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Research on Price Determination of Skill-Based Knowledge Products

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Abstract: Current research on the pricing of knowledge products often focuses on those as consumer goods, with insufficient attention to skill-based knowledge products, which serve as intermediate goods and do not directly contribute to consumer utility. Within the scope of this study, a specific type of skill-based knowledge serves as a prerequisite for producing related consumer goods. Skill-based knowledge products can be provided by individuals possessing such knowledge, allowing those originally lacking this production skill to acquire it by purchasing the relevant knowledge product, thus enabling a shift in their specialized production. This paper explores the price determination of these skill-based knowledge products within the context of division of labor and general equilibrium, incorporating factors such as consumer preferences, transaction efficiency, time costs of learning, and intermediary fees in knowledge transactions.

Keywords: skill-based knowledge, knowledge product price determination, general equilibrium, division of labor.

1. Introduction

1.1. Research Background

Entering the 21st century, China has witnessed rapid growth in residents' per capita disposable income. As basic survival-related consumption occupies a decreasing share of income, there is significant room for an upgraded consumption structure. A new consumption pattern is emerging, characterized by an emphasis on categories like science, education, and cultural entertainment. Knowledge products effectively facilitate human capital investment. Additionally, with the arrival of the information age, a fast-paced and increasingly complex living environment has triggered widespread anxiety, fueling a strong motivation for learning. These factors collectively drive the demand for paid knowledge. Individuals possessing various forms of knowledge may choose to externalize their knowledge, transforming it into specific knowledge products and selling it at a profit after evaluating the cost-benefit balance. This process generates a supply of paid knowledge. Moreover, policies aimed at strengthening intellectual property protection are gradually intensifying, with more robust and comprehensive mechanisms in place to safeguard various types of knowledge products, further supporting the growth of the paid knowledge industry. Driven by these factors, the knowledge payment industry has seen rapid development in recent years.

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The paid knowledge market is still emerging in China and is experiencing a phase of explosive growth. According to the "2020-2024 China Paid Knowledge Industry In-Depth Research and Investment Forecast Report" [1], the size of China's paid knowledge market in 2018 was RMB 14.83 billion, with a user base of 292 million. By 2019, the market size had reached RMB 27.8 billion, and the user base had grown to 360 million. Currently, paid knowledge in China can be divided into several categories based on content, such as course-based learning, community live streaming, question-and-answer tipping, and document payment [2]. Platforms that facilitate these knowledge transactions can be categorized into comprehensive course-sharing platforms, social knowledge service platforms, specialized training platforms, and community reading and learning platforms [3]. A survey by iiMedia Research on users of paid knowledge reveals that users expect to see an improved cost-performance ratio in products, demanding both higher content quality and an optimized pricing mechanism. At the same time, several issues with knowledge product supply are becoming increasingly apparent amidst rapid industry growth [4]: First, buyers tend to be highly subjective in assessing the value of knowledge products, leading to strong subjective influence in price determination and a lack of unified standards. Second, knowledge products lack an evaluation mechanism; due to their unique nature, users find it difficult to know in advance if the content quality meets their expectations, and they are often unable to return purchases. Third, while some paid knowledge platforms promote knowledge dissemination, the actual content provided tends toward entertainment and superficial knowledge, which does not align with users' original intent for purchasing such products. Moreover, issues such as low entry barriers, lack of gatekeepers, and severe content homogeneity continue to challenge knowledge product supply [5].

1.2. Research Objectives

As the structure of consumption and industries continues to upgrade and competition intensifies in today's economic society, the demand for new skills required by emerging industries has gradually increased with the contraction of traditional industries. In this context, some workers engaged in the production of traditional consumer goods may use fragmented time to acquire knowledge and skills needed in fields with promising growth prospects. This demand for skill-based knowledge has facilitated the formation of the knowledge products market, where individuals who already possess such skills can turn them into products and sell them through platforms to those in need of knowledge. Skill-based knowledge differs from other types of directly consumable knowledge, as directly consumable knowledge is part of the consumer's utility function and fulfills their mental needs, with its price influenced by consumers' subjective value assessments. Skill-based knowledge, however, is not part of the consumer's utility; rather, products that convey this knowledge function as an intermediate good, where the buyer needs to use it to produce a final product before consumption can occur. For instance, producing software as a final product requires programming knowledge as an input factor, but learning programming skills alone does not directly enhance consumer preferences. If workers purchase paid courses to learn such skills, these courses effectively function as intermediate goods.

