The Influence of Technological Innovation on the Duration of Enterprise Export—A Theoretical Model from the Perspective of Heterogeneity

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Abstract: This paper undertakes a profound exploration of the differential impacts that autonomous innovation and imitation innovation exert on technological innovation outcomes, commencing from the perspective of input mode heterogeneity. The research also dives into the effects of direct versus indirect exports on technological innovation outcomes, viewed through the lens of output mode heterogeneity. Furthermore, a theoretical model is constructed from the viewpoint of heterogeneity in innovation and export modes, elucidating how technological innovation impacts the duration of a company's export activities. This comprehensive analysis not only unveils the intricate interplay between different innovation modes and their influence on the quality and effectiveness of technological advancements but also underscores the pivotal role of export modalities in shaping the impacts of these innovations on global trade dynamics.

1. Defining Types of Technological Innovation and Their Influencing Factors

1.1 Types of Technological Innovation

Technological innovation can be categorized into product innovation and process innovation based on its content. Product innovation involves the invention of new products and improvement of existing ones, while process innovation involves altering methods of production or processing.

1.2 Input Pattern Heterogeneity – Autonomous Innovation and Imitative Innovation

Regardless of whether product innovation or process innovation is being pursued, enterprises must, through some input mode, integrate advanced technology, methods, or ideas with existing products or processes to achieve improved results. Autonomous innovation and imitative innovation are two common ways of distinguishing innovation input patterns in current research.

1.3 Output Pattern Heterogeneity – Direct Export and Indirect Export

The mode of product output of a company can be divided into indirect export and direct export based on whether the company's products go through an export intermediary during the overseas selling process. Indirect export means that the company does not participate in export trade directly but achieves product export indirectly by selling to domestic exporters or appointing export agents. Direct export refers to the company bypassing domestic intermediaries, allowing its specialized export department to have direct business contact with overseas consumers, and sell its products directly to overseas markets.

2. Basic Settings of the Theoretical Model of Technological Innovation Type's Impact on the Duration of Enterprise Export

Based on existing models such as Melitz (2003), Bustos (2011), Caldera (2010), and Türkcan (2014), this paper explores the impact of technological innovation on the duration of enterprise export from both the supply and demand perspectives[1-4]. The paper assumes that there are only two countries in the world: the home country and the destination country. To better distinguish variables within different countries, all variables in the destination country are indicated with an asterisk (*). Furthermore, the model assumes heterogeneity between each enterprise, manifested in

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different levels of productivity. Each product is produced by only one enterprise, which is a single-product company. Therefore, the enterprise's export decision is based on relatively constant industry characteristics.

2.1 Consumer Demand Function

To analyze the impact of technological innovation on the duration of enterprise export, it is assumed that the consumer's utility function takes the CES form, with the elasticity of substitution σ between different types of products remaining constant. Additionally, based on the CES function, a product attribute factor λ is incorporated, referring to the product attribute ladder model by Grossman and Helpman (1991, 1993)[5] The factor λ reflects the consumer's demand for a product and the popularity of the product. A larger value of λ means that the consumer's demand for the product in the market is larger and the product is more popular. The specific form of the utility function is as follows:

$$\mathrm{U} = \left[\int_{\omega\in\Omega}[\lambda(\omega)q(\omega)]^{\rho}\,d\omega\right]^{\frac{1}{\rho}},\ 0<\rho<1 \tag{1}$$

The elasticity of substitution between different types is $\sigma = 1/(1-\rho)$ and $\sigma > 1$. According to the principle of utility maximization, the demand function for category ω can be derived:

$$\mathrm{q}(\omega) = \frac{[\widetilde{p(\omega)}/\lambda(\omega)]^{-\sigma}}{P^{1-\sigma}}E = \left[\frac{p(\omega)}{P}\right]^{-\sigma}\frac{E}{P} \tag{2}$$

Where, E is the consumer budget constraint, $\mathrm{p}(\omega) = \widetilde{\mathrm{p}(\omega)}/\lambda(\omega)$ is the adjusted price of category ω, P is the price index, and $\mathrm{P} = \left[\int_{\omega\in\Omega}\mathrm{p}(\omega)^{1-\sigma}\mathrm{d}\omega\right]^{1/(1-\sigma)}$.

2.2 Producer Supply

It is assumed that each company has heterogeneity at the productivity level ωi, but all companies have the same unit variable cost c. Therefore, under the CES utility function, the profit-maximizing price is the product of the company's markup rate and marginal cost $\widetilde{p(\omega)} = \frac{1}{\rho}\cdot\frac{c}{\omega_i}$.

