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Technical Standards, Brand Reputation and Technological Innovation of Latecomers

—A General Equilibrium Model Based on Information Asymmetry, Division of Labor and Specialization

Ke Li*

College of Economics, Nihon University, Tokyo, Japan
Email: li.ke@nihon-u.ac.jp

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Abstract

This paper utilizes the general equilibrium analysis of endogenous information cost and endogenous intermediate product specialization to study the conditions and principles of technology localization in developing countries. The model depicts a positive cycle mechanism between technical standards, brand reputation and enterprise technological innovation and R&D capabilities that will evolve together with the evolution of international division of labor network structure. The results show that: 1) the key to the commercialization of domestic technology is to maintain sufficient brand-building growth rate; 2) there is an optimal degree of consistency between technology latecomers and international technical standards, so as to realize technology localization in the change of equilibrium transaction structure; 3) the trade income of latecomers can always benefit from the increase in the degree of consistency between their own and international technical standards, yet the trade income of first-mover enterprises will experience phased fluctuations, and implement the strategy of improving technical standards to prevent latecomers. Based on the conclusions of this study, the author proposes a path for less developing economies to achieve technological innovation and improve the influence of international standard setting, as well as related policy arrangement.

Keywords

Technical Standards, Brand Reputation, Market Structure, Technological

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Innovation of Latecomers, Specialization and Division of Labor

1. Research Background and Literature Review

The success of an enterprise's Research and Development (R&D) and innovation activities largely depends on how to reduce the information asymmetry of technology transactions. As Schumpeter (1934) wrote, the commercialization process of new technologies depends on market recognition. The challenges may be manifested in the opposition of various groups threatened by innovation, the difficulty of finding necessary collaborators, and the difficulty of winning consumers. In the global industrial division network, most of the enterprises in less developing economies are new entrants in the international technology market (latecomers) and are born in the market where the technology products of first-mover companies have been used for a long time. Relying on brand influence and market leadership, high-technology enterprises have built barriers to entry for technical standards. How can latecomers to technology win the trust of downstream buyers and be willing to buy their self-developed technical standards? How to deal with market barriers to market strategies that high-technology companies may implement? For example, China has a complete industrial chain advantage and a domestic market with great potential, so why do local enterprises still have to sacrifice profits, make small profits and sell quickly, and even fall into the dilemma of ineffective price involution in the process of domestic technology substitution?

This paper will focus on the market disadvantages of latecomer economies compared with first-mover enterprises due to the asymmetry of technology transaction information in the process of technology localization. To avoid market risks, potential buyers prefer first-mover products with greater brand influence. At the same time, the background knowledge of existing technical standards that the buyer already has is also an important basis for their purchasing decisions, which are dominated by high-technology companies. The problem of information asymmetry encountered by enterprises in developing countries in the commercialization stage of R&D results is actually based on the competition between latecomers and first-mover enterprises in terms of technical standards and brand influence. Technical standards and brand influence are not only the comparative advantages of first-mover companies, but also may become their strategic tools to prevent latecomers from entering the international technology market.

This research hopes to expand the discourse on technical standards, the right to formulate standards for latecomers, brand reputation, and related theories of information economics. First, in the existing literature on technical standards, past studies have mainly focused on the effects of technical standardization, such as the impact of technical standards as a protective trade policy tool on trade scale and economic welfare in international trade (Jorgensen & Schroder, 2006; Mangelsdorf, 2011). The impact of technology standardization on enterprise technological in-

novation has also been partially discussed (Zhou et al., 2017; Wang et al., 2023; Zhang et al., 2024). Although some of the literature has verified the effect of technology standardization in developing countries, it has not explored its role in technology catch-up in latecomers. Ernst et al. (2014) discussed the role of technology standardization in enterprise innovation and economic development in latecomer countries and emphasized the consideration of national conditions in standard formulation. Hu et al. (2024) examined the impact of technical standards alliances on technological innovation and catch-up among latecomers. Although these studies have involved the independence and openness of latecomers in the formulation of technical standards, they still belong to the analysis from a static perspective. In addition, the following studies focus on the strategic issues in the competition of technical standards between countries, such as Ruhlig and ten Brink (2021) and Padula and Pizetta (2022), to analyze the competition and impact of international technology standardization from a political and economic perspective. Another example is Edwards and Poyago-Theotoky (2013), which investigated how the consistency or differentiation of technical standards can be used as a tool for technical trade barriers to the technological innovation game of enterprises in the international market. Some scholars (such as Ruhlig & ten Brink, 2021) have paid attention to the problem of China's technical standard formulation, and the conclusions drawn by these studies are still biased because they are not fully based on the practical dilemma of China's technology localization.

In other relevant literature, Xu et al. (2025) paid attention to the effect of enterprise participation in standard formulation and verified the impact of digital technology enterprise participation in standard formulation on enterprise technological innovation. Meanwhile, earlier studies such as Leiponen (2008) have discussed the relationship between competition and cooperation between enterprises in the industry in the process of technical standard formation, indicating that all member enterprises can benefit from technical standards on the premise of maintaining openness. This is an ideal state for standard setting. In particular, in the real world of "standards are king" and "winners take all", enterprises are more concerned about the right to speak in standard formulation. Lin et al. (2014) have discussed the subject of standard formulation in the discourse power of standard formulation. Li et al. (2010) discuss the market conditions of becoming a high-end enterprise in the industrial network, the interaction and checks and balances between high-end and low-end enterprises, as well as the survival dilemma and breakthrough path of low-end enterprises. Zhou et al. (2023) clarified the mechanism for latecomers to enhance their voice in international technical standards through micro-level case studies. However, the technical standards research known to the author so far has not touched on the practical factors of most Chinese enterprises starting to undertake cross-border transfer of manufacturing and lack of brand accumulation, and there is a lack of research on the entry barriers that high-technology enterprises may implement by technology standardization strategies, and how latecomers can enhance their voice in such situations.

Moreover, there is relevant literature on corporate brand-building which can be sorted out as follows. At present, the brand-building literature directly related to the theme of this paper has not been retrieved, and the studies with relatively close correlation are as follows. Tsao et al. (2006) studied the interaction between seller brand signal strategies and buyer responses. This is also one of the logical bases for the author to set the promotion coefficient as the parameter relationship of brand influence. Lee et al. (2016) demonstrated the importance of integrating brand orientation with innovation orientation. Sun and He (2019) demonstrated the relationship between institutional behavior (taking quality standards as an example) and brand equity. Zhang et al. (2024) demonstrated the mediating role of advanced standards in the high-quality development of regional quality brands and manufacturing industries, where "regional brand" is a cluster concept. This paper deals with the relationship between technology standardization, brand and high-quality development, but still does not talk about technology localization itself. Moreover, this paper will cut into this topic from a dynamic perspective and analyze the related problems of technology standardization strategy in the context of information asymmetry and division of labor specialization. The author intends to rely on the following dynamic mechanism to fill this gap in the current research field: taking the technical standards of the same industry as one dimension, taking corporate brand-building as another time dimension, and integrating these two dimensions into the analysis framework of information costs at the same time. By analyzing the changes in information costs and the evolution of the corresponding division of labor structure in the process of latecomers leaping from technology introduction to independent research and development, a positive cycle mechanism will be formed.

The information cost field, based on the model construction and the evolution of the transaction structure related to the localization of technology in endogenous latecomers, is reviewed as follows. The relationship between brand-building and technological upgrading of enterprises, i.e., enterprises continuously improve the brand's commitment to the market through continuous technological iterative upgrades to improve product performance, quality, compatibility, etc., so as to accumulate brand reputation and output this signal to buyers, which is a long-term interaction between buyers and sellers and between products and brands. This is consistent with the product reputation model proposed by Kreps et al. (1982). This paper will extend the model to the competition between latecomers and first-mover companies in terms of brand reputation to buyer signal push. In the promotion of technical signals, although the brand reputation established by long-term repeated games is complementary to technical standards at every point in time, it shows stable characteristics that are completely different from the changes in technical standards in the evolution of transaction structure, which has become a key factor for latecomers to achieve technology localization. In the construction of technical standard plates, brand reputation accumulation and buyer recognition of latecomers, this paper follows the basic logic of Ng and Yang's (1997) infor-

mation correction and division of labor evolution test model. In the case of the existing technical standards of the first-mover enterprise, the potential buyer and the latecomer are both individuals who freely enter and exit the transaction process in the Walras mechanism, and the trust relationship between the two will be established by product upgrading and continuous trial and error, and accumulated in the brand reputation of the latecomer from scratch. The author will label the results of cross-generational technology product trading experiments as the brand reputation accumulation parameters in the model (the parameters of first-mover countries and latecomers are different), and exogenize the growth rate of brand-building expenditure. In other words, the author adopts the evolution model of "exogenous transaction cost and endogenous information cost" to simplify the relationship between "brand-building growth rate and brand reputation" in this paper. Thus, the analysis can focus on the dispute between latecomers and first-mover companies, and how to achieve technology localization in latecomers.

In addition, due to the fact that potential buyers have different degrees of information asymmetry in the face of first-mover and latecomer suppliers in technology product transactions: the existing technical standards and brand reputation of first-mover companies are the result of the previous game and trial-and-error accumulation between the two parties; The information gap between buyers and latecomers with missing brands and standard differences is obviously greater than the former. Compared with the existence of poor information, it is more difficult for latecomers to enter the technology market than to enter the ordinary product market. Due to the existence of the first-mover enterprise, the amount priced by the latecomer in the price involution below the equilibrium price level is actually the cost of a "trial and error" purchase paid for potential buyers. After a "trial and error", if the enterprise attaches importance to brand-building and accumulates brand reputation through technological iterative innovation, the "trial and error" cost paid in the future will decrease. This is the process of catching up with high technology. Otherwise, enterprises will have to pay expensive "trial and error" costs every time, thus falling into involution and allowing the rental value to survive. The accumulation of brand reputation is the choice path for latecomers to reduce the relative information asymmetry in the time dimension. Latecomers can shorten this process with the help of technology standardization strategies. By selecting the optimal level of standardization and using the existing widely used technical standards as a reference frame, the information asymmetry between potential buyers and latecomers can be reduced. At the same time, latecomers can promote the time dimension of brand-building and the peer dimension of technology standardization at the same time to narrow the relative disadvantage with first-mover enterprises, so as to improve the success rate of commercial transformation of new technologies.

The structure of this paper is as follows: Section 2 will establish a basic model for intra-industry transactions between high-technology and latecomer; in Section 3,

the model will be subjected to general equilibrium analysis and inframarginal comparison static analysis of the specialized mode and division of labor structure. Section 4 will summarize the internal logical relationships, results and economic implications of equilibrium and comparative statics on the basis of the analysis of equilibrium and comparative statics. Section 5 makes conclusions and makes policy implications and recommendations.

2. Basic Model

Here, we consider the existence of two economies with a continuum of consumer-producers. This continuum assumption means that the two economies have very large population sizes M_1 and M_2. This hypothesis avoids the absence of equilibrium results due to integer problems when discussing the division of labor specialization (see Sun et al., 2004). At the same time, everyone in the economy is a consumer-producer unity and has homogeneous, non-satisfied, continuous and rational preferences, which will be represented by the following utility functions:

$$u_i(x,y) = f\left(x_i^c, y_i^c\right),\ i = 1,2 \tag{1}$$

where $x_i^c = x_i + k_F x_i^d$ and $y_i^c = y_i + k_F y_i^d$ represent the number of two consumer goods x and y that each individual needs to consume, respectively; x_i and y_i are the number of self-sufficient products per consumer-producer, and x_i^d and y_i^d are the number of products that each person buys from the market. k_F ($0 < k_F < 1$) is the transaction efficiency coefficient of the consumer goods market. Moreover, we assume that the market efficiency of consumer goods products in both countries is the same, so that $k_F x_i^d$ and $k_F y_i^d$ are the actual quantity of products that are purchased and consumed from the market transaction process, while the other part $1 - k_F$ of them is depleted during the transaction. We assume that the utility function $f(\cdot)$ is continuous, increasing, and quasi-concave. Without losing generality, we assume that $f(\cdot) = \left(x_i^c\right)^{\frac{1}{2}} \cdot \left(y_i^c\right)^{\frac{1}{2}}$ [1].

