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Forecasting the Timing of the Emergence of a Dominant Design: The Case of the Projectors

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Abstract. The timing of market entry is important for companies to achieve commercial success. The relationship between good market entry timing and the emergence of a dominant design was discussed. However, the dominant design was assumed to be known only in retrospect. In this study, targeting the projector industry, we demonstrate that the timing of the emergence of the dominant design can be forecast in advance by deriving the time relationship between product launch and patent application. The emergence of dominant designs and the timing of their emergence were identified based on the analysis of product trends in the market. The timing of the patent application that the dominant design will emerge was forecast based on the analysis of technology trends using patent information. The cycle type of the projector industry was considered, and the time lag between patent application and product launch was inferred. This study provides a useful insight into the dominant design.

Keywords: Dominant design; Patent analysis; Process innovation; Product innovation; Projector

1. Introduction

Companies are expected to create innovations to survive and maintain competitiveness in the market (Berawi, 2021). They comprehend their customers' needs, develop new products that fulfill the desired value, and subsequently introduce these products to the market. When customers find satisfaction in the value of the product, the company, in turn, captures value (Kotler and Armstrong, 2011). In this way, commercial success is achieved.

The market entry of innovative products significantly changes the competitive environment (Gerken, Moehrle, and Walter, 2015) and requires firms to improve their business, product, and process development (Taleb and Pheniqi, 2023). The timing of a new market entry is a strategic decision for firms, and its timeliness is crucial to forming a competitive advantage (Tatiana and Mikhail, 2020; Suarez, Grodal, and Gotsopoulos, 2015).

Several researchers have studied the order of entry for first movers and latecomers, and a variety of findings are known: whether early or late entry is more advantageous depends on firm-specific characteristics (Lieberman and Montgomery, 1988); newcomers are more likely to gain market share with early entry, while incumbents are more likely to perform better if they wait while newcomers test the markets (Mitchell, 1991); early entry

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during the growth phase of the industry life cycle is helpful for survival, but is detrimental during the maturity phase (Agarwal, Sarkar, and Echambadi, 2002). However, these studies are based on relative time order - earlier or later.

In contrast, with respect to the specific time, several previous studies disclose the timing of entry. Entry was particularly advantageous during a window just before the emergence of a dominant design (Christensen, Suarez, and Utterback, 1998). The firms that ended up capturing the new market appeared just when the dominant design was about to emerge (Markides and Geroski, 2004). In the concept of a dominant category, firms that enter during the time window between the emergence of the dominant category and the emergence of a dominant design tend to perform better than firms that enter during other phases (Suarez, Grodal, and Gotsopoulos, 2015). A good time for market entry is when. At least, it's common knowledge that it precedes the emergence of a dominant design (Baum *et al.*, 1995; Suarez and Utterback, 1995).

Suppose the timing of market entry can be identified early and with high probability. In that case, companies will be closer to commercial success by developing and implementing strategies to coincide with the timing of market entry.

2. The emergence of a dominant design and the timing of its emergence

What is a dominant design? Utterback (1994) defined that a dominant design was the one that won the allegiance of the marketplace. Anderson and Tushman (1990) defined a dominant design as a single configuration or a narrow range of configurations that accounted for over 50 percent of new product sales or new process installations and maintained a 50 percent market share for at least four years. Moreover, Koski and Kretschmer (2007) stated that horizontal and vertical innovations that were imitated widely by competitions form a dominant design. Thus, the emergence of a dominant design is a situation in which a certain design is widely recognized in the market at a certain time, and the timing itself is nothing other than the timing of its emergence.

The emergence of a dominant design is analyzed from the perspective of markets and products. Utterback (1994) discussed the emergence of dominant designs from the entries and exits of firms in the market for eight cases, including the manual typewriter and automobile industries. Srinivasan, Lilien, and Rangaswamy (2006) constructed case histories for each product category's evolution for 63 office products and consumer durables and then identified if and when a dominant design emerged. Koski and Kretschmer (2007) discussed the dominant design in mobile telephony based on the development of design and features from product information. Similarly, Cecere, Corrocher, and Battaglia (2015) analyzed the emergence of the dominant design in smartphones by focusing on the evolution of product characteristics. Huenteler *et al.* (2016) showed the emergence of dominant designs for solar PV by market share of different designs and for wind power by the share of firms with different designs active in the market. The number of firms, product development and evolution, and share of designs, which previous researchers used as factors in their analysis, are observed as a result after firms and products have appeared on the market. Dominant designs can only be known in retrospect (Anderson and Tushman, 1990), and it is doubtful that they can be recognized except in retrospect (Utterback, 1994).