To enter the domestic market, enterprise i must pay a fixed entry cost, then randomly obtain the corresponding productivity level ωi. After observing its own productivity level, the enterprise decides whether to enter the market and whether to engage in production activities after entering the market. We assume that the enterprise decides whether to engage in innovative activities based on its own productivity level after deciding to enter the market[6].

If the enterprise does not engage in innovative activities, then the enterprise only needs to pay the fixed cost of production f. It is easy to obtain the revenue and profit of the enterprise without any innovation:

$$r_0(\varphi) = \left[P\rho\frac{\varphi\lambda(\omega)}{c}\right]^{\sigma-1}E \tag{3}$$

$$\pi_0(\varphi) = \frac{r_0(\varphi)}{\sigma} - f \tag{4}$$

When an enterprise carries out process innovation, the unit cost of the enterprise is reduced to $c_{pc} < c$. In addition to this, the enterprise will also pay additional innovation costs of f_{pc} for process innovation. Based on this, we can also obtain the expressions for the revenue and profit of enterprises undergoing process innovation:

$$r_{pc}(\varphi) = \left[P\rho\frac{\varphi\lambda(\omega)}{c_{pc}}\right]^{\sigma-1}E \tag{5}$$

$$\pi_{pc}(\varphi) = \frac{r_{pc}(\varphi)}{\sigma} - f - f_{pc} \tag{6}$$

The impact of the enterprise's product innovation activities on the enterprise is mainly reflected

in the improvement of the "product attribute factor" $\lambda_{pd}(\omega) > \lambda(\omega)$ in the demand function, while the enterprise also needs to pay additional innovation costs f_{pd} for product innovation. Based on this, we get the revenue and profit of enterprises that are innovating their products:

$$r_{pd}(\varphi) = \left[P\rho\frac{\varphi\lambda_{pd}(\omega)}{c}\right]^{\sigma-1}E \tag{7}$$

$$\pi_{pd}(\varphi) = \frac{r_{pd}(\varphi)}{\sigma} - f - f_{pd} \tag{8}$$

Before analyzing the relationship between technological innovation and the duration of enterprise exports, first analyze the enterprise's choice of different types of technological innovation. Comparing formula (4) and formula (6), when $\pi_{pc}(\varphi) > \pi_0(\varphi)$, the enterprise will choose to carry out process innovation, that is:

$$\left(\frac{1}{c_{pc}^{\sigma-1}} - \frac{1}{c^{\sigma-1}}\right)[P\rho\varphi\lambda(\omega)]^{\sigma-1}E > \sigma f_{pc} \tag{9}$$

Similarly, comparing formula (4) and formula (8), when $\pi_{pd}(\varphi) > \pi_0(\varphi)$, the enterprise will choose to carry out product innovation activities, that is:

$$\left[\lambda_{pd}(\omega)^{\sigma-1} - \lambda(\omega)^{\sigma-1}\right]\left(\frac{P\rho\varphi}{c}\right)^{\sigma-1} > \sigma f_{pd} \tag{10}$$

When the company's increase in product quality is large enough, and the increase in revenue brought by product innovation activities is greater than the additional costs brought by product innovation activities, the company will choose to carry out product innovation activities. And when the company's reduction in production costs is large enough, even if the benefits brought by process innovation through cost reduction are greater than the additional costs brought by process innovation, the company will choose to carry out process innovation activities.

Different types of innovative activities have different costs. It is generally believed that product innovation aimed at achieving higher quality or higher technology levels contains greater innovation uncertainty, and the upfront R&D expenditure for successful R&D is large. In comparison, process innovation focuses on compressing the production unit cost on the existing technological path, and the corresponding R&D expenditure is smaller. The relationship with innovation costs is:

$$f_{pc} < f_{pd}$$

Recall formulas (9) and (10). While keeping parameters such as c, P, and E constant, the company will choose different innovative behaviors based on its final extracted production rate, and the slope of the revenue curve for process innovation and product innovation is:

$$\frac{\lambda(\omega)}{c} < \frac{\lambda(\omega)}{c_{pc}} < \frac{\lambda_{pd}(\omega)}{c}$$

2.3 Technological Innovation and Corporate Export Decision

It is assumed that entering the export market requires paying an entry cost of f_{exp} and a variable iceberg cost of $\tau > 1$. The enterprise decides whether to enter the export market by comparing the profits W in the domestic market and the profits when exporting. When $\pi^* > \pi$, the company chooses to export.