Moreover, we assume that the production function for each consumer-producer is as follows:

$$x_i^p = x_i + x_i^s = \max\left\{0, \left(z_i + k_M z_i^d\right)^{\alpha}\left(l_x - b\right)\right\} \text{ and } 0 < \alpha, k_M < 1 \tag{2}$$

$$y_i^p = y_i + y_i^s = \max\left\{0, l_y - b\right\}, \tag{3}$$

$$z_i^p = z_i + z_i^s = \max\left\{0, T_i\left(l_z - \theta\right)\right\}, \text{ and } 0 < b < \theta < L,\ 0 < T_i < 1 \tag{4}$$

The production process of product x requires the use of an intermediate product z. Besides, x_i^p, y_i^p and z_i^p represent the number of products x, y and z produced by each individual. Among them, x_i^s, y_i^s and z_i^s are the amount of out-

[1] In the hypermarginal-general equilibrium analysis, the specific difference in the form of the explicit function here does not affect the analysis conclusion. We abstract away the differences in people's preferences for x and y and the differences in consumption preferences between these two countries and simplify the mathematical operations to serve the analysis goal of this paper on production technology innovation.

put used for sale to the market; x_i, y_i and z_i are the amount of output for self-use. The labor time that must be allocated for the production of the three products is l_x, l_y, and l_z. The learning cost of the final products *x* and *y* is the same b, and the intermediate product *z* needs to pay more learning cost θ. The input-output elasticity of intermediate goods and labor required for product *x* production is α and 1, respectively. The intermediate goods can be obtained by self-supply z_i or external purchase z_i^d. If it is purchased externally, the transaction fee will be proportional $1-k_M$, and k_M is the transaction efficiency coefficient of the intermediate goods market. The greater the value of k_F and k_M indicate higher efficiency in the consumer goods and intermediate goods markets.

Unlike the production of final products, there is an output promotion factor in the production of intermediate product *z*. In this paper, intermediate product *z* can be regarded as a technical standard, such as technically complex professional equipment, special processes, key components, etc. Often, there is a more serious information asymmetry in technology product trading than in consumer goods trading, and the expected benefits of expertise that laypeople can master are often not enough to offset the cost of professional learning. Even customers with certain professional knowledge will be at a significant information disadvantage in the face of technological innovation. Theoretically, the more complex the technology, the broader the downstream application scenarios of the technology, and the larger the pricing space. In fact, the more serious the information asymmetry, the more cautious buyers are in the face of high-priced technology products. As a result, the pricing space of new technologies is more susceptible to information asymmetry, and their innovation, durability, compatibility and other indicators are more dependent on industry standards and corporate brand reputation. This requires technical standard manufacturers not only to develop new products, but also to be recognized by industry and downstream customers for their technical standard performance. Therefore, technical standard producers can use brand-building to accumulate reputation in technology or rely on the quality standards of the entire industry to improve their reputation and reduce the information asymmetry between buyers and sellers. Consequently, the coefficient T_i consists of two parts: τ_0 ($0<\tau_0<1$) is the technical standard, that is, the proportion of *z* producer extracted from sales revenue for brand-building[2]; τ_i ($0<\tau_i<1$) is the reputation influence coefficient of the enterprise in the Country I (CI), which is determined by the comprehensive effect of the company's own brand reputation accumulation and the first-mover comparative advantage in the technical standards of the Country I (CI). The following analysis will show that technical standards are complex and changeable when the international division of labor changes. Consequently, the meaning of τ_i is mainly determined by the accumulation of brand-building. Without losing its generality, this paper assumes that economy

[2]We will no longer show the mathematically complex calculations of different extraction ratios between these two countries; while instead, we extract the important economic implications in a mathematically simple way.

$0 < \tau_2 < \tau_1 < 1$, which means the country C1 is a high-technology country and has a comparative advantage of technological reputation.

From the practice, it is rare to improve information asymmetry by simply having one of the above two inequalities $0 < \tau_0 < 1$ and $0 < \tau_i < 1$, so that we assume that the generalization coefficient of technical standards is the intersection of the two parameters, that is

$$T_i = \tau_i \cdot \tau_0 \tag{5}$$

This equation means that economy C1 has a comparative advantage in the promotion of technical standards ($T_1 > T_2$). However, it should be pointed out that the sales revenue of technology z in the two countries is not the same, hence the share of technology sales revenue allocated to brand-building extracted from the two countries is different. The same proportion of the two countries τ_0 only indicates that the proportion of brand-building investment in the two countries maintains the same growth rate. This setting also exogenizes the brand-building decisions of enterprises in the two countries. Equation (5) also reflects the expectation of the enterprise's production arrangement on the certainty of the sales market. Obviously, companies with a comparative advantage in branding and technology standardization have more optimistic expectations in both domestic and international markets, which constitute their competitiveness in the technology market.

It is assumed that the efficiency factor of the transaction between the producer of the technical product z and the buyer is k_M, and k_M depends on the information cost of the technical standard S_i, i.e., $k_M = 1 - S_i$. The information costs incurred in the natural transaction state are recorded as s_0 and $s_0 \in (0,1)$. If there is an improvement in the information dilemma, the information cost may be recorded in the form of:

$$S_i = \frac{s_0}{\left(1+\tau_j\right)^{\frac{1}{2}} \cdot \left(1+\beta\right)^{\frac{1}{2}}}, \text{ where } j = i \text{ or } -i \text{ and } \beta \in [0,1] \tag{6}$$

Among them, if the information cost of domestic sales of intermediate products is mainly affected by the existing technical standards and brand reputation in the country, then $j = i$. If the information cost of cross-border sales is determined by the existing technical standards and brand advantages of the exporting country, then $j = -i$. In this model, we only deal with technology exports from first-mover countries to latecomers, so it is reasonable to assume that the technical standards of the exporting countries in the parameters τ_j determine the relevant information costs included in the transaction. As a result, exporting countries with technical standards and brand comparative advantages will enjoy higher technical transaction efficiency than importing countries in intermediate goods transactions. β ($0 \le \beta \le 1$) indicates the degree of consistency of technical standards between the two countries. The larger the value of β, the higher the degree of consistency, the easier it is to mutually recognize technology between the two countries, and the information asymmetry between the two countries will decrease. If the specific sim-

ilarities and differences between local standards and international standards are listed and mutually recognized efficiently and do not affect compatibility, or the closer the local standard is to the international standard, it means that the value of β is larger. When $\beta = 1$, the two countries will form a unified market for technical standards; When $\beta = 0$, the technical standards between the two countries were self-contained and the cost of mutual recognition was extremely high, consequently they became two separate markets. It is worth noting that the difference in technical standards is not necessarily the difference between advanced standards and backward standards, but more in the information costs existing in cross-border technology transactions, which will affect the market demand and corresponding pricing of technology products. In short, the larger values of τ_j and β, the information asymmetry between the two countries on the transaction of technology products is lower, and the transaction efficiency of technology products is higher.

In addition, it is assumed that each consumer-producer in both countries has the same labor endowment L and $L > 1$. Its distribution of labor time for the three products *x*, *y* and *z* satisfies the following constraints:

$$l_x + l_y + l_z = L \quad \text{and} \quad 0 \le l_x, l_y, l_z \le L \tag{7}$$

The production of each product requires a positive learning cost (b, θ), which means the existence of a specialized economy. If an individual is engaged in the production of more than one product, he needs to learn one more production skill and bears a higher total learning cost; on the contrary, he will increase the level of specialization by focusing on fewer types of production, and the return on the learning cost can be more fully reaped. The learning cost is also an entry cost; hence we also assume $\theta > b$, which means the technology industry has higher barriers to entry.

When the producers of technical products in both countries take the same percentage τ_0 from the sales of *z* for brand-building related to technical standards, the budget constraints for each person are:

$$p_x x_i^s + p_y y_i^s + p_z \left(1 - \tau_0\right) z_i^s = p_x x_i^d + p_y y_i^d + p_z z_i^d \tag{8}$$

In this model, both the product market and the labor market are competitive. Based on the assumption of increasing or constant return of individual specialization and the assumption of individual continuum in each economy, the Walras general equilibrium mechanism will exist in this large economy. Besides, in this model there are two dilemmas: one is between the increasing (or unchanged) return of specialization by the division of labor and the total transaction costs; the other dilemma is between the cost of brand-building and the benefits of brand reputation premium in the technology products *z*. Everyone in both countries needs to decide: 1) what to produce and how much to produce for self-sufficiency; 2) what and how much to sell in the market; 3) what and how much to buy from the market. For more specific, everyone needs to decide on the values of the following 9 variables: $x_i, x_i^d, x_i^s, y_i, y_i^d, y_i^s, z_i, z_i^d, z_i^s \ge 0$, and there are total of 512 possible

corner solutions and internal solutions, which is from $2^9 = 512$.

3. General Equilibrium Analysis

Since our model may include corner solutions, the standard marginal analysis will no longer be applicable. Therefore, we will utilize the "three-step method of inframarginal analysis" for further discussions. In the first step, by excluding all non-economically feasible corner and internal solutions, we figure out all the set of optimal decisions for each individual and solve all possible corner solutions, which will be completed in Section 3.1. The second step is to solve each set of price-compatible corner solutions into a market structure division of labor and solve the corner equilibrium of each structure with division of labor, which will be completed in Section 3.2. The third step is to analyze the overall cost and benefit of all market structures with division of labor to determine the parameter conditions for each corner equilibrium to become general equilibrium, which will be completed in Section 3.3.

3.1. Specialization Mode and Corner Solution

Everyone's decision set contains some possible corner and inner point solutions. However, not all mathematical analytical solutions have economic implications. To narrow the scope of the decision set, Yang and Ng (1993) and Wen (1998) applied the Kuhn-Tucker condition to establish and generalize the optimal decision theorem. Moreover, since the model in this paper includes the specialized division of labor of intermediate goods, we will establish Lemma 1, which has been applied to the extended lemma proven by Gao and Anwar (2024).

Lemma 1. *The optimal decision of each individual will be to sell at most one product, not to sell and buy the same product at the same time, and not to buy and self-sufficiency the same product; If a consumer product is sold on the market, it is self-sufficient at the same time; If* $\alpha \in (0,1)$, i.e., $\alpha + 1 > 1$, *it does not use the intermediate products required for its own use unless it makes an optimal decision to produce the final product.*

We define a "Configuration" as a combination of zero and positive variables which are compatible with Lemma 1. It utilizes the Kuhn-Tucker condition to exclude most of the corner solutions and screens out a total of 5 corner solutions and corresponding specialization configurations. In the trading networks of the two countries, these five configurations can be combined to create a division of labor that is intrinsically compatible with multiple economic meanings. To focus on the core issues of this paper, we will analyze only two of these cross-border transaction structures within the industry. This treatment mathematically expands the parameter space required by each structure for general equilibrium but does not affect the research conclusions. Trading structure and corner equilibrium analysis will be the main work in Section 3.2.

The five specialization patterns compatible with Lemma 1 are analyzed below:

1) **Self-sufficiency configuration (A).** In this mode, each person makes all three

products *x*, *y*, and *z* by themselves. There is no professional division of labor, so there is no trading market. The pattern is defined by $x_i, y_i, z_i > 0$ and $x_i^s = y_i^s = z_i^s = x_i^d = y_i^d = z_i^d = 0$. It is worth noting that in the case of self-sufficiency, the individual is completely certain about the intermediate *z* performance he needs, so we assign T_i a value of 1 in this mode.

2) ***x* and *z* integration configuration (*xz*|*y*).** This mode produces both technical products *z* and terminal consumer goods *x*, in which the practitioners of this model are self-sufficient to produce product *x*, self-sufficient consumer goods *x* and sell the remaining consumer goods in the consumer goods market, and the required consumer goods *y* are purchased from the market. The pattern is defined by $z_i, x_i, x_i^s, y_i^d > 0$ and $y_i^s = z_i^s = x_i^d = y = z_i^d = 0$. Similarly, in the case of *xz* integrated, the individual is completely certain about the performance of the intermediate product *z* that he needs, so T_i we still assign a value of 1 in this mode.

3) ***y* specialization configuration (*y*|*x*).** This mode indicates a full specialization in the production of consumer goods *y*, and those who choose this model are called experts. A part of the output of *y* is for self-use, the rest of the output is sold, and the income is used to purchase consumer goods *x*. The pattern is defined by $y_i, y_i^s, x_i^d > 0$ and $x_i^s = z_i^s = x = z = y_i^d = z_i^d = 0$.

4) ***x* specialization configuration (*x*|*yz*).** This mode indicates a full specialization in the production of consumer goods *x*, and those who choose this model are called *x* experts. Part of the output *x* is for personal use, and the rest of the output is sold, and the required technical standard *z* and consumer goods *y* are purchased from the corresponding market. The pattern is defined by $x_i, x_i^s, z_i^d, y_i^d > 0$ and $y_i^s = z_i^s = x_i^d = y = z = 0$.

