the new product, one must identify such factors as product family, class, line, and brand. Product family consists of all product classes that satisfy the same core need. Product class is the group of products within the family possessing the same function. Product line is a group of products within the class that either perform similar functions, have similar prices, or are sold to the same customer segment. The brand is the name associated with the product or line of products. Product line has several characteristics: Width is the number of product lines that the company offers; length usually is the number of brands within a product line; depth is the number of variations of the product offered in each line; and consistency is the number of related product lines in terms of either production and manufacturing requirements, distribution channels, or end use (Trott, 2008).

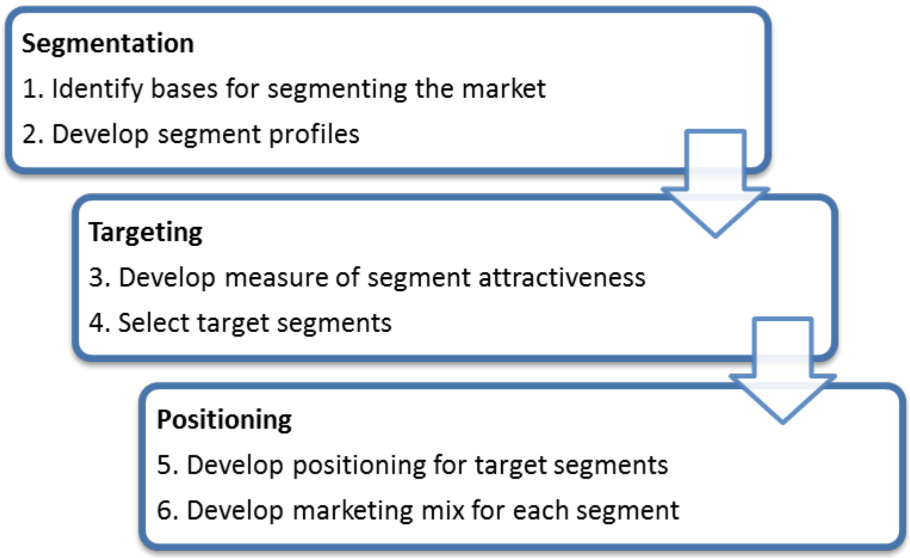
Once the idea is evaluated and the product categorized and described, the company turns to manufacturing and production, which this paper does not investigate.

2.3 Marketing

The marketing strategy for the product is based on the expected behavior of the customer and the related market environment. To assess these factors, the company applies segmentation, targeting, and positioning, depicted in Figure 3 (adapted from Kotler, 2011).

Figure 3

Segmentation, Targeting, and Positioning



The three processes depend on each other (Figure 3). Segmentation of the market is concerned with identifying the bases for segmenting and with developing segment profiles (Kotler, 2011). The segments are based on customer characteristics and needs. The variables used for segmenting the market fall into four categories: geographic, demographic, behavioral, and psychographic. Each category is subdivided by such factors as age and life-cycle (for the demographic category), decision roles (behavioral), and VALS (psychographic). VALS ("Values and Lifestyles") is a research methodology developed by Arnold Mitchell in 1978 which can be used for psychographic market segmentation: It assists the businesses to adapt their products and services in order for them to appeal to the potential customers most likely to purchase them (Yankelovich & Meer, 2006).

Next, to identify which market segments are the most attractive to enter, the firm targets them (Kotler, 2011). Segments are commonly chosen on the basis of such factors as size, potential growth, structural attractiveness, and the firm's resources and capabilities. After picking target segments, the firm draws up the most effective marketing mix for its new product.

In "positioning," the firm designs an image for the product in the mind of the target market (Kotler, 2011). Once the firm decides on the positioning message, it is time to work on the "marketing mix"—a tool crucial for determining a firm's offering. It is often referred to as four Ps or seven Ps. The four Ps classification was proposed by E. J. McCarthy in 1960 and stands for product, price, place, and promotion—the four factors describing the product's characteristics and environment (Goi, 2009). The seven Ps concept adds three factors—people, process, and physical evidence, which represent the increasing dimension of service marketing (Rafiq & Ahmed, 1995).

2.4 Launch

The final step in the theoretical model concerns the launch of the new product. The launch must try to use the strengths of the new product to build its competitive value. The launch strategy depends on the marketing mix and the generic strategy for the product (Chiu, Chen, Shyu, & Tzeng, 2006). The generic strategies representing differentiation, cost leadership, and focus influence the launch since each represents the competitive advantage that the firm wants for its product.

The competitive value can also be assessed with the VRIO model, vital to choosing how to launch a product or service. The VRIO model, labeled by Barney in 1991, stands for value, rareness, imitability, and organization. It is a framework for evaluating the resources and capabilities owned by a firm and also for distinguishing between temporary and sustainable competitive advantages (Anderson & Birrer, 2011). Assessing its own resources and organizational abilities will aid the firm in developing its launch strategy.

3. Methods

The methodology of this work discusses case composition, the procedure of case analysis, and the method of conducting a questionnaire. The framework for case composition has been derived from Yin (2009), which guided us in identifying the logic of the case study, collecting data, analyzing the evidence, and composing the case. The plan for this practical case addresses the company's environment and its way of growth and development partly by introducing products. The plan defines the research questions and sets up the framework for data collection, evaluation, and case composition.

Next, research design concerns what questions to study, what data are relevant, what data are available for collection, and how to analyze the results (Yin, 2009). The available data are mostly secondary. The analysis identifies models from the theoretical framework, with the aim of finding patterns in the data and pointing to the differences. Preparing to collect evidence means "asking good questions" and "being a good listener" (Yin, 2009), which in this work means not only seeing the main picture but also pointing out small but valuable details.

Collecting evidence, the fourth step of the research process, is the most important. The three main sources of evidence are documentation, or secondary data; survey results, or the primary data; and direct observation. Secondary data consist mainly of scholarly articles obtained from ProQuest, Emerald, and EBSCO Host academic databases. We chose articles relevant to new product development. For the survey, the sampling type is accidental or convenience sampling, in which one draws the sample from that part of the population that is available and convenient to reach. Fifty KIMEP University students were one population and 50 individuals outside KIMEP were a second. The questionnaire identified features that Kazakhstani customers value in Samsung Electronics' products; this was done to determine resources and capabilities that the firm uses to build its competitive advantage in the local market. The third source of evidence, direct observation, includes visiting the event that launched a Samsung Electronics product in Kazakhstan, to see how Samsung built awareness of a new product among targeted customers.

The fifth step of the research analyzes the evidence through any of four strategies: relying on theoretical propositions, developing a case description, using quantitative and qualitative data, or examining rival explanations (Yin, 2009). We chose the first strategy—relying on theory. These theoretical propositions shaped data collection and enabled us to relate theoretical models to the practical case. The analysis hewed to the "pattern matching" technique, which compares the actual pattern with the one predicted (Yin, 2009). We compared the practical case results with the theoretical framework to identify any related patterns.

The last step, sharing the results, involves the final composition and reporting of the case study. At this level, several methods have been applied including the chronological and "theory-building" types of case structure where the events follow the theoretical framework with some deviations. The work continues with the case of Samsung Electronics.

4. Research Results. Case Study: Samsung Electronics

Samsung Group, a South Korean multinational conglomerate, is the largest South Korean chaebol. It comprises numerous subsidiaries united under the Samsung brand. Samsung Electronics, a multinational electronics company, is one of the largest subsidiaries of Samsung Group. Samsung Electronics owns sales networks and assembly plant sites in more than 61 countries with a total of 196 subsidiaries worldwide and employs more than 220,000 people (Kwon, 2012). Relying on its business philosophy of "devoting our human resources and technology to creating superior products and services, thereby contributing to a better global society" (Kwon, 2012), Samsung Electronics by 2011 had become the world's largest mobile phone maker, largest television manufacturer, largest vendor of smartphones, and the second-largest semiconductor chip maker. However, to achieve its ambitious goals and become a true innovator, the company has undergone many challenges on its long road to success.

4.1 The Origin

Samsung Electronics first appeared in 1969 as a small subsidiary of Samsung Group named Samsung Electric Industries, established in Suwon, South Korea. The first products produced by the subsidiary included televisions, calculators, washing machines, air conditioners, and refrigerators. In 1970, Samsung Group established another subsidiary, Samsung-NEC, jointly with Japan's NEC Corporation, to produce home and audio/video appliances. In 1974, the group began to acquire Korea Semiconductor, which specialized in semiconductors and was one of the first chip-makers in the country at that time. With the help of the acquisition, Samsung added chip-making to its portfolio. In 1980, additional important decisions were made to develop Samsung Electronics. The founder of Samsung, Lee Byung-Chull, announced that Samsung was becoming a DRAM (dynamic random access memory) vendor. This led Samsung to producing 64-kilobytes DRAM chips, among the first in the world.

In 1988 the two directions of electric industries and semiconductor production merged to form the Samsung Electronics Company. Under its new brand name, Samsung Electronics launched its first mobile phone in 1988. However, Samsung Electronics gained only 10% of the domestic mobile phone market while Motorola remained the market leader with a 60% share (Mitchell, 2010). Reasons for the low sales included the poor quality of the mobile phones, the design and manufacturing of which the company had tried to copy from the market leaders. The overall performance of Samsung Electronics during the early period fluctuated; however, some main premises for future growth were established.

4.2 "From Product Copycat to Developer"

The early 1990s was a challenging time for Samsung Electronics to shift from development and production of already existing designs to true innovation. In the early days of its electronic business, Samsung had received assistance from abroad, such as from the Japanese companies Sharp and NEC. However, such a technology transfer has drawbacks: Foreign companies may withdraw their help in the fear that they will create a new competitor (Clifford, 1991). Meanwhile, Samsung Electronics struggled in its design and production of the products since the company still lacked a significant research and development base.

The change first came from the ideas of Lee Joo Hyung, the senior executive managing director of consumer products in the R&D center. Lee realized that Samsung, having accumulated the necessary technological support, could develop further. Under his supervision, engineers took the first steps towards innovation by coming up with a vacuum cleaner adapted for cleaning the oily paper covering the heated floors of Korean homes and "kimchi refrigerators" adapted for the Korean fiery cabbage dish. Even though these products were created exclusively for the Korean environment, they marked the first innovation that the company had developed without copying from foreign rivals.