Most current research on knowledge payment market pricing focuses only on the consumption characteristics of the knowledge products themselves, considering mainly subjective factors such as consumer preferences. However, such studies fall short in explaining the price determination of skill-based knowledge products. Knowledge products directly consumed as final goods have their prices heavily influenced by subjective consumer preferences. In contrast, the pricing mechanism for knowledge products centered on skill-based knowledge is more complex: producing a final consumer good requires specific skill endowments, and individuals with certain knowledge endowments can either produce the associated consumer goods or teach these skills to others by producing and selling skill-based knowledge products. An individual with a certain initial knowledge endowment can also

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acquire another knowledge endowment by purchasing skill-based knowledge products, thereby enabling them to engage in specialized production of a different product. Addressing the current pricing inefficiencies in the knowledge payment market and the lack of research on the pricing of skill-based knowledge, this paper aims to explore the economic logic behind price determination for skill-based knowledge products. This analysis is situated within the framework of competitive markets, the evolution of specialization, and general equilibrium theory.

1.3. Literature Review on Knowledge Product Pricing

Teese highlighted the "fundamental paradox of information" in studies on technology transfer [6,7], suggesting that certain types of knowledge and technology transactions face difficulties in establishing clear prices, making the transaction process challenging. Other scholars have pointed out [8] that the knowledge payment market exhibits characteristics of a "lemon market," where buyers lack complete information, allowing some sellers of low-quality content to capture a larger market share by offering lower prices, which hinders healthy market development. In terms of pricing models for knowledge products, Zhou Bo [9] argued that knowledge products cannot be priced based on marginal cost, as in traditional theory, but rather depend on the probabilistic distribution of consumer utility since providers cannot precisely determine the utility for each individual consumer. Zhou also included factors such as knowledge depreciation in his pricing model. In other models, he examined the impact of variations in quality levels of knowledge products on equilibrium prices under competitive market conditions. Liu Zhengchi et al. [10] pointed out that demand in the knowledge payment market is often distinctly personalized, and different levels of customization lead to variations in production costs for knowledge products. They further incorporated customization levels into the pricing model and explored how different customization levels influence whether providers adopt a posted price or a negotiated pricing strategy. Xu Youzhi et al. [11] investigated pricing issues in knowledge transactions within supply chains, exploring different pricing strategies for explicit and tacit knowledge in transactions. Another study [12] analyzed users' irrational responses to different knowledge pricing strategies, such as pricing individual knowledge items versus the entire knowledge repository, noting that consumers tend to overestimate their learning and utilization abilities, which leads to choices that deviate from maximizing utility. In empirical research and field experiments related to knowledge pricing, Kay Cahill [13] analyzed the failure of "Google Answers," attributing a significant internal cause to the inadequate pricing strategy, which failed to sufficiently incentivize researchers (the providers of answers). Emphasizing high quality at low prices, along with an unreasonable refund mechanism, ultimately made this model unsustainable. YAN CHEN et al. [14] conducted a field experiment to examine how variables like price influence the effort level and quality of responses, finding that price had limited motivational effects on responders, often affecting the length of the response rather than its quality. The study also emphasized the importance of establishing a reputation system in designing knowledge markets. Song Xiaobing et al. [15] empirically analyzed how consumers' perception of social mobility affects their willingness to pay for knowledge. Liu Zhengchi et al. [16] considered the role of online communities as a key source of information on the value of knowledge products. Based on this, they developed a dynamic game model to study how community learning mechanisms influence pricing strategies for knowledge products.

Overall, existing research, whether based on theoretical modeling or empirical analysis, primarily focuses on paid knowledge intended for direct consumption. Few studies analyze skill-based knowledge that requires further integration into production processes. Skill-based knowledge products, as intermediate goods, differ from other types of intermediate products, necessitating further research on their unique pricing mechanisms.