5) ***z* specialization configuration (*z*|*xy*).** This mode indicates that the technical product *z* is produced in full specialization, and those who choose this model are called *z* experts. *Z* specialists specialize in the production and sale of technical standards *z* on the technology market, and the required *X* and *Y* products are purchased from the consumer goods market. The pattern is defined by $z_i^s, x_i^d, y_i^d > 0$ and $x_i^s = y_i^s = z = x = y = z_i^d = 0$.

The summary of the corner solutions of the above five specialization configurations is shown in Table 1.

3.2. Analysis of the Market Structure with Division of Labor and Corner Equilibrium

A combination of all individuals' configurations constitutes a "Market Structure" (or Trading Structure). This paper hopes to focus on analyzing how latecomers to technology can change from undertaking manufacturing outsourcing to achieving domestic technology substitution. Hence, this paper will focus on the following two types of intra-industry market structures: 1) RZC, a structure in which technology trading and outsourcing coexist, and 2) INE, a structure in which latecomers carry out domestic technology substitution. We can investigate structural changes to reveal the rules and paths of how technologically less developed countries achieve technology localization in the international division of labor network.

Table 1. Specialization mode and corresponding corner solution.

Mode	Corner solutions	Indirect utility functions
A	$z_i=\frac{\alpha(L-\theta)-2\alpha b}{2+\alpha}$, $x_i=\frac{\alpha^{\alpha}(L-\theta-2b)^{\alpha+1}}{(2+\alpha)^{\alpha+1}}$, $y_i=\frac{L-\theta-2b}{2+\alpha}$.	$u_i^A=\left(\frac{L-\theta-2b}{2+\alpha}\right)^{1+\frac{\alpha}{2}}\alpha^{\frac{\alpha}{2}}$
$(xz\|y)$	$y_i^d=\frac{\alpha^{\alpha}(L-\theta-b)^{1+\alpha}}{2(1+\alpha)^{1+\alpha}}P_X$, $x_i^s=\frac{\alpha^{\alpha}(L-\theta-b)^{1+\alpha}}{2(1+\alpha)^{1+\alpha}}$, $z_i=\frac{\alpha(L-\theta-b)}{1+\alpha}$, $x_i=\frac{\alpha^{\alpha}(L-\theta-b)^{1+\alpha}}{2(1+\alpha)^{1+\alpha}}$.	$u_i^{XZ}=\frac{\alpha^{\alpha}(L-\theta-b)^{1+\alpha}}{2(1+\alpha)^{1+\alpha}}\sqrt{k_F P_X}$
$(y\|x)$	$x_i^d=\frac{L-b}{2P_X}$, $y_i^s=\frac{L-b}{2}$, $y_i=\frac{L-b}{2}$.	$u_i^Y=\frac{L-b}{2}\sqrt{\frac{k_F}{P_X}}$
$(x\|yz)$	$z_i^d=\alpha^{\frac{1}{1-\alpha}}(L-b)^{\frac{1}{1-\alpha}}k_M^{\frac{\alpha}{1-\alpha}}\left(\frac{P_X}{P_Z}\right)^{\frac{1}{1-\alpha}}$, $y_i^d=\frac{1-\alpha}{2}\alpha^{\frac{\alpha}{1-\alpha}}(L-b)^{\frac{1}{1-\alpha}}k_M^{\frac{\alpha}{1-\alpha}}\frac{P_X^{\frac{1}{1-\alpha}}}{P_Z^{\frac{\alpha}{1-\alpha}}}$, $x_i^s=\left(\frac{1-\alpha}{2}\alpha^{\frac{\alpha}{1-\alpha}}+\alpha^{\frac{1}{1-\alpha}}\right)(L-b)^{\frac{1}{1-\alpha}}k_M^{\frac{\alpha}{1-\alpha}}\left(\frac{P_X}{P_Z}\right)^{\frac{\alpha}{1-\alpha}}$, $x_i=\frac{1-\alpha}{2}\alpha^{\frac{\alpha}{1-\alpha}}(L-b)^{\frac{1}{1-\alpha}}k_M^{\frac{\alpha}{1-\alpha}}\left(\frac{P_X}{P_Z}\right)^{\frac{\alpha}{1-\alpha}}$.	$u_i^X=\frac{1-\alpha}{2}\alpha^{\frac{\alpha}{1-\alpha}}(L-b)^{\frac{1}{1-\alpha}}\frac{k_M^{\frac{\alpha}{1-\alpha}}}{P_Z^{\frac{\alpha}{1-\alpha}}}\sqrt{k_F P_X^{\frac{1+\alpha}{1-\alpha}}}$
$(z\|xy)$	$z_i^s=\tau_i\cdot\tau_0(L-\theta)$, $x_i^d=\frac{L-\theta}{2}(1-\tau_0)\tau_i\tau_0\frac{P_Z}{P_X}$, $y_i^d=\frac{L-\theta}{2}(1-\tau_0)\tau_i\tau_0 P_Z$.	$u_i^Z=\frac{L-\theta}{2}(1-\tau_0)\tau_i\tau_0\frac{k_F}{\sqrt{P_X}}P_Z$

Among them, $P_X=p_x/p_y$, $P_Z=p_z/p_y$.

According to Yang (2001, Chapter 13), a general equilibrium exists for a general class of the models of which the model in this paper is a special case under the assumptions that the set of individuals is a continuum, preferences are strictly increasing and rational; and both local increasing returns and constant returns are allowed in production and transactions. A general equilibrium in this model is defined as a set of relative prices of goods and all individuals' labor allocations and trade plans, such that: 1) Each individual maximizes her utility, that is, the consumption bundle generated by her labor allocation and trade plan maximizes her utility function for given prices; 2) All markets clear.

The analysis of these two trading structures and corner equilibrium is as follows.

1) The structure of technology trading and outsourcing (Structure RZC). In this structure, C1, the technologically advanced country, specializes in producing and exporting technological products *z*, and its consumer goods *x* and *y* are imported from its trading partner country (technologically advanced country) C2; On the other hand, C2 produces and exports consumer goods *x* and *y*, where the technical products *z* required for the production of *x* are obtained by imports. There is intra-industry trade between the two countries brought about by the division of labor in the *X* supply chain. Manufacturers in both countries need to

work closely together to get all the essentials. When C2 decides whether to import technical products *z*, there are information disadvantages in terms of their quality, performance, compatibility, etc., so that C2 may rely on C1's technical standards and the industry brand influence of technology product suppliers to make import decisions, that is $k_M = 1 - \frac{s_0}{(1+\tau_1)^{\frac{1}{2}}(1+\beta)^{\frac{1}{2}}}$. If the technology transaction is too inefficient, it may cause the transaction to not occur, thus deviating from the structure of the division of labor between the two countries.

Since each individual of C2 is homogeneous before the division of labor and the model has symmetry feature, therefore the utility equalization condition should be met when equilibrium, that is, the utility level of the domestic *x* expert and *y* expert equilibrium is equal, $u_2^Y = u_2^X$. Suppose that C2 has a population of M_{2X} and M_{2Y} who are engaged in the production of products *x* and *y*. When trade equilibrium is reached, all three products should meet the market clearance conditions. According to Walras' law, the clearing conditions of the three markets are not independent of each other. Therefore, according to the equalization of utility and the clearing conditions of any two of them, such as $M_1 z_1^s = M_{2X} z_2^d$ and $M_{2Y} y_2^s = M_1 y_1^d + M_{2X} y_{2X}^d$, the equilibrium relative price of all trading products, the size of the number of occupations in the two countries, and the equilibrium of the real income level of the two countries can be solved.

2) The market structure of domestic substitution of technology in latecomers (Structural INE). In this structure, C1, the technology pioneer country, specializes in R&D and exports technology products *z*, and its consumer goods *x* and *y* are imported from C2. In country C2, technologically backward countries, there are some individuals specializing in the production of consumer goods *x* and some specializing in producing *y*. At the same time, there are also some individuals specializing in the R&D of technical products to partially replace imports. In other words, the technical products required for the production process of C2's *x* experts can be obtained through two channels: import or purchase of domestic products. The information asymmetry of imported technology will depend on the brand influence of the exporter of the technical product *z* in the source country (C1) and the degree of consistency of technical standards between the two countries ($k_M = 1 - \frac{s_0}{(1+\tau_1)^{\frac{1}{2}}(1+\beta)^{\frac{1}{2}}}$), that is, the information disadvantage of purchasing domestic technical products is based on the brand reputation of domestic suppliers and the degree of consistency between existing professional information and domestic technical standards. As a matter of fact, it is also the degree of consistency between technical standards between the two countries. In this structure, international cooperation resulting from the specialization of the division of labor remains. At the same time, there is competition between the two countries due to the domestic substitution of technological products from latecomers. The relatively complete industrial division network of technologically less developed

countries coexists with the complete technological specialization of first-mover countries.

When all practitioners in C2 of technologically less developed countries achieve maximum utility equilibrium, they must also meet the utility equalization conditions, including the utility between imported technology and x experts using domestic technology, that is $u_2^Z = u_2^Y$, $u_2^Y = u_{2D}^X$, and $u_{2D}^X = u_{2IM}^X$. From this point, we can derive the relative price and equilibrium income level of x produced by imported technology, x produced by domestic technology, and y and z products. Here, we assume that the prices of C2's imported z and domestic z are equal in the domestic market, otherwise the equilibrium structure will deviate from the domestic alternative trading structure. In addition, we use M_{2XD}, M_{2XIM}, M_{2Y} and M_{2Z} to represent the number of x experts using domestic technology, the number of x experts using imported technology, and the number of y experts and the number of z experts in C2. Any three conditions cleared by the market of the two countries, as well as the equation of the sum of the population of each profession in C2, such as M_{2X}, $z_{2IM}^d = M_1 z_1^s$, $M_{2XD} z_{2D}^d = M_{2Z} z_{2D}^s$, $M_1 y_1^d + M_{2XD} y_{2XD}^d + M_{2XIM} y_{2XIM}^d + M_{2Z} y_{2Z}^d = M_{2Y} y_2^s$ and $M_{2XD} + M_{2XIM} + M_{2Y} + M_{2Z} = M_2$, can obtain the scale of the domestic specialization modes of the above technologically less developed countries.

These two trading structures are shown in Figure 1.

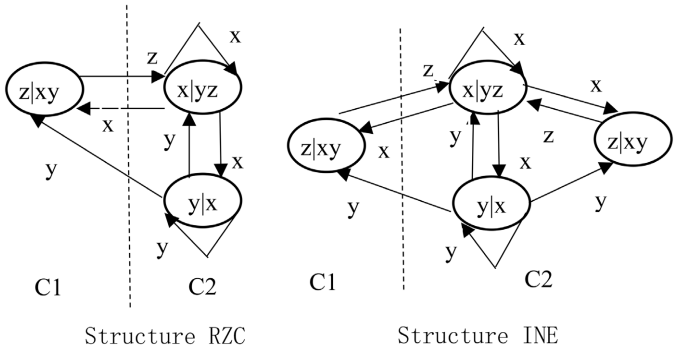


Figure 1. Market structures with specialization and division of labor.

In Figure 1, the circle represents a group of experts engaged in the relevant specialization mode, the beginning of the arrow indicates selling the product, and the end indicates buying the product; The left side of the vertical dotted line is economy C1, and the right side is economy C2. In the structural RZC, there is intra-industry trade between the producers of the economy C1 specializing in the production and export of technological products z and C2 x. In the structural INE, x producers in the economy C2 can either import technology z or buy domestic technology z; C2 and C1 carry out intra-industry trade, and at the same time have a certain domestic substitution ability of product z.

The specific equilibrium price and real income of each corner equilibrium analyzed above are shown in Table 2. The relative number of the professionals of each country when the corner equilibrium reached is shown in Table 3.

Table 2. The trading structures and their corner equilibrium.