New alliances appeared when Motorola joined Samsung in creating a pen-based notebook computer and when NEC joined Samsung to develop the flat-screen technology (Darlin, 1992). In 1990, yet another alliance emerged, between Samsung, Goldstar Co., and Orion Electric Co., to develop tubes for HDTV (high-definition resolution).

This led to one of the first patent clashes in the history of Samsung Electronics. Even though Samsung and Goldstar eventually signed a cross-licensing contract to develop HDTV, the fierce rivalry between these two electronics giants of South Korea continued (Chai, 1993; *Business Korea,* 1993).

At the same time, Samsung continued to move on its own. It introduced a refrigerator free of chlorofluorocarbons, which were coolant compounds linked to ozone depletion and the greenhouse effect. Samsung's CFC-free refrigerator was the first in Korea and the second in the world. The effort not only added weight to Samsung Electronics' innovator status but boosted South Korea's image as a country, reducing international environmental pressure on it (Chai, 1993).

Development of other products also received continued attention from Samsung. John Garrison, then Samsung's vice president of marketing, announced the launch of a line of color TVs, including 13-, 19-, 25-, 27-, and 31-inch models. These offered a sophisticated package of features varying from auto-channel programming to frequency-synthesized tuning to a variable sleep timer, as well as caption-vision functions (*Dealerscope Merchandising*, 1994).

As for the DRAM chip line, Samsung Electronics remained the world leader in producing memory chips when it became the first firm to develop a 256-megabit DRAM chip ahead of its rivals NEC and Toshiba of Japan and IBM and Texas Instruments of the United States (*Business Korea*, 1994). Samsung continued on the path of innovation when it introduced a commercially viable digital video disc player (DVD), hoping to become a market leader for this new product (*Wall Street Journal*, 1996).

Meanwhile, the alliances continued to develop. Samsung Electronics and AST Research Inc. planned to develop new products including a NetPC system, leading to Samsung's acquisition of 46% of AST Research shares (Foley, 1997). Samsung's chip manufacturing continued to challenge its rivals. Its new Alpha chip was claimed to run up to 500MHz; competitor Intel's Pentium Pro ran at only 200MHz (Chong-Tae, 1997).

However, even though the media in the 1990s had kept announcing innovations under the Samsung Electronics brand, the inside picture of the company was not as bright. At that time Samsung Electronics had strived to gain market presence and share worldwide by entering alliance contracts and introducing its products in such emerging markets as the Confederation of Independent States (CIS). As Soon-hoon Bae, chairman and CEO of Daewoo Electronics, pointed out, "Samsung Electronics wants to be like the Sony Corporation" (Young, 1997). This message in fact underlies the internal situation in Samsung: While struggling to present as many innovations as it can, the company probably still saw itself subconsciously as a follower and wanted to be like somebody else rather than construct its own vision of the future.

The next challenge at the heart of the plan of Samsung Electronics was to move from DRAM producer to multimedia system provider. But this appeared a failure due to slumping prices for DRAM in 1996 that forced Samsung to cut its expenditures by two thirds, slowing down its production and development of projects. As a result, Samsung Electronics lost its long-term lead in the electronics market to LG Electronics. Another difficulty appeared in the complications of transferring Samsung Electronics business to the world arena due to the need to adapt products to new environments. Moreover, the acquisition of AST Research had failed since that company had already been in bad shape with revenues plummeting; consequently, the performance of AST continued to worsen in the Asian financial crisis, leading to more losses for Samsung Electronics (Young, 1997).

Despite the challenges, Samsung Electronics continued to develop new products that eventually yielded positive results. Sales of flat-panel computer monitors began to rise towards the end of the 1990s (Correia & Spiwak, 1998). Next, Samsung became the first in Korea to manufacture an MP3 player (Rawsthorn, 1998).

At the same time, Samsung started to build an infrastructure to increase its technological capabilities, expanding its Korean R&D centers involved in the assimilation and adaptation of acquired and learned foreign technologies (Kim, 1998). Samsung established several foreign-based R&D centers to receive relevant and up-to-date information from local centers. The new developed network destination of Asia provided Samsung with low-cost resources in Southeast Asia and access to the multitudes of customers in such dynamic countries. The Asian production network included Thailand, China, Vietnam, India, Singapore, and Beijing (Kim, 1998). Such an expansion in production and manufacturing networks had let Samsung Electronics acquire new partners, learn new technologies, and increase its market presence worldwide. With increased spending on research and development and the constant striving to understand new markets and business environments, Samsung Electronics, despite the challenges of the 1990's, was ready to enter a new phase in its development into an innovator.

4.3 "Innovate or Die"

Severely hit by the Asian financial crisis at the end of the 1990s, Samsung Electronics along with the Samsung group experienced large losses both in financial terms and in its decreased amount of research and development. With the message from the group chairman, Lee Kun Hee, to "innovate or die," Samsung entered a new path, starting from the hire of Eric Kim as a branding manager (Pesola, 2003). Samsung doubled the number of its designers to 300 (Pesola, 2003) and improved the operations of its R&D center. These measures yielded results almost immediately. The company led Korea's semiconductor industry, contributing to the overall national wealth (*Business Korea*, 2000). Samsung Electronics entered 2000 with $22.8 billion in revenue, and it showed all the potential of becoming the world leader in electronics.

To become a global brand, Samsung Electronics focused on four directions – home, mobile and office networks, and core components. For efficient and effective operations, Samsung Electronics has adopted the process known as Six Sigma (Jong-Yong & Chua, 2002). The Six Sigma projects, totaling 3,290 in 2000 and 2001, halved defects by the end of 2001, increasing the firm's revenues and global market shares. Its market share of memory chips rose to 29%; of monitors, to 21%; and of microwave ovens, to 25% (Jong-Yong & Chua, 2002). Thus, by the early 2000s, the company had repositioned itself from a mere copycat to a serious competitor with innovative technologies and a well-trained workforce. Samsung Electronics' president of the memory division, Chang-Gyu Hwang, declared in 2002 that the firm was rewriting the famous Moore's Law; semiconductor performance doubled every 18 months by "doubling the density of NAND chips every year, from 512Mbits [in 2001] to 1Gbit [in 2002], 2Gbits in 2003, and 4Gbits in 2004" (Robertson, 2002).

The joint venture with Toshiba Corporation in 2003 allowed Samsung to develop a line of optical disc drives that led to a large portfolio of products ranging from slim drives for laptops to half-height drives for desktops (Hara, 2003). Another partnership, with Samsung's eternal rival Sony, had let the companies combine their resources to develop large-screen LCD TVs (Chin, 2003). As for its chip line, in 2004 Samsung Electronics announced that it had created the first 2-gigabit DDR2 SDRAM built on 80-nanometer technology (Purchasing, 2004).

The next fundamental change in the marketplace of electronic appliances hit the market in 2005 when Samsung Electronics announced that it had teamed with Lowe's to launch a complete line of digitally controlled appliances operated from a computerized touch screen, including refrigerators, washing machines, dryers, and microwave ovens (Duff, 2005). Alliance with Lowe's was indeed a wise decision since the majority of the appliance company's customers preferred the so-called "do-it-yourself" offerings. The new products presented them a chance to link items and change some functions. The next range of innovations presented by Samsung Electronics included the updated DVD-RW drive in 2005, followed by a line of high-end mobile phones and development of the SLR (single lens reflex) digital cameras.

One reason for the continued success of Samsung Electronics in 2000s lay in the transformation of its R&D center, Samsung Advanced Institute of Technology (SAIT), into a "key engine" of Samsung business operations worldwide (Park & Gil, 2006). In 2004, 80% of SAIT's R&D projects reached commercialization, compared with 61% in 2002 and only 18% in 1997. The applications for U.S. patents filed by SAIT had also increased, to 85% of 1,400 patent applications in 2004 (Park & Gil, 2006).

SAIT's challenges included the rapid change of Samsung Electronics from an imitator to a global leader, posing the threat of not catching up with the latest innovations and not being able to satisfy the ever-diversifying needs of customers. Another challenge was to provide business clients with constant updates of technologies while also creating products. A third challenge was that globalization created a need to satisfy target groups located in very different environments.

Despite challenges, Samsung Electronics continued to develop new products and design innovations, achieving several substantial victories over the 2000s. In 2007, the company became the world's second-largest mobile phone producer, surpassing Motorola for the first time (Moon, 2007). In 2009 Samsung attained revenues of $117.4 billion, overtaking Hewlett-Packard as the world's largest technology company when measured by sales (Song & Oliver, 2010).

4.4 The Era of Patent Wars

After 2010, Samsung Electronics fought patent wars. In early 2011, Apple announced that it was suing Samsung Electronics for allegedly violating rules of trademarks and patents and copying the design for its Galaxy line from Apple's iPhone and iPad models (*Business News*, 2011). Samsung objected that the Galaxy design had resulted from only the company's own research, development, and design. Later Samsung countersued, accusing Apple of infringing patents. In August 2011, Apple was granted a preliminary injunction by the court of Dusseldorf against the sale of Samsung Galaxy Tab 10.1 in Europe (Richmond, 2011). Samsung in turn claimed in the Federal Court of Australia that Apple's iPhone and iPad had infringed on seven Samsung patents (*Business News*, 2011).

The fight continued. In August 2012, a U.S. court ordered Samsung to pay Apple $1.05 billion in damages for intellectual property infringement (*BBC News Technology*, 2012). But the Tokyo District Court declared that Samsung Electronics had not violated patent law in regard to Apple's patent that allowed transferal of media content between devices (Reuters, 2012). In October 2012, Samsung Electronics sued Apple again, stating that iPhone 5 infringed on Samsung patents through two standard patterns and six features patterns. Samsung had begun investigating patent infringements as soon as Apple released iPhone 5 to the market (Rosenblatt, 2012).

4.5 Samsung Electronics in Kazakhstan

Samsung Electronics entered Central Asia in 1996. The subsidiary in Kazakhstan is supervised by Samsung Electronics CIS, with the main office in Moscow. The Central Asian region for Samsung operations includes Kazakhstan, Kyrgyzstan, Uzbekistan, Turkmenistan, Tajikistan, and Mongolia. The main office for the region is in Almaty.

Samsung Electronics faces regional risks. One danger of entering foreign environments arises from differences in language, lifestyle, mindset, customs, and religion. For example, according to the Constitution of Kazakhstan, the Russian language is officially spoken along with the national Kazakh language. On the other hand, the countries of Central Asia share a similar culture, language, religion, and (to some extent) mentality.