On the other hand, from the perspective of technology and invention, there are prior studies concerning the emergence of a dominant design that focuses on patent information. Clymer and Asada (2008) demonstrated the emergence of dominant designs for each firm based on the number of patents in nine categories for inkjet printers. Brem, Nylund, and Schuster (2016) evaluated whether a dominant design existed in a certain patent class

during a certain year, focusing on the percentage of patents that cited the same patent in a patent class. Ishii, Kaminishi, and Haruyama (2021), Ishii *et al.* (2019) illustrated the emergence of dominant designs by investigating the innovation of products and processes using the number of patents from Japanese patent classification for inkjet printers and projectors.

It is generally accepted that patents represent a significant indicator of research and development activities and innovation for companies (Rocheska *et al.*, 2017; Griliches, 1998). Inventions are filed as patents, generally published after 18 months, and some are granted. An innovative product is developed using the invention, offered to the market, and positioned as a dominant design through wide market recognition. Therefore, if it takes several years to several decades from the time when analyzable published patent information is available to when the dominant design emerges, we believe that we can forecast the emergence of the dominant design and the timing of its emergence with high probability during this period.

In the previous study, the analysis of patent information indicated the emergence of a dominant design, but it has not been specifically verified whether a dominant design had really emerged in the market. Ishii, Kaminishi, and Haruyama (2021) identified the emergence of a dominant design in a product launched three years after the timing of the emergence forecast by the patent analysis, one of which was the world's first laser light source projector. However, whether the product is appropriate as the emergence of dominant design in light of the definition by the previous researchers has not been fully discussed.

The purpose of this study is to answer the question of whether the timing of the emergence of a dominant design cannot be forecast. If so, companies can gain a competitive advantage and increase their chances of commercial success by entering the market before the timing of its emergence. The analysis proceeds as follows. From the market and product perspectives, we identify whether a dominant design emerged and when it emerged. Next, from the technology and invention perspectives, we apply patent analysis to forecast the emergence of the dominant design and the timing of its emergence. We then use the actual identified results and the forecast results to clarify the issues and consider their validity.

3. Methods

The analysis was conducted in three steps: selecting a product category, identifying the actual emergence of a dominant design based on the analysis of product trends, and forecasting the emergence of a dominant design based on the analysis of technology trends. Figure 1 shows the three-step process in this study. In the first step, a product category that has reached the mature stage of its product life cycle was selected as the analysis target. This is because it can be assumed that a dominant design has already emerged. In the next step, a large number of products introduced to the market by each company were investigated, and their product trends were analyzed. Based on the trend analysis, the emergence of a dominant design was identified, i.e., the product attributes that were widely recognized in the market and the timing of its emergence. In the last step, some patent information on the product was extracted, and their technology trends were analyzed. Based on the trend analysis, the timing of the emergence of a dominant design was forecast.

3.1. Selecting a product category

Focusing on the projector industry, we considered the specific segment to be analyzed. When trying to identify product attributes that were widely recognized in the market, product type and brightness were thought to have a particularly large impact on product

design in projectors. These two product perspectives, along with market share information, were used to select the segment.

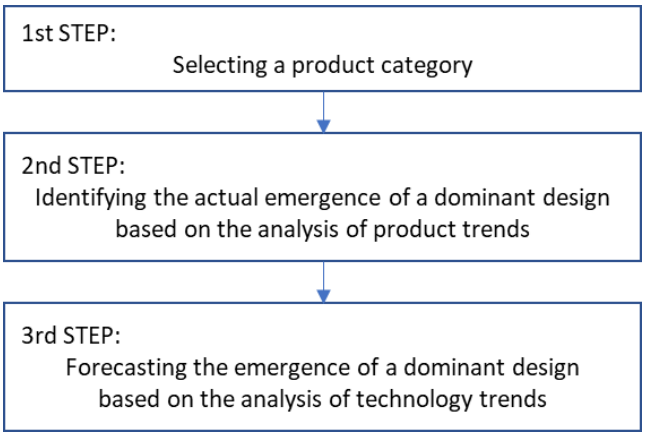


Figure 1 Three-step process for forecasting the timing of the emergence of a dominant design

3.2. Identifying a dominant design based on the perspective of markets and products

Koski and Kretschmer (2007) discussed the emergence of a dominant design from the perspective of vertical and horizontal innovation, focusing on the design and features of cellular handsets. In the product category of projectors selected above, we considered that product selection at the time of purchase was influenced by the average acceptability of all users, whereas consumer-oriented products such as cell phones emphasize the preferences of individual users. In this analysis, we focused on the design and features related to the core benefits that the product category provides to its users, with particular attention to the perspective of vertical innovation.

In this section, the following procedure was used for the analysis. First, we selected product attributes that represent fundamental and essential design features from the user's viewpoint. Second, the coefficient of variation and coverage were evaluated as indicators according to the characteristics of the attributes, and the evolution of their attributes was analyzed. Third, the actual emergence of a dominant design as a product category was identified based on when each attribute was a dominant design.

