Factors Influencing the S-curve: Analyzing the Float Process Technology of the Glass Industry

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Abstract: This paper employs data on patent applications for the glass industry’s float process from 1954 through 2015. Furthermore, it assesses whether the S-curve of technological progress emerges. Assigning time to the horizontal axis, something like the S-curve emerges in the US and Europe but not in Japan. The S-curve represents the physical limits of technology. Specifically, Foster (1986) defined the S-curve as the function that expresses the relation between the amount of effort expended toward performance improvement and its outcome. The magnitude of the effort expended depends on the company as well as social factors. This paper performs company-level analysis using actual data to examine (1) the extent to which companies respond to the demands of the market and (2) the effect of the grant-back clauses in licensing agreements suggested by Ogami (2015).
Introduction

The S-curve is prone to an oversimplified understanding that it represents the physical limitations of technology. Henderson (1995) suggested that the S-curve does not naturally rise to the level of physical limitations of technology, but it is socially shaped. Specifically, Foster (1986) defined it as the function that expresses the relation between the amount of effort expended toward performance improvement and its outcome. The magnitude of the effort expended on performance improvement depends on the company as well as social factors. This paper analyzes patent applications for the glass industry’s float process from 1954 through 2015 to demonstrate that the resulting S-curves are shaped by social factors.

Method

This paper assesses trends in research and development of the float process technology. From Japan Platform for Patent Information (J-PlatPat), we gathered information and classified it as main group C03B18/00 (glass formation in contact with the surface of a fluid) of FI (Japan Patent Office’s sub-classification of the international patent classification). This main group includes FI 18/00, 18/02, 18/04, 18/06, 18/08, 18/10, 18/12, 18/14, 18/16, 18/18, 18/20, and 18/22.

We searched the J-PlatPat over the entire period without time conditions to best understand the float process. The “patent and
utility model patent text search” searches only applications starting in 1993. Nevertheless, the “patent and utility model patent classification search” supports searching applications since the commencement of the Patent Act. To search on the J-PlatPat, we specified “Patent (A, A1, B)” for “Kind”; further, we specified “C03B18/00” for “FI/F term” and “Examined/Granted applications (B, Y)” for “Priority of search result display.” The fields for “Theme code” and “Publication date” were left blank (unspecified).

Based on the search results, we examined the following publications: a) “Published patent application” (bulletin issued 18 months following patent application); b) “Japanese translation of PCT international application” (bulletin issued when international application in a foreign language is transferred to Japan under the Patent Cooperation Treaty); c) “Domestic re-publication of PCT international application” (information is provided when an international application in Japanese specifies Japan, although “Domestic re-publication of PCT international application” is an administrative service aiming at providing information for search for prior art; not legal bulletins); and d) “Patent (bulletin listing patents for which patent rights have been granted). From these, we then utilized the information regarding year of application, patent rights holder, and country of residence of patent rights holder (classified on the basis of address of patent rights holder).

Result

Figure 1 summarizes the trend in float process-related patent applications, with cumulative number of patent applications and number of applications for each year on the vertical axis. There were 748 applications from 1954 to 2015.

Pilkington Brothers Limited, which developed the float process, began licensing it to other companies in 1962 (Mori, 2007), with a
cumulative number of eight patent applications up to that point (from 1954 to 1961), followed by a rapid increase starting in 1962. There were seven applications in 1962, 26 in 1963, and double-digit yearly numbers in the ensuing decade. In other words, it is clear that the increase in the number of licensees was accompanied by an increase in the number of patent applications. Yet, the term of the licensing agreements was 16 years (Wierzynski, 1968); starting in 1978, immediately after the relationship with the first licensee terminated, the number of applications dropped to single digits. Thereafter, the number of patent applications continued to decline, indicating an S-curve. Subsequently, however, there was another spike, and the new century saw double-digit numbers of applications every year except for 2000, 2001, 2004, and 2015. What is the reason for the

**Figure 1.** Patent applications for float process

*Source: Created by author from J-PlatPat search results.*
emergence of this phenomenon? In this paper, we performed two analyses.

**Analysis 1**

Let us look at applications by Japanese, European (primarily Pilkington), and US firms. As shown in Figure 2, patent applications by European and US firms plateaued, tracing an S-curve after the period when the licenses expired. However, Japanese firms can be seen taking a clearly different direction. Cumulative applications by Japanese firms nearly drew even with European firms in 1992 (161 for Japanese firms and 162 for European firms), overtook them in 1993, and numbered 10 or more in 11 years up to 2015.