But Kazakhstan develops faster than its neighbors and is more open to innovations. The products that Samsung Electronics provides in Central Asia include TVs, AV products, cameras, home appliances, personal computers (PCs), printers, and monitors. In his interview with *Business Year*, Seung Koo Kim, president of Samsung Electronics Kazakhstan and Central Asia, states that Kazakhstan is a significant hub for Samsung in the region. Being a frontier economy with a population of 16.3 million, and being the ninth largest country in the world by land area, Kazakhstan represents the fastest growing market in Central Asia.

As Kim points out, Samsung believes that Kazakhstani consumers are smart and diversified, ranging from premium-products customers to price-oriented ones. For Samsung, Kazakhstan is a test market. Products are often introduced in Kazakhstan to monitor customer demand before expanding the launch to the rest of Central Asia. According to Kim, the top-selling products for Samsung in Kazakhstan are in the mid-range; the company had to drop some of the cheapest offerings. Samsung has dominated the local market in high-end HD and 3D televisions. For mobile phones, the position of Samsung is first or second.

To remain the leader, Samsung Electronics focuses on smart phones and tablet PCs, which other brands do not have to the same extent. Samsung works in multiple directions simultaneously, trying to acquire a share of various offerings from its portfolio, including home appliances, IT products, and mobile and tablet products. As Kim notes, the strategic goal for Samsung in Kazakhstan and Central Asia is to launch products that local customers need. For example, Samsung launched a line of vacuum cleaners, including a robot and devices with increased power adapted to the large amount of carpet usage in Central Asia.

Samsung tries to minimize commercial risk by strengthening its market presence, working with reliable business partners, and managing its global supply chain. The main Samsung production centers are in South Korea, China, and Vietnam. But to address local needs and strengthen its local presence, Samsung in 2011 entered a “Neo Sun Light” joint venture with the Uzbeks and the British. The Uzbek government supported the venture by launching a production center for Samsung Electronics in Tashkent. Neo Sun Light plans to start production in 2013, with the goal of manufacturing 42,000 washing machines, 60,000 gas stoves, 85,000 vacuum cleaners, and 70,000 microwaves by the end of the year (Iskhakov, 2011). Samsung concentrates on these products because they are the ones most demanded by Central Asian customers with large families.

Kazakhstan’s government supports Samsung products. As an example, officials found the latest model for Galaxy Tab more interesting than other tablet PCs, because it supported the Kazakh language. The government intends to use the Galaxy Tab in schools and universities. This is a key aim of Samsung: to get the Galaxy Tab recognized as an educational tool for learning languages, mathematics, and drawing. Samsung established service centers to support users of this product.

In fact, Samsung has more than 100 service centers in Kazakhstan. The company’s policy is to establish a service center in any city with a population of more than 100,000. Thanks to Samsung’s huge service network, the firm delivers 95% of spare parts to customers in three days.

Its Kazakhstani customers include wholesalers, retailers, and end customers—or, in Samsung terms, “sale-in” and “sale-out.” Sale-in occurs when Samsung sells to large retail stores such as Technodom, Sulpak, and Planeta Electroniki in Almaty. In sale-out, end customers buy Samsung products from retail stores. Samsung states that sale-out is the most critical factor for its operations.

To market new products in Kazakhstan, Samsung uses its worldwide approach of ATL/BTL. ATL, or Above the Line, stands for external advertising, including traditional media channels and the Internet. BTL, or Below the Line, happens behind the scenes, including closed meetings with client representatives and press. The trend is to focus more on ATL during the introduction of the product;

however, most of the time the company focuses on both directions. Samsung Electronics faces no direct competition from its current main rival, Apple, since Apple does not have an established regional subsidiary in Kazakhstan. This allows Samsung to operate more actively in the local environment, exploring local tastes and being the first to offer solutions.

In June 2012, Samsung Electronics launched the Galaxy S III. Kazakhstani social networks advertised the event among youths. The launch was held in the Republic Square of Almaty and was free to visitors, who were greeted by volunteers and marketing employees of Samsung Kazakhstan. The event included interactive zones. In one, visitors could play with large realistic models of "Angry Birds" characters. In another, visitors could take a picture with the large display of the Samsung Galaxy S III social network page. And in yet another, talented volunteers drew portraits of visitors with the Galaxy S III drawing device. The most important zone explained features of the Galaxy S III to visitors who could try the product along with other recent Samsung models. The event closed with a show of the invited pop-group and with a lottery where two visitors won Galaxy S III phones. The event was well-organized, right down to the raincoats provided for free to all visitors when it started raining.

Despite increasing sales of new products in Kazakhstan, not every new product can be adapted to the local clientele. One example is the 4G LTE Mobile Hotspot, the mobile Wi-Fi hotspot device introduced by Samsung Electronics in 2011. This product takes advantage of the 4G LTE network and allows the customer to connect with up to five Wi-Fi enabled devices simultaneously. Moreover, it offers a transition between 4G LTE and 3G speeds while on the go. (The 4G network is the fourth generation of cellular mobile communications standards, which provides mobile ultra-broadband Internet access.) According to the product manager of Samsung Electronics Kazakhstan (contacted via e-mail), the primary reason for not offering this Hotspot in Kazakhstan is the lack of 4G network coverage. "The environment is different here: People are not using the smartphone to pay for metro, to scan the products in supermarkets, or for payment for other services. The model would not go."

According to the GSM/K-Cell manager interviewed (by phone), "There is no 4G coverage in Kazakhstan yet. The 3G potential is still not discovered fully and its speeds are enough at the moment. Moreover, only a few customers own devices supporting 4G."

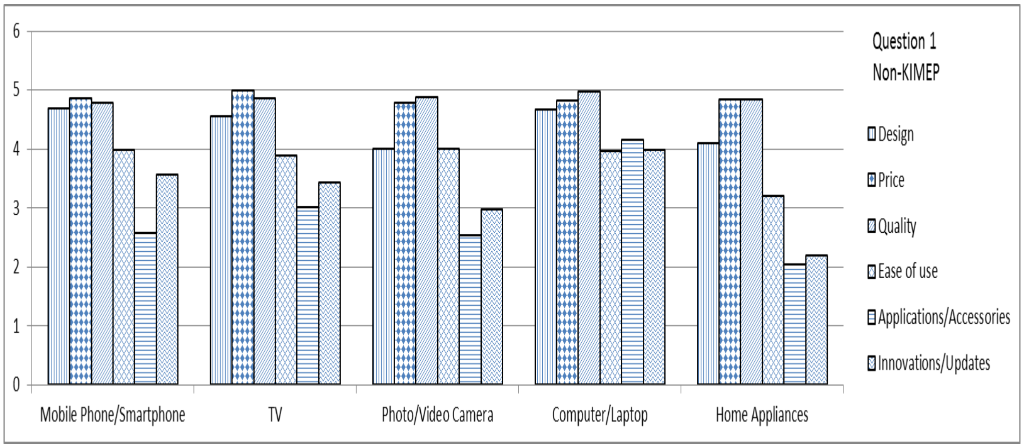
4.6 The View of Kazakhstani Customers

To understand the perceptions and the preferences of Kazakhstani customers towards the brand of Samsung Electronics, we conducted a survey that identified the importance and attractiveness of certain features of electronic products. As it turned out, the sample of non-KIMEP Kazakhstanis, comprising people aged 30 to 60, identified price and quality as the most important features. Less important were applications and accessories, as well as innovations and updates; and of above-average importance was ease of use. Perhaps older Kazakhstani customers prefer durable and reliable products selling at a reasonable if not low price.

Non-KIMEP respondents put the same importance on all product categories, meaning that price and quality are important for them no matter which product is under consideration. The average results of the survey for non-KIMEP respondents for Question 1 are indicated in Figure 4, with the scale on the vertical axis representing "1" as "totally not important"; 2 as "not important"; 3 as "neutral"; 4 as "important"; and 5 as "very important."

Figure 4

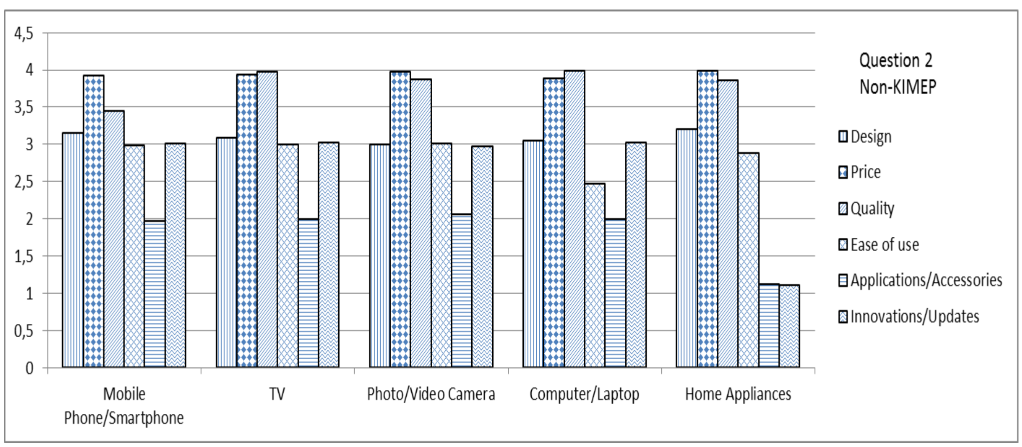
Importance of Product Features (Question 1, Non-KIMEP Respondents)



The second question of the survey concerned the attractiveness of features of Samsung Electronics products. Again, the non-KIMEP sample indicated that price and quality were more attractive than applications, accessories, innovations, or updates. Concerning those last four features, respondents were most likely to rate them as "not attractive" and "neutral" for home appliances, while they were more likely to rate mobile phones, smartphones, and computers as "attractive." Figure 5 indicates these responses; on the vertical axis, a 1 means "not attractive"; a 2 means "neutral"; a 3 means "attractive"; a 4 means "very attractive"; and a 5 means "don't use."