For non-innovative enterprises, the company will choose to export when the following formula holds:

$$\frac{\tau^{(1-\sigma^*)}}{\sigma^*}r_0{}^*(\varphi) > f_{exp} \tag{11}$$

Where $r_0{}^*(\varphi) = \left[P^*\rho^*\frac{\varphi\lambda(\omega)}{c}\right]^{\sigma^*-1}E^*$, it is easy to conclude that for non-innovative companies,

the threshold productivity value faced by the export decision is:

$$\bar{\varphi}_0 = \left(\frac{f_{exp}\sigma^*}{E^*}\right)^{\frac{1}{\sigma^*-1}} \cdot \frac{\tau c}{P^*\rho^*\lambda(\omega)} \quad (12)$$

Enterprises conducting product innovation R&D and process innovation R&D will achieve quality upgrade effects and cost compression effects, improve product attribute factors λ(ω), and reduce marginal costs c. The threshold productivity rate $\bar{\varphi}_{\mathrm{pd}}$ for companies engaging in product innovation and the threshold productivity rate $\bar{\varphi}_{\mathrm{pc}}$ for companies engaging in process innovation will be less than $\bar{\varphi}_0$ for non-innovative companies. Even if a lower inherent productivity rate is extracted, it is still possible to obtain a positive profit that covers export costs. The probability of innovative companies entering the export market is significantly greater than that of non-innovative companies, and the role of innovative companies in suppressing export exits and extending export time is significantly stronger than that of non-innovative companies.

Assuming that the logic of a company's decision on innovative behavior is that when paying the same scale of product innovation R&D and process innovation R&D, if the former brings much greater benefits than the latter and can cover export costs, then the company will choose to enter the export market through the former, and vice versa.

The profits brought by different types of R&D before enterprise export are:

$$\pi_{pc}^*(\varphi) = \frac{\tau^{(1-\sigma^*)}}{\sigma^*} r_{pc}^*(\varphi) - f - f_{pc} - f_{exp}$$

$$\pi_{pd}^*(\varphi) = \frac{\tau^{(1-\sigma^*)}}{\sigma^*} r_{pd}^*(\varphi) - f - f_{pd} - f_{exp}$$

Considering that no matter what kind of innovation the enterprise adopts, the input is the same, that is $\mathrm{f_{pc}} = \mathrm{f_{pd}}$. The enterprise is actually making a choice of innovation type according to the following formula:

$$\frac{\lambda_{pd}(\omega)}{\lambda(\omega)} \cdot \frac{c_{pc}}{c} \gtrless 1$$

Through calculation, as long as the initial product quality λ(ω) before export R&D is small, for enterprises entering the export market for the first time, the marginal quality upgrade brought by product innovation before export is larger, thereby obtaining marginal innovation benefits, which will be greater than process innovation. Correspondingly, the threshold productivity rate corresponding to product innovation will also drop more, so the enterprise can improve the probability of export entry through product innovation. On the other hand, for incumbent export companies that have successfully entered the export market, the initial product quality λ(ω) is already quite large, the marginal quality upgrade brought by unit product innovation R&D is gradually declining, eventually leading to the increase in benefits brought by process innovation R&D over product innovation R&D, so process innovation can more effectively suppress the export exit of incumbent enterprises and prolong the incumbency time.

3. Theoretical Model of the Impact of Corporate Technological Innovation on Export Duration - Considering the Heterogeneity of Innovation Modes

3.1 Analysis of Export Profit for Innovative Enterprises under Autonomous Innovation Mode

The profits of export enterprises carrying out process innovation and product innovation under the autonomous mode are:

$$\pi_{pcs}^*(\varphi) = \frac{\tau^{(1-\sigma^*)}}{\sigma^*} r_{pcs}^*(\varphi) - f - f_{pcs} - f_{exp}$$

$$\pi_{pds}^{*}(\varphi) = \alpha \frac{\tau^{(1-\sigma^{*})}}{\sigma^{*}} r_{pds}^{*}(\varphi) - f - f_{pds} - f_{exp}$$

Among them, α is the perceived product innovation coefficient. According to the research results of Chen Shu (2015)[7], when carrying out product innovation in an autonomous mode, the role of the perceived product innovation coefficient is quite significant and obvious, so there is reason to believe that this time $\alpha > 1$; If the enterprise invests the same R&D cost ($f_{pcs} = f_{pds}$) to carry out process innovation in an autonomous mode, although it can reduce the marginal cost of the product, this inherent nature of innovation is extremely difficult for consumers to perceive, and the perceived product innovation coefficient can be ignored.