The float process was originally developed to substitute for the

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**Figure 2.** Patent applications by Japanese, US, and European firms

*Source: Created by author from J-PlatPat search results.*
method of manufacturing automotive glass (Pilkington, 1969, 1970). Patent applications from 1954 to 1980 for the float process, which targeted the automotive glass market, indicate an S-curve. Eventually, however, the float process came to be adopted to manufacture plate glass for construction, especially for skyscrapers (Mori, 2007), around the 1980s to satisfy the requirements of both the construction glass and automotive glass markets. Then, starting in the second half of the 1990s, demand for substrate glass for LCD displays started to pick up in earnest (Shintaku & Yoshimoto, 2009). As Japanese companies proactively responded to the requirements of such new markets and worked to capture the new demand, the S-curve began a new extension again.

Figure 3 illustrates actual patent applications in Japan by Pilkington, the developer for the float process, and two major Japanese glass manufacturers. Pilkington vigorously applied for

![Figure 3. Comparison of Pilkington and two Japanese firms](image)

*Source:* Created by author from J-PlatPat search results.
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patents up to 1969, with a cumulative total of 70 applications, but stopped making almost any applications in 1970. From 1970 to 2015, they made only 31 applications. The two Japanese firms, in contrast, continued to apply for patents. The growth of Asahi Glass is especially notable.

Analysis 2

Figure 4 provides more detail about the trends in patent applications during the term of the license agreements between Pilkington and Asahi Glass, that between Pilkington and Nippon Sheet Glass, and thereafter. The term of the license agreements with Pilkington is 16 years (Wierzynski, 1968). Figure 4 indicates 20 years of five phases (first dividing 16 years into four phases of four years each and then adding one more phase, 5th phase, of four years after

![Figure 4. Patent applications during and following licensing agreement](image)

Source: Created by author from J-PlatPat search results.
the termination of the agreement), showing patent applications for each phase. Since Nippon Sheet Glass signed the agreement in 1965 (Nihonitagarasu Kabushikigaisya, 1968) and Asahi Glass in 1966 (Asahigarasu Kabushikigaisya Rinji Shashi Hensanshitsu, 1967, 2007), the phases for the two are offset by one year. As shown in Figure 4, both Asahi Glass and Nippon Sheet Glass had the most patent applications in the second phase, started declining in the third phase, had the fewest applications in the fourth phase, and then an increasing number again in the fifth phase after the termination of the agreement.

In the first phase, the situation occurred as the technology had just been introduced (with instructions from Pilkington, of course), there was no full information required to progress with development. In the second phase, it is reasonable to assume that greater in-house expertise had been built up at Asahi Glass and Nippon Sheet Glass, leading to active development. In fact, Asahi Glass made 10 patent applications in the first phase and its applications tripled in the second phase approximately to 29.

In the third phase, applications of both firms declined to single-digit levels; in the fourth phase, Asahi Glass dropped to one application and Nippon Sheet Glass to four. After which, however, in the fifth phase, following the termination of the agreement, applications increased to six for Asahi Glass and nine for Nippon Sheet Glass. The underlying factor is the existence of grant-back clauses in the license agreements; the existence of grant-back clauses suppressed R&D on promising technology seeds and made the results of technology development inaccessible to the public or difficult to be shared to monopolize development benefits. Thus, if we limit ourselves to the period of the license agreement, patent applications in the fourth phase declines and an S-curve emerges, making it appear as if there were limitations on technology.
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Conclusion

In an analysis of patent applications for the glass industry’s float process from 1954 through 2015, assigning time to the horizontal axis, an S-curve emerges in the US and Europe but not in Japan. There are two plausible reasons for this.

(1) Market demands: Back when the float process originated, satisfying the demands of the market for automotive glass gave rise to an S-curve. Subsequently, however, the unanticipated emergence of the construction glass market and LCD display substrate glass market started a new extension of the float process S-curve.

(2) Effect of grant-back clauses in license agreements as suggested by Ogami (2015): A license agreement is concluded with grant-back clauses; licensees can purchase and sell the patented technology. In such a situation, the license patent applications will increase in the early and middle periods of the term. However, starting in the phase where there is awareness of the agreement ending, companies slow down R&D on promising technology seeds or decide not to reveal or share the results of technology development to outwit other companies after the license ends (monopolize the development results).

Foster (1986) defined the S-curve as the function expressing the relation between the amount of effort expended toward performance improvement and the outcome. The magnitude of the effort expended on performance improvement depends both on the company and social factors.
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References


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