The attributes were divided into quantitative and binary attributes. The quantitative attributes were evaluated based on whether the coefficient of variation (CV) was homogeneous, and binary attributes (presence or absence of attributes) were evaluated based on whether the coverage was sufficiently high. As a criterion to determine whether the attribute reached a dominant design, i.e. whether the attribute was widely recognized in the market, a threshold of 0.8 was set for the coverage, considering that an attribute that was installed in 80% of the products was sufficiently recognized in the market. Given a binomial distribution with "installed" as 1 and "not installed" as 0, the coefficient of variation is 0.5 when 80% of the products were equipped with the attribute. The threshold of the coefficient of variation was set to 0.5, which was equivalent to the threshold of the coverage.

3.3. Forecasting a dominant design based on the perspective of technology and patents

To derive the timing of the emergence of a dominant design quantitatively based on patent information, we returned to the figure of "The Dynamics of Innovation" by Utterback (1994) and redefined the timing of its emergence. Utterback (1994) stated that the emergence of dominant design shifts the competitive emphasis from product innovation to process innovation and that the market acceptance of product innovation and the

emergence of dominant design are hallmarks of a transition phase. In light of this context and the figure, we considered the boundary between the fluid phase and the transitional phase, where the curves of product innovation and process innovation crossed, to be the timing of the emergence of a dominant design.

Methods for separating patent applications into product innovation and process innovation were disclosed, such as using the Japanese patent classification (Ishii, Kaminishi, and Haruyama, 2021; Ishii *et al.*, 2019) and using claim categories (Wittfoth, Berger, and Moehrle, 2022). It was also mentioned that text mining, a variation of data mining that extracts information from structured data, was effective for analyzing large amounts of data, such as patent information (Surjandari, Naffisah, and Prawiradinata, 2015). Masuda and Haruyama (2021) pointed out that a clear perspective on forecasting technology trends was provided by using the approach that separates published patents into product and process inventions by performing text mining on the title of inventions.

To predict the timing of the emergence of a dominant design, we applied Masuda and Haruyama (2021) approach, wherein patent applications were categorized into product and process inventions. The intersection point of these two curves was then derived.

In this section, the following procedure was used for the analysis. First, the patent population for the projector under analysis was collected using the patent database of the Japan Patent Office (JPO). Second, the patent population was then divided into two subpopulations, product inventions and process inventions, using Masuda and Haruyama's approach (Masuda and Haruyama, 2021). Third, the crossing point was derived from these two curves, and the timing of the emergence of a dominant design was forecast.

4. Results

According to the method described in Section 3, the timing of the actual emergence of the dominant design in the product category was identified. The timing of the emergence was forecast based on the patent analysis of the product.

4.1. Selecting a product category

Table 1 shows the product types and their main applications. The product types were segmented into three main categories: business and education, home, and mobile. The installation and usage methods differ by product type, which limits the size and weight of the product and influences the product design. In addition, the resolution of the required image display panel (e.g., liquid crystal display panel) tends to differ depending on the application, and the choice of the image display panel and its controller influences the product design.

Table 1 Segmentation of projectors in terms of product types

Product types	Main applications
Business and Education	Corporate and educational products for presentation use in offices and educational facilities, mainly for projecting still images
Home	Consumer products for home theater use, mainly for projecting moving images
Mobile	Specialized lightweight products for portable use

Brightness is one of the fundamental attributes of projectors and is required to ensure visibility according to the space and situation in which the projector is used. Table 2 shows the brightness required for different applications. The brightness was segmented into three categories, with the central range of brightness set at 2,000 - 4,000 lumens. Projectors tend to be equipped with high-power light sources depending on the brightness, which increases the size and weight of the product and has a significant impact on the product design.

Table 2 Segmentation of Projectors in terms of brightness

Brightness	Main applications
< 2000 lumens	Relatively dark rooms or small spaces (e.g. home or mobile applications)
2,000 - 4,000 lumens	Bright and medium-sized spaces, such as general meeting rooms or classrooms
> 4,000 lumens	Larger space, such as large conference rooms or halls

According to market research, the volume share of Japanese manufacturers in the global market for the projector industry in the 2010s exceeded 50%. We assumed that the product trends among Japanese manufacturers roughly reflect global market trends. In the analysis of product trends described below, we focused on the products launched by Japanese manufacturers in the Japanese market and analyzed the product information on their websites. For the analysis of technology trends, we focused mainly on patent information from the Japan Patent Office (JPO), where patent applications of Japanese manufacturers are filed.

In the Japanese market in the early 2010s, the volume of the business and education category accounted for approximately 80% of all projectors, of which the volume of the 2,000 - 4,000 lumens brightness category accounted for approximately 85%. This product category was regarded as the main category of the projector industry and was selected to be analyzed in this study. The volume of this product category slowly increased, peaked in 2016, and decreased since then. We considered that the projector industry had reached the maturity stage of its product life cycle and that a dominant design already emerged.