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2. Model Research on the Pricing of Skill-Based Knowledge Products

2.1. Logical Description of the Model

Assume there are two types of skill-based knowledge: one for high-end industries and one for traditional industries. Each individual's initial knowledge endowment is determined exogenously by pre-market factors such as education, resulting in two types of workers with different initial knowledge endowments. Initially, knowledge products are not yet available. Workers with knowledge of high-end industry skills specialize in the production of high-end consumer goods, while workers with knowledge of traditional industry skills specialize in the production of traditional consumer goods. At this stage, the price ratio between high-end consumer goods (referred to as Y) and traditional consumer goods (referred to as Z) depends on the ratio of people with each type of knowledge endowment and the relative contribution of each consumer good to utility. The greater a product's contribution to utility or the fewer workers with the skills to produce it, the relatively higher its price. Assume that workers producing Y derive greater utility than those producing Z, which may be due to various factors. The utility of workers producing Y is directly proportional to the relative price of Y to Z, whereas the utility of workers producing Z is inversely proportional to this price ratio. If there are more workers with initial Y-type knowledge endowments, or if Y contributes more to utility, and the labor time required for producing each unit of product is the same, the relative price of Y may be higher, leading to a higher utility level for workers producing Y. This utility difference creates incentives for workers producing Z to learn the knowledge of producing Y, hoping to achieve higher utility. With the emergence of a new knowledge market, workers initially engaged in producing Y may choose to sell products based on their skill-based knowledge (referred to as X) after weighing the costs and benefits. As a result, a continuous flow of workers with initial Z skill-based knowledge begins to purchase knowledge product X, using it as an intermediate product to produce Y, incurring a certain learning cost, R. At this stage, there are four types of workers in the market: (1) workers with high-end industry knowledge endowments who produce X (numbered n1), (2) workers with high-end industry knowledge endowments who continue to produce Y (numbered n2), (3) workers with traditional industry knowledge endowments who continue to produce Z (numbered n3), and (4) workers with traditional industry knowledge endowments who (through learning) now produce Y (numbered n4). Before reaching a steady state in specialization, the prices of X, Y, and Z are influenced by the number of workers engaged in each specialized production, while the number of each type of worker remains variable. In the steady-state of specialization, however, the quantity of each type of worker becomes stable (determined endogenously). Achieving a steady state in specialization requires meeting the "equal utility principle," meaning that individuals with the same initial knowledge endowment will ultimately attain the same utility level, regardless of which product they produce.

2.2. Model Setup

① In the market, there are n workers initially endowed with skills for producing high-end consumer goods Y and N workers initially endowed with skills for producing traditional consumer goods Z. At the initial stage, the former group exclusively produces Y, while the latter group exclusively produces Z. Workers initially endowed with high-end skills now face two choices: (1) transfer knowledge to produce Y by creating and selling a skill-based knowledge product X, or (2) directly produce high-end consumer goods Y. Those opting for the first choice are referred to as "Type 1 workers" with a population of n1, while those opting for the second choice are "Type 2 workers" with a population of n2 = n - n1. Workers initially endowed with traditional skills also have two choices: (1) produce traditional consumer goods Z or (2) purchase X to transition into producing Y. Those in the first group

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are “Type 3 workers” with a population of n3, and those in the second group are “Type 4 workers” with a population of n4 = N - n3. Here, we assume that each individual produces only one product at a time; for example, if a Type 2 worker plans to produce X in the future, they will cease producing Y, meaning that each worker is specialized in one product at a time.

② The production function for each type of worker is defined below. Each worker’s production function is based on their labor endowment (set at 1 unit) and any intermediate product inputs, if applicable. We assume no preference for leisure; thus, all available time is dedicated to production.

Type 1 workers’ production function: $x_1{}^p = x_1{}^s = Al_1 = A$, where A represents relative labor productivity.