Market structure	Equilibrium price	Per capita real income level
Structure RZC	$P_Z = \frac{\alpha(L-b)}{(L-\theta)(2-\alpha-\alpha\tau_0)\tau_1\tau_0}\frac{M_2}{M_1}$, $P_X = \frac{\frac{1}{(1-\alpha)^{1-\alpha}}\left(\frac{M_2}{M_1}\right)^{\alpha}}{\left[(L-\theta)(2-\alpha-\alpha\tau_0)\tau_1\tau_0\left(1-\frac{s_0}{(1+\tau_1)^{\frac{1}{2}}(1+\beta)^{\frac{1}{2}}}\right)\right]^{\alpha}}$.	$u_1^{RZC} = \frac{\alpha(L-b)k_F(1-\tau_0)(1-\alpha)^{\frac{1-\alpha}{2}}}{2(2-\alpha-\alpha\tau_0)^{1-\frac{\alpha}{2}}} \times\left[(L-\theta)\tau_1\tau_0\left(1-\frac{s_0}{(1+\tau_1)^{\frac{1}{2}}(1+\beta)^{\frac{1}{2}}}\right)\right]^{\frac{\alpha}{2}}\left(\frac{M_2}{M_1}\right)^{1-\frac{\alpha}{2}}$, $u_2^{RZC} = \frac{(1-\alpha)^{\frac{1-\alpha}{2}}(L-b)\sqrt{k_F}}{2\left(\frac{M_2}{M_1}\right)^{\frac{\alpha}{2}}} \times\left[(L-\theta)(2-\alpha-\alpha\tau_0)\tau_1\tau_0\left(1-\frac{s_0}{(1+\tau_1)^{\frac{1}{2}}(1+\beta)^{\frac{1}{2}}}\right)\right]^{\frac{\alpha}{2}}$.
Structure INE	$P_Z = \frac{L-b}{L-\theta}\frac{1}{\sqrt{k_F}(1-\tau_0)\tau_0\tau_2}$, $P_X\big\vert_{2D} = \frac{\left[\alpha(L-\theta)\left(\sqrt{k_F}(1-\tau_0)\tau_0\right)\tau_2\right]^{-\alpha}}{(1-\alpha)^{1-\alpha}\left(1-\frac{s_0}{(1+\tau_2)^{\frac{1}{2}}(1+\beta)^{\frac{1}{2}}}\right)^{\alpha}}$, $P_X\big\vert_{IM} = \frac{\left[\alpha(L-\theta)\left(\sqrt{k_F}(1-\tau_0)\tau_0\right)\tau_2\right]^{-\alpha}}{(1-\alpha)^{1-\alpha}} \times\frac{\left(1-\frac{s_0}{(1+\tau_2)^{\frac{1}{2}}(1+\beta)^{\frac{1}{2}}}\right)^{\frac{\alpha(1-\alpha)}{1+\alpha}}}{\left(1-\frac{s_0}{(1+\tau_1)^{\frac{1}{2}}(1+\beta)^{\frac{1}{2}}}\right)^{\frac{2\alpha}{1+\alpha}}}$.	$u_1^{INE} = \frac{L-b}{2}(1-\alpha)^{\frac{1-\alpha}{2}}\left(\alpha(L-\theta)(1-\tau_0)\tau_0\right)^{\frac{\alpha}{2}} \times k_F^{\frac{2+\alpha}{4}}\frac{\tau_1}{\tau_2^{\frac{1-\alpha}{2}}}\frac{\left(1-\frac{s_0}{(1+\tau_1)^{\frac{1}{2}}(1+\beta)^{\frac{1}{2}}}\right)^{\frac{\alpha}{1+\alpha}}}{\left(1-\frac{s_0}{(1+\tau_2)^{\frac{1}{2}}(1+\beta)^{\frac{1}{2}}}\right)^{\frac{\alpha(1-\alpha)}{2(1+\alpha)}}}$, $u_2^{INE} = \frac{L-b}{2}(1-\alpha)^{\frac{1-\alpha}{2}}k_F^{\frac{2+\alpha}{4}}\left(\alpha(L-\theta)(1-\tau_0)\tau_0\tau_2\right)^{\frac{\alpha}{2}} \times\left(1-\frac{s_0}{(1+\tau_2)^{\frac{1}{2}}(1+\beta)^{\frac{1}{2}}}\right)^{\frac{\alpha}{2}}$.

Note: $P_X\big\vert_{2D}$ and $P_X\big\vert_{IM}$ represent the relative price of product x produced using domestic and imported technology respectively.

Table 3. The relative number of professionals in each corner equilibrium.

Market structure	Balance the size of the professional population
Structure RZC	$M_{1Z} = M_1$, $M_{2X} = \frac{1-\alpha}{2-\alpha-\alpha\tau_0}M_2$, $M_{2Y} = \frac{1-\alpha\tau_0}{2-\alpha-\alpha\tau_0}M_2$.
Structure INE	$M_{1Z} = M_1$, $M_{2XIM} = \frac{(1-\alpha)\tau_1}{\alpha\sqrt{k_F}(1-\tau_0)\tau_2}\left(\frac{1-\frac{s_0}{(1+\tau_1)^{\frac{1}{2}}(1+\beta)^{\frac{1}{2}}}}{1-\frac{s_0}{(1+\tau_2)^{\frac{1}{2}}(1+\beta)^{\frac{1}{2}}}}\right)^{\frac{\alpha}{1+\alpha}}M_1$,

$$M_{2XD}=\frac{(1-\alpha)\left[\alpha(1-\tau_0)\sqrt{k_F}M_2-\left((1-\alpha)\left(\frac{1-\frac{s_0}{(1+\tau_1)^{\frac{1}{2}}(1+\beta)^{\frac{1}{2}}}}{1-\frac{s_0}{(1+\tau_2)^{\frac{1}{2}}(1+\beta)^{\frac{1}{2}}}}\right)^{\frac{\alpha}{1+\alpha}}+(1-\alpha\tau_0)\right)\frac{\tau_1}{\tau_2}M_1\right]}{\alpha(1-\tau_0)\sqrt{k_F}\left[2-\alpha(1+\tau_0)+\alpha(1-\tau_0)\sqrt{k_F}\right]},$$

$$M_{2Z}=\frac{\alpha(1-\tau_0)\sqrt{k_F}M_2-\left((1-\alpha)\left(\frac{1-\frac{s_0}{(1+\tau_1)^{\frac{1}{2}}(1+\beta)^{\frac{1}{2}}}}{1-\frac{s_0}{(1+\tau_2)^{\frac{1}{2}}(1+\beta)^{\frac{1}{2}}}}\right)^{\frac{\alpha}{1+\alpha}}+(1-\alpha\tau_0)\right)\frac{\tau_1}{\tau_2}M_1}{2-\alpha(1+\tau_0)+\alpha(1-\tau_0)\sqrt{k_F}},$$

$$M_{2Y}=\frac{1-\alpha\tau_0}{2-\alpha(1+\tau_0)+\alpha(1-\tau_0)\sqrt{k_F}}\left\{\left[\frac{1-\alpha}{\alpha(1-\tau_0)\sqrt{k_F}}\left(1-\left(\frac{1-\frac{s_0}{(1+\tau_1)^{\frac{1}{2}}(1+\beta)^{\frac{1}{2}}}}{1-\frac{s_0}{(1+\tau_2)^{\frac{1}{2}}(1+\beta)^{\frac{1}{2}}}}\right)^{\frac{\alpha}{1+\alpha}}\right)+1\right]\cdot\frac{\tau_1}{\tau_2}M_1+M_2\right\}.$$

3.3. General Equilibrium and Inframarginal Comparative Statics

When general equilibrium occurs in a division of labor structure, it means that no one is willing to deviate from the chosen specialized model under the relative price of the corner equilibrium of that structure. In other words, the structure becoming a general equilibrium structure will depend on the condition that the equilibrium real income level per capita of each specialization model in the structure is not lower than the income level of any other model it can choose from. In the case of cross-border trade, the author assumes that there is no cross-border movement of the population. Therefore, it is possible to compare the income levels of the various options within each country, but not across borders. In this way, we can obtain a series of inequalities containing all exogenous parameters compared between the two countries, and each division of labor transaction structure corresponds to a set of inequalities. Sun et al. (2004) prove that Walras' general equilibrium will exist in an analytical framework that includes positive transaction costs, endogenous consumption and production specialization allocation, and increasing (or constant) specialization return. Sun et al. (2003) simplify the calculation process of general equilibrium analysis by proving that the Pareto optimal corner equilibrium is also the highest per capita real income. Accordingly, these inequality groups can be used to divide all parameter spaces into corresponding parameter subspaces, and the corner equilibrium of the structure corresponding to each subspace is a general equilibrium. As the parameter values change between the subspaces of each parameter, the general equilibrium will fall into the corresponding structure discontinuously, which is the static analysis process of the inframarginal comparison of the general equilibrium.

If the structural RZC becomes a general equilibrium, it requires economy C1 to meet $u_1^{RZC} > u_1^{INE}$ and meanwhile economy C2 to satisfy $u_2^{RZC} > u_2^{INE}$. If the structure INE becomes a general equilibrium, C1 is required to be satisfied $u_1^{RZC} < u_1^{INE}$ and C2 is satisfied $u_2^{RZC} < u_2^{INE}$. The conditions under which each structure becomes a general equilibrium structure depend on the relative size of the populations of the two economies. After that, this paper will only conduct the static analysis of general equilibrium and inframarginal analysis when C2 is a country with relatively large population, which is shown in Table 4[3].

Table 4. General equilibrium and inframarginal comparison statics.

Parameter subspace	Equilibrium structure
$s_0\frac{\mu(1+\tau_1)^{\frac{1}{2}}-(1+\tau_2)^{\frac{1}{2}}}{(\mu-1)(1+\tau_1)^{\frac{1}{2}}(1+\tau_2)^{\frac{1}{2}}}<(1+\beta)^{\frac{1}{2}}<s_0\frac{\gamma(1+\tau_1)^{\frac{1}{2}}-(1+\tau_2)^{\frac{1}{2}}}{(1+\tau_1)^{\frac{1}{2}}(1+\tau_2)^{\frac{1}{2}}(\gamma-1)}$	Structure RZC (Technology Trade & Outsourcing Structure)
$s_0\frac{\gamma(1+\tau_1)^{\frac{1}{2}}-(1+\tau_2)^{\frac{1}{2}}}{(1+\tau_1)^{\frac{1}{2}}(1+\tau_2)^{\frac{1}{2}}(\gamma-1)}<(1+\beta)^{\frac{1}{2}}<s_0\frac{\mu(1+\tau_1)^{\frac{1}{2}}-(1+\tau_2)^{\frac{1}{2}}}{(\mu-1)(1+\tau_1)^{\frac{1}{2}}(1+\tau_2)^{\frac{1}{2}}}$	Structure INE (Domestic Substitution Structure for Technology in Latecomer Countries).

Note: Assuming α that k_F, τ_1 and τ_2 are unchanged, the population condition of C2 with a relative large population is $\frac{M_2}{M_1}\geq\frac{1}{\alpha\sqrt{k_F}}\frac{\tau_1}{\tau_2}\frac{2-\alpha-\alpha\tau_0}{1-\tau_0}$, where it is the threshold value τ_0 required to define C2 as a relative large population in the general equilibrium structure RZC. Here, $\mu\equiv\left(\alpha\sqrt{k_F}\frac{1-\tau_0}{2-\alpha-\alpha\tau_0}\frac{M_2}{M_1}\frac{\tau_2}{\tau_1}\right)^{\frac{(1+\alpha)(2-\alpha)}{\alpha(1-\alpha)}}$, $\gamma\equiv\alpha\sqrt{k_F}\frac{1-\tau_0}{2-\alpha-\alpha\tau_0}\frac{M_2}{M_1}\frac{\tau_2}{\tau_1}$.

4. The Main Findings of Inframarginal Static Analysis

After the above inframarginal static analysis of each corner equilibrium analysis, we can derive the following main propositions. Next, this paper will prove these propositions and elaborate on their solid economic implications, in order to reveal the rules and paths of technological innovation and economic development in technologically less developed countries.

First, as shown in Table 4, there is only one non-empty set of parameters for structural RZC and structural INE to become general equilibrium. However, the parameter has important economic implications: the proportion of technology revenues extracted for brand-building remains the same in both countries. If the initial non-empty parameter subspace makes the structure RZC a general equilibrium structure, the increase of the parameter value τ_0 will eventually make the parameter subspace condition of structure INE valid under the premise τ_0 that the initial non-empty parameter subspace makes the structure INE subspace condition unchanged, and the general equilibrium structure will jump to the structure INE. Therefore, proposition 1 is true.