4.2. Identifying a dominant design by product trends

4.2.1. Selecting some attributes

Brightness was selected as an attribute for the design aspect. The rationale behind this lies in the limited product category of brightness (2,000 - 4,000 lumens). When the price remains constant, there is a tendency to favor brighter products. As a result, brightness is considered a fundamental attribute in the context of vertical innovation. In the business and education category, size, weight, and resolution are not considered important attributes for selecting a product. Since business and education projectors are always installed in meeting rooms and classrooms or suspended from ceilings, size, and weight do not have much influence on product selection. Similarly, resolution has no impact if it is sufficient for business and education applications. Some users purchase higher-priced products due to their smaller size, lighter weight, and higher resolution, but they are limited.

Next, we consider the features aspect. The main role of projectors is to project image information input from a PC or other device onto a screen. A D-subminiature (D-sub) connector that supports analog signals is necessary basic equipment for inputting image information to the projector. A high-definition multimedia interface (HDMI) connector supports digital signals. Especially for business and education applications, it is essential to have a universal serial bus (USB) type-A connector that allows image information to be input from a USB memory device without a PC, and a wired and/or wireless local area network (LAN) connection that allows remote input of image information and remote control of the projector. For projection onto a screen, manual and/or automatic keystone correction (KC) to correct for image distortion is a fundamental feature, especially vertical KC, since the projector is usually installed squarely facing the screen, not at an angle. Horizontal KC is only required for special installations.

The following fundamental and essential attributes were selected as required for business and education projectors: brightness, various connectors (D-Sub, HDMI, USB type-

A), LAN connection, and vertical KC. For each of these attributes, we quantitatively analyzed the evolution of the coefficient of variation and the coverage to evaluate the emergence of a dominant design.

4.2.2. Actual emergence of a dominant design

We examined the products launched in the Japanese market between 2000 and 2017 by the top three Japanese manufacturers of volume share in the early 2010s, EPSON, NEC, and HITACHI, to analyze product trends. The volume share of these three companies in the global market was approximately 40%. The number of 2,000 - 4,000 lumens business and education projectors listed from each manufacturer's website was 344 in total (EPSON: 143 products (EPSON, 2022), NEC: 121 products (NEC, 2022), HITACHI: 79 products (HITACHI, 2022). Figure 2 shows the product trends of each company. The first products were first launched in 2000, and the number of products peaked in 2011.

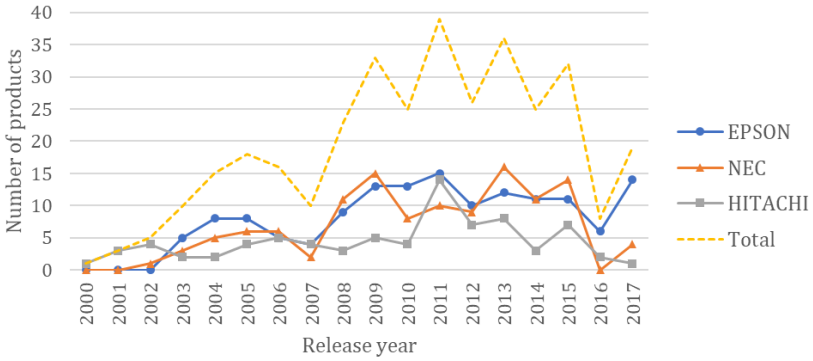


Figure 2 Product trends of each company

For each attribute, the analysis was conducted after 2003, when the number of products reached double digits. Figure 3 shows the mean value and the coefficient of variation (CV) for the brightness of products launched each year. A three-year simple moving average was used for smoothing. The reason for using a three-year period was to remove one-year-level irregularities while minimizing the effects of five-year-level long-term fluctuations to obtain the timing of the emergence of a dominant design on an annual basis. The mean value was approximately 2,500 lumens in 2003, increasing monotonically to approximately 3,500 lumens in 2016. The calculated coefficient of variation decreased monotonically, without peaks, and their heterogeneity was not observed. Here, CV is calculated by dividing the standard deviation of the brightness of the projectors divided by their mean brightness each year. The CV remained homogeneous since 2003, with a value less than half of the threshold of 0.5. Brightness, a fundamental attribute of the design aspect, became the dominant design at an early stage.