Type 2 workers’ production function: $y_2{}^p = y_2 + y_2{}^s = l_2 = 1$

Type 3 workers’ production function: $z_3{}^p = z_3 + z_3{}^s = l_3 = 1$

Type 4 workers’ production function: $y_4{}^p = y_4 + y_4{}^s = [(l_4 - R)\ kx_4{}^d]^{\frac{1}{2}} = [(1 - R)\ kx_4{}^d]^{\frac{1}{2}}$, where R represents the time cost of learning (with 0 < R < 1), and k indicates transaction efficiency (with 0 < k < 1). The superscripts p, s, and d respectively denote production volume, supply volume, and demand volume, while products without superscripts represent self-supplied quantities. Subscripts represent the worker type (the same applies below). For example, $y_2{}^p = y_2 + y_2{}^s$ implies that the production volume of Y by Type 2 workers equals the sum of self-supplied and supplied volumes. Self-supplied quantity refers to the portion of output consumed by the producer. Based on Wen’s theorem [17], the optimal decision does not involve simultaneous buying and selling of the same product; if a producer can supply more than their self-supplied amount of a product, the demand for that product would be zero while the supply remains positive.

③ The utility function is specified as follows. Each type of worker in the market we described above plays both the role of producer and consumer. The consumer’s utility is the objective function that each type of individual seeks to maximize, comprising the quantities of two consumed goods, Y and Z (including both self-supplied and demanded quantities). It is assumed that the contribution of Y to consumer utility is represented by α, while the contribution of Z to consumer utility is represented by β. Product X does not directly contribute to utility since it is a form of skill-based knowledge. Assume a Cobb-Douglas type utility function, represented as $\mathrm{U} = (\mathrm{y} + \mathrm{ky}^{\mathrm{d}})^{\alpha}\left(\mathrm{z} + \mathrm{kz}^{\mathrm{d}}\right)^{\beta}$, where k denotes transaction efficiency. The specific utility functions for each type of worker are:

$$\mathrm{U}_1 = (ky_1{}^d)^{\alpha}(kz_1{}^d)^{\beta}$$

$$\mathrm{U}_2 = y_2{}^{\alpha}\ (kz_2{}^d)^{\beta}$$

$$\mathrm{U}_3 = (ky_3{}^d)^{\alpha} z_3{}^{\beta}$$

$$\mathrm{U}_4 = y_4{}^{\alpha}\ (kz_4{}^d)^{\beta}$$

④ Each type of worker must consider their budget constraint when making consumption decisions:

$$\text{s.t.1.}\quad cP_x x_1{}^s = P_y y_1{}^d + P_z z_1{}^d$$

$$\text{s.t.2.}\quad P_y y_2{}^s = P_z z_2{}^d$$

$$\text{s.t.3.}\quad P_z z_3{}^s = P_y y_3{}^d$$

$$\text{s.t.4.}\quad P_y y_4{}^s = P_x x_4{}^d + P_z z_4{}^d$$

Here, c (with 0 < c < 1) represents the share of sales revenue that producers of X retain, while 1 - c is the intermediary fee percentage charged by the knowledge payment platform.

⑤ Market equilibrium is reached when the supply and demand for each product are balanced at a certain price ratio, or in other words, when the market is in general equilibrium:

$$n_1 x_1{}^s = n_4 x_4{}^d$$

$$n_2 y_2{}^s + n_4 y_4{}^s = n_1 y_1{}^d + n_3 y_3{}^d$$

$$n_3 z_3{}^s = n_1 z_1{}^d + n_2 z_2{}^d + n_4 z_4{}^d$$

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⑥ Based on the specific production functions, utility maximization objectives, and budget constraints, we can determine the sales, self-supplied, and purchasing decisions for each category of individuals in the market.

2.3. Evolution of the Division Between Skill-based Knowledge Products and Consumer Goods

① When solving optimization problems, the production function and budget constraints can be integrated into the utility function, expressing it as a function of product supply or demand. This transforms the original optimization problem into an unconstrained decision problem, where the optimal product supply is determined through first-order conditions. Then, based on general equilibrium conditions and budget constraints, the equilibrium price ratio of the products can be calculated.