Figure 5

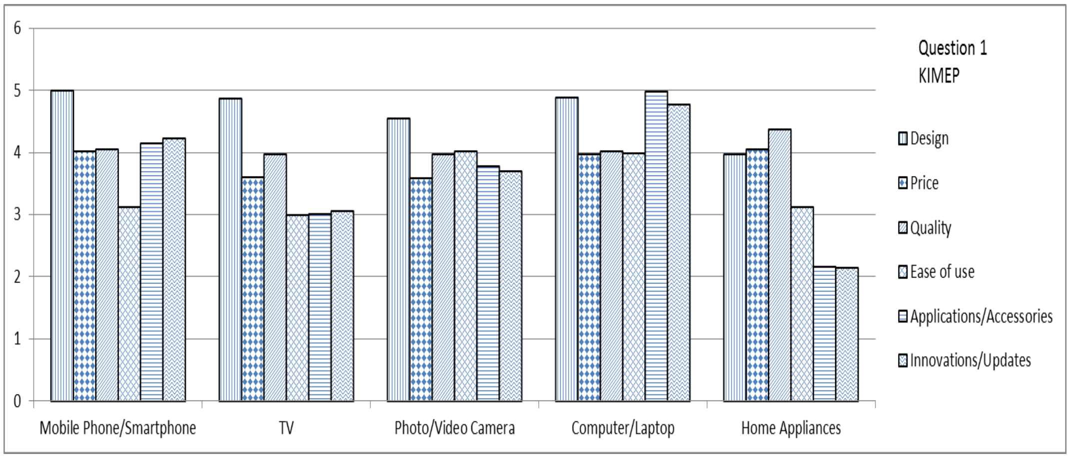
Attractiveness of Product Features (Question 2, Non-KIMEP Respondents)



The next sample represents KIMEP University's population of students, who answered the same questions as did the non-KIMEP sample. The two samples differed in their answers. The evidence from the first question, which focused on the importance of the listed features for the electronic products in general, revealed that the younger generation pays more attention to the product's design, accessories, and innovations or updates. It is logical to conclude that younger customers do not value price and quality as the main factors influencing their decision, since the majority of them are not concerned with the income of their family. Moreover, students appear to focus less on such features as quality while being more concerned with design and innovativeness. As for product categories, as predicted, students pay less attention to home appliances than to mobile phones or smartphones, computers, TVs, audio, and video cameras. The average results of the survey for KIMEP respondents for Question 1 are indicated in Figure 6 with the scale on the vertical axis the same as before: A 1 denotes "totally not important"; 2, "not important"; 3, "neutral"; 4, "important"; and 5, "very important."

Figure 6

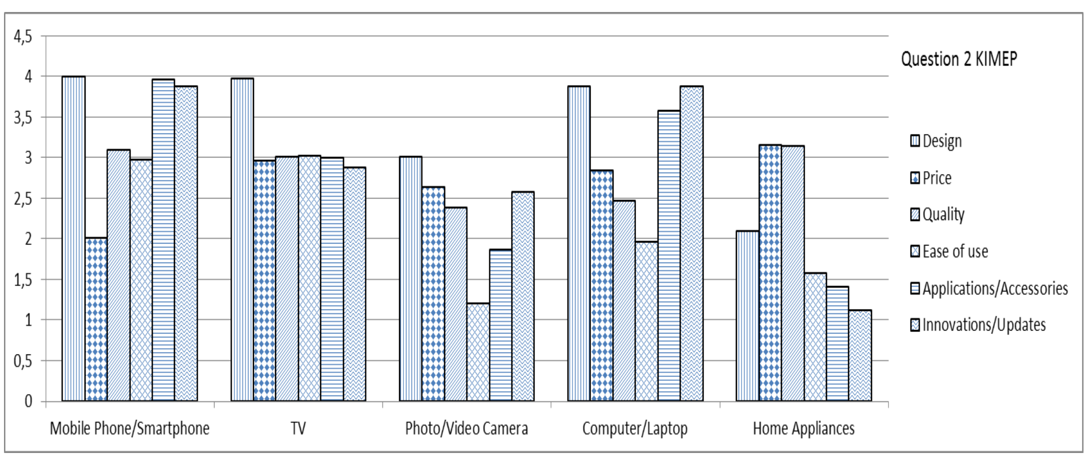
Importance of Product Features (Question 1, KIMEP Respondents)



In answers to the second question, KIMEP students focused on design, innovations, and updates. Also, they valued Samsung Electronics mobile phones and smartphones the most. Computers and laptops also received high ratings in terms of attractiveness, followed by TV, cameras, and home appliances. Figure 7 summarizes the survey results for KIMEP respondents. On the vertical axis, a 1 denotes that the product was "not attractive"; 2, "neutral"; 3, "attractive"; 4, "very attractive"; and 5, "don't use."

Figure 7

Attractiveness of Product Features (Question 2, KIMEP Respondents)



The survey results yield several conclusions. First, Kazakhstani customers are aware of the Samsung Electronics brand, and they use the company's products. Evidently, the company's products are properly positioned and possess the features that Kazakhstani customers need, including quality, affordable prices, and ease of use. Second, the older population carries remnants of the Soviet era and is most concerned with family well-being, so it especially values price and quality. But the KIMEP respondents represent the wave of young, stylish, and active customers financed by their families of the middle and upper-middle classes of Kazakhstan. These customers see the design of the product as the most important attribute to support their image and style. They also perceive innovations, updates, accessories, and applications as important for their device. These young customers appear to be medium to heavy users of Samsung Electronics products, especially mobile phones, smartphones, laptops, and TV sets. They value the same qualities in all Samsung products, placing less emphasis on price, quality, and ease of use. Therefore, Samsung Electronics has fulfilled its goals in the younger target market, providing youths with the devices they want while simultaneously satisfying their need for accessories, product innovations, and updates. Samsung Electronics has established its presence in Kazakhstan with a strong desire to build its market share and become a leader in the electronics market.

A range of factors contributes to Samsung's success: the lack of fierce competition due to the absence of Apple in the local market; the ability to adapt quickly to the new environment; the diversified product portfolio; and the constant striving to understand and meet customer needs. So the company is strengthening its position in Kazakhstan. Even though the challenge of competition and the risks of changing environments are always present, the company has been able to increase its market share, present innovations, and continuously improve operations.

5. Discussion

This section applies the theoretical framework discussed in the literature review in order to identify and discuss any similarities or differences between the theoretical and practical parts of this paper. Established as a flagship subsidiary of Samsung Group, Samsung Electronics has always received support in product development from one of the largest South Korean chaebols.

As was mentioned in the discussion of pre-development, government support is sometimes crucial for product development, so the company's structure is mostly an advantage to Samsung Electronics. Moreover, government support helps the company to adapt to a new business environment; for example, the Kazakhstani government backed the launch of new products and aided Samsung in building market share.

In Samsung's early years, its pattern of operations seemed to represent the technology-push linear model, in which the company relied mostly on copying the manufacturing of its rivals and constantly sought to engage in technology transfer as in the case of a joint venture with NEC and Korea Semiconductor. This work has investigated product development by Samsung Electronics, both new products and improved products.

In the 1990s, the technology transfer models started to backfire on Samsung's growth when rivals started to fear the new competitor. At the same time, Samsung failed to account for the importance of research and development and merely relied on the design and production of new products. With Lee's entry, Samsung started to evaluate its new ideas with such criteria as technical resources, competitive rationale, research direction and balance, channel, and strategic fit. This led to the development of only the best ideas into products.

Monitoring the evaluation criteria had not always been easy for Samsung Electronics. The failure with AST Research resulted from Samsung not paying enough attention to market stability. Furthermore, prices of DRAM products slumped. Samsung lost market share due to its lack of planning and of current market evaluation. Nevertheless, Samsung created a competitive advantage for itself when it entered the emerging market of Asia, leading to channel fit and low-cost manufacturing.

In the next phase, Samsung Electronics presented innovations in all new products, ranging from “new to the world” products, such as 512-bit NAND chips, digitally controlled home appliances, and SLR digital cameras, to “new to the firm” large screen LCD displays, and to product line extensions of mobile phones and television sets. Samsung Electronics has fully experienced the patentability criterion in its patent wars with Apple.

The product description, however, is not as obvious, since Samsung mostly divides its products according to the classifications of mobile phone, TV, audio and video, PC, and home appliances, with each new model most often representing product line stretching or improvement. Samsung’s marketing seems directed at gaining customers from target groups, since its portfolio is substantial, offering products for a wide range of tastes. As is obvious from Kazakhstani operations, Samsung strives to meet customer needs by adapting its products to local requirements, such as introducing in Central Asia its most powerful line of vacuum cleaners. The company’s marketing reflects knowledge of the local mentality as well, since customers rank as important those features for which Samsung has delivered high value, according to survey results. The value factor in the VRIO model for Samsung in Kazakhstan, therefore, would differ with each target group, ranging from price and quality for older customers to design and updates for younger ones.

As for the rarity factor, Samsung Electronics faces no direct competition in Kazakhstan, and even though Apple is strong in the smartphone and tablet markets, it does not explore the local market and adapt to its needs the way that Samsung does. Imitability is a risky factor, as seen in patent wars. Concerning the organizational factor, Samsung aces here as is evident from its Galaxy S III launching event, which was thoroughly planned and organized.

Samsung Electronics appears to be a true innovator. While sometimes following the theoretical models closely, Samsung seems to address other issues in unique ways. Nevertheless, Samsung management seems well aware of the theoretical base for developing new products and constantly tries to improve the transfer of new ideas to products. Samsung has gone a long way towards becoming a successful developer and an innovative market leader of consumer electronics products.

6. Conclusion

This work has developed and analyzed a theoretical framework of new product development, and it has composed a case study of Samsung Electronics. This research is of interest due to the ever-increasing importance of electronics products in the consumer’s life and to the constant need for innovation that every business faces to remain competitive. The paper summarizes and discusses new product development in a theoretical framework consisting of the four main stages for any new idea: pre-development, development, marketing, and launching. Each stage has its own models and rationale. Pre-development defines the source of the new idea, the type of future innovation, and the role of government in developing the new product. In development, one evaluates whether the new idea is reasonable and whether there are resources to implement it; and one categorizes and describes the new product. Marketing concerns the strategies of segmentation, targeting, and positioning, while the launch develops the VRIO model for the new product.

After the theoretical model was established, the case study of Samsung Electronics was designed. The main sources of evidence for the case study included a review of secondary data, direct observation of the launching event in Kazakhstan, and a survey of values that Kazakhstani customers place on Samsung products. The case study tells the story of Samsung’s gradual development from a copycat producer into an innovator and market leader. It also discusses Samsung’s numerous product innovations as well as its alliances to develop new ideas and share resources.