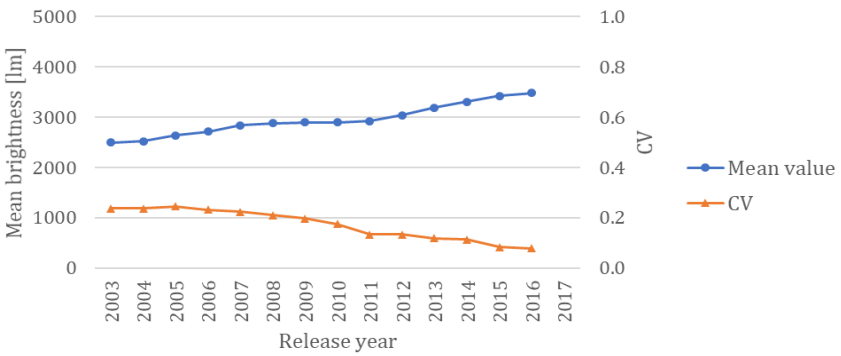
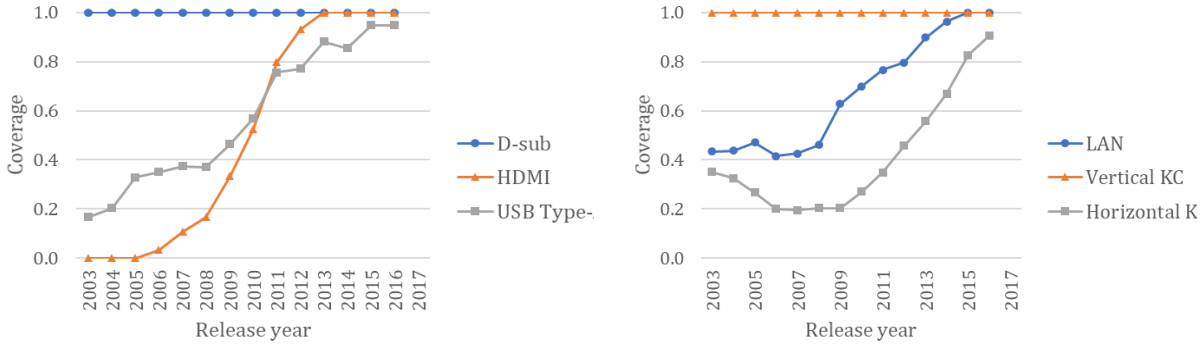


Figure 3 Mean value and the coefficient of variation (CV) for brightness

Figure 4(a) shows the three-year simple moving averages of the coverage of the D-Sub connector, HDMI connector, and USB type-A connector, which are the image information input equipment. The coverage of each feature is calculated as the number of products equipped with the feature divided by the total number of products. The D-sub connector remained at the coverage of 1.0 since 2003 and was an analog input connector equipped as a fundamental feature of this product category from the early stage. The HDMI connector, a digital input connector that enables simultaneous transmission of digital images and audio, spreads to flat-panel TVs and optical disc devices, then to projectors. The coverage of HDMI connectors rapidly increased, exceeding 0.8 in 2011 and reaching 1.0 in 2013, as they eliminated the need for audio cables. The USB type-A connector coverage gradually increased, exceeding 0.8 in 2013.



(a) (b)

Figure 4 The coverage: (a) D-sub, HDMI and USB Type-A connectors; (b) LAN connection and Vertical/Horizontal KCs

Figure 4(b) shows the three-year simple moving averages of the coverage of LAN connection and vertical/horizontal keystone corrections. The LAN connection coverage increased gradually and reached 0.8 in 2012. The coverage of vertical keystone correction remained at 1.0 since 2003, indicating that it became a fundamental feature early on. In contrast, the coverage of horizontal keystone correction exceeded 0.8 in 2015. We assume that the equipment of this feature was delayed because the feature is not used in the normal installation of the projector (i.e. installed squarely against the screen) and is required only for limited users.

The attributes for the features aspect are summarized below. The D-sub connector and vertical KC achieved full coverage with a rating of 1.0 in 2003, establishing each as the dominant design. The HDMI connector, USB type-A connector, and LAN connection became the dominant design in 2011, 2013, and 2012, respectively, when they reached the threshold of coverage.

The attributes of design and features consist of the fundamental attributes that were available early on: brightness, D-sub connector, and vertical keystone correction, and the essential attributes that became dominant design at approximately the same time from 2011 to 2013: HDMI connector, USB type-A connector, and LAN connection. Since each attribute was the dominant design in 2013, the dominant design as the product category was formed at this time.

4.3. Forecasting the timing of the emergence of a dominant design through patent analysis

Patents published by the JPO were used in this patent analysis. The database of published patents on projectors was generated using two search queries: the theme code of 2K203, which is an original Japanese patent classification, and the publication date from

1/1/1981 to 12/31/2020. The database contains approximately 30,000 patents with a search date of 3/2022.

In discussing a dominant design, we focused on granted patents in that companies ensure the protection and utilization of inventions to contribute to the development of industry (JPO, 1959) and bring their products to the market.

Approximately 11,000 patents granted by the search date were extracted from the database. The period from the filing date to the registration date was calculated for each patent. Figure 5 shows the mean (M) and standard deviation (SD) of the period. The period decreased monotonically, and M+3*SD was approximately 7.2 years as of 2014-2015. As of 2022, the search date, most of the patents filed by 2015 will have been granted. Therefore, when conducting a patent analysis using granted patents, the effective filing date is up to m2015. Furthermore, based on the market information shown in Section 4.1, the dominant design is considered to have emerged before 2016, so information on patent applications up to 2015 is sufficient.