Proposition 1: If the technologically less developed country has a relatively

[3]The derivation process is detailed in **Appendix A.1**.

large population (by $\frac{M_2}{M_1} \geq \frac{1}{\alpha\sqrt{k_F}} \frac{\tau_1}{\tau_2} \frac{2-\alpha-\alpha\hat{\tau}_0}{1-\hat{\tau}_0}$ definition), then:

1.1) In the parameter subspace of $s_0 \frac{\mu\left(1+\tau_1\right)^{\frac{1}{2}} - \left(1+\tau_2\right)^{\frac{1}{2}}}{\left(\mu-1\right)\left(1+\tau_1\right)^{\frac{1}{2}}\left(1+\tau_2\right)^{\frac{1}{2}}} < \left(1+\beta\right)^{\frac{1}{2}} < s_0 \frac{\gamma\left(1+\tau_1\right)^{\frac{1}{2}} - \left(1+\tau_2\right)^{\frac{1}{2}}}{\left(1+\tau_1\right)^{\frac{1}{2}}\left(1+\tau_2\right)^{\frac{1}{2}}\left(\gamma-1\right)}$, the general equilibrium structure is the structure RZC;

1.2) If the two countries extract the same proportion from the proceeds from the sale of their respective technical products τ_0 for brand-building expenses, with the increase of this ratio, the parameter conditions will enter the parameter subspace $s_0 \frac{\gamma\left(1+\tau_1\right)^{\frac{1}{2}} - \left(1+\tau_2\right)^{\frac{1}{2}}}{\left(1+\tau_1\right)^{\frac{1}{2}}\left(1+\tau_2\right)^{\frac{1}{2}}\left(\gamma-1\right)} < \left(1+\beta\right)^{\frac{1}{2}} < s_0 \frac{\mu\left(1+\tau_1\right)^{\frac{1}{2}} - \left(1+\tau_2\right)^{\frac{1}{2}}}{\left(\mu-1\right)\left(1+\tau_1\right)^{\frac{1}{2}}\left(1+\tau_2\right)^{\frac{1}{2}}}$, and the general equilibrium structure will transition to structure INE;

1.3) After INE becomes a general equilibrium structure, the per capita real income of C2 will increase with the improvement of the brand reputation of technology products τ_2 in the technologically advanced countries, but the equilibrium income of the technologically advanced countries will decrease (see **Appendix A.1** for details).

Proposition 1 summarizes the optimal decision-making of latecomers in brand-building and its main role and effect. Its economic implications are as follows: for technologically less developed country C2 has a relatively large population, i.e., $\frac{M_2}{M_1} \geq \frac{1}{\alpha\sqrt{k_F}} \cdot \frac{\tau_1}{\tau_2} \cdot \frac{2-\alpha-\alpha\hat{\tau}_0}{1-\hat{\tau}_0}$, and the population is unchanged in short term, the competition in the market of the latecomer countries will pay attention to and compete to strengthen the brand influence of their technology products. If the proportion of brand-building expenses extracted by latecomers in technology transactions can remain synchronized with that of first-mover enterprises, the result of brand-building competition will lead to a gradual transition from structural RZC to structural INE, that is, from the coexistence of technology trading and outsourcing to the model of domestic technology substitution in latecomers. Due to the small scale of related industries at the beginning of the acquisition of domestic technology development capabilities in technologically less developed countries, the amount of money that enterprises can extract and pay for brand-building is less than that of first-mover countries. However, as long as the expenditure growth rate (commission ratio) remains consistent with that of the first-mover countries, it will eventually break through the critical conditions that trigger this structural change τ_0[4]. If enterprises in technologically

[4]The general equilibrium structure change caused by the change of τ_0 does not apply to the constraints of the above small country model. The technical standard strategy of large and small countries is completely different, and the threshold value of population size is fixed here with the parameter τ_i ($i = 1, 2$) of the RZC stage. If country 2 is still has large population, when τ_0 changes to cross the critical threshold of these two countries, the trade pattern enters the steady state of INE as a general equilibrium.

less developed countries can achieve continuous brand accumulation, then the transaction income of technology products in first-mover countries will become less and less. Therefore, the first-mover has a strong incentive to prevent latecomers from improving their technical standards and brand-building and this response is the endogenous optimal decision of the first-mover country to maximize its transaction returns based on the change of transaction structure. In general, as the competition between the two countries in terms of technical standards and brand-building intensifies, it will trigger a further increase in the commission growth rate of brand-building. Enterprises in technologically less developed countries will also be more competitive than first-mover countries, and their accumulated brand reputation will also be from weak to strong. In this process, the attitude of high-technology companies towards latecomers will gradually turn to exclusion and competition. As long as latecomers focus on the growth rate of brand-building expenditure of first-mover enterprises, brand competition itself will strengthen the conditions and trends for domestic substitution of technology.

Secondly, when the general equilibrium structure is INE, imports and domestic technologies compete in the technology market of latecomer economy C2, but their downstream buyers (x experts) have different degrees of awareness of the two technologies. On the one hand, the buyer will judge the performance, quality and other information based on the existing brand awareness of the technical product; on the other hand, the degree of consistency of technical standards between the two countries will also affect the buyer's direct judgment of various information about product z. These information asymmetries will result in different equilibrium prices for downstream products x that produce z using technical standards from different sources. How these factors affect its competitiveness in the downstream markets can be revealed in Proposition 2.

Proposition 2: When the general equilibrium structure is the structure INE of domestic technology substitution in latecomers:

2.1) The greater the comparative advantage of the high-technology country in technology standardization and brand-building, the lower the price of downstream products produced by imported technology;

2.2) The higher the brand reputation influence accumulated by the technologically less developed countries, the more it will help to alleviate the relative price disadvantage of downstream products produced by domestic technology;

2.3) The increase in the consistency of technical standards between the two countries will reduce the relative price disadvantage of downstream products produced by domestic technology in technologically less developed countries;

2.4) The more production of end product x is depending on technical product z, the more price advantage of downstream products produced by imported technology.

Proof: From Table 2, it can be seen that the relative price of product x produced using imported technology and domestic alternative technology is

$\frac{P_X|_{IM}}{P_X|_{2D}} = \left(\frac{1-\frac{s_0}{(1+\tau_2)^{\frac{1}{2}}(1+\beta)^{\frac{1}{2}}}}{1-\frac{s_0}{(1+\tau_1)^{\frac{1}{2}}(1+\beta)^{\frac{1}{2}}}} \right)^{\frac{2\alpha}{1+\alpha}}$. If we mark $\varphi \equiv \frac{P_X|_{IM}}{P_X|_{2D}}$ and $k_M(\tau) = 1-\frac{s_0}{(1+\tau)^{\frac{1}{2}}(1+\beta)^{\frac{1}{2}}}$, then we have $\frac{\partial k_M}{\partial \tau} = \frac{s_0}{(1+\beta)^{\frac{1}{2}}(1+\tau)} > 0$ and $\tau_1 > \tau_2$, which results in $\frac{k_M(\tau_2)}{k_M(\tau_1)} < 1$. With the constant value of β, $\tau_1 > \tau_2$ makes the equilibrium price of imported technology production will be superior to the domestic price under the same condition, i.e., $P_X|_{IM} < P_X|_{2D}$. Besides, $\frac{\partial \varphi}{\partial \tau_1} < 0$, $\frac{\partial \varphi}{\partial \tau_2} > 0$, $\frac{\partial \varphi}{\partial \beta} > 0$ and $\frac{\partial \varphi}{\partial \alpha} < 0$.

The economic implication of Proposition 2 is that when the technologically less developed countries have a certain ability to substitute technology domestically, it is easier for technologically less developed countries with better reputation in brand-building to narrow the price disadvantage of downstream products produced by their localized technology in market competition. At the same time, technologically advanced countries will continue to consolidate their advantages in brand and technical standards to maintain the market competitiveness of their exported technology products. The competition between the two countries in terms of technical standard plates and product reputation accumulation is actually a competition for future market share of domestic technology. In domestic technology substitution transactions, the more technology-intensive the product, the more obvious the price competition disadvantage compared with imported technology. Late-developed countries can rely on the strategy of consistency of technical standards to gradually narrow the information gap in technology transactions and improve the information asymmetry between buyers and sellers in domestic technology transactions. From the perspective of price competition, the strategy of technical standard consistency is the priority of technologically less developed countries.

C2, a latecomer country that chooses the strategy of technical standard alignment, will greatly realize the competition between domestic technology and imported technology under the condition of complete technical standard integration. Then, there is a dilemma: C1, a high-technology country that completely focuses on high-end technology specialization, needs to compare the prices of two *x* when importing *x* products. If C1 uses C2 domestic technology to produce *x*, it will be cheaper; however, if such *x* is blindly imported, it will lead to less demand for technology products imported from C1, which leads to the decline of the C1 technology industry, thus deviating from the general equilibrium structure INE. Yet, this paper will prove that this case does not exist. As mentioned earlier, $\frac{\partial k_M}{\partial \tau} = \frac{s_0}{(1+\beta)^{\frac{1}{2}}(1+\tau)} > 0$. If the maximum value β is 1, the minimum value of

the derivative is still true, i.e., $\frac{\partial k_M}{\partial \tau} = \frac{s_0}{\sqrt{2}(1+\tau)} > 0$. Therefore, as long as there is $\tau_1 > \tau_2$, it must exist $\frac{k_M(\tau_2)}{(\tau_1)} < 1$, so that $P_X|_{IM} < P_X|_{2D}$ can still be established. Therefore, C1 in the general equilibrium structure INE has an incentive to maintain the brand competitive advantage of domestic technology, so as to keep the domestic technology sector not withering, regardless of C2's technology standardization strategy.

Next, if the general equilibrium occurs in the structural RZC or structural INE, how will the choice of technical standards between the high-technology country C1 and the technology less developed country C2 affect the equilibrium income of the two countries? When the equilibrium trading structure changes, whether the priority of C2 is still to keep the technical standards consistent with the current standards? What is the optimal choice for C1? Is the best choice between the two countries mutual or conflicting? The analysis of the above problems can be summarized as Proposition 3.

Proposition 3: When the general equilibrium is structural RZC, the equilibrium income of C1 and C2 will increase as the degree of consistency of technical standards β between the two countries increases. When the general equilibrium is structured INE, the equilibrium income of the first-mover C1 will decrease due to the increase of β in the face of latecomer enterprises with weak technical standards and brand reputation. Facing the latecomers with deep technical standards and brand reputation, their balanced income increases with the increase of β; the equilibrium income of C2 in technologically less developed countries has always increased with the rise of β.

Proof: It can prove that $\frac{\partial u_1^{RZC}}{\partial \beta} > 0$, $\frac{\partial u_2^{RZC}}{\partial \beta} > 0$, $\frac{\partial u_2^{INE}}{\partial \beta} > 0$ and

$$\frac{\partial u_1^{INE}}{\partial \beta} = \frac{(L-b)\alpha^{\frac{\alpha}{2}+1}(1-\alpha)^{\frac{1-\alpha}{2}}(L-\theta)^{\frac{\alpha}{2}}k_F^{\frac{2+\alpha}{4}}}{8(1+\alpha)(1+\beta)^2(1+\tau_1)^{\frac{1}{2}}(1+\tau_2)^{\frac{1}{2}}} \frac{\left((1-\tau_0)\tau_0\right)^{\frac{\alpha}{2}}\tau_1 s_0}{\tau_2^{\frac{2-\alpha}{2}}} \times \frac{\left[2(1+\tau_2)^{\frac{1}{2}} - (1-\alpha)(1+\tau_1)^{\frac{1}{2}}\right](1+\beta)^{\frac{1}{2}} - (\alpha+1)s_0}{\left(1-\frac{s_0}{(1+\tau_1)^{\frac{1}{2}}(1+\beta)^{\frac{1}{2}}}\right)^{\frac{1}{1+\alpha}}\left(1-\frac{s_0}{(1+\tau_2)^{\frac{1}{2}}(1+\beta)^{\frac{1}{2}}}\right)}.$$

The plus or minus depends on the plus or minus of $\frac{\partial u_1^{INE}}{\partial \beta}$ depend on the value of $\left[2(1+\tau_2)^{\frac{1}{2}} - (1-\alpha)(1+\tau_1)^{\frac{1}{2}}\right](1+\beta)^{\frac{1}{2}} - (\alpha+1)s_0$. Hence, $\frac{\partial u_1^{INE}}{\partial \beta} > 0$ when $\tau_2 > \frac{1}{4}\left[\frac{(\alpha+1)s_0}{(1+\beta)^{\frac{1}{2}}} + (1-\alpha)(1+\tau_1)^{\frac{1}{2}}\right]^2 - 1$. On the contrary, $\frac{\partial u_1^{INE}}{\partial \beta} < 0$, the

τ_2 value when $\tau_2 < \frac{1}{4}\left[\frac{(\alpha+1)s_0}{(1+\beta)^{\frac{1}{2}}} + (1-\alpha)(1+\tau_1)^{\frac{1}{2}}\right]^2 - 1$.