The case study marked the management’s role in Samsung development, as in the example of a powerful slogan, “innovate or die.” It also discussed the channel decisions, along with the challenging patent wars of the last few years. The focus shifted to the Kazakhstani environment, where Samsung Electronics has a strong presence. The case study then summarized the results of the survey of the importance that Kazakhstani customers place on certain product features, and the value they perceive from them.

In conclusion, this research has identified that the theoretical framework for new product development is a crucial base for screening, evaluating, implementing, and monitoring a new idea and its transformation into a product. Samsung Electronics is unique in its new product development. With the help of the chaebol parent, the company has transformed itself from a copycat of other manufacturing styles to a world leader in electronics. In the initial stages and throughout early development, Samsung used the theoretical models of technology push and technology transfer; later the company reorganized itself to understand consumer needs first and to adapt to increasingly diverse demands around the world.

As for Kazakhstani customers, Samsung adapted to their atmosphere and distinguished between the mindsets of the old and the young. As a result, Samsung has a strong presence in the local market; customers perceive that Samsung products have the features important for them. With its risky strategy to be "all-in-one," Samsung Electronics has proven to be one of the few firms worldwide that lives up to the message.

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7. Summary

English: This paper develops a theoretical framework for new product development dividing it into stages of pre-development, development, marketing, and launch. The second part of the work presents a case study of the electronics giant and the flagship subsidiary of Samsung Group, Samsung Electronics, highlighting the main steps in the company's development and its unique development of new products, worldwide and in Kazakhstan. Similarities and differences between the theoretical base and the case study are identified and analyzed.

Russian: В этой статье разрабатывается теоретическая основа для разработки нового продукта, разделенная на этапы предварительной разработки, разработки, маркетинга и запуска. Вторая часть работы представляет собой тематическое исследование гиганта электроники и флагманской дочерней компании Samsung Group, компании Samsung Electronics, с выделением основных шагов в развитии компании и ее уникальных разработок новых *продуктов во всем мире и в Казахстане. Выявлены и проанализированы сходства и различия между теоретической базой и тематическим исследованием.*

Kazakh: Бұл мақалада алдын-ала әзірлеу, әзірлеу, маркетинг және іске қосу кезеңдеріне бөлінген жаңа өнімді әзірлеудің теориялық негіздері жарияланады. Жұмыстың екінші бөлігі - бұл электроника алыбы мен Samsung Group компаниясының флагмандық еншілес компаниясы - Samsung Electronics-тің іс зерттеуі, бұл компанияның дамуындағы негізгі қадамдарды және оның бүкіл әлемде және Қазақстанда жаңа өнімдер шығарудың ерекше кезеңдерін көрсету. Теориялық құрылым мен іс зерттеу арасындағы ұқсастықтар мен айырмашылықтары анықтырылады және талдандырылады.

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Effects of Economic Freedom on the Kazakhstani Manufacturing Industry

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Abstract: This article examines the effects of economic freedom on manufacturing in Kazakhstan. Output from four manufacturing subsectors—food, metal, chemical, and machinery—are tested as dependent variables, while oil prices, the real exchange rate, and an index of economic freedom are explanatory determinants. The results indicate that economic freedom has a significant positive long-run relationship with manufacturing output. Contrary to the Dutch Disease concept, oil prices and exchange rates have positive but weak effects on manufacturing.

JEL Classifications: E02, E23

Keywords: Dutch Disease, Manufacturing, Kazakhstan, Economic Freedom, Cointegration

1. Introduction

Corden (1984) states that by the Dutch Disease, the exports of natural resources (primarily oil and gas) crowd out the manufacturing industry and lead to deindustrialization of the country due to the appreciated exchange rate and movement of the labor force from the manufacturing sector to the non-tradable or raw-materials sector. Instead of the effect of Dutch Disease, this article will examine the effects of economic freedom on manufacturing in Kazakhstan.

The main objective is to examine links of aggregate growth of the oil and gas sector to manufacturing, particularly asking if both sectors move in the same direction. The hypothesis is that rapid growth of the oil and gas sector crowded out development of manufacturing. A second goal is to see if manufacturing suffered from real appreciation of the domestic currency. Third, such factors as credit availability and government participation are embedded in the country's Index of Economic Freedom, which is an exogenous variable in the econometrics model. The purpose is to test the extent to which the business environment can account for manufacturing. Finally, we wish to determine which manufacturing subsectors are most (least) vulnerable to oil exports, the real exchange rate, and the business environment. One can infer how to improve manufacturing based on its relationship with these three determinants.

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2. Literature Review

Timmings (2004) defines manufacturing as the conversion of raw materials into products by means of physical labor and machinery (physical capital) to create wealth and satisfy demand. Manufacturing is pointless if the return on the investment is lower than the interest we earn from the deposits and if there is no market for manufactured goods (Timmings, 2004). The oil sector is regarded as detrimental to growth in manufacturing. Sachs and Warner (1995) state that the abundance of natural resources such as oil (as opposed to highly developed manufacturing) can raise macroeconomic volatility and lower long-term economic growth.

Algozhina (2006) confirms the presence of Dutch Disease in Kazakhstan based on such symptoms as a strong exchange rate and high inflation. Kuralbayeva, Karlygash, and Mutant (2001) extend the analysis of Dutch Disease in this nation by using the Balassa-Samuelson effect on higher real wages and by including the terms of trade introduced by De Gregorio and Wolf (1994). Gronwald, Mayra, and Orazbayev (2009) analyzed the effects of changes in oil prices on the Kazakhstani economy from 1994 to 2007 by using a standard vector autoregressive model. All macroeconomic variables, such as the real exchange rate, exports, budget revenues, and real GDP, exhibited a substantial negative relation to the oil price.

However, research comparing the growth rates of Kazakhstan's manufacturing, oil, and gas sectors in relation to business and economic freedom remains to be fully developed. Such research is crucial to manufacturing in Kazakhstan.

3. The Model and the Analysis

The manufacturing sector depends not only on demand and exchange rates but on the business environment. The better this environment, the more opportunities that private businesses will get to produce goods and services. Therefore, the variables for our econometric model include: a dependent variable—manufacturing output (M) for each of four subindustries (machinery, chemical, metal, and food); and independent (determining) variables—oil prices (P), the real exchange rate (E), and the Index of Economic Freedom (F). Our econometric model is:

$$M_t = \alpha_0 + \alpha_1 P_t + \alpha_2 E_t + \alpha_3 F_t + u_t$$

Here, α_0 is the intercept, α_1, α_2, and α_3 are parameter coefficients, and u_t is the random error term. All variables are expressed in logarithmic terms. Monthly data from December 2002 to September 2011 on output from each of four manufacturing subsectors, the exchange rate, oil prices, and oil output are extracted from the national statistical committee of Kazakhstan, whereas the Index of Economic Freedom is obtained from the Heritage Foundation website.

4. Regression Analysis

We analyze correlations between the variables and their orders of integration. Table 1 shows that correlations between the exchange rate and four manufacturing sectors are all negative. As the exchange rate gets stronger, manufacturing output declines. The correlation is rather strong considering the large number of observations: it ranges from -0.298 for chemical sector to -.665 for metal sector).

The oil price, however, is positively correlated with manufacturing output, ranging from 0.43 (metal) to 0.65 (machinery). The Index of Economic Freedom correlates positively with output; the highest correlation is 0.876 with the metal industry and the lowest is 0.724 with the chemical industry. The greater the economic freedom, the larger is the output.

Table 1
Correlation Matrix of Logged Variables

	LEXCH	LCH	LFD	LMACH	LMET	LO	LIEF
LEXCH	**1**						
LCH	**-0.298**	1					
LFD	**-0.321**	0.877	1				
LMACH	**-0.333**	0.712	0.834	1			
LMET	**-0.465**	0.76	0.833	0.827	1		
LO	**-0.384**	0.789	0.826	0.816	0.816	1	
LIEF	**-0.655**	0.724	0.7977	0.786	0.876	0.816	1

In principle, two time series may seem to correlate because they relate to a time trend rather than directly to one another. In such a case, the seeming correlation may deceive us. Another problem is that a time series may change in basic ways over time, invalidating predictions that are based on past data.

To cope with such problems, we can test whether the nature of a time series remains the same over time—that is, whether the series is stationary. This is the purpose of a unit root test. We use the popular Augmented Dickey-Fuller and Phillips-Perron values. The tests show that oil prices, exchange rates, the Index of Economic Freedom, and metal industry values are integrated of order one; that is, the first differences of the time series are stationary. Food, chemical, and machinery sectors are integrated at level; that is, the original time series are stationary. A vital question about time series that are nonstationary at level is whether the relationship between them is stationary; i.e., whether they are cointegrated. In that case, after analyzing the regressions, we should apply the Error Correction Model, which measures the impact of external shocks on the variables.

Table 2
Probability of the Unit Root Tests

	Augmented Dickey-Fuller Test			**Phillips-Perron Test**		
	Level	**1st difference**	**Order of integration**	**Level**	**1st difference**	**Order of integration**
Oil price	0.213**	0.000	I(1)	0.245**	0.000	I(1)
Exchange rate	0.1695**	0.0000	I(1)	0.1907**	0.000	I(1)
Index of Econ. Freedom	0.672**	0.0000	I(1)	0.653**	0.000	I(1)
Food	0.00**		I(0)	0.0003**		I(0)
Chemical	0.0000**		I(0)	0.000**		I(0)
Machinery	0.0000**		I(0)	0.000**		I(0)
Metal	0.7174	0.000	I(1)	0.1811**	0.000	I(1)
Note: * indicates 'with intercept,' ** indicates 'with intercept and trend'						

Table 3 summarizes the regressions. It shows how the oil price, exchange rate, and economic freedom index affect the output of each manufacturing sector. Oil prices have a statistically significant relationship with the machinery, chemical, and metal industries at the 5% level of significance. A 10% change in oil prices leads to a 6.3% change in the machinery sector, a 4.1% change in the chemical sector and a 5% change in the metal sector. However, the relationship with the food (0.0943) industry is insignificant and small; a 10% change in the oil price would lead to only a .9% change in the food sector.

At the 5% level of significance, the exchange rate has a significant relationship with the machinery and chemical industries only. A 10% change in the exchange rate would lead to a 4.9% change in machinery output and a 3.5% change in chemical output. The relationships with metal and food industries were insignificant and weak. A 10% change in the exchange rate leads to only a 4.4% change in metal output and a 2% decline in food output.