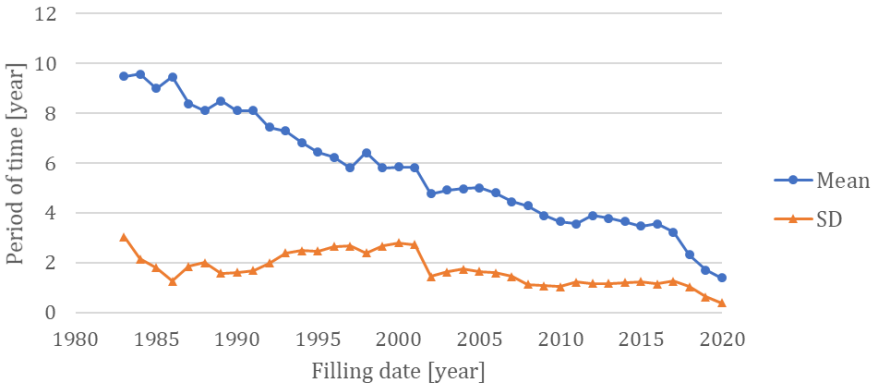


Figure 5 The period from the filling date to the registration date

In the subsequent analysis, granted patents for which patent applications were filed by 2015 were extracted from the database and used as the population. The population consisted of approximately 9,900 patients. The population was separated according to whether the title of the invention contained a noun phrase consisting of a process innovation-related keyword and the word method, generating two sub-populations. The former was process inventions, and the latter was product inventions (Masuda and Haruyama, 2021). Since innovation output can be related to the number of patents (Watanabe, Tsuji, and Griffy-Brown, 2001; Crepon, Duguet, and Mairessec, 1998), we replaced process innovation with process inventions and product innovation with product inventions to measure the extent of innovation.

Figure 6 shows the trends of product innovation and process innovation, normalized to 1 for the total number of patents granted by 2015 for product inventions and process inventions, respectively. This figure corresponds to that of "The Dynamics of Innovation" by Utterback (1994). Here, a three-year simple moving average was used for smoothing. Product innovation peaked around 2005, and as product innovation decreased, process innovation increased, peaking in 2012 and decreasing thereafter. This indicated a shift from product innovation to process innovation. The crossing point of the two curves was in 2007-2008. This timing of patent application forecasts the timing of the emergence of the dominant design.

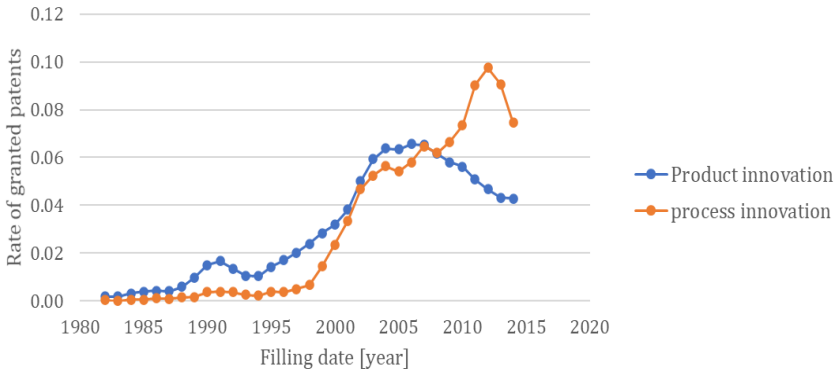


Figure 6 The trends in product and process innovations by granted patents

5. Discussion

In Section 4.2, we showed the actual emergence of the dominant design in the market and the timing of its emergence based on the product trend. In Section 4.3, we showed the timing of patent application, forecasting the emergence of the dominant design based on the technological trend from the patent analysis. In relation to these two results, what is the time lag between filing a patent application and introducing a product to the market? Combining the results of previous studies and this study, we discussed the cycle type of the projector industry and estimated its time lag.

Then, although there is no doubt that the emergence of a dominant design is the result of a market response, we examined whether it was possible to forecast the emergence of the dominant design in advance, i.e., whether the forecast of the timing of its emergence by patent analysis was valid compared to the fact of the timing of its emergence in the market.

In Section 3.3, we showed how to find the trends of product innovation and process innovation, which are a type of technology trend, using Japanese patents, and accordingly, we depicted these trends in Figure 6 in Section 4.3. We examined whether the method used in this study is also applicable to non-Japanese patents.

5.1. Time lag between patent application and product launch on the market

There was a positive relationship between patents and new product announcements (Artz *et al.*, 2010), and patents were a useful information source for anticipating perspective products (Gerken, Moehrle, and Walter, 2015). Specifically, there are previous studies on the time lag between patent applications and product launches. As an example for one industry, Gerken, Moehrle, and Walter (2015) observed that the time lag between patent filing and market launch was approximately 30 months on average and up to 56 months for 13 different automotive parts and components. Ernst (1997) also showed a time lag of 2 to 3 years from patent application to sales increases for 50 machine tool manufacturers. As an example for many industries, Napolitano and Sirilli (1990) surveyed 157 inventions for various product groups and found that the time lag between patent application and productive use was 32% within one year, 64% within two years, the 96th percentile within five years, and the longest within six years. Suzuki (2011) also surveyed 2,398 randomly selected Japanese patents and reported that the time lag between patent application and product or manufacturing use was 19 months on average, 60 months at the 95th percentile, and 24 years at the longest.