According to the research results described by Liu Haiyang et al. (2019)[8], in addition to influencing factors such as product quality and price, the survival of export companies in the international market will also be affected by unexpected events $\zeta \sim N(0, \zeta^2)$, here we assume that the impact follows a normal distribution. In the case of risk, the profit obtained by the enterprise is $\pi^{*} - \zeta$, where π^{*} is the profit of the export enterprise in a risk-free state. If the export profit is negative, exports are stopped for that year. Therefore, the probability that the enterprise will continue to exist in the international market after export is:

$$P(\pi^{*} - \zeta \geq 0) = P(\zeta \leq \pi^{*}) = \Phi(\pi^{*}/\zeta)$$

Where $\Phi(\cdot)$ is the standard normal distribution, carrying out product innovation in an autonomous innovation mode, compared to carrying out process innovation, improves the export profits of the enterprise and increases the survival probability of the enterprise in the face of shocks in the international market:

$$P\left(\zeta \leq \pi_{pds}^{*}\right) - P\left(\zeta \leq \pi_{pcs}^{*}\right) = \Phi\left(\frac{\pi_{pds}^{*}}{\zeta}\right) - \Phi\left(\frac{\pi_{pcs}^{*}}{\zeta}\right) > 0$$

In the above formula, if the distribution of unexpected shocks $\zeta \sim N(0, \zeta^2)$ is known, and since $\pi_{pds}^{*} > \pi_{pcs}^{*}$, under the premise of autonomous innovation mode, the difference in the survival probability of enterprises in the international market that carry out product innovation and process innovation is certain, and the size is $\Phi\left(\frac{\pi_{pds}^{*}}{\zeta}\right) - \Phi\left(\frac{\pi_{pcs}^{*}}{\zeta}\right)$, therefore we can get:

Proposition 1: Product innovation under the autonomous innovation mode, compared to process innovation, can increase the profits of export enterprises and prolong the duration of enterprise exports.

3.2 Analysis of Export Profit for Innovative Enterprises under Imitation Innovation Mode

Based on the above research, the profits of export enterprises carrying out process innovation and product innovation in an imitation mode are:

$$\pi_{pci}^{*}(\varphi) = \frac{\tau^{(1-\sigma^{*})}}{\sigma^{*}} r_{pci}^{*}(\varphi) - f - f_{pci} - f_{exp}$$

$$\pi_{pdi}^{*}(\varphi) = \beta \frac{\tau^{(1-\sigma^{*})}}{\sigma^{*}} r_{pdi}^{*}(\varphi) - f - \gamma f_{pdi} - f_{exp}$$

Referring to the research results of Zhuang Ziyin and Li Hongwu (2018)[9], when enterprises carry out product innovation in an imitation innovation mode, they are influenced by the international intellectual property protection system, such as causing a negative impact on the brand image of the enterprise, which will affect the purchasing behavior of consumers, and thus reduce the profits generated by technological innovation of export enterprises. Therefore, the international intellectual property protection coefficient β and $\beta \leq 1$ can be obtained; at the same time, the litigation coefficient γ and $\gamma \geq 1$ can be obtained, indicating that the imitation innovation mode may increase the innovation cost of the enterprise due to the litigation costs it brings to the enterprise. If the enterprise invests the same R&D cost ($f_{pci} = f_{pdi}$) to carry out technological

innovation in an imitation innovation mode, on the premise that reducing the marginal cost of the product c is equivalent to improving the product quality ladder factor $\lambda(\omega)$, carrying out process innovation in an imitation innovation mode compared to product innovation, can increase the profits of enterprise exports. Similar to the analysis when deriving Proposition 1, the difference in the survival probability of the above two types of enterprises facing shocks is:

$$\mathrm{P}\left(\zeta \leq \pi_{pci}^{*}\right) - \mathrm{P}\left(\zeta \leq \pi_{pdi}^{*}\right) = \Phi\left(\frac{\pi_{pci}^{*}}{\zeta}\right) - \Phi\left(\frac{\pi_{pdi}^{*}}{\zeta}\right) > 0$$

From this, we can get:

Proposition 2: Process innovation under the imitation innovation mode, compared to product innovation, can increase the profits of export enterprises and prolong the duration of enterprise exports.

4. Theoretical Model of the Impact of Corporate Technological Innovation on Export Duration - Considering Export Mode Heterogeneity