Economic freedom relates significantly and strongly to all four manufacturing subsectors. A rise of 1% in the Economic Freedom Index relates to 4.5% growth in machinery, 1.3% growth in metal, and 4.6% growth in chemicals. But the relationship with the food industry was significantly negative: A 1% improvement in the freedom index related to a 2.6% decline in food.

Since a 1% rise in economic freedom related to an increase of more than 1% in manufacturing, the relationship can be viewed as elastic, whereas the relationships of output in manufacturing subsections to oil prices and exchange rates were inelastic.

Table 3
Regression Summary

	Dependent variables, log			
	machinery	**chemical**	**metal**	**food**
Lo (log oil price)	0.634 **(0.000)**	0.407 **(0.0083)**	0.496 **(0.0155)**	0.0943 **(0.419)**
Lexch (log exchange rate)	0.489 **(0.0062)**	0.35 **(0.0126)**	0.443 **(0.0714)**	-0.198 **(0.0969)**
Lief (log IEF index)	4.507 **(0.000)**	1.3 **(0.000)**	4.577 **(0.0023)**	-2.587 **(0.009)**
Residual integration	-9.727 **(0.000)**	-11.483 **(0.000)**	-11.702 **0.000**	-11.944 **0.000**
R-squared	0.73	0.78	0.871	0.913
Adjusted R-squared	0.722	0.78	0.866	0.908
Durbin Watson	1.87	2.21	2.24	2.09
LM test (serial correlation)	**(0.8398)**	**(0.1556)**	**(0.5516)**	**(0.124)**
Heteroskedasticity test	**(0.2309)**	**(0.0538)**	**(0.2413)**	**(0.209)**
AIC	0.612	-0.29	0.051	-1.308
F-statistic	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**

Note: Figures in parentheses are P-values.

The four econometric models fit data well. R-squared values indicate that the models accounted for 73% to 91% of the variation in output over time.

Key results:

1. We see in descriptive statistics that fuel, service, and manufacturing sectors in Kazakhstan grew in output, wages, and employment from 2000 until about 2014.

2. Oil prices positively affect the machinery industry the most, and the chemical and food industries the least.

3. Exchange rates may affect machinery more than chemicals.

4. Exchange rates correlate with the index of economic freedom. which potentially leads to multicollinearity. This may be the reason why the exchange rates do not relate significantly to output of all four manufacturing subsectors. But the simple correlation is only -.66.

5. The index of economic freedom is the largest determinant of manufacturing output among all exogenous variables. The effect of the economic freedom index on manufacturing output is elastic, while the effects of oil prices and exchange rates are inelastic.

6. The index of economic freedom, consisting of 10 major economic, financial, and political freedom indicators, has a much stronger effect on manufacturing than do exchange rates and oil prices. Perhaps improving the business environment of Kazakhstan would boost manufacturing. This in turn may diversify Kazakhstan's economy and cut its dependence on global prices for fuel and raw materials.

7. Oil prices and exchange rates relate positively but weakly to manufacturing. A negative relationship might have signaled Dutch Disease. A positive relationship implies that the manufacturing sector did not suffer from high oil export revenues and appreciated exchange rate.

We should mention two technical issues. First, the economic freedom index is annual, so we have only 10 observations of it. This may diminish the power of the test—that is, the probability of correctly rejecting a false null hypothesis. But this may be beside the point, since we do find statistical significance for the positive coefficient on the economic freedom index, which is our main concern in this paper. Second, the economic freedom index is bounded, ranging from 0 to 100. It may be hard to interpret the impact of index changes at the bounds upon manufacturing output. So we prefer to focus on medium values of the index.

5. Conclusion

This article studied the effects of the business environment, expressed by the Index of Economic Freedom, on output of four subsectors of manufacturing in Kazakhstan—food, metal, chemicals, and machinery. Earlier research focused on determinants of Dutch Disease and the consequent changes in employment and wages across fuel, manufacturing, and service sectors. That research revealed that all three sectors (fuel, manufacturing, service) grew for at least 10 years. The service sector enjoyed the highest rate of growth and manufacturing the lowest rate.

The asserted merits of relative deindustrialization were not confirmed. Output from each of the four manufacturing industries turned out to correlate positively with oil prices and, with one exception, with exchange rates. Moreover, three of the four industries correlated positively and strongly with the index of economic freedom. A cointegration test revealed a long term relation between the independent and dependent variables.

These results suggest a need for research into such policies as easing business-startups, improving access to credit, subsidizing infant industries, investing in research, development, and education, and attracting foreign direct investment to manufacturing. The findings can also be useful to researchers who are interested in Dutch Disease and the growth of manufacturing in Kazakhstan.

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6. Summary

English: An econometric analysis finds that economic freedom has a significant positive long-run relationship with manufacturing output in Kazakhstan.

Russian: Эконометрический анализ показывает значительную долгосрочную связь экономической свободы с объемом производства в Казахстане.

Kazakh: Эконометрикалық талдау экономикалық бостандықтың Қазақстандағы өндірістік өніммен ұзақ мерзімді байланысының едәуір болуын көрсетіп жатыр

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2-, 3-, and 4-Partition Problems and Their Relation to the Equality P=NP

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Abstract: This paper considers the 2-, 3-, and 4-Partition problems in light of the algorithm for enumeration of non-negative integer solutions of linear Diophantine equations proposed by Voinov and Nikulin in 1995. We conclude that all these problems are not NP-complete. It assumes also that the 12 problems listed by Garey and Johnson in 1979, which had been claimed to be NP-complete in the strong sense, are also not NP-complete. This is a significant conclusion in the context of bin-packing and cutting-stock problems, which can now be proven to be solvable in polynomial time using, e.g., the aforementioned algorithm. The results obtained provide intriguing and rather strong evidence in favor of the equality P=NP.

Mathematics Subject Classifications (2010): 05A15, 05A18, 11D04, 11D07, 11D75, 05K05, 68Q17, 90C10, 90C27

Keywords: Combinatorial optimization, 2-, 3-, and 4-Partitions, Bin-packing and Cutting-stock problems, P=NP

1 Introduction

Algorithms for the solution to discrete optimization problems are classified into four complexity classes: P, NP, NP-complete, and NP-hard (see, e.g., Garey & Johnson, 1979).
The class P refers to problems that are solved deterministically in polynomial time, that is, time which is bounded above by a polynomial in the size of the problem's input. NP and NP-complete classes include problems that cannot be solved in polynomial time, but the solutions can be verified in polynomial time by nondeterministic algorithms. NP-hard or strongly NP-complete problems cannot be both solved and verified by using polynomial time algorithms. It is quite possible that P=NP, but as of this date there are no strong proofs of this equality or the corresponding inequality $P \neq NP$.

It is known that some discrete optimization problems can be solved in polynomial time by using the algorithm developed by Voinov and Nikulin (1995). They are: the partition problem (2-Partition in this paper), the knapsack problem (0-1, bounded, or unbounded), the subset sum problem, and the Frobenius problem (see Voinov, 2017; Voinov & Pya, 2017; Voinov, Pya, & Voinov, 2018; and Voinov, 2019). The proof follows from the fact that each of these problems can be reduced to one of enumerating all non-negative integer solutions of a linear Diophantine equation or an inequality of

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arbitrary dimension. However, several of them deserve special consideration. Garey and Johnson (1979) listed 12 problems that they claimed to be NP-complete in the strong sense. This assertion was justified based on the polynomial in time transformation of them from the 3-Partition problem, which was considered strongly NP-complete. The problems comprising the list are: [GT40] Bandwidth and [GT41] Directed Bandwidth on page 200, [GT65] Weighted Diameter on page 205, [ND46] Intersection Graph for Segments on a Grid and [ND47] Edge Embedding on a Grid on page 219, [SR1] Bin Packing and [SR2] Dynamic Storage Allocation on page 226, [SR4] Expected Retrieval Cost on page 227, [SS1] Sequencing With Release Times and Deadlines on page 236, [SS5] Sequencing to Minimize Weighted Tardiness on page 237, [SS10] Resource Constrained Scheduling on page 239, and Flow-shop Scheduling on page 241.

As the 3- and 4-Partition problems play such a crucial part in the alleged NP-completeness of all these problems, they merit special investigation.

The rest of this paper is organized as follows. Section 2 provides the relevant theoretical background and an algorithm for constructing partitions on exactly 2, 3 and 4 parts. Section 3 analyzes the solvability of 2-, 3-, and 4-partitions and the time complexity of the algorithm introduced in the previous section. Section 4 gives a discussion and the conclusions. The Appendix provides important technical details.

2 Theoretical Background

Let $a_1, a_2, ..., a_l,\ l \in Z^+$, be arbitrary positive integers such that $a_i - a_1 \neq 0,\ i = 2,3,...,l$. The subset sum problem for any sum $n \in N$ means finding all existing vectors $(s_1, s_2, ..., s_l)$ with $s_i \in [0,1],\ i = 1,2,...,l,$ such that

$$a_1 s_1 + a_2 s_2 + \cdots + a_l s_l = n\ . \tag{1}$$

Voinov and Nikulin (1995) (consult also Voinov & Nikulin, 1996) introduced an algorithm that enumerates all non-negative integer solutions of Equation (1) using the corresponding generating function and the binomial theorem. All those solutions with exactly $M \in N$ parts
can be ascertained using the generating function

$$\Psi_n(z) = (z^{a_1} + \cdots + z^{a_l})^M = \sum_{n = M\min(a_i)}^{M\max(a_i)} R_n(M,l) z^n. \tag{2}$$

The number $R_n(M,l)$ of compositions for such representations is

$$R_n(M,l) = \sum_{s_l=0}^{\left[\frac{n-Ma_1}{a_l-a_1}\right]} \sum_{s_{l-1}=0}^{\left[\frac{n-Ma_1-s_l(a_l-a_1)}{a_{l-1}-a_1}\right]} \cdots \sum_{s_3=0}^{\left[\frac{n-Ma_1-s_l(a_l-a_1)-\cdots s_4(a_4-a_1)}{a_3-a_1}\right]} \cdot \tag{3}$$

$$\cdot \frac{M!}{(M - s_2 - \cdots - s_l)! s_2! \cdots s_l!}, \tag{4}$$

where $s_2 = \dfrac{n - Ma_1 - s_l(a_l - a_1) - \cdots - s_3(a_3 - a_1)}{a_2 - a_1}$ and $s_1 = M - s_2 - \cdots - s_l$ must be non-negative integers equal to 0 or 1. Otherwise $R_n(M,l)$ will be zero. The notation $[a]$ denotes the greatest integer part of a. If the value of the term in (4) is set to 1, then formulas (3) and (4) give the exact number of equation (1) solutions. They can be written explicitly as

$$\{a_1^{M-s_2-\cdots-s_l}, a_2^{s_2}, ..., a_l^{s_l}\}\ , \tag{5}$$

where $(s_2, s_3, \ldots, s_l)$ are sets of summation indices defined by (3). This notation means that in a particular partition (a solution of Equation (1) with exactly M parts) there will be $M - s_2 - \cdots - s_l$ terms equal to a_1, s_2 terms of a_2, and so on.