It was noted that the companies' environment influenced the time lag between patent disclosure and market launch, and one of the factors was the cycle type of an industry (Gerken, Moehrle, and Walter, 2015). In the studies by Gerken, Moehrle, and Walter (2015)

and Ernst (1997), automotives and machine tools are durable goods. Although their survey samples were not very large, the two results were relatively close, with an average time lag of approximately 2.5 years and 56 months at the longest. The studies by Suzuki (2011) and Napolitano and Sirilli (1990) were cross-industry analyses, and their survey samples were large and included a mixture of durable and non-durable goods. According to these two results, the time lag was approximately 20 months on average, 5 years at the 95th percentile, and 6 - 24 years at the longest. The comparison of average time lags supports the point that durable goods have a longer application lag than non-durable goods (Pakes and Schankerman, 1984). Projectors are one of the durable goods, and the time lag can be inferred to be approximately 5-6 years up to the 95th percentile, based on the above previous studies.

Furthermore, we considered the cycle type of the durable goods industry. Srinivasan, Lilien, and Rangaswamy (2006) surveyed 63 office products and consumer durables. They indicated the time between product introduction and the emergence of a dominant design was 6.50 years on the mean and 4.94 years on the standard deviation for the 30 products in which the dominant design emerged. From these mean and standard deviation values, the 90th percentile was calculated to be approximately 13 years. Further scrutiny of their findings involved examining three office input/output products similar to projectors: dot matrix printers, fax machines, and photocopiers, revealing an average time span of 12 years for these products.

Based on the analysis of product trends in this study, the time between the product launch and the emergence of the dominant design was 13 years, since the product launch was in 2000 from Figure 2, and the timing of the emergence of the dominant design was in 2013. Compared to the study by Srinivasan, Lilien, and Rangaswamy (2006), the time for projectors was close to the 90th percentile time for the 30 products and close to the meantime for three office input/output products. Hence, we can infer that the cycle type of projectors is slower than that of the durable goods industry. By adding this consideration of the cycle type to the results of previous studies on the time lag between patent application and product launch, we can assume that the cycle type of projectors is slower than that of other durable goods and that the time lag between patent application and product launch is approximately 5-6 years.

5.2. Is it impossible to forecast the timing of the emergence of the dominant design?

Product trends analysis indicated that the timing of the emergence of the dominant design was in 2013. The granted patent analysis suggested that the timing of patent applications forecasting the emergence of the dominant design was 2007-2008. Previous studies show that the time lag between patent application and product launch can be approximately 5-6 years. The three results are well related. This means that for the product category of business and education projectors, the timing of the emergence of the dominant design can be forecast based on the patent application information in 2007-2008 without waiting for 2013, when the emergence of the dominant design is recognized in the market. However, as shown in Figure 5, in the case of projectors, the period from the filing date to the registration date of patents is approximately four years on average, so that by the time granted patents become available for analysis, dominant designs will have emerged. Therefore, it is preferable if published patents can be analyzed instead of granted patents.

We attempted to verify this by extracting published patent applications filed by 2018 from the database, considering that it typically takes 1.5 years from application to publication. This subset was used as the population and analyzed in a manner similar to that outlined in Section 4.3. Figure 7 shows the three-year simple moving average trends of product and process innovations, normalized to 1 for the total number of published patents

by 2018 for product and process inventions, respectively. Since the dynamics in Figure 7 were very similar to the case of the granted patent in Figure 6, we believe that substitution with published patents is feasible. The crossing point of the two curves was in 2007.

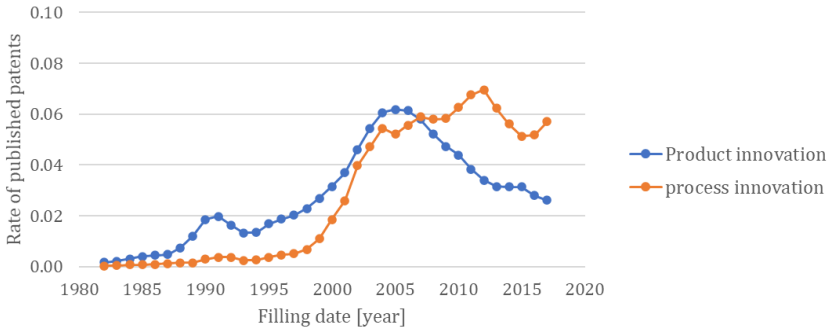


Figure 7 The trends of product and process innovations by published patents

Figure 8 shows the ratio of granted patents to patent applications derived from the database. The ratio increased gradually, and no large fluctuation was observed at the one-year level; the large fluctuation after 2016 was due to the relationship between the period from filing to registration and the search date, as mentioned above. Although the ratio varies from industry to industry, provided that the ratio does not fluctuate significantly from year to year, it is possible to substitute published patents for granted patents to conduct such trend analysis as in this study.