In the initial state, only two consumer goods, Y and Z, are present, with n1 = 0, n2 = n, n3 = N, and n4 = 0. Through the purchasing and selling decisions of types 2 and 3 individuals, and general equilibrium conditions, it is shown that the relative price of Y and Z is directly proportional to their respective utility contributions and inversely proportional to the ratio of people with the two initial knowledge endowments: $\frac{P_y}{P_z} = \frac{\alpha N}{\beta n}$.

② Once knowledge product X enters the market, the supply and demand decisions of types 1 and 4 individuals for X, along with market-clearing conditions, allow us to derive the price ratio of Y and X:

$$\frac{P_y}{P_x} = \sqrt{\frac{4An_1}{k(1-R)n_4}}$$

In this market phase, price ratios are influenced by the relative population sizes involved in producing each product. The division of labor has not yet stabilized; as long as individuals perceive that adjusting their supply strategies enhances consumer utility, population shifts among divisions will continue. Thus, parameters affecting the price ratio include the size of n1, n4, the relative labor productivity of knowledge products A, the transaction efficiency k, and the learning time cost R. If n1 is large, n4 is small, A is high, k is low, and R is high, then the price ratio of Y to X will be higher. With Z's price normalized to 1, and using the market-clearing condition for product Y, the relative prices of X and Y to Z can be derived as follows:

$$P_x = \frac{\alpha n_3\sqrt{k(1-R)n_4}}{2\sqrt{An_1}\beta n_2+(\alpha+2\beta-\alpha c)An_1\sqrt{k(1-R)n_4}};$$

$$P_y = \frac{\alpha n_3}{\beta n_2+\frac{\alpha+2\beta-\alpha c}{2}\cdot\sqrt{Ak(1-R)n_1 n_4}}$$

Thus, we observe that the price ratio between Y and Z will be higher when n3 is smaller (or n4 is larger), α is smaller relative to β, A is higher, k is higher, R is lower, and the platform intermediary cost rate 1 - c is higher. Consequently, with the price ratio relationships between the three products, knowing the trading price of one product allows for the calculation of the other two products' prices.

③ In the market described in point 2, the division of labor structure is dynamic. This is because individuals with similar initial knowledge endowments experience different utility levels when engaging in specialized production, which incentivizes individuals to change their worker types. This indicates that the price ratios determined by general equilibrium are also fluctuating. As these utility differences diminish, the division of labor will stabilize, reaching a steady state. Achieving this steady-state division of labor requires meeting the equal utility condition: for workers who are initially endowed with traditional skill-based knowledge, the utility of producing X should be equivalent to that of producing Y, denoted as $U_1 = U_2$. Similarly, for workers who are initially

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endowed with high-skill knowledge, the utility of producing Z should equal that of producing Y, i.e., $U_3 = U_4$.

From the first equal utility condition, the price ratio of Y to X at market stability is obtained as $\frac{P_y}{P_x} = k^{\frac{\alpha}{\alpha+\beta}}Ac$. Thus, as α decreases relative to β, k and A increase, and 1 - c decreases, the steady-state price ratio between X and Y decreases. Based on the second equal utility condition, the steady-state price ratio of Z to Y can be derived as $\frac{P_z}{P_y} = \frac{k^{1+\frac{\beta}{\alpha+\beta}}Ac(1-R)}{4}$

Therefore, as α increases relative to β, A rises, 1 - c declines, and R decreases, the steady-state price ratio between Y and Z will be lower. Given the price ratios between the three products in a steady-state market, if the price of one product is known, the other two products' prices can be calculated. For instance, assuming the price of Z is 1, then $P_y = \frac{4}{k^{1+\frac{\beta}{\alpha+\beta}}Ac(1-R)}$, $P_x = \frac{4}{k^2A^2c^2(1-R)}$. This shows that as the relative labor productivity A decreases, platform intermediary fees 1 - c increase, and learning time cost R rises, the relative price of skill-based knowledge product X also rises.

2.4. Analysis of Skilled Knowledge Product Prices in the Division-of-Labor Steady State

This section focuses on how the price of skilled knowledge products is determined in the steady state of division of labor. We examine whether various factors influence price determination and the direction of these influences.