The following numerical example illustrates the above approach. Let one get all non-negative integer solutions of the equation $2s_1 + 3s_2 + 5s_3 + 16s_4 = 18$ with exactly M = 6 parts. Due to (3), the number of such solutions will be

$$R_{18}(6,4) = \sum_{s_4=0}^{0} \sum_{s_3=0}^{\left[\frac{6-14s_4}{3}\right]} 1$$

with the three sets of indices (s_1, s_2, s_3, s_4) presented in Table 1.

Table 1
Sets of Indices Defined by the Above Summation Procedure

s_1	s_2	s_3	s_4
0	6	0	0
2	3	1	0
4	0	2	0

For our numerical example, $s_2 = 6 - 14s_4 - 3s_3$, $s_1 = 6 - s_2 - s_3$, and, hence, we have three solutions: $\{a_1^0, a_2^6, a_3^0, a_4^0\}$, $\{a_1^2, a_2^3, a_3^1, a_4^0\}$, $\{a_1^4, a_2^0, a_3^2, a_4^0\}$ or in terms of partitions, 3+3+3+3+3+3=18, 2+2+3+3+3+5=18, and 2+2+2+2+5+5=18.

The algorithm given by the formulas in (3), (4), and (5) was realized as the function *nlde*(*a* = *c*($a_1,\ldots,a_l$),*n*, *M*,*at.most*=*F*) in R-package "nilde" (Pya, Voinov, Makarov, & Voinov, 2019). Using the script
library(nilde)
nlde(a=c(2,3,5,16),18,6,at.most=F)
one obtains for the above example the same three solutions:

```
[1] 2 3 5 16
The number of solutions: three.
Solutions:
     sol.1  sol.2  sol.3
 s1    0      2      4
 s2    6      3      0
 s3    0      1      2
 s4    0      0      0
```

From this it follows that one may solve any subset sum problem using the above approach for enumerating all partitions on exactly M parts and then selecting those with $s_i \in [0,1]$, $i = 1, 2, \ldots, l$. This can be done by the following R-command *nlde*(*a* = *c*($a_1,\ldots,a_l$),*n*, *M*,*at.most*=*F*,*option*=*1*). For the above example, the command *nlde*(*a* = *c*(2,3,5,16),18, 6,*at.most*=*F*,*option*=*1*) returns "no solutions," as it should.

3 A Computer Experiment

Garey and Johnson (1979), on page 90, defined the Partition (2-Partition in this paper) Problem as follows: "Let the set $A = \{a_1, a_2, ..., a_n\}$ and sizes $s(a_1),\ s(a_2), ..., s(a_n)$ in Z^+ constitute an arbitrary given instance of partition. Define B to equal $\sum_{a \in A} s(a)$. If B is not evenly divisible by 2, then we know that no subset $A' \subseteq A$ can possibly satisfy

$$\sum_{a \in A'} s(a) = \sum_{a \in A - A'} s(a) \qquad (6)$$

so we can immediately respond 'no' for this instance."

Garey and Johnson used an artificial instance of partition for which $A = \{a_1, a_2, a_3, a_4, a_5,\ s(a_1) = 1, s(a_2) = 9, s(a_3) = 5, s(a_4) = 3, s(a_5) = 8.$

The answer for this instance is "yes," since $s(a_1) + s(a_2) + s(a_4) = 13 = B/2 = 26/2.$

To obtain this result they used a trivial algorithm for partitioning and showed that it is not polynomial in time. They concluded that $P \neq NP$.

Voinov (2019) revisited this instance and showed that the R-command *nlde*(*a* = *c*(1,9,5,3,8),13, *option=1*) gives a polynomial-in-time solution of this example, if *n* is considered as the size of the problem.

In this paper we analyze the time complexity of the algorithm described in Section 2, using a different approach. To do this, we first present the 2- Partition problem, similar to that for 3-Partition of Garey and Johnson (1979), page 96, as follows:

3.1 2-Partition

Instance: A finite set *A* of 2*m* elements, a bound $B \in Z^+$, and a "size" $s(a) \in Z^+$ for each $a \in A$ such that each $s(a)$ satisfies $B/3 < s(a) < B$, and such that $\sum_{a \in A} s(a) = mB$. Question: Can *A* be partitioned into *m* disjoint sets $S_1, S_2, ..., S_m$ such that for $1 \le i \le m,\ \sum_{a \in S_i} s(a) = B.$ (Notice that the above constraints on the item sizes imply that every such S_i must contain exactly two elements from *A*.)

Garey and Johnson wrote that the set *A* should be arbitrary, but instead they used an artificial instance. In view of this, we decided to use sets generated at random. To realize this idea, we developed the corresponding R-script (see the Appendix). Let for example *B* = 90, *m* = 2 and *M* = 2. In this case $31 \le s(a) \le 89,\ mB = 180$, which is divisible evenly by 2. Using the standard PC (with RAM=16 GB, CPU G4600 @3.6 GHz) and the script provided in the Appendix we have generated many solutions of the problem answering "yes" on the Question. Two examples of those solutions are given below for illustration.

[1] 39 48 51 42

The number of solutions: two. Solutions:

	sol.1	sol.2
s1	0	1
s2	1	0
s3	0	1
s4	1	0

[1] 34 35 56 55
The number of solutions: two. Solutions:

	sol.1	sol.2
s1	0	1
s2	1	0
s3	0	1
s4	1	0

The line [1] presents a random sample. The next lines show solutions of the problem. Note that they are disjoint and that for all of them $\sum_{a \in S_i} s(a) = B$. These results do not contradict the theory of Garey and Johnson that the partition is impossible if *mB* is not divisible by 2. Indeed, if, e.g., *mB* is 181, then by using the above script, it can be shown that there are no solutions satisfying (6). So our computer experiment confirms that conclusion of Garey and Johnson.

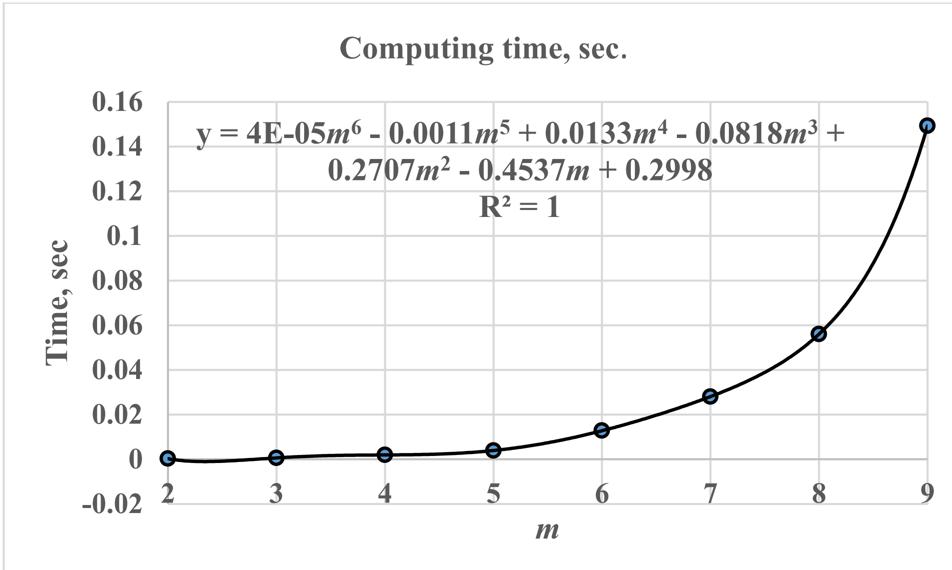
Garey and Johnson, using a trivial algorithm for partitioning, have shown that the Partition problem cannot be solved in polynomial time. Their principal conclusion was that the Partition Problem, and all others that are reduced to this one (see Karp, 1972), are NP-complete. In our opinion, the question is still unanswered, because other possible algorithms (except that used in Garey & Johnson, 1979) of partitioning have not been considered. That is why we decided to investigate the time complexity of the algorithm presented by the formulas in (3), (4), and (5). Using the script of the Appendix, we generated at random 2,000 sets *A* of size *mB* with *B* = 90 for m = 2, 3, ..., 9. Table 2 presents average times as a function of *m*.

Table 2
Computing Times, Sec. for M=2

m	Time, sec.
2	0.000294
3	0.000625
4	0.001977
5	0.003917
6	0.012833
7	0.028069
8	0.056067
9	0.149287

The trend line of this function, produced by Microsoft Office 2013, is presented in Figure 1.

Figure 1
Computing Times as a Function of m



From that figure, we see that the best fit is the polynomial function of order <6. For a more detailed analysis of this curve fitting, we used the contemporary recommendations of Das, Chakraborty, and Mitra (2014) and Rossiter (2016). For eight models we computed the sum of squared errors (SSE), R^2, adjusted R^2, root mean squared error (RMSE), and Akaike's information criterion (AIC). The results of computations are in Table 3.

Table 3
Curve Fitting Parameters

Model	SSE	R^2	Adj. R^2	RMSE	AIC
Exp. using lm()	0.103213	0.996900	0.996400	0.1135855	-6.100169
Exp. using nls()	0.000040	0.997835	0.997475	0.0022311	-68.98107
Polynom. of degree 3	0.000288	0.984300	0.972600	0.0060015	-49.14882
Polynom. of degree 4	0.000065	0.996500	0.991700	0.0028522	-59.05152
Polynom. of degree 5	0.000011	0.999400	0.998000	0.0011486	-71.60379
Polynom. of degree 6	**0.000000**	**1.000000**	**1.000000**	**0.000019**	**-134.987**
Power with intercept	0.009511	0.483013	0.396849	0.0344800	-25.17496
Power without intercept	0.00097	0.994703	0.993820	0.0034901	-61.82201

From this table we see that the best fit is achieved for the polynomial function of order 6.