4.1 Analysis of Export Profits of Product Innovation Enterprises - Considering Export Mode Heterogeneity

If a company chooses to engage in direct export, it needs to pay a fixed cost of $\mathrm{f_{expd}}$ to enter the foreign market. When a company implements indirect exports, the presence of trade intermediaries greatly alleviates the fixed costs $\mathrm{f_{expi}}$ required for exports, making exports relatively easy. Therefore, we assume here that the fixed costs faced by companies doing indirect exports are lower than those of direct exports, that is, $\mathrm{f_{expi}} < \mathrm{f_{expd}}$. On the other hand, while indirect export enterprises enjoy the reduction of export fixed costs by trade intermediaries, they also have to bear the shortcomings brought about by this: in the process of trading with trade intermediaries, due to the existence of intermediaries, they cannot control the pricing power of goods, and at the same time, they have to pay a considerable service fee to the intermediary in proportion, which results in a reduction in the export income of the enterprise. According to the above analysis, the profit of product innovation enterprises when choosing direct export mode and indirect export mode is:

$$\pi_{\mathrm{pdd}}^{*}(\varphi) = \mu\frac{\tau^{(1-\sigma^{*})}}{\sigma^{*}}\mathrm{r}_{\mathrm{pd}}^{*}(\varphi) - \mathrm{f} - \mathrm{f_{pdd}} - \mathrm{f_{expd}}$$

$$\pi_{pdi}^{*}(\varphi) = \eta\frac{\tau^{(1-\sigma^{*})}}{\sigma^{*}}r_{pd}^{*}(\varphi) - f - f_{pdi} - f_{expi}$$

Based on the research of Ma Hong (2018)[10], we get the direct export learning effect coefficient $\mu > 1$, which is the coefficient of the increase in export income brought by the productivity and product quality improvement caused by the export learning effect for product innovation enterprises; according to the research results of Ma Linmei and Zhang Qunqun (2014)[11], $\eta < 1$ is known, which is the reduction coefficient of export income for indirect export enterprises because they have adopted trade intermediaries. Under the assumption of $\mathrm{f_{pdd}} = \mathrm{f_{pdi}}$, whether product innovation enterprises adopt direct export or indirect export can obtain greater export profits, thereby prolonging the export duration of the enterprise, can be judged by the following formula:

$$\frac{\mu - \eta}{f_{expd} - f_{expi}}\frac{\tau^{(1-\sigma^{*})}}{\sigma^{*}}r_{pd}^{*}(\varphi) \lesseqgtr 1$$

According to previous analysis and research, the value of μ obtained from the learning effect brought by direct export by product innovation enterprises cannot be ignored. There is reason to believe that this effect can cover the increase in export costs brought by direct export compared to indirect export, especially in terms of prolonging export duration, which continuously consolidates the competitiveness and profitability of export enterprises in the export market. Similar to the

analysis when deriving Proposition 1, the difference in the survival probability of the above two types of enterprises facing shocks is:

$$\mathrm{P}\left(\zeta \le \pi_{pdd}^{*}\right) - \mathrm{P}\left(\zeta \le \pi_{pdi}^{*}\right) = \Phi\left(\frac{\pi_{pdd}^{*}}{\zeta}\right) - \Phi\left(\frac{\pi_{pdi}^{*}}{\zeta}\right) > 0$$

From this, we can get:

Proposition 3: Exporting via the direct export mode, compared to indirect export, can increase the profitability of product innovation enterprises and further prolong the duration of enterprise exports.

4.2 Analysis of Export Profit of Process Innovation Enterprises - Considering Export Mode Heterogeneity

For export enterprises that carry out process innovation, regardless of the export mode, the additional growth in revenue brought is negligible, but if the direct export mode is adopted, according to the above analysis, it will add extra export costs compared to indirect export. Therefore, the profit of enterprises carrying out process innovation when adopting different export modes is as follows:

$$\pi_{pcd}^{*}(\varphi) = \frac{\tau^{(1-\sigma^{*})}}{\sigma^{*}} r_{pc}^{*}(\varphi) - f - f_{pcd} - f_{expd}$$

$$\pi_{pci}^{*}(\varphi) = \frac{\tau^{(1-\sigma^{*})}}{\sigma^{*}} r_{pc}^{*}(\varphi) - f - f_{pci} - f_{expi}$$

According to the research results described by Jin Xiuyan and Xu Peiyuan (2016)[12], it is obvious that for process innovation, because export does not bring an effective learning effect, under the condition of $f_{expi} < f_{expd}$, direct export leads to lower export profits of process innovation enterprises. Similar to the analysis when deriving Proposition 1, the difference in the survival probability of the above two types of enterprises facing shocks is:

$$\mathrm{P}\left(\zeta \le \pi_{pci}^{*}\right) - \mathrm{P}\left(\zeta \le \pi_{pcd}^{*}\right) = \Phi\left(\frac{\pi_{pci}^{*}}{\zeta}\right) - \Phi\left(\frac{\pi_{pcd}^{*}}{\zeta}\right) > 0$$

From this, we can get:

Proposition 4: Exporting via the direct export mode, compared to indirect export, will reduce the profitability of process innovation enterprises, thus shortening the duration of enterprise exports.

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