The implications of proposition 3 are as follows. First, both countries tend to maintain the same technical standards in the structure RZC, and the optimal choice of the two is mutual. Since the latecomer countries in this trade structure do not yet have the ability to develop technological products, the implementation of the technical standards of the technologically advanced countries is conducive to domestic technology buyers to reduce the information cost of purchasing imported technologies, thereby improving transaction efficiency and production efficiency. Maintaining the consistency and cooperation of technical standards between the two countries is an inherent requirement between the two in this structure. Second, after the general equilibrium change to the latecomer countries to carry out the domestic technology substitution structure INE, the division of labor and cooperation between the two countries has led to competition between imported technology and domestic technology. When the technical standards and brand reputation of enterprises in technologically less developed countries are weak and there is a large gap with first-mover enterprises, technologically advanced countries can rely on their own brand reputation and the first-mover comparative advantage composed of existing technical standards to promote their technical standards in the market of technologically less developed countries. If the technical standards gap between the two countries is large, the domestic technology of the latecomer country will be at a greater disadvantage, and the first-mover country will be more likely to control this market. In the meanwhile, the high-technology country has a technical standard consistency strategy of the less developed country with a motivation to lag behind. The essence is that the brand reputation advantages and differences in technical standards of technologically advanced countries can jointly build barriers to entry in the technical field. After that, if the reputation of the technology standard and brand of the enterprises in the technologically less developed countries continues to improve and crosses a certain threshold (as shown in Proposition 1), its influence in the domestic market can attract some downstream buyers to purchase domestic technology, which will effectively restrict the possible response of the technologically advanced countries in terms of technical standards. The best option for the first-mover country at this time is to restore the consistency of technical standards between the two countries to maintain the market unity of the two source technologies, so as to delay the technical competition of the latecomers with the help of the first-mover comparative advantage. For technologically less developed countries, they must pay attention to the accumulation of brand reputation during the rise of domestic substitution capacity of technology. Meanwhile, only if the latecomer always maintains a higher consistency between the technical standards and its current standards, it can be faster to inform the buyers who originally used imported technology understand the performance, quality, reliability of domestic technology; and

then better develops their domestic market. Otherwise, if the latecomer country adopts technical standards that are different from its existing standards, the information cost of all domestic technologies will have to be repaid, which is obviously detrimental to the promotion of domestic technology.

To sum up, the optimal choice of technical standards in technologically less developed countries should always remain in line with international standards and do not alter with the changes of their status in international division of labor. While the attitude of technologically advanced countries towards the consistency of technical standards will change with the potential competition they face and the brand influence of their peers. The results are consistent with proposition 3, that is, the two countries choose their best technical standard strategies based on the equilibrium trading returns. The unchanging standard consistency of the latecomer countries and the change of the technical standards of the first-mover countries coexist, which means sometimes the two meets in halfway and sometimes there are differences.

This proposition can explain the motivation of technology pioneers to set up the blockade in technology patents. For example, controlling the technology route with high patent fees can increase the cost of domestic technology in the less developed countries that use the strategy of technical standard consistency to develop extended technology and want to obtain the downstream market, thereby delaying the technological catch-up of the less developed countries on this route. To some extent, this proposition also can explain why the progressive innovation in the history of science and technology mostly occurs within the original economy, while breakthrough technological innovation is more likely to occur outside the economy, which is because the latecomers who are hindered by the consistency strategy may choose new technological development routes.

Next, it will wonder how will the change in the degree of consistency of technical standards between the two countries affect the size of the working population in the technology sector after the less developed countries gain independent technology development capabilities? Will the attitude of the two countries towards technical standards be the same as before? To answer these questions, we have Proposition 4.

Proposition 4: When the general equilibrium structure is INE, with the increase of the degree of consistency of technical standards β between the two countries, the population scale of domestic technology product z, downstream product x which using domestic technology, and consumer goods y will expand, and the population scale of x product using imported technology will decrease.

Proof: It can be proved that $\frac{\partial M_{2Z}}{\partial \beta} > 0$, $\frac{\partial M_{2XD}}{\partial \beta} > 0$, $\frac{\partial M_{2Y}}{\partial \beta} > 0$, and $\frac{\partial M_{2XIM}}{\partial \beta} < 0$. A detailed derivation process can be found in **Appendix A.2**.

This proposition suggests that the increase in the degree of consistency of technical standards between the two countries will bring more population of the do-

mestic sectors that originally used imported technology to the domestic alternative technology industries (z and x sectors) or y product sectors. This scale effect means that the convergence of standards plays a positive role in promoting the international division of labor network and forms a positive effect on all network nodes. Separate technical standards can easily lead to enterprises (corresponding nodes) in technologically less developed countries being forced to withdraw from the network of division of labor at an exponential rate.

Proposition 2, Proposition 3 and Proposition 4 show that the latecomers that benefit from the strategy of aligning technical standards have the motivation to maintain the same standards as those of first-mover enterprises. The interests of first-movers' technology products in the latecomers' markets will experience a phased decline, therefore the first-movers intend to differentiate the technical standards of the two countries. Consequently, the change in the equilibrium income level of the two countries is more preciously and ultimately explaining the attitude of the technologically advanced countries towards the difference in technical standards between the first-movers and the latecomers.

Based on the above analysis, this paper can reveal the following points: First, the decisive premise of the change from division of labor and trading structure to the domestic substitution structure of technology in latecomers is that the proportion of brand-building expenditure of latecomers should maintain at least the same growth rate as that of first-movers. Second, there is an optimal range of technical standard consistency to ensure the evolution of this optimal trading structure. Third, the equilibrium income of both countries has increased with the improvement of the brand influence of domestic enterprises. Fourth, the equilibrium income of latecomers to technology always increases with the increase of the degree of consistency of technical standards, while the equilibrium income of first-movers shows sinusoidal fluctuations of first rising, then declining, and then rising with the increase of consistency, which also corresponds to the various stages of brand reputation improvement of latecomers. Fifth, the technology standardization strategy generated by the high-technology country based on the optimal welfare has a comprehensive inhibition effect on the entry of latecomers into the international technology market by manipulating their price advantage and industrial scale advantage.

These results of this model also highlight that latecomers who lack the power in standard-setting will frequently encounter the challenges from the technology standardization strategy of first-mover enterprises, and it will be more difficult to continue to benefit from the standardization strategy. In contrast, accumulating brand reputation is a more stable choice for latecomers to remove the barriers to entry. Fortunately, the iterative innovation of technology can not only continue to confirm the brand commitment to improve brand reputation, but also the evolution of international technology standardization is also the result of iterative innovation of technology. In other words, the continuous technological innovation of latecomers and the simultaneous development of brand reputation will help

enhance their voice in the formulation or update of technology standardization. The improvement of the discourse power in standard formulation will enhance the influence of the brand, reduce the commercialization risk of technological innovation of latecomer enterprises, and promote the iterative innovation of enterprises. Following this way, it can generate a positive cycle among the right of discourse power in technology standardization, the accumulation of brand reputation, and the technological innovation of latecomers. When each link can create its own positive value, this cycle will be self-reinforced. Besides, when any of these links turn to a positive value, it will promote its self-reinforcing power.

Based on all the above four propositions, there will be a game between the high-technology country and the less developed country before and after the change of trading structures[5]. The general form of the game can be summarized as follows: for the technologically less developed countries, in the process of development of local technical departments, the optimal strategy for technical standards is to keep technical standards in line with international standards; the best choice for brand-building is to focus on the growth rate of brand-building of first-mover enterprises and strengthen the accumulation of the brands reputation of independent technology standard. Meanwhile, the strategy of high-technology countries towards technology standards is constantly changing due to the accumulation of brand reputation in the technology market. Maintain the consistency of technical standards between the two countries when the latecomers do not have the ability to develop their own technology. When the latecomers have just entered the technology market and have low brand awareness, there is an incentive to widen the difference in technical standards between the two. When the technical standards and brand influence of the latecomers compete with them, the consistency of the technical standards between the two is restored in order to always maintain their first-mover comparative advantage in technical standards and brand-building. The above rule and phenomenon also exist in the stage of domestic technologies substitution in technologically less developed countries. In the long run, there is an upper limit to the competition between technical standards and brand-building. With the improvement of technical standards and the continuous accumulation of brand reputation in technologically less developed countries, the gap between the two types of countries' technology products in terms of brand influence will eventually and gradually disappear.

5. Basic Conclusion and Policy Implications

5.1. Basic Conclusion

This paper establishes a general equilibrium analysis framework to discuss the changes in the structure with division of labor and technology transactions with the corresponding parameter conditions from the perspective of information

[5]The game mentioned in this paper is the set of all consumer-producer optimal decisions when the Walrasian mechanism of decentralized decision-making reaches equilibrium, that is, the "game" form of decision results, which is different from the endogenous strategic behavior in game theory.

asymmetry in the technology market. This study reveals the conditions required by latecomers to achieve domestic substitution of technology, including the optimal options for technical standards and brand-building, and the consistency of technical standards. In addition, it provides a theoretical explanation for the strategic correspondence of technologically advanced countries in these two aspects.

For technology latecomers, the key factor to break through the information barriers of domestic technology is to enter the market, to realize domestic substitution of technology, to strengthen their brand-building, to accumulate brand reputation, and to maintain at least the proportion of brand-building expenditure that is synchronized with the first-mover enterprises. Secondly, the technology development of latecomers needs to maintain higher consistency with the international standard system, which will always help the growth of transaction income whether it is in the past stage of intra-industry contractor or has entered the stage of domestic substitution of technology. Finally, the consistency of technical standards is of great significance for latecomers to enter the field of global technology development: on the one hand, it can reduce the price disadvantage of local technology in the downstream market; on the other hand, it will help expand the scale of local domestic substitution sectors and slow down the market impact of technology supply from first-mover enterprises in the international market on local new technology enterprises. Unlike traditional trade protection measures, the relative openness of technical standards can build a more open technology market, thereby ensuring the localization of technology and future innovation and development in latecomers.

For high-technology enterprises, the first-mover comparative advantage in technical standards and the advantage of incumbents in brand influence have created the price competitiveness of their technology products in the market of technology importing countries. Before latecomers master the ability of technical self-development, this competitiveness may be obscured by the high-price monopoly of the incumbent. However, when it faces competition from latecomer countries, the price competitive advantage is undoubtedly revealed, especially in technology-intensive industries where the barriers to entry formed by price advantages are higher. Secondly, this first-mover comparative advantage leaves enough room for high-technology countries to rely on technology standardization strategies to prevent new entrants, thus allowing them to choose technology standardization strategies based on their own balanced income changes in the international division of labor and trade patterns. For example, promoting the consistency of technical standards in latecomers in the international industrial outsourcing structure; while in the early stage of domestic substitution of technology for latecomers, the standard differences are widened and patent containment is implemented. When technology companies in less developed countries accumulate enough brand reputation, the first-movers can resume the consistency of technical standards, although their downstream demand scale is shrinking at this time.

5.2. Policy Implications

According to the research results of this paper, the localization of technology in developing countries should focus on the positive dynamic cycle mechanism among industry technical standards, enterprise brand-building, and enterprise technology research and development. The technology R&D of local enterprises is in line with international standards, which can reduce information costs and gain market recognition faster, thereby improving the effectiveness of brand-building. Enterprises should follow clear technical standards to engage in technology innovation and sell to buyers with fewer information disadvantages in the convergence standard system, and constantly confirm their brand commitment with updated products, higher quality, and more complete performance, so as to accumulate brand reputation. Having a deep enough brand influence will help enterprises participate in the formulation of technical standards for continuous iteration and innovation and enhance their discourse power. At the same time, if enterprises take the initiative to participate in the formulation of technical standards, they will more effectively promote enterprise technology R&D and market recognition, and enter a new round of positive cycle, so as to achieve continuous R&D and innovation.

Enterprises in less developing economies often try to set up a different set of standards to avoid the risks in the process of technology localization when encountering frequent and intense barrier challenges from first-mover enterprises. However, the existence of a positive loop mechanism suggests that this approach is no more efficient than improving alignment with existing standards. Only by embracing the international market, the latecomer enterprises can fully share the cost of innovation and R&D, which is the only way to grow into an international-class enterprise. Latecomers should join in the international standard system as soon as possible, and accumulate the power to influence the future, and even lead the formulation of future standards through technological innovation and brand-building.