3.2 3-Partition

The 3-Partition Problem was defined by Garey and Johnson (1979), page 96, as follows: Instance: A finite set *A* of *3m* elements, a bound $B \in Z^+$, and a "size" $s(a) \in Z^+$ for each

$a \in A$, such that $B/4 < s(a) < B/2$, and such that $\sum_{a \in A} s(a) = mB$. Question: Can A be partitioned into m disjoint sets $S_1, S_2, ..., S_m$ such that for $1 \le i \le m$, $\sum_{a \in S_i} s(a) = B$. (Notice that the above constraints on the item sizes imply that every such S_i must contain exactly 3 elements from A.)

Garey and Johnson claimed that the answer to this Question is "no," and hence the 3-Partition problem is NP-complete in the strong sense. They affirmed this claim by saying that it is solved by a "pseudo-polynomial time algorithm" that can be a polynomial time for restricted problems. Below we present several counter examples disproving that assertion of Garey and Johnson.

Let $m = 2$, $M = 3$, $B = 90$. Using the script of the Appendix, many random sets A of size $mB = 180$ such that $23 \le s(a) \le 44$ were generated. Many 3-partitions satisfying the Question and hence answering "yes" have been obtained.

Four examples of those solutions for $m = 2$, $M = 3$, and $m = 3$, $M = 3$ are given below for illustration.

For m=2.
[1] 35 29 28 34 26 28
The number of solutions: two.
Solutions:

	sol.1	sol.2
s1	0	1
s2	0	1
s3	1	0
s4	1	0
s5	0	1
s6	1	0

[1] 41 27 27 23 26 36
The number of solutions: two.
Solutions:

	sol.1	sol.2
s1	0	1
s2	1	0
s3	1	0
s4	0	1
s5	0	1
s6	1	0

Let now $m = 3$, $M = 3$, $B = 90$.

[1] 30 25 29 36 25 25 40 24 36
For this sample the number of solutions on exactly three parts is 11, but only three of them (listed below) are disjoint, and satisfy the Question.

	sol.1	sol.7	sol.9
s1	0	1	0
s2	1	0	0
s3	1	0	0
s4	1	0	0
s5	0	0	1
s6	0	0	1
s7	0	0	1
s8	0	1	0
s9	0	1	0

[1] 28 25 37 24 25 23 30 37 41
For this sample the number of solutions on exactly three parts is eight, but only one of them (given below) is disjoint satisfying the Question.
The number of solutions: eight.

	sol.1	sol.5	sol.7
s1	1	0	0
s2	1	0	0
s3	1	0	0
s4	0	0	1
s5	0	0	1
s6	0	1	0
s7	0	1	0
s8	0	1	0
s9	0	0	1

Note that as the Question claimed, all solutions are disjoint and hence fully satisfy the problem's conditions. It simply means that the 3-Partition Problem is not strongly NP-complete.

An experiment analogous to that conducted in subsection 3.1 produced the data shown in Table 4 (see also Figure 2).

Table 4
Computing Times, Sec. for M=3

m	Time, sec.	St. dev. of the mean
1	0.00018	0.00008
2	0.00214	0.00026
3	0.01120	0.00038
4	0.02666	0.00036
5	0.07056	0.00043
6	0.16342	0.00050

Figure 2
Computing Time, Sec. for M=3

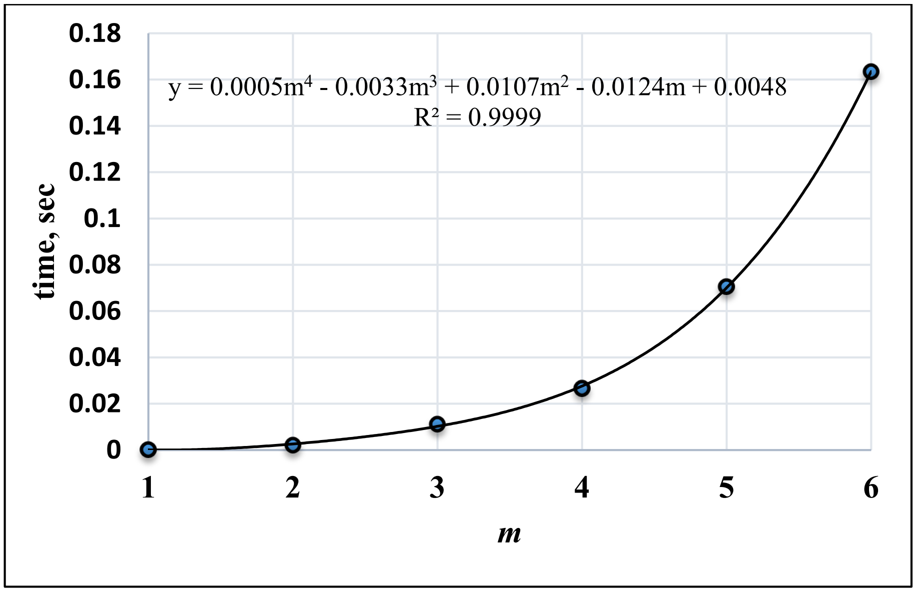


Figure 2 tells us that the 3-Partitions are enumerated in time bounded above by a polynomial in *m* of order 4.

From all the above results, it follows that the 3-Partition Problem is not only not NP-complete in the strong sense, but, being solvable in polynomial time, is not NP-complete at all.

3.3 4-Partition

Garey and Johnson wrote that the "4-Partition Problem is identical to 3-Partition except that the set *A* contains *4m* elements and each $s(a)$ must satisfy $B/5 < s(a) < B/3$. Thus each set in the desired partition will contain exactly four elements."

Let $m = 2$, $M = 4$, $B = 90$. Using the script of the Appendix, many random sets *A* of size $mB = 180$ such that $19 \leq s(a) \leq 29$ were generated. Many 4-partitions satisfying the Question and hence answering "yes" have been obtained.

Two examples of those solutions for $m = 2$, $M = 4$ are given below for illustration.

[1] 23 27 23 25 21 20 19 22
The number of solutions: six.
Solutions:

	sol.1	sol.5
s1	1	0
s2	0	1
s3	0	1
s4	1	0
s5	0	1
s6	1	0
s7	0	1
s8	1	0

[1] 20 19 24 28 22 20 22 25
The number of solutions: four.
Solutions:

	sol.1	sol.2
s1	0	1
s2	1	0
s3	1	0
s4	0	1
s5	1	0
s6	0	1
s7	0	1
s8	1	0

Note that as the Question claimed, all solutions are disjoint and hence fully satisfy the problem's conditions. It simply means that the 4-Partition Problem is not strongly NP-complete.

4 A Discussion and Conclusions

Over the last several years, it has been proven that the partition problem, the knapsack problem, the subset sum problem, and the Frobenius problem are all solvable in polynomial time (see Section 1). Moreover, the R-package "nilde" that can solve the above problems in polynomial time has been developed and published (consult Pya, Voinov, Makarov, & Voinov, 2019). During the same period, based on the conclusions of Garey and Johnson (1979) that the 3-Partition Problem is NP-complete in the strong sense, the prevailing opinion was that bin-packing and cutting-stock problems are also strongly NP-complete (consult Delorme, Lori, & Martello, 2016 and 2018). On the contrary, the results presented in Section 3 prove that the 3-Partition problem is not NP-complete in the strong sense. Instead, it is solvable in polynomial time, and thus is not even NP-complete. Since bin-packing problems can be reduced to 3-partition problems in polynomial time, they are also proven to be not strongly NP-complete. To confirm this conclusion, the R-package "nilde" (Pya, Voinov, Makarov, & Voinov, 2019) can be employed, which can solve any one-dimensional bin-packing problem in polynomial time using the function *bin.packing(input.a,input.n,bin.globals*) (see Voinov, Makarov, & Voinov, 2019).

As the cutting-stock problem is a particular case of the bin-packing one (consult Delorme, Lori, & Martello, 2016, p. 2; and Delorme, Lori, & Martello, 2018, p. 236), it follows that the one-dimensional cutting-stock problem is also solvable in polynomial time, and thus is not NP-complete.

The aforementioned results provide strong evidence for the equality P=NP. This intriguing conclusion is significant not only for the theory of NP-completeness, but especially for practitioners because the results obtained in this research help in the development of much faster (polynomial in time) software to solve these kinds of problems.

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5. Summary

English: The paper is devoted to the solution of 2-, 3-, and 4-partition problems. The main result is that these problems, as well as all NP-hard ones, are solvable in polynomial time. That is evidence in favor of the equality P=NP.

Russian: Статья посвящена решению задач 2, 3 и 4-разбиений. Основной результат состоит в том, что эти задачи, также как и все NP-трудные проблемы, разрешимы в полиномиальное время, что свидетельствует в пользу равенства P=NP.

Kazakh: Мақала 2, 3 және 4-бөлімдердің мәселелерін шешуге арналған. Негізгі нәтиже-бұл міндеттер, барлық NP сияқты, қиын мәселелер көпмүшелік уақытта шешіледі, бұл p=NP теңдігінің пайдасын көрсетеді.

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7. Appendix

```
library(nilde)
  set.seed(1044)
generateSample<- function(){
 x<-array (0,dim=4)
x<-sample(31:89,4,replace=T) y<-sum(x)
while(y!=180){
x<-sample(31:89,4,replace=T) y<-sum(x)
}
return(x)
}
for (b in 1:5){ m<-50
system.time<- rep(NA,m) for(i in 1:m){
newSample<-generateSample()
b<-nlde(a=newSample,n=90,M=2,at.most=F,option=1) while(b[1]==0){
newSample<-generateSample()
b<-nlde(a=newSample,n=90,M=2,at.most=F,option=1)
}
print(newSample) startTime<-Sys.time()
nlde(a=newSample,n=90,M=2,at.most=F,option=1)
endTime<- Sys.time()
system.time[i]<- endTime – startTime
print(b)
}
mean.time<- mean(system.time)
std.time <- var(system.time)^0.5/m^0.5
message ("Total number of nlde executions: ",m) message ("Mean system time: ",mean.time)
message ("Standard Dev of system time: ",std.time)
}
```

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