① Initial Knowledge Endowments: Individuals with each type of initial endowment have two options in specialized production. Each individual compares the utility level of the two choices and dynamically adjusts their worker type until achieving an "equal utility principle": individuals with the same initial knowledge endowment, regardless of their production choice, ultimately reach equal utility levels. At this point, the number of individuals producing each product becomes an endogenous variable, and the prices of knowledge product X and consumer goods Y and Z are no longer dependent on N and n. The emergence of skilled knowledge products can somewhat mitigate inequality caused by pre-market factors.

② Transaction Efficiency, Learning Costs, and Intermediation Fee Rate of Knowledge Payment Platforms: Transaction efficiency impacts the utility of Type 1 individuals more than that of Type 2 individuals, as Type 1 engages in specialized production of skilled knowledge, and both final products require transactions for acquisition. When transaction efficiency k decreases, a higher relative price of X to Y is necessary to incentivize individuals with initial endowments in knowledge of producing Y to engage in X production. Likewise, when the relative productivity of knowledge products is lower or the intermediary fee rate of knowledge trading platforms is higher, a higher relative price of X to Y is required to compensate.

With other conditions constant, the utility of Type 3 individuals is inversely related to the price ratio of Y to Z, while the utility of Type 4 individuals is directly proportional to this price ratio. Transaction efficiency impacts the utility of Type 4 individuals more significantly than that of Type 3 because Type 4 needs to purchase both Z and knowledge product X. When transaction efficiency k is lower, a higher relative price of Y to Z is necessary to incentivize individuals with initial traditional industry skills to shift to Y production. Learning cost negatively affects the utility of Type 4 individuals; thus, as learning cost R increases, a higher relative price of Y to Z is required to motivate individuals with initial traditional industry skills to acquire new skills.

③ Subjective Preferences for Consumer Goods: Type 1 individuals do not produce final goods and therefore incur higher transaction costs for purchasing final good Y compared to Type 2 individuals. Thus, as α/β increases—indicating that Y contributes relatively more to consumer utility—the utility loss from the transaction cost of purchasing Y is higher for Type 1 individuals, necessitating a higher relative price of X to Y to encourage individuals with high-skilled industry endowments to produce X. Conversely, if α/β is lower, meaning that Z contributes relatively more to consumer utility, Type 4 individuals, who acquire Z through transactions, experience greater utility loss from transaction costs compared to Type 3 individuals who produce Z themselves. Thus, a higher relative price of Y to Z is needed to provide an incentive. As a result, a higher α/β raises the equilibrium price of X relative to Y while lowering the equilibrium price of Y relative to Z, creating offsetting effects on the equilibrium price of X relative to Z. Therefore, in this model, the price of skilled knowledge product X relative to Z is not influenced by subjective preferences but rather by other objective factors.

3. Conclusion

This paper investigates the pricing issue of skill-based knowledge products through the perspectives of division of labor theory and general equilibrium. The knowledge payment market studied here comprises numerous knowledge product providers and consumers, each possessing specific knowledge endowments and conducting transactions on a knowledge trading platform. Therefore, the market structure discussed in this paper is competitive, and the prices examined are not monopoly-driven but rather endogenous product price ratios determined by market division, general equilibrium conditions, and steady-state conditions. In our model analysis, we consider various factors influencing the pricing of knowledge products, such as consumer preferences, the relative labor productivity in knowledge product production, the intermediary fees charged by knowledge platforms to providers, the learning time costs of knowledge product purchasers, and the number of different types of producers before the market reaches steady state. When the market has not yet achieved a steady state, the number of people engaged in different specialized productions is not stable. At this stage, the product price ratios are endogenously determined by maximizing individual utility and the general equilibrium of supply and demand across various products, with the price ratios being influenced by the number of workers involved in each type of specialized production. Once the market reaches steady state, individuals with identical initial knowledge endowments are expected to be indifferent regarding the utility level they can achieve from any type of specialized production within their division of labor choices. At this point, the price ratios are determined by the condition of equal utility, and the number of workers engaged in each type of specialized production becomes an endogenous variable. The steady-state product price ratio is influenced by transaction efficiency, relative labor productivity, intermediary fees charged by knowledge platforms to providers, and the learning time costs of knowledge product purchasers.

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