Based on the above research, this paper highlights the following policy suggestions: First, enterprises in developing countries should pay attention to and start brand-building as soon as possible, and continue to promote technology updates and iterations to improve product quality in order to accumulate brand influence by continuously confirming the brand commitment of enterprises. Even if the share of technology sales revenue allocated to brand-building of latecomers in the initial stage is much lower than that of first-mover enterprises, the proportion should be gradually increased, and finally the proportion of expenditure should be maintained synchronously, so as to break through the dilemma caused by the strategic and repeated domestic substitution of technology in terms of technical standards, and gain more voice in formulating technical standards. Second, the construction of technical standards in technologically less developed countries must fully improve the consistency with international standards and actively participate in the formulation of technical standards. By actively integrating into the international

standard system, we can maintain the simultaneous growth of enterprises' own R&D strength and the power to formulate standards, so as to enhance the ability of enterprises in latecomers to resist risks related to the use of technology. Third, strengthening international cooperation with standard certification bodies, promoting the classification and mutual recognition of technical standard modules, reducing the cost of technical standard certification for enterprises, and improving the efficiency of standard certification for international technical exchanges. Clear and consistent technical standards will help break the market's "superstition" about foreign technology, which will grant the latecomers a fair and transparent market competition environment, will improve the accuracy of innovation support measures, and will enable enterprises to gain better development capabilities and space in the international market. Fourth, improving the effectiveness of intangible assets formed by enterprises based on brand reputation in daily financing, expanding the positive expectations of enterprises in brand-building and long-term reputation accumulation, and guiding the long-term innovation behavior of enterprises. Finally, economies with large domestic markets need to pay more attention to formulating technical standards in new fields at the beginning of the success and breakthrough over new technological innovation, so as to fully grasp the discourse power of high technology.

In view of the reality that latecomers' enterprises usually start with a large number of cross-border transfer of manufacturing industry and lack brand reputation accumulation, this paper tries to reveal the principle behind the barriers to entry through technology standardization strategies faced by first-mover enterprises in the process of realizing domestic technology substitution in developing countries. It proves that latecomers can reduce the disadvantage of information competition by relying on their brand-building and standard consistency. It clarifies the positive cycle mechanism between technology standardization, brand reputation and technological innovation of latecomers. Therefore, it addresses the theoretical basis that latecomers should systematically solve the limitation of information asymmetry in the process of domestic substitution to innovation leadership by improving the discourse power of standard formulation.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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Appendix A1. The Process of Proof of Proposition 1

Propositions 1.1) and 1.2):

The specialized selection of C1 in the technology pioneer country makes the structure RZC and INE the conditions for the general equilibrium structure:

For C1, if the structure RZC becomes a general equilibrium, it is required $u_1^{RZC} > u_1^{INE}$.

Let $\mu \equiv \left[\left(\alpha\sqrt{k_F}\dfrac{1-\tau_0}{2-\alpha-\alpha\tau_0}\dfrac{M_2}{M_1}\right)\Big/\left(\dfrac{\tau_1}{\tau_2}\right)\right]^{\frac{(1+\alpha)(2-\alpha)}{\alpha(1-\alpha)}}$, then the condition is equivalent to $(1+\beta)^{\frac{1}{2}}(\mu-1) > s_0\dfrac{\mu(1+\tau_1)^{\frac{1}{2}}-(1+\tau_2)^{\frac{1}{2}}}{(1+\tau_1)^{\frac{1}{2}}(1+\tau_2)^{\frac{1}{2}}}$. The constraints for β depend on the size of μ. According to the rough valuation of the assumed conditions $0 < \left(\alpha\sqrt{k_F}\dfrac{1-\tau_0}{2-\alpha-\alpha\tau_0}\right)\Big/\left(\dfrac{\tau_1}{\tau_2}\right) < 1$. If the relative population size of C2 is large enough $\dfrac{M_2}{M_1} > \dfrac{\dfrac{\tau_1}{\tau_2}}{\alpha\sqrt{k_F}\dfrac{1-\tau_0}{2-\alpha-\alpha\tau_0}} > 1$, then the $\mu > 1$. If structural RZC become a general equilibrium, the constraint condition to C1 is $(1+\beta)^{\frac{1}{2}} > s_0\dfrac{\mu(1+\tau_1)^{\frac{1}{2}}-(1+\tau_2)^{\frac{1}{2}}}{(\mu-1)(1+\tau_1)^{\frac{1}{2}}(1+\tau_2)^{\frac{1}{2}}}$. If the relative population size of C2 is low, i.e., $\dfrac{M_2}{M_1} < \dfrac{\dfrac{\tau_1}{\tau_2}}{\alpha\sqrt{k_F}\dfrac{1-\tau_0}{2-\alpha-\alpha\tau_0}}$, then $\mu < 1$, the constraint condition of C1 in the general equilibrium RZC becomes $(1+\beta)^{\frac{1}{2}} < s_0\dfrac{\mu(1+\tau_1)^{\frac{1}{2}}-(1+\tau_2)^{\frac{1}{2}}}{(\mu-1)(1+\tau_1)^{\frac{1}{2}}(1+\tau_2)^{\frac{1}{2}}}$, and only when $\mu < \left(\dfrac{1+\tau_2}{1+\tau_1}\right)^{\frac{1}{2}}$, it can be guaranteed that the constraint is not empty. The trade between C1 and C2, a country with a small population, may be in the general equilibrium of RZC. In the given case of α, τ_1, τ_2, and k_F, the value of the relatively large population can be fixed, i.e., $\tau_0 = \hat{\tau}_0$.

The condition for structural INE to become a general equilibrium is exactly the opposite: for the case where C2 is a relatively large population $\dfrac{M_2}{M_1} > \dfrac{\dfrac{\tau_1}{\tau_2}}{\alpha\sqrt{k_F}\dfrac{1-\hat{\tau}_0}{2-\alpha-\alpha\hat{\tau}_0}}$, then $\mu > 1$, the constraint condition of C1 for structural INE to become a general equilibrium is

$$(1+\beta)^{\frac{1}{2}} < s_0 \frac{\mu(1+\tau_1)^{\frac{1}{2}} - (1+\tau_2)^{\frac{1}{2}}}{(\mu-1)(1+\tau_1)^{\frac{1}{2}}(1+\tau_2)^{\frac{1}{2}}}.$$

Keeping the definition of C2 as a relatively large population unchanged, i.e., $\frac{M_2}{M_1} > \frac{\frac{\tau_1}{\tau_2}}{\alpha\sqrt{k_F}\frac{1-\hat{\tau}_0}{2-\alpha-\alpha\hat{\tau}_0}} > 1$, the constraints of C1 are:

If $(1+\beta)^{\frac{1}{2}} > s_0 \frac{\mu(1+\tau_1)^{\frac{1}{2}} - (1+\tau_2)^{\frac{1}{2}}}{(\mu-1)(1+\tau_1)^{\frac{1}{2}}(1+\tau_2)^{\frac{1}{2}}}$, the equilibrium trading structure is RZC;

If $(1+\beta)^{\frac{1}{2}} < s_0 \frac{\mu(1+\tau_1)^{\frac{1}{2}} - (1+\tau_2)^{\frac{1}{2}}}{(\mu-1)(1+\tau_1)^{\frac{1}{2}}(1+\tau_2)^{\frac{1}{2}}}$, the equilibrium trading structure is INE.

The conditions for the selection of C2 to make the structures RZC and INE become general equilibrium structures are:

Structural RZC becomes a general equilibrium requirement C2 to be met $u_2^{RZC} > u_2^{INE}$. Let $\gamma \equiv \alpha\sqrt{k_F}\frac{1-\tau_0}{2-\alpha-\alpha\tau_0}\frac{M_2}{M_1}\frac{\tau_2}{\tau_1}$, then the principle is the same as above. If the definition of a large population country is constant, i.e., $\frac{M_2}{M_1} > \frac{\tau_1}{\tau_2}\frac{2-\alpha-\alpha\hat{\tau}_0}{\alpha\sqrt{k_F}(1-\hat{\tau}_0)}$, then the condition is equivalent to

$$(1+\beta)^{\frac{1}{2}} < s_0 \frac{\gamma(1+\tau_1)^{\frac{1}{2}} - (1+\tau_2)^{\frac{1}{2}}}{(1+\tau_1)^{\frac{1}{2}}(1+\tau_2)^{\frac{1}{2}}(\gamma-1)}.$$

The structural INE becomes a general equilibrium requirement that C2 meets $u_2^{RZC} < u_2^{INE}$. If the definition of a large population country remains unchanged, $\frac{M_2}{M_1} > \frac{\frac{\tau_1}{\tau_2}}{\alpha\sqrt{k_F}\frac{1-\hat{\tau}_0}{2-\alpha-\alpha\hat{\tau}_0}}$, the condition is equivalent to

$$(1+\beta)^{\frac{1}{2}} > s_0 \frac{\gamma(1+\tau_1)^{\frac{1}{2}} - (1+\tau_2)^{\frac{1}{2}}}{(1+\tau_1)^{\frac{1}{2}}(1+\tau_2)^{\frac{1}{2}}(\gamma-1)}.$$

Compare the value of γ and μ, $\mu \equiv \left(\alpha\sqrt{k_F}\frac{1-\tau_0}{2-\alpha-\alpha\tau_0}\frac{M_2}{M_1}\frac{\tau_2}{\tau_1}\right)^{\frac{(1+\alpha)(2-\alpha)}{\alpha(1-\alpha)}}$ and $\gamma \equiv \alpha\sqrt{k_F}\frac{1-\tau_0}{2-\alpha-\alpha\tau_0}\frac{M_2}{M_1}\frac{\tau_2}{\tau_1}$, then we have $\mu = \gamma^{\frac{(1+\alpha)(2-\alpha)}{\alpha(1-\alpha)}}$. It should be noted that in the structural RZC, this paper defines the critical value of τ_0, then the condition that C2 is a relative large population by the critical value of $\hat{\tau}_0$, that is, under the conditions of α, k_F, τ_1 and τ_2 are constant, C2 is a relatively large population $\frac{M_2}{M_1} \geq \frac{1}{\alpha\sqrt{k_F}}\frac{\tau_1}{\tau_2}\frac{2-\alpha-\alpha\hat{\tau}_0}{1-\hat{\tau}_0}$. Maintain this definition, $\mu > 1$ and

$\gamma > 1$ both are true, then $\mu > \gamma$. Based on the above analysis, it can be obtained that the conditions for the general equilibrium falling on the structural RZC are:

C1: $(1+\beta)^{\frac{1}{2}} > s_0 \dfrac{\mu(1+\tau_1)^{\frac{1}{2}} - (1+\tau_2)^{\frac{1}{2}}}{(\mu-1)(1+\tau_1)^{\frac{1}{2}}(1+\tau_2)^{\frac{1}{2}}}$

C2: $(1+\beta)^{\frac{1}{2}} < s_0 \dfrac{\gamma(1+\tau_1)^{\frac{1}{2}} - (1+\tau_2)^{\frac{1}{2}}}{(1+\tau_1)^{\frac{1}{2}}(1+\tau_2)^{\frac{1}{2}}(\gamma-1)}$

Comparing the two inequality conditions, it can derive the following:

$$s_0 \frac{\gamma(1+\tau_1)^{\frac{1}{2}} - (1+\tau_2)^{\frac{1}{2}}}{(1+\tau_1)^{\frac{1}{2}}(1+\tau_2)^{\frac{1}{2}}(\gamma-1)} - s_0 \frac{\mu(1+\tau_1)^{\frac{1}{2}} - (1+\tau_2)^{\frac{1}{2}}}{(\mu-1)(1+\tau_1)^{\frac{1}{2}}(1+\tau_2)^{\frac{1}{2}}}$$

$$= \frac{s_0 \left(\left(\alpha\sqrt{k_F} \dfrac{1-\tau_0}{2-\alpha-\alpha\tau_0} \dfrac{M_2}{M_1} \dfrac{\tau_2}{\tau_1} \right)^{\frac{(1+\alpha)(2-\alpha)}{\alpha(1-\alpha)}-1} - 1 \right) \alpha\sqrt{k_F} \dfrac{1-\tau_0}{2-\alpha-\alpha\tau_0} \dfrac{M_2}{M_1} \dfrac{\tau_2}{\tau_1} \left[(1+\tau_1)^{\frac{1}{2}} - (1+\tau_2)^{\frac{1}{2}} \right]}{(1+\tau_1)^{\frac{1}{2}}(1+\tau_2)^{\frac{1}{2}} \left(\alpha\sqrt{k_F} \dfrac{1-\tau_0}{2-\alpha-\alpha\tau_0} \dfrac{M_2}{M_1} \dfrac{\tau_2}{\tau_1} - 1 \right) \left(\left(\alpha\sqrt{k_F} \dfrac{1-\tau_0}{2-\alpha-\alpha\tau_0} \dfrac{M_2}{M_1} \dfrac{\tau_2}{\tau_1} \right)^{\frac{(1+\alpha)(2-\alpha)}{\alpha(1-\alpha)}} - 1 \right)} > 0$$

since $\dfrac{(1+\alpha)(2-\alpha)}{\alpha(1-\alpha)} - 1 = \dfrac{2}{\alpha(1-\alpha)} > 2$.