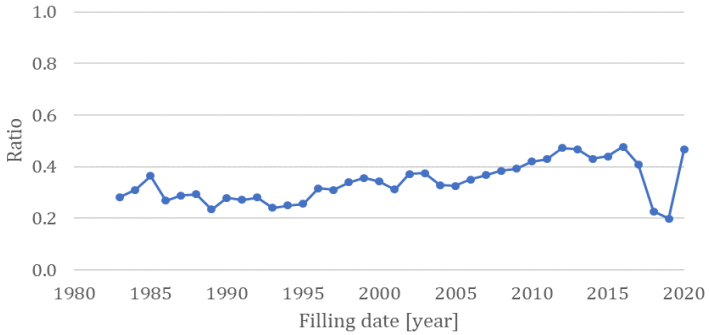


Figure 8 The Ratio of granted patents to patent applications

Arundel and Kabla (1998) found that only four sectors, including precision instruments, had patent propensity rates for both product and process innovations combined that exceeded 50%. Since office input/output products are a type of precise instrument, we believe that this is one of the factors that contribute to the good relationship between product trends and patent trends for projectors. In the product category of business and education projectors, the emergence of dominant design in the Japanese market was in 2013, and their sales reached their peak in 2016. The results of this study support the argument that the dominant design would spark increased demand and that product-class sales would peak after their emergence (Anderson and Tushman, 1990).

5.3. Applicability of this method to non-Japanese patents for finding the trend of technology

As shown in Section 3.3, this study used the method to divide the invention population into subpopulations of product inventions and process inventions (Masuda and Haruyama, 2021). In this method, a set of keywords related to process innovation, such as production, manufacturing, and quality improvement, are extracted, and process inventions are separated by whether the title of the invention contains a sequence of words that combines these keywords with the word "process." This is based on Article 2(3) of the Japan Patent

Act (JPO, 1959), which basically classifies inventions into product and process inventions. Therefore, in this study, the JPO patent database was used, and a text mining algorithm was applied to Japanese text.

We have examined whether this method is applicable to non-Japanese patents. Both the Manual of Patent Examining Procedure in the United States Patent and Trade Office (USPTO, 2023) and the Guidelines for Examination in the European Patent Office (EPO, 2023) state that there are only two basic types of claims that constitute inventions: product claims and process claims. As can be seen from the title of the invention in US patents and EP patents, it is very likely that process inventions can be separated by the inclusion of a sequence of words combining the above keywords and the word "method." In addition, since words are separated by spaces in English text, it is easier to perform text mining than in Japanese text, and the accuracy of the analysis is higher.

In this study, when generating the population for the analysis of Japanese patents, we utilized the theme code, a unique patent classification in Japan, as a search query. Since the theme code is indirectly related to the International Patent Classification (IPC), it is possible to generate a population that is almost similar to the population generated by the theme code by combining the IPC. Naturally, expansion to other patent classifications, such as the Cooperative Patent Classification (CPC), is also possible.

Based on the above, it is likely that the patent analysis method for non-Japanese patents will be quite similar to that for Japanese patents. This method may not be limited only to Japanese patents.

6. Conclusions

In this study, using projectors as the target of analysis, we identified the product attributes in which the dominant design emerged and the timing of its emergence based on the product trend in the market. Then, we conducted the patent analysis as the technology trend and derived the timing of patent application to forecast the timing of the emergence of the dominant design by using published patents. Furthermore, we considered the cycle type of the projector industry and inferred the time lag between the filing of a patent application and the introduction of a product. Although the emergence of a dominant design is known only when a design is widely recognized in the market, we clarified that there are industries in which the timing of the emergence of the dominant design can be forecast in advance using patent information, one of the indicators of innovation. It is important for companies to strategically identify the timing of market entry to achieve commercial success, and this study provides one useful insight for identifying such timing. It should be noted that even if the emergence of dominant designs from patent analysis is forecast, it does not necessarily mean that dominant design will actually emerge in the market. However, it is meaningful to show the possibility of forecasting the emergence of dominant designs and the timing of their emergence in the market based on technology trends. This allows companies to prepare for dominant designs that will emerge. In other words, it is a strategic guide. The emergence of a dominant design for all industries and products is not forecast. Since patent analysis is performed after patent information is published and generally available, it is impossible to forecast the emergence of a dominant design for a product whose time lag between patent application and product launch is shorter than 18 months. Therefore, it can be effectively applied to industries where the cycle type is relatively slow.

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