The parameter constraints for structural RZC to become general equilibrium are:

$$s_0 \frac{\mu(1+\tau_1)^{\frac{1}{2}} - (1+\tau_2)^{\frac{1}{2}}}{(\mu-1)(1+\tau_1)^{\frac{1}{2}}(1+\tau_2)^{\frac{1}{2}}} < (1+\beta)^{\frac{1}{2}} < s_0 \frac{\gamma(1+\tau_1)^{\frac{1}{2}} - (1+\tau_2)^{\frac{1}{2}}}{(1+\tau_1)^{\frac{1}{2}}(1+\tau_2)^{\frac{1}{2}}(\gamma-1)}.$$

The conditions for the general equilibrium falling on the structural INE are:

C1: $(1+\beta)^{\frac{1}{2}} < s_0 \dfrac{\mu(1+\tau_1)^{\frac{1}{2}} - (1+\tau_2)^{\frac{1}{2}}}{(\mu-1)(1+\tau_1)^{\frac{1}{2}}(1+\tau_2)^{\frac{1}{2}}}$

C2: $(1+\beta)^{\frac{1}{2}} > s_0 \dfrac{\gamma(1+\tau_1)^{\frac{1}{2}} - (1+\tau_2)^{\frac{1}{2}}}{(1+\tau_1)^{\frac{1}{2}}(1+\tau_2)^{\frac{1}{2}}(\gamma-1)}$

On the right of $\dfrac{M_2}{M_1} > \dfrac{1}{\alpha\sqrt{k_F}} \dfrac{\tau_1}{\tau_2} \dfrac{2-\alpha-\alpha\tau_0}{1-\tau_0}$, due to $\dfrac{\partial\left(\dfrac{2-\alpha-\alpha\tau_0}{1-\tau_0}\right)}{\partial\tau_0} = \dfrac{2(1-\alpha)}{(1-\tau_0)^2} > 0$, the increase of τ_0, the right side of the inequality in the population condition increases $\dfrac{1}{\alpha\sqrt{k_F}} \dfrac{\tau_1}{\tau_2} \dfrac{2-\alpha-\alpha\tau_0}{1-\tau_0}$. In the case that the relative population is fixed by critical conditions $\dfrac{M_2}{M_1}(\hat{\tau}_0)$, the increase of τ_0

will deform the above inequality equivalent to $\alpha\sqrt{k_F}\frac{1-\tau_0}{2-\alpha-\alpha\tau_0}\frac{M_2}{M_1}\frac{\tau_2}{\tau_1}<1$, where $s_0\frac{\gamma\left(1+\tau_1\right)^{\frac{1}{2}}-\left(1+\tau_2\right)^{\frac{1}{2}}}{\left(1+\tau_1\right)^{\frac{1}{2}}\left(1+\tau_2\right)^{\frac{1}{2}}\left(\gamma-1\right)}-s_0\frac{\mu\left(1+\tau_1\right)^{\frac{1}{2}}-\left(1+\tau_2\right)^{\frac{1}{2}}}{\left(\mu-1\right)\left(1+\tau_1\right)^{\frac{1}{2}}\left(1+\tau_2\right)^{\frac{1}{2}}}<0$.

The constraints on structural INE becoming a general equilibrium are:

$$s_0\frac{\gamma\left(1+\tau_1\right)^{\frac{1}{2}}-\left(1+\tau_2\right)^{\frac{1}{2}}}{\left(1+\tau_1\right)^{\frac{1}{2}}\left(1+\tau_2\right)^{\frac{1}{2}}\left(\gamma-1\right)}<\left(1+\beta\right)^{\frac{1}{2}}<s_0\frac{\mu\left(1+\tau_1\right)^{\frac{1}{2}}-\left(1+\tau_2\right)^{\frac{1}{2}}}{\left(\mu-1\right)\left(1+\tau_1\right)^{\frac{1}{2}}\left(1+\tau_2\right)^{\frac{1}{2}}}.$$

Proof of Propositions 1 - 3:

It can be proved that $\frac{\partial u_1^{INE}}{\partial\tau_2}<0$ and $\frac{\partial u_2^{INE}}{\partial\tau_2}>0$, among them,

$$\frac{\partial u_1^{INE}}{\partial\tau_2}=u_1^{INE}\left[\frac{1}{1-\frac{s_0}{\left(1+\tau_2\right)^{\frac{1}{2}}\left(1+\beta\right)^{\frac{1}{2}}}}\cdot\frac{\alpha\left(1-\alpha\right)}{4\left(1+\alpha\right)}\cdot\frac{s_0}{\left(1+\beta\right)^{\frac{1}{2}}\left(1+\tau_2\right)^{\frac{1}{2}}}-\frac{1-\frac{\alpha}{2}}{\tau_2}\right].$$ The plus or minus value of $\frac{\partial u_1^{INE}}{\partial\tau_2}$ depends on

$\frac{1}{1-\frac{s_0}{\left(1+\tau_2\right)^{\frac{1}{2}}\left(1+\beta\right)^{\frac{1}{2}}}}\cdot\frac{\alpha\left(1-\alpha\right)}{4\left(1+\alpha\right)}\cdot\frac{s_0}{\left(1+\beta\right)^{\frac{1}{2}}\left(1+\tau_2\right)^{\frac{1}{2}}}-\frac{1-\frac{\alpha}{2}}{\tau_2}$, where the first part $\frac{1}{1-\frac{s_0}{\left(1+\tau_2\right)^{\frac{1}{2}}\left(1+\beta\right)^{\frac{1}{2}}}}$, $\frac{\alpha\left(1-\alpha\right)}{4\left(1+\alpha\right)}$ and $\frac{s_0}{\left(1+\beta\right)^{\frac{1}{2}}\left(1+\tau_2\right)^{\frac{1}{2}}}$ their value are taken $\left(0,1\right)$ respectively, and the total value of the three is still $\left(0,1\right)$; while the second part $\frac{1-\frac{\alpha}{2}}{\tau_2}>1$. Hence, the difference between the two is negative $\frac{\partial u_1^{INE}}{\partial\tau_2}<0$.

$$\frac{\partial u_2^{INE}}{\partial\tau_2}=\frac{\alpha}{2}\frac{L-b}{2}\left(1-\alpha\right)^{\frac{1-\alpha}{2}}k_F^{\frac{2+\alpha}{4}}\left(\alpha\left(L-\theta\right)\left(1-\tau_0\right)\tau_0\right)^{\frac{\alpha}{2}}$$

Next,

$$\times\left(\tau_2\left(1-\frac{s_0}{\left(1+\tau_2\right)^{\frac{1}{2}}\left(1+\beta\right)^{\frac{1}{2}}}\right)\right)^{\frac{\alpha}{2}-1}\left(1-\frac{s_0}{\left(1+\beta\right)^{\frac{1}{2}}\left(1+\tau_2\right)^{\frac{1}{2}}}\frac{2+\tau_2}{2+2\tau_2}\right),$$

its positive and negative value will depend on $1-\frac{s_0}{\left(1+\beta\right)^{\frac{1}{2}}\left(1+\tau_2\right)^{\frac{1}{2}}}\frac{2+\tau_2}{2+2\tau_2}$. Obviously, $\frac{2+\tau_2}{2+2\tau_2}\in\left(0,1\right)$ therefore $1-\frac{s_0}{\left(1+\beta\right)^{\frac{1}{2}}\left(1+\tau_2\right)^{\frac{1}{2}}}\frac{2+\tau_2}{2+2\tau_2}>0$, furthermore $\frac{\partial u_2^{INE}}{\partial\tau_2}>0$.

Appendix A2. The Process of Proof of Proposition 4

It can be proved that

$$\frac{\partial M_{2Z}}{\partial \beta}=-\frac{\frac{\alpha}{1+\alpha}\frac{\tau_1}{\tau_2}M_1(1-\alpha)s_0(1+\beta)^{-\frac{3}{2}}}{2-\alpha(1+\tau_0)+\alpha(1-\tau_0)\sqrt{k_F}}\times\frac{\left(1-\frac{s_0}{(1+\tau_1)^{\frac{1}{2}}(1+\beta)^{\frac{1}{2}}}\right)^{\frac{\alpha}{1+\alpha}-1}}{2\left(1-\frac{s_0}{(1+\tau_2)^{\frac{1}{2}}(1+\beta)^{\frac{1}{2}}}\right)^{\frac{\alpha}{1+\alpha}+1}}\left(\frac{1}{(1+\tau_1)^{\frac{1}{2}}}-\frac{1}{(1+\tau_2)^{\frac{1}{2}}}\right)>0,$$

$$\frac{\partial M_{2XD}}{\partial \beta}=-\frac{\frac{\alpha}{1+\alpha}(1-\alpha)^2\frac{\tau_1}{\tau_2}M_1s_0(1+\beta)^{-\frac{3}{2}}}{2\alpha(1-\tau_0)\sqrt{k_F}\left[2-\alpha(1+\tau_0)+\alpha(1-\tau_0)\sqrt{k_F}\right]}\times\frac{\left(1-\frac{s_0}{(1+\tau_1)^{\frac{1}{2}}(1+\beta)^{\frac{1}{2}}}\right)^{\frac{\alpha}{1+\alpha}-1}}{\left(1-\frac{s_0}{(1+\tau_2)^{\frac{1}{2}}(1+\beta)^{\frac{1}{2}}}\right)^{\frac{\alpha}{1+\alpha}+1}}\left(\frac{1}{(1+\tau_1)^{\frac{1}{2}}}-\frac{1}{(1+\tau_2)^{\frac{1}{2}}}\right)>0,$$

$$\frac{\partial M_{2XIM}}{\partial \beta}=\frac{(1-\alpha)\tau_1M_1s_0(1+\beta)^{-\frac{3}{2}}}{2(1+\alpha)\sqrt{k_F}(1-\tau_0)\tau_2}\frac{\left(1-\frac{s_0}{(1+\tau_1)^{\frac{1}{2}}(1+\beta)^{\frac{1}{2}}}\right)^{\frac{\alpha}{1+\alpha}-1}}{\left(1-\frac{s_0}{(1+\tau_2)^{\frac{1}{2}}(1+\beta)^{\frac{1}{2}}}\right)^{\frac{\alpha}{1+\alpha}+1}}\times\left(\frac{1}{(1+\tau_1)^{\frac{1}{2}}}-\frac{1}{(1+\tau_2)^{\frac{1}{2}}}\right)<0,$$

$$\frac{\partial M_{2Y}}{\partial \beta}=-\frac{\frac{\alpha}{1+\alpha}(1-\alpha)(1-\alpha\tau_0)\frac{\tau_1}{\tau_2}M_1s_0(1+\beta)^{-\frac{3}{2}}}{2\left(2-\alpha(1+\tau_0)+\alpha(1-\tau_0)\sqrt{k_F}\right)\left(\alpha(1-\tau_0)\sqrt{k_F}\right)}\times\frac{\left(1-\frac{s_0}{(1+\tau_1)^{\frac{1}{2}}(1+\beta)^{\frac{1}{2}}}\right)^{\frac{\alpha}{1+\alpha}-1}}{\left(1-\frac{s_0}{(1+\tau_2)^{\frac{1}{2}}(1+\beta)^{\frac{1}{2}}}\right)^{\frac{\alpha}{1+\alpha}+1}}\left(\frac{1}{(1+\tau_1)^{\frac{1}{2}}}-\frac{1}{(1+\tau_2)^{\frac{1}{2}}}\right)>0.$$

In summary, we have $\frac{\partial M_{2Z}}{\partial \beta}>0$, $\frac{\partial M_{2XD}}{\partial \beta}>0$, $\frac{\partial M_{2Y}}{\partial \beta}>0$, and $\frac{\partial M_{2XIM}}{\partial \beta